ENVIRONMENTAL HEALTH
AND CLIMATE CHANGE
The **FJPH**, is a Fiji based Journal published for Public Health practitioners, public health researchers, clinicians and all allied health practitioners. Our goal is to provide evidence based information and analysis they need to enable them to make the right choices and decisions concerning their health and health services provided to ensure better health for all.

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1. Original Academic/Scientific Research Papers - Research-based works addressing a specific area of public health or any other general topic in health - between 3,000 and 4,500 words.
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3. Perspectives –Reviews, Opinion pieces that analyze or discuss a recent issue or development in public health - between 250 and 2,500 words.
4. Field notes –Journal-style pieces, with a more personal voice, words.

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2. The call for submissions and a description of the optional theme can be found in the Health Research web page.
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3. The manuscript is the author's own original work, and the authors are the sole authors of the manuscript.
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1. Original scientific Research - Research-based works addressing a specific area of public health or any other general topic in health
2. Abstracts – structured abstracts for original research and
3. Perspectives – Reviews, Opinion pieces that analyze or discuss a recent issue or development in public health
4. Field notes – Journal-style pieces, with a more personal voice, based on direct work in the field

**Formatting**

- All manuscripts should be submitted as double-spaced, size 10, Times New Roman font in microsoft Format (.doc or .docx only).
- Do not include the name of the manuscript's authors any pages except the title page.

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Perspectives are opinion-based pieces. Field Notes take a more personal, informal tone that addresses public health work the author has done in the field. For both Perspectives and Field Notes, we are looking for submissions that address fresh and exciting developments in public health from an interdisciplinary perspective. Perspectives and Field Notes should be grounded in the pre-existing literature base. For citations and references, use APA style. If tables and figures are used, please include them at the end of the submission.

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- Tables, figures and images should be the original work of the manuscript's authors and should be included at the end of each manuscript.
- Captions should describe what the table/figure/image shows and the conclusion that should be drawn.
- Labels and axes should be clearly marked and readable.
- All tables, figures, and images should be submitted in high resolution please.
- References

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The theme of this issue of FJPH is Environmental Health and Climate Change. This subject is very relevant and important for the health and well-being of Fijians and other Pacific islanders, as they are facing “triple burden of diseases”, i.e., communicable disease, non-communicable disease, and health impacts of climate change. Air and sea temperature rise, sea-level rise, more severe tropical depression and cyclone, more frequent floods, and more severe droughts will increase the risk, prevalence, incidence and mortality of drowning, injuries and climate-sensitive diseases such as dengue fever, leptospirosis, typhoid fever and diarrhoea in the Pacific island populations.

Two important contributions of Original Research in this issue are studies on the association of climate factors with health outcomes. Oli et al. reports that dengue incidence is influenced by temperature and rainfall in Ba, Lautoka and Nadroga in the period of 1996-2010. The relationship is not uniform across the different communities. This may indicate the existence of confounding and effect modifying factors such as socio-economic and geographic conditions of the communities. Melver et al. presents climate-based early warning system (EWS) for diarrhoea in two pilot sites of PCCAPHH (Piloting Climate Change Adaptation to Protect Human Health) project. Both papers conclude that public health services including surveillance system should be strengthened to address climate-sensitive diseases.

Vulnerability and capacity assessment is the first step of health adaptation process at the national and community levels. Johnson et al. reports the results of such an assessment in five ‘disease hotspots’ in the western subdivision of Viti Levu, also supported by the PC-CAPHH project. Sanitation, shelter, water quality, mosquito control, and hygiene behaviour are confirmed to be areas of vulnerability in these rural communities. This shows that environmental health services should be scaled up for disease prevention in hotspot areas.

In Perspective of this issue, Muller et al. reviews the history of dengue outbreaks in Fiji and the literature regarding the efficacy of young papaya leaf juice in increasing platelet counts in dengue patients. As solid evidence is still awaited, it will be interesting to see the results of the current clinical trial at the CWM Hospital.

There are several informative reports in Field Note of this issue, which demonstrate the currently available capacity of national and local environmental health team in responding to climate-sensitive diseases in Fiji. The first report summarizes an investigation of outbreak by Subdivisional Outbreak Response Team (SORT), and exhibits a challenge in identifying and treating the healthy carrier responsible for typhoid outbreak. The second report is a success story of improving rural water supply and sanitation through the Master Apprentice Program in selected villages in the Island of Taveuni, engaging the Village Health Workers and Turaganikoro was crucial. The third report is an investigation of outbreak by Subdivisional Outbreak Response Team (SORT), and exhibits a challenge in identifying and treating the healthy carrier responsible for typhoid outbreak.

The 2015 Yanuca Declaration endorsed at the Eleventh Pacific Health Ministers Meeting recognized that “the real and potential impacts of climate variability on health and health systems represent an immediate challenge in the Pacific”, and committed Pacific health ministers to strengthening of environmental health capacity and building climate resilience of the health system in the Pacific.

Climate change is a defining issue of the 21st century. As was mentioned by the Lancet in 2009 and 2015, respectively climate change is the biggest global health threat of the 21st century, and at the same time, tackling climate change could be the greatest global health opportunity of the 21st century. If the health sector leaders actively join and contribute to the national process of implementing the Sustainable Development Goals (SDGs) of the UN General Assembly and the outcomes of the Twenty First Conference of Parties (COP21) of UNFCCC in Paris in 2015, Pacific island countries and areas will benefit enormously from global climate financing mechanisms such as Green Climate Fund (GCF) in building health resilience to climate change in the coming years.
Global climate change is a significant health hazard faced by humankind. The World Health Organization (WHO, 2009a) explained that the changing climate will inevitably affect the basic requirements for maintaining health which includes clean air and water, sufficient food, and adequate shelter. The present warming of the earth and climate variability could increase levels of atmospheric pollutants and a growth in disease transmission due to unclean water and contaminated food (WHO, 2009a). Furthermore, every year air pollution problems contribute to about 1.2 million human deaths and another 2.2 million deaths due to diarrhea caused by insufficient clean water supply and sanitation. About 3.5 million people die from malnutrition each year, and there are approximately 60,000 deaths annually as a result of natural disasters (WHO, 2009a). It is estimated that the health of millions of people will be affected by the impacts of climate change (IPCC, 2007). Such health impacts include: more cases of malnutrition; increased mortality, morbidity and injuries attributed to extreme weather events; a higher burden of diarrheal diseases; advanced rate of cardio-respiratory ailments due to pollution; and the emergence of infectious diseases in new localities. Many of these impacts of climate change will be discussed in more detail below.

The WHO (2003) indicated that weather, climate variability and climate change are the three meteorological-based threats to health. The health impacts associated with changes in climatic conditions are placed into three categories. The first category includes those direct impacts caused by weather or climate extremes. These include injuries and illnesses during or after floods, droughts, windstorms and heat waves. The second category encompasses the impacts of environmental and ecological changes that occur in response to climate change. Examples of this second category include the alterations in the geographical distribution and intensity of communicable diseases that are spread by vectors, rodents, food and/or water. The capacity of climate change to alter ecological systems has been observed to have the potential in favouring disease transmission and the emergence of diseases in areas where they have been non-existent, for example, malaria in south and eastern Africa.

The third category relates to the diverse health impacts like trauma and stress caused by social disruptions to communities, such as loss of homeland or important resources (see also Ebi, 2011; de Wet and Hales, 2000). These three health consequences form a complex ‘cause and effect’ chain from climate change to changing patterns of health determinants and outcomes (Ebi, 2011). Health determinants include wealth, status of the public health infrastructure, access to health care, availability of sufficient and safe water supply and nutrition and sanitation (Ebi, 2011). Thus, the vulnerability of communities to the health impacts of climate change is determined by both climatic and non-climatic factors (Ebi, 2011).

Climate variability and change in Fiji cause severe disasters as a result of droughts, floods or tropical cyclones. A major impact from these disasters is seen in the health sector where there is an observed increase in hospital admissions and treatments from injuries and infectious diseases such as diarrhea, typhoid, dengue and leptospirosis. There is also an influx in malnutrition and stress related ailments. Dengue is identified as one of the four important climate-sensitive diseases in Fiji (Piloting Climate Change Adaptation to Protect Human Health, 2012). The other three important climate sensitive diseases are diarrhea, typhoid and leptospirosis. The National Dengue Strategic Plan (2010-2014), which aims to reduce the disease burden due to major parasitic and vector borne diseases, recommends that research be conducted on the effects of climate change on dengue (Component 6, Expected Result 36, Activity 36.7: 49). Climate models for Fiji have shown that the country’s climate will continue to change (ABM & CSIRO, 2011; GRF, 2012).

There were more than 24,000 reported cases of dengue in the 1997/98 epidemic including 13 deaths with an estimated cost of FJD12 million (Prakash et al., 2001; Singh et al., 2005). Rainfall and temperature (ambient) are the key climate components contributing to dengue epidemic risk in Fiji (de Wet & Hales, 2000). In the Asia-Pacific region, temperature, rainfall and relative humidity are seen as important climatic factors contributing to the growth and dispersion of the mosquito vector and dengue outbreaks (de Wet & Hales, 2000; patz et al., 2005).
In order to reduce the impacts of climate change on dengue incidence in Fiji, it is vital to understand the relationship between dengue and climate change. The aim of this study therefore is to explore the links between dengue incidence and climate variability and change in three localities in Fiji. To do so, this study analyses existing data on dengue incidence and temperature, humidity and rainfall from 1996-2010 for the three selected communities and the relevant subdivisions.

**Study sites and methods**

The districts of Ba, Lautoka and Nadroga were selected because of the consistent and high number of dengue cases reported particularly during epidemics. The Health Information Unit data is sourced from the National Notifiable Diseases Surveillance System (NNDSS) that records cases of dengue reported monthly from health facilities in Fiji. The cases reported to NNDSS are not necessarily confirmed dengue cases. This study recorded dengue incidence as ‘positive’ cases at the district laboratories, divisional laboratory of Lautoka and the national reference laboratory in Tamavua, Suva. ‘In-patients’ at the three hospitals diagnosed with dengue were accounted for dengue incidence as well.

The study was non-experimental and it used a causal-comparative type of research. The variables included dengue incidence (as the dependent variable), as well as temperature, humidity and rainfall (as the independent variables).

Herrera-Martinez and Rodriguez-Morales (2010), in a study in Venezuela, used a descriptive method to collate historical data of reported cases of dengue from its western pediatric hospital. Moreover, it used epidemiological data of weekly records of confirmed dengue cases from 2001-2008, in children below the age of eighteen. This research in Fiji adopted this approach and used data pertaining to three different subdivisions in the Western Division of Viti Levu in Fiji. Campbell-Lendrum et al. (2003) also influenced the choice of research methods as the selection of study sites relied on long-term records available at the Fiji Ministry of Health Information Unit and available climate data at the Fiji Meteorology Services.

The approval of the National Health Research Committee was obtained prior to commencement of data collection. A search for the 1996-2010 dengue data was conducted in triangulation at the Ba Mission Hospital, Lautoka Hospital and Sigatoka Hospital in Nadroga. Data sources included the serology registers within the hospital laboratories, the in-patient registers or PATIS (Patient Information System) and the notifiable diseases files for Ba. Data was inputted and recorded on the Excel spreadsheet. Cases were entered only once unless being re-tested or re-admitted as a result of re-infection. There were follow up visits to address the ‘gaps’ identified after the first set of data collection. The ‘gaps’ consisted of missing or unclear information, such as residential addresses or ages; double entries; and missing registers. Verification was conducted at the Fiji Center of Communicable Diseases Control in Suva.

Missing data in this research is the result of ‘unfound’ registers. Missing information within the available register affected the study in the categorising of cases into proper localities within the studied subdivisions. Extensive in-patient and laboratory registers’ searches were conducted in two hospitals. Despite these efforts, the result of the search could not account for the dengue data for Lautoka for the periods January to December 1996, January to June 1997 and January to March 2001; and for Sigatoka Hospital for the periods January to December 1997 and 1998.

The climate data for the study areas was provided by the Fiji Meteorology Services after following their approval protocols. Data, recorded in the months for the required period, was sent through electronically in Excel.

The two analysis programs used in this study were Excel and SPSS. Specifically, frequency, cross tabulation, correlation and regression were all utilised. Significant outcomes from the statistical analysis are included in the results and analysis sections. The STATA program was also explored for trial modeling with the assistance of the University’s Research Statistician. Missing data was handled as missing values and imputed according to the replacing methods used in SPSS for the fair and complete distribution of data in analysis.

The main limitation was the time taken for approval of the research by the National Health Research Committee which took six months. Then there are missing registers and incomplete entries within the available registers. For the missing registers, the hospital laboratory registers and in-patient registers were used to complement each other; however, there was a shortfall in register storage in Lautoka and Sigatoka hospitals that resulted in some missing values. Incomplete entries had to be cross-checked in the Patient Information System (PATIS) or interview with the laboratory technicians and the hospital recorders. The unavailability or limited access to climatic and health data at the same temporal and geographical scale makes studying the health impacts of climate variability and change difficult (Ebi et al., 2003). Therefore, care must be exercised in analysing and interpreting this data.

**Climate and dengue data analysis: Understanding the relationships**

The results at the three study sites of Ba, Lautoka and Nadroga are presented and discussed with some national dengue and climate data for Fiji. The mean temperatures, humidity and rainfall for Fiji for the period 1955-2009 are presented in Figure 1.

**Figure 1:** The mean values of humidity, minimum temperature, maximum temperature and rainfall for Fiji from 1955-2009.
These averages are consistent with ABM and CSIRO (2011) that specified the average temperature for Fiji to be steadily at 25°C and fluctuating between 20°C and 27°C. The statistics used to analyse the Fiji dengue trend is from the National Notifiable Diseases Surveillance System of the Ministry of Health as graphically presented in Figure 2.

This may indicate that the epidemic started in Lautoka before it expanded to the other nearby districts in the western division. Lautoka is the central business district for the western division and also accommodates the divisional hospital, which could explain this. Lautoka recorded the highest number of dengue cases which quickly peaked for the three epidemics. The 1998 epidemic shows that the first individual cases were reported in 1997, in the months of November and December respectively, for Ba and Lautoka. It peaked in the months of January to March with the last cases reported in May for Ba and June for Lautoka.

The national dengue trend from 1957-2010 shows a significant decline in the number of dengue cases for the progressive epidemic periods. The dengue incidence rate is proportional to the national dengue cases implying that the impact of the epidemic on the given population is the same. Figure 2 indicates that the episodes of the epidemics were occurring at an interval of four to nine years. There were five years that did not record any incidence of dengue from 1957-2010. It was not specified if the recorded ‘0’ for those five years were missing data and unreported cases or there was not any dengue occurrence. The recording of dengue cases in all years indicates that clinical dengue continued to be present even in non-epidemic years. The epidemic in 1975 recorded the highest number of dengue cases followed by the 1997/98 outbreak which registered almost 50% less cases than the 1975 epidemic. It is worthy to note that one of the high annual rainfall (2918mm) years for Fiji was recorded in 1975 and on the contrary 1997/98 was a dry period as the result of El Niño. This result suggests that even though dengue infection is not directly affected by rainfall, it is enhanced by the vector density which is favoured by both conditions experienced in 1975 and 1997/98. The rainy condition of 1975 and the dry spell of 1997/98 may have occurred at a time of inconsistent vector control and surveillance in Fiji resulting in an increase in mosquito breeding containers. Fagbami et al. (1995) and Andre et al. (1992) explained that the 1989 epidemic peaked in October and November 1989 recording about 900 incidences cases of dengue. This is at the end of the cooler dry season from May to October for Fiji and the prolonged impacts of the 1986/87 drought could have exacerbated the dengue epidemic (ABM and CSIRO, 2011). The climatic condition for this period is conducive for the development of the aedes mosquito (WHO, 2003; Patz et al., 2005). Figure 3 shows that the three peaks of dengue epidemics are similar in 1998, 2002/03 and 2008/09 for the three study sites except for Nadroga, 1998 (missing data). Figure 3 shows similar epidemic ‘spikes’ indicating that the epidemics affected the whole of Fiji and not only the study sites.Lautoka records the highest number of dengue cases, as well as an earlier peak, when compared to Ba and Nadroga. It should be noted that Lautoka started registering dengue cases two to three months earlier than the other two study sites.

The total number of confirmed dengue cases in this study from 1996 to 2010 is 1,279: 391 for Ba; 586 for Lautoka and 302 for Nadroga. The total number of dengue cases for the country for the same period is 12,867 indicating a 10% contribution of dengue from the three study sites. This could be understated as the national data provides for all reported cases and this study has used data of confirmed cases.

The study revealed that 53% of those who had dengue in the fifteen-year study period from the three study sites were Indo-Fijians; 41% were indigenous Fijians and 6% belonged to other ethnicities. In comparison to the 1989 epidemic, the national surveillance data revealed that there were more indigenous Fijians (64%) than Indo-Fijians (31%) and the rest were from other minority ethnic groups (Andre et al., 1992). There were more males than females affected and the highest number of dengue patients was from the age of eleven to twenty closely followed by those aged twenty one to forty years. The trend shows that the very active and younger age-groups are more vulnerable than those in the older age demographics. Results of this study indicate that the population below the age of forty has a higher risk of contracting dengue particularly during an epidemic.

The next set of figures compare the dengue incidence time-series with the minimum and maximum temperatures for the three study sites of Ba, Lautoka and Nadroga.
Figure 4 shows that the dengue cases are being recorded in the months that display higher temperatures. Temperature (ambient) is one of the key climate components contributing to dengue epidemic risk in Fiji (de Wet and Hales, 2000). Dengue outbreaks are determined by the presence of a vulnerable individual, the dengue virus and its vector mosquito which are temperature dependent (WHO, 2003; Patz et al., 2005). Ling Hii et al. (2009) explained that aedes mosquitoes have shortened reproduction rates at higher temperatures of 32°C and their feeding rate is doubled as compared to lower temperatures of 24°C. Focks and Barrera (2007) explained that the mosquitoes become infective earlier than usual and bite more frequently, increasing the rate of dengue virus transmission as the gonotrophic cycle (reproductive-feeding cycle) are shortened due to higher temperatures.

It is observed in communities in the western division that the young men are more exposed than women to mosquito bites when they are outside from dawn, during the day, and at dusk. The vulnerable age group would be school aged children and part of the work force. Most of the school classrooms in Fiji are not air-conditioned and neither are they equipped with mosquito proofing. The aedes mosquitoes take blood meals during the day, from dawn to dusk. Therefore, during an epidemic, the vulnerable individuals are those that are exposed and attract the infected mosquitoes during their peak biting hours. The association with temperature in this study considers that the ‘male’ human population in the communities expose themselves with bare upper torsos while involved in physical activities or relaxing outside and inside of their homes during the hot days. Body odour and carbon dioxide are also mosquito attractants, which may explain the impacts on the more ‘active young’ age group.

It is also noted that the use of air-conditioning units and mechanical ventilation can reduce the vector-human contact thus decrease dengue risk. Therefore, limiting exposure can be a reason for the inability of a single case to develop into an epidemic. Vector surveillance and control program in place could interrupt the transmission of the dengue virus thus containment of single sporadic dengue cases from progressing into an epidemic. The comparison of dengue incidence with humidity and rainfall for the three study sites is presented in Figure 5.

Figure 5 shows a period of low rainfall in the months prior to the epidemic of 2002/03 in Ba while the 1997/98 and 2008/09 epidemics peaked during the dry season. El Niño events also affected Ba in 1997/98 reducing rainfall by about 20-50%. Dengue cases continued to be registered in Ba even after January of 2009, which recorded the highest rainfall for Ba from 1996-2010. The 2008/09 epidemic had the lowest incidence as compared to the earlier epidemics in the 15 year period under study. The trend observed for Lautoka in Figure 5 indicates that there were peaks in the dengue cases during the dry season for the 2002/03 and 2008/09, while the 1997/98 epidemic peaked after the dry season. In addition, there were registered dengue cases in Lautoka after the district started recording some rainfall.

The 1998 epidemic generally followed a period of dryness in the three districts. GRF (2012) stated that moderate to strong El Niño events reduce rainfall by about 20-50% as experienced in 1997/98 resulting in major droughts over most part of Fiji. This impacted dengue incidence as described by de Wet and Hales (2000) that the 1997/98 epidemic was the worst in Fiji with about 24,000 cases, 17,000 hospital admissions and 13 deaths occurred during a severe drought period relating to the El Niño event. Local climate changes associated with ENSO affects dengue occurrence by causing changes in household water storage practices and surface water pooling (Hales et al., 2003). The Fiji Meteorology Services reported in 2003 that the 1997/98 drought was the worst to affect Fiji in the twentieth century and it contributed to a dengue outbreak in Fiji (FMS Report, 2003). The need for water was critical thus an increase in water storage in containers including drums. These water storages are potential mosquito breeding zones when not properly protected with lids and covers.
In addition, the transportation of stored waters to new areas is also a means of disseminating the vector and its infectious agents, thus increasing the risk of dengue transmission to other localities.

Rainfall, by itself, is not a useful predictor of epidemic risk, but the abundance of breeding sites, which is important in terms of adaptation to climate change (de Wet and Hales, 2000). This highlights the need for stagnant water for mosquito breeding and humid conditions for adult viability. The 2002/03 and 2008/09 epidemics show similar rainfall trends for the three sites which is very low rainfall between two to three months before the dengue outbreaks. However, Figure 5 shows that the ensuing epidemics occurred during the months of very high rainfall in the study sites. Pham et al. (2011) and Chowell et al. (2011) noted that more rainfall increases the breeding of mosquitoes in the available potential breeding containers, which contributes to more mosquitoes and thus a greater chance of having more female mosquitoes that are capable of carrying the dengue virus. Projections by ABM and CSIRO (2011) show that extreme rainfall days are likely to occur more often in Fiji, which highlights the need for mosquito breeding grounds to be eliminated as part of adaptation initiatives focused on reducing dengue incidence due to rainfall. This factor was termed by Degalier et al. (2009) as ‘environmental controls’. It is concluded from this that despite the presence or absence of rainfall, controlling the mosquitoes’ breeding and harbouring environment will reduce dengue transmission risk.

This study found humidity to be showing very little variation and similarly for its little impact on the studied dengue incidences. There was variability in humidity before and during the three epidemics in the study period. However, researchers and dengue control agencies should be mindful that studies have shown relative humidity to be an important climatic factor contributing to the growth and dispersion of the mosquito vector and dengue outbreaks (de Wet and Hales, 2000; Patz et al., 2005).

Pearson correlation analysis was used to demonstrate the status of significance of the association between dengue incidence and the climate variables (Table 1).

**Table 1: Correlation summary of dengue cases and climate variables for the study sites**

<table>
<thead>
<tr>
<th>Climate variables</th>
<th>Correlation</th>
<th>P-Value</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Ba</td>
<td>Ltk</td>
</tr>
<tr>
<td>Maximum Temperature</td>
<td>.248</td>
<td>.189</td>
</tr>
<tr>
<td>Minimum Temperature</td>
<td>.198</td>
<td>.129</td>
</tr>
<tr>
<td>Rainfall</td>
<td>.007</td>
<td>.027</td>
</tr>
<tr>
<td>Humidity</td>
<td>-</td>
<td>-.018</td>
</tr>
</tbody>
</table>

Pearson correlation analysis has identified some statistically significant results, which confirms that these results were not simply due to chance. In Ba, dengue incidence is significantly correlated to temperatures (minimum and maximum) whereas in Lautoka the correlation of dengue and maximum temperature alone is statistically significant and in Nadroga the correlation of dengue incidence and rainfall is statistically significant. Van Kleef et al. (2009) and Ebi (2011) verified that the geographic boundary of dengue cannot be determined by the effects of climate variability and change alone in a given locality.

Other factors such as mosquito control and surveillance, available breeding sites for mosquitoes, poverty, and individual and communal lifestyles that contribute to exposure to infected mosquitoes all contribute in varying ways to dengue incidence in different localities.

**Transmission patterns: Understanding the risks**

This section uses the dengue data to chart the transmission patterns and geographical distribution of dengue in Ba for the first ten confirmed cases during the 2002/03 epidemic and for Lautoka in 2008/09.
While the first dengue case in the 2002/03 epidemic in Ba did not have a confirmed address the second and fourth cases were reported from Raviravi - an integrated residential and agricultural area that is dominated by sugar cane farming. The residents are mostly Indo-Fijians who are also fishermen living near the coast. The two cases were reported within ten days of each other but there was no certainty on their exact locations to assume 'clustering'. There were three cases recorded on the same day and they were all logged in as three different thirds on the list. These cases were from Namosau, Navau and an unknown address. Areas such as Moto, Nailaga, Rakawai, Raviravi, Vatalaulau and Varadoli recorded more than ten cases in a single eight to nine month duration epidemic. These areas are highly populated and are not spatially connected to each other. It is observed that there are more cases within the urban area and the immediate peri-urban areas such as Vatalaulau, Namosau, Rakawai and Tauvegavega. However, the spread into the rural areas is noted in Ba for the 2002/03 epidemic.

Figure 7 highlights the clustering of cases within the periphery of the city of Lautoka. This validates the information that dengue is an urbanised disease. The first dengue case in the 2008/09 epidemic in Lautoka was reported from Simla, an upper middle class residential area at the periphery of Lautoka city. Simla accumulated a total of nine dengue cases in this outbreak and later recording the twenty-third, two twenty-fourth and the twenty-fifth cases. These latter cases (four) were reported within three days and clustering could have been identified if the specific addresses of the patients were made available to determine spatial spread between the cases.

There were three dengue cases reported as second in this study. The three cases were from Lololo a rural community, from Sukanaivalu Road and Takakubu which are neighbouring communities close to the city. Lololo recorded only one case while Sukanaivalu Road which also confirmed the sixth dengue case had four dengue cases and eight cases were from Takakubu. The Waiyavi area, located close to the city recorded the most number of cases at 17 for the 2008/09 epidemic.

The total number of dengue cases for Lautoka in the 2008/09 epidemic was 202 compared to the 280 cases in the 2002/03 episode. The observed decrease in dengue incidence in the two epidemics (2002/03 and 2008/09) could be attributed to the early response in interrupting dengue transmission by the district's public health team in 2008. In addition, changes to infrastructure, water supply and sanitation status in Lautoka contributed to early and effective intervention to address epidemic problem. Lautoka recorded the most number of confirmed cases because of the agglomeration of population and essential services in the second city of Fiji as compared to the other two study areas of Ba and Nadroga. Furthermore, Lautoka is more vulnerable to epidemic occurrences because of its mobile population and the proximity to one of the country's main ports of entry for trade and travel activities from other countries. Singh et al. (2005) implied that the vulnerability of these islands to dengue virus is increased for those receiving travelers and are trading with South East Asia. South East Asia is known to be one of the leading countries with a high burden of dengue epidemics. Dengue affects hundreds of millions of people every year (Hales et al., 2002). Fagbami et al. (1995) noted that dengue was the main cause of morbidity in the South Pacific region.

Conclusion and recommendations
Statistical correlation analysis used in this study indicates that dengue incidence in the three study sites is related to climate. In Ba, dengue incidence is significantly correlated to the temperatures (minimum and maximum). Lautoka’s dengue incidence is related to the maximum temperature implying that as the maximum temperature increased in Lautoka there was also an increase in dengue cases. In Nadroga, the association was observed for dengue incidence and rainfall concluding that there were more cases of dengue during the period of high rainfall. This finding mirrors that of other studies including Chen et al. (2010) who concluded that warmer temperatures (with a three month lag) contribute to increased rates of dengue fever transmission in Southern Taiwan. Moreover, Chowell et al. (2011) confirmed that the highly persistent and large outbreaks in Peru occurred most frequently during the heavy rainy season, when favourable environmental conditions promoted vector development. Similar to the findings in Chowell et al. (2011), the 2002/03 and 2008/09 epidemics in the study sites occurred during the heavy rainy season.
Climatic factors do not influence the occurrence of dengue in isolation. Localised environmental factors and socio-economic conditions of the study communities influence this incidence of dengue. In conclusion, the study reveals that the risk of dengue transmission increases with climate variability and change if the non-climatic factor of mosquito control and surveillance is poor. Climate projections for Fiji have shown that the country’s climate will continue to change. The temperature in Fiji will continue to rise by at least an estimated range of 0.4-1.0°C by 2030 (ABM and CSIRO, 2011; GRF, 2012). There would be more very hot days and warm nights and a decline in cooler weather. It is predicted that extreme rainfall days are likely to occur more often in Fiji. This study has shown how climate influenced the dengue incidence in Ba, Lautoka and Nadroga citing literature of mosquitoes’ dependence on climate in the crucial periods of reproduction, maturation and survival. Therefore, it is essential that public health infrastructure is strengthened to combat the threat of climate change and its impact on dengue incidence.

The responsibility of data storing and archiving should be well comprehended by relevant authorities within the Ministry of Health and appointment to such positions be guided by principles and accountabilities from Fiji’s Archives Department. Capacity building within the health facilities that collaborate with public health in dengue management is correspondingly essential. In addition, improvement and wider coverage of PATIS should be considered so that specific disease databases can be reliably and easily accessed.

In proposing this recommendation, it corresponds to earlier assertions by Woodward et al. (2000) that vulnerable nations need social policies that are capable of transferring economic developments into human capacity building. The responsibility is positioned upon the leaders of agencies that can make the required changes, particularly those in the public health hierarchy. The implementation of the preceding recommendations has the potential to address other climate-related health issues in Fiji and other Pacific island countries.

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Early warning systems for climate-sensitive infectious diseases in Fiji: lessons learned and next steps


Keywords: Early warning systems, climate - sensitive infectious disease

Abstract

Background: The Piloting Climate Change Adaptations to Protect Human Health (PCCAPHH) project in Fiji has as one of its three main objectives the establishment and trialling of climate-based early warning systems for climate-sensitive infectious diseases, which have been tested and implemented for climate-sensitive health risks such as heatwaves, dengue fever and cholera elsewhere in the world.

Aims: This paper summarises the relevant literature on climate-based disease early warning systems in the Pacific context, and describes the methodology and results of the analysis of climate and diarrhoeal disease data for Ba and Suva subdivisions – the two PCCAPHH project pilot sites – in an effort to determine whether a climate-based early warning system for diarrhoea may be implemented by the Fiji Ministry of Health.

Methods: Negative binomial regression of climate and diarrhoeal disease data was undertaken, and models built incorporating climatic factors at different temporal (monthly) lags. The best models for Ba and Suva subdivisions were used as the basis for the construction of a “diarrhoea risk index” based on an anomaly function, which used as a reference the observed numbers of cases over a long-term trend.

Results: Diarrhoea risk index models were constructed for both Ba and Suva subdivisions, and an early warning system mechanism based on these models and novel linkages between key stakeholders (including the Fiji Meteorology Service, Fiji Ministry of Health and community agencies) is proposed.

Conclusion: Climate-based early warning systems, such as those proposed for diarrhoeal disease in these two pilot sites in Fiji, form part of a suite of health system adaptation measures which may be used to protect human health from short-term hydro-meteorological disasters such as floods, as well as the longer term detrimental impacts of climate change.

Introduction

Early warning systems (EWSs) are a concept originating in the field of disaster risk reduction and are predicated upon the provision of timely information enabling actions to minimise the impact of an anticipated event. EWSs have long been considered to be one of the key opportunities for the health sector with respect to climate change and health adaptation (Connor et al., 2010; WHO, 2003), including in the setting of small island developing states (SIDS) (Ebi et al., 2006).

The empirical basis of an early warning system rests on three fundamental assumptions: that of biological plausibility, where-in environmental or other natural phenomena are logically and provably linked to a particular hazard or outcome; that of temporal lag, whereby sufficient time lags between the warning signs and the event occurrence to enable appropriate action; and that of intervention feasibility, which implies that it is possible to take anticipatory or avoidant action to minimise the impact of the event.

The common ground between disaster risk reduction and climate change adaptation is increasingly recognised within national and international adaptation frameworks, including those issued by organisations such as the United Nations Office for Disaster Risk Reduction (UNISDR), the International Federation of the Red Cross (IFRC) and the World Health Organization (WHO).

In the Pacific region, several countries have compiled Joint National Action Plans for climate change and disaster risk reduction (JNAPs), including Cook Islands, Marshall Islands, Nauru, Niue, Tonga and Tuvalu (SPREP, 2013), and a forthcoming report by WHO entitled Human Health and Climate Change in Pacific island countries summarises the efforts and plans of Pacific island countries (PICs) to increase the resilience of health systems to both climate change and natural disasters (WHO, in press).

Disaster risk practice is therefore a suitable starting point for consideration of climate-based EWSs for health risks (e.g. epidemics of communicable disease), since there are established resources, policies and experience in this field.

EWSs have been defined as: “The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss” (IFRC, 2012).

Implicit in the idea of an EWS is a high degree of shared understanding about the nature of the hazard, the reasons for the warning and the nature of action, including preparation that is needed to reduce loss or harm. An EWS must be based on sound knowledge of risks and the risks must be able to be monitored or forecast. But EWSs are more than just prediction tools; to be effective, they must include mechanisms to disseminate and communicate critical information, and enable interventions that are proactive (as opposed to reactive or responsive), appropriate, timely and sufficient (Basher, 2006).

There is increasing international interest in EWSs. Many international agencies and non-government organisations (NGOs) are developing programmes and resources to support the expansion of early warning capacity. This expanded interest appears to be based in part on the effectiveness of early warning systems in reducing mortality from severe weather events such as storms (Ebi & Schmier, 2005), and more recent observations of a similar potential for such reductions in relation to heatwaves (Huang et al., 2013).

Climate-based EWSs for health hazards such as communicable disease epidemics are a relatively recent development, and are less well developed than those used to anticipate the health impacts...
of natural disasters and extreme weather events. There is convincing evidence that many communicable diseases of global concern are climate-sensitive, including vector-borne diseases such as dengue fever (Chowell et al., 2011; Hii et al., 2012) and malaria (Thomson et al., 2006; Yu et al., 2014); zoonoses such as leptospirosis (Weinberger et al., 2014); and water- and food-borne diseases causing diarrhoeal illnesses and other gastrointestinal infections (Hashizume et al., 2007; Singh et al., 2001; Wu, Yunus, Streathfild & Emch, 2013).

Each of these climate-sensitive diseases differ in terms of the empirical basis for early warning systems – i.e. the above mentioned fundamental assumptions of biological plausibility, temporal lag and intervention feasibility. To take one example, vector-borne diseases such as dengue fever and malaria are driven, in part, by the relationship between mosquito life cycle breeding habitats, larval multiplication, biting behaviour and viral replication, all of which may be affected by environmental factors such as rainfall, temperature and humidity (Bouzid et al., 2014; Hunter, 2003). However, these factors together form only part of a much larger and more complex ecological system which includes human behaviour, individual and herd immunity, spatial dynamics, intervention measures and myriad other factors. In another example, the case of diarrhoeal diseases, the many pathogens causing gastrointestinal infection may be affected by temperature – with many bacteria and viruses replicating faster at higher temperatures – and rainfall, particularly in the extreme, i.e. scarcity (e.g. drought) and abundance (e.g. flood), when drinking water sources are more prone to contamination and the safety of water, sanitation and hygiene systems are compromised (Falagas et al., 2010; Wu et al., 2013).

While it is outside the purview of this paper to elaborate in further detail the complexities of these ecological links, it is clear from the rapidly expanding body of evidence on the topic that environmental and climate factors are significant links in the mechanistic models of disease, and are thus correlated, to varying degrees, with climate-sensitive disease dynamics. There are also sound theoretical reasons to expect that early interventions might be beneficial to reduce the burden of climate-sensitive infectious diseases. A framework for the development of EWSs for climate-sensitive infectious diseases has been proposed (see Figure 1).

Major national and international collaborative efforts are underway to develop climate-based models for early warning of outbreaks of, inter alia, malaria, dengue fever, diarrhoeal disease and meningitis (WHO & WMO, 2012), including some Pacific-specific models, such as that developed for dengue fever in New Caledonia (Descloix et al., 2012). However, the science of climate-based disease EWSs is still in its infancy, scant progress has been made to date in testing and evaluating such models and, despite the abundant recommendations for the utilisation of EWSs as health adaptations to climate change, most such systems remain in the theoretical domain at present.

This paper discusses the development of a climate-based EWS for diarrhoeal illness in Fiji. Fiji is one of seven countries involved in a global climate change and health adaptation pilot project entitled Piloting Climate Change Adaptations to Protect Human Health (PCCAPHH), along with Barbados, Bhutan, China, Jordan, Kenya and Uzbekistan. The project is implemented by the Fiji Ministry of Health (MoH), funded by the Global Environment Facility (GEF), and facilitated by WHO, in collaboration with the United Nations Development Programme (UNDP). The project’s overall aim “...to increase adaptive capacity of national health system institutions, including field practitioners, to respond to climate-sensitive health risks” is to be achieved via three main outcomes, the first of which is to devise an EWS “…to provide reliable information on likely incidence of climate-sensitive diseases”.

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**Figure 1. Framework for developing EWSs for climate-sensitive diseases (Source: Kuhn et al., 2005)**

<table>
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<tr>
<th>Data requirements</th>
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<tr>
<td>Weekly or monthly incidence data</td>
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<td>Frequently updated data on rainfall, temperature, humidity, stream-flow, vegetation indices</td>
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<tr>
<td>Regional and national seasonal forecast, drought and surveys</td>
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<td>Population migration and displaced person</td>
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<td>Supplementary data (as capacity allows)</td>
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<td>Entomological indices</td>
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<td>Parasitological indices</td>
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<td>Drugs resistance testing</td>
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<tr>
<th>Vulnerability assessment</th>
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<tr>
<td>• Evaluate epidemic potential of the disease</td>
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<td>• Identify geographical location of epidemic-prone populations</td>
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<tr>
<td>• Identify climatic and non-climatic disease risk factors</td>
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<tr>
<td>• Quantify the link between climate variability and epidemic</td>
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<tr>
<th>Early warning and detection components</th>
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<tr>
<td>• Seasonal climate forecasts (lead-time in months – low geographical resolution)</td>
</tr>
<tr>
<td>• Monitoring of disease risk factors (lead-time in weeks or months – higher geographical resolution)</td>
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<tr>
<td>• Disease surveillance (lead-time negligible-confirmation of epidemic in process)</td>
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<tr>
<th>Control response</th>
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<tr>
<td>• Assess opportunities for timely vector control and act accordingly</td>
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<td>• Raise community awareness and call for greater personal protection</td>
</tr>
<tr>
<td>• Ensure prompt and effective case management</td>
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<th>Post-epidemic assessment</th>
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<tr>
<td>• Was the early warning system useful</td>
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<tr>
<td>• Were the indicators sufficiently sensitive/specific?</td>
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<tr>
<td>• Were effective preventive/treatment control opportunities enabled?</td>
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<tr>
<td>• What were the strengths/weakness in control operations?</td>
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<tr>
<td>• Does the epidemic preparedness plan need to be modified?</td>
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<tr>
<th>Implementation measures</th>
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<tr>
<td>Develop national and district epidemic response</td>
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<tr>
<td>Plans – define range of control interventions – assign clear roles and responsibilities</td>
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<tr>
<td>Identify data sources and indicators</td>
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<tr>
<td>Identify key informants (this may be in other sectors, e.g. Food security, drought/flood monitoring)</td>
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<tr>
<td>Carry out cost-effectiveness analysis of timely preventative control and treatment options</td>
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The PCCAPHH project in Fiji focuses on four priority climate-sensitive communicable diseases – diarrhoeal disease, dengue fever, leptospirosis and typhoid fever – that are collectively considered to be the country’s “four plagues”. An extensive review of these four diseases was conducted in the early stages of the project, including the epidemiology, distribution and climate-sensitivity of each disease, and the identification of “hotspot” subdivisions and subsequently two project pilot sites, where the burdens of disease appeared to be highest and/or the climate-sensitivity seemed strongest, and the potential for public health intervention(s) to reduce the contemporary and future burden of such climate-sensitive diseases was deemed greatest (McIver et al., 2012).

In this paper, the process of devising and implementing an EWS for diarrhoeal disease in the two regions of Fiji selected as the PCCAPHH project pilot sites is described, including the methodology and results of statistical modelling of climate and disease data, and the mechanism by which such a system may be implemented in Fiji.

The analysis and discussion that follow are limited to consideration of the climatic drivers of diarrhoeal disease in two regions in Fiji. It must be understood that the environment in general, and climate in particular, form only a relatively small piece of the overall picture of the epidemiology of diarrhoeal disease in Fiji.

There are many other, important factors that contribute to the burden, or alleviation, of diarrhoeal disease in these two pilot sites and other regions in Fiji; detailed discussion of these factors is outside the purview of this paper, which focuses on the potential for climatic factors to form the basis of an EWS as a pilot strategy for climate change adaptation in Fiji.

In addition, the implications of EWSs as a health adaptation strategy in the context of Pacific SIDS are discussed, including some of the foreseeable challenges and opportunities. It is hoped that the lessons learned from this pilot project in Fiji will prove useful in the wider landscape of climate change and health adaptation, both in the Pacific region and in other settings around the world.

**Methods**

This study focussed on the potential for climate-based early warning systems to provide timely information regarding increased incidence of diarrhoeal disease in the two PCCAPHH project pilot sites of Ba and Suva subdivisions (see Map 1). A number of key factors determined the selection of these two subdivisions as pilot sites for the project. Principal among these factors were the differing climates on the two sides of the main island of Viti Levu without hyphon (Suva being in the wetter south-west region and Ba in the drier north-east), the burden of diarrhoeal diseases and the other three climate-sensitive diseases prioritised in the PCCAPHH project (dengue fever, leptospirosis and typhoid fever), and the climate-sensitivity of the diseases themselves – i.e. the extent to which each of the diseases appeared to be associated with climatic factors and thus amenable to intervention with early warning (McIver et al., 2012).

Map 1. Regions (medical subdivisions) of Fiji shaded according to average annual diarrhoeal disease incidence (per 100 000 population) over the period 1995-2009, with stars indicating Ba and Suva subdivisions.
Data
Available weather variables included: monthly average of daily minimum (Min) and maximum (Max) temperatures (°C); monthly average of daily average relative humidity (RH) (%); and total monthly rainfall (RR) (mm). The rainfall variable was transformed using log10 (1+RR) due to substantial skew, thus limiting the effects of outliers on model validity. The monthly timescale was selected for two principal reasons: first, there is a strong precedent in the literature on environmental epidemiology and time series analysis supporting the use of monthly temporal windows; second, both meteorological and disease data were available in raw form at monthly average and/or aggregate timescales, whereas daily or weekly timescales would have required some form of imputation or transformation of one of the two datasets, thus introducing another potential source of error. Missing weather values for Ba were imputed using linear regression on the other three variables, the previous month’s value of the missing variable, and year and month as factors. Where other weather variables were also missing in the same month, the regression was limited to year, month and the previous value. In Ba, one implausibly low value of maximum temperature was deleted (April 2006, 25.3°C), then imputed to 32.1°C.

Diarrhoeal disease data was sourced from Fiji’s National Notifiable Disease Surveillance System (NNDSS). Weekly notifications of the number of cases of diarrhoeal disease from all medical areas within each subdivision over the study period of 1995-2009 were collated into monthly datasets. Given that the NNDSS is the standard reporting system for notifiable diseases across Fiji, it is assumed, for the purposes of this study, that both the validity of the data and potential sources of bias are consistent between the two subdivisions under study. Similarly, while there may be intrinsic differences between the scope and effectiveness of public health practice (including data collection and practical action) between the two subdivisions, it is outside the scope of this study to address these and other related sources of error and bias, so it is assumed that both subdivisions have equal capacity to report and react to information.

The models presented below analyse total monthly reported cases of diarrhoeal disease ignoring age, sex and race, and attempt to capture the variation in these rates as functions of time (long-term trend and month of the year) and recent weather (up to 12 months past). Such models are purely empirical, in that they do not attempt to take into account biological or other mechanistic factors which may confound or otherwise affect the relationship between climate variables and cases of diarrhoeal disease.

Model building
Monthly disease rates were modelled using negative binomial regression. This class of model is standard for analysing count data that are overdispersed, i.e. that are more variable than a Poisson model would assume. Long-term trend was captured using orthogonal natural splines with six degrees of freedom, generated using the “splinegen” function in Stata - a data analysis and statistical software package (Stata Corporation, College Station, Texas). Annual cycles were captured using cosinor analysis, that is, sine and cosine functions that repeat once, twice or more within a year and are assumed to apply identically in every year. The required number of harmonics was determined by comparison with a model that treated months as a 12-level factor: the number of harmonics was set to the minimum, such that the factor model was not a statistically significant improvement, since this indicated that the cosinor model had captured all important cyclic annual variation in disease rates. In a baseline model for each disease analysed in each location, each of the four weather variables was modelled as distinct effects at lags 1 (the previous month) to lag 12 (one year ago). Lag 0 (the current month) was not used in the models as it would not be available for predictive purposes, i.e. early warning.

The baseline model thus included trend, cycles, and up to twelve monthly lags for each weather variable.

From this baseline model, simple summaries of one or more weather variables were identified visually. For example, if a certain range of lags appeared to have a strong and similar effect on disease risk, then the average over those months was deemed a reasonable representation of the effect of that variable for the purpose of modelling that disease in that location. These summary measures, or weather indicators, were then used in a new model to obtain coefficients and to re-estimate monthly effects.

An index was then constructed incorporating the monthly effects (i.e. time of year) and the weather indicators with their coefficients. The association of past disease rates with the index was examined in order to locate a threshold above which a warning of impending disease might be issued.

Alternative methods for model-building and validation were considered, including a binary outcome measure (e.g. epidemic month/period versus non-epidemic month/period), and prospective validation. The authors concluded that the diarrhoea anomaly and risk index approach outlined above, and elaborated in the Results section below, provided the best opportunity for piloting an EWS for diarrhoeal disease in Fiji. Future work for the PC-CAPHH project team will include prospective validation of this model, to explore the sensitivity and specificity of the warning capacity of the models.

Results
Substantial numbers of cases of diarrhoea were reported in all twelve months of the year in both subdivisions. While a certain amount of natural variability is to be expected with any disease, the analysis above attempted to control for this natural variability to elucidate the proportion of disease variability attributable to climatic factors. Thus, in the graphs that follow (Figures 2 and 3), the absolute numbers of cases of diarrhoeal disease are less important than the trends, which have been adjusted to best capture the contribution of climatic factors to disease activity. It is important to note that, despite the differences in climate between the two pilot sites, the overall climate in Fiji is tropical, with a wet season from approximately November to April; diseases such as diarrhoeal illness typically increase during this period in Fiji and elsewhere in the Pacific (McIver, 2014). In Ba subdivision, cosinor terms with four degrees of freedom (annual and half-yearly cycles) proved sufficient to capture annual cycles (Figure 2).

Figure 2. Monthly counts of diarrhoea cases in Ba subdivision (1995-2009), adjusted for weather variables and annual cycles (cosinor terms with four degrees of freedom, with spline trend of six degrees of freedom). NB. January values shown as solid circles.
In Suva, once again cosinor terms with four degrees of freedom were sufficient (see Figure 3).

The traces of parameter estimates for the four weather variables in Ba (Figure 4) suggested use of simple predictive indicators. The coefficients were estimated by regression using these indicators: $I_{\text{min}} = \text{average of monthly minimum temperature over lags 6 to 12 (seven months)}$: coefficient -0.447

$I_{\text{max}} = \text{average of monthly maximum temperature over lags 7 to 10 (four months)}$: coefficient 0.782

$I_{\text{rr}} = \text{average of log10-transformed monthly rainfall over lags 9 to 12 (four months)}$: coefficient 1.18

RH: not used.

In addition, an adjustment $K(m)$ for each month $m$ is to be applied, based on a fitted cosinor function. The resulting diarrheal risk index for Ba was calculated as:

$$DRI_{ba} = K(m) + (-0.447) \times I_{\text{min}} + (0.782) \times I_{\text{max}} + (1.18) \times I_{\text{rr}}$$

This index expresses short-term variation in expected incidence of diarrhoea, against a background of more slowly varying disease rate. Therefore, to assess its performance and to identify a diarrhoeal risk alert threshold, the index's value in relation to the ratio of observed cases to the local trend was considered. This ratio, termed "Diarrhoeal Anomaly", is shown in Figure 5.

Since the index is based only on month of the year and weather values at least six months in the past, the index can be projected up to five months into the future. For instance, assuming that in May the weather data for April are available, then the index can be calculated as far ahead as October.

**Table 1: Statistical significance of weather variables (lags 1 to 12, 12df Wald test) in predicting disease frequency.**

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<tr>
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<th>Suva</th>
<th>Ba</th>
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<tr>
<td><strong>Min</strong></td>
<td>0.063</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>0.17</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>RR</strong></td>
<td>&lt;0.001</td>
<td>0.001</td>
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<tr>
<td><strong>RH</strong></td>
<td>0.004</td>
<td>0.098</td>
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**Figure 3.** Monthly counts of diarrhoea cases in Suva subdivision (1995-2009), adjusted for weather variables and annual cycles (cosinor terms with four degrees of freedom, with spline trend of six degrees of freedom). NB. January values shown as solid circles.

**Figure 4.** Coefficients for lagged weather variables in Ba (with 95% CI). The graph for humidity (rh) shows rate ratio per 10 percentage points of relative humidity. The graph for temperature (rr) shows rate ratio per degree of temperature.

**Figure 5.** Diarrhoeal anomaly in Ba (rate relative to trend) against risk index calculated from weather data at least six months prior to the month of prediction.
The traces of coefficients for Suva (Figure 6) suggest no effect of temperature, confirming the significance test. Indicators for RR and RH might be calculated as the difference between lag 3 and lag 12, for both variables, i.e. \( I_{RR} = RR_{3} - RR_{12} \) (using RR on the log scale); and \( I_{RH} = RH_{3} - RH_{12} \). Refitting the model using just these two indicators of weather, plus trend and cycles, gives coefficients -1.00 for \( I_{RR} \) and 0.0815 for \( I_{RH} \). Thus the diarrhoeal risk index for Suva is calculated as:

\[ DRIsu = K(m) + (-1.00) \times I_{RR} + (0.0815) \times I_{RH} \]

**Discussion**

EWS have long been considered one of the most promising areas for innovation in the field of climate change and health adaptation. Climate-based EWSs represent both a challenge and an opportunity for the health sector, in that they may improve the sector’s ability to anticipate events such as epidemics, thus reducing the overall health impact thereof.

There are a number of climate-sensitive infectious diseases of international public health concern in the context of climate change; the majority of these are the subject of various types of research related to climate-based EWSs in different parts of the world (Grasso et al., 2012). While a significant proportion of this research has focused specifically on cholera, diarrhoeal disease more broadly has not yet attracted significant research attention in relation to EWS development.

The work undertaken by the PCCAPHH project, and the mathematical models of diarrhoea risk described above in Suva and Ba – two regions with quite different climates and contrasting socio-demographic indicators - may pave the way for trialling a climate-based EWS for diarrhoeal disease in Fiji. At a conceptual level, there are four distinct questions or tasks in designing an EWS for climate-related health issues. These involve identifying:

- the relevant risk(s) (what it is, where does it exist, and crucially, how important is it?);
- whether it is possible to monitor and/or forecast the risk(s) with sufficient accuracy;
- whether it is possible to communicate the risk in a timely and effective way; and
- whether the population or target sector is able and willing to respond to the communications in a timely and effective way.

In Fiji, the main provider of meteorological analysis and forecasting is the Fiji Meteorology Service (FMS), which has been a key partner in the PCCAPHH project. In collaboration with the FMS, the MoH may be in a position to trial a climate-based EWS for diarrhoeal disease in one or both of the project pilot site subdivisions, based on the models described above, with a lead-time of approximately three of five months for anticipatory interventions to reduce the burden of disease.

For example, in Ba, it appears that high disease risk (rates more than double the current trend) tend to occur at index values above approximately 17.8. All instances of rates more than three times the current trend were associated with index values above this threshold.

In Suva, however, while a clear trend is evident of increasing risk of diarrhoea with increasing risk index, there is ambiguity surrounding a suitable threshold (or early warning system “trigger”). All months where the ratio of incidence to trend exceeded 3 had positive risk index (\( DRI > 0 \)) (see Figure 7). However, if warnings are issued whenever \( DRI > 0 \), based on historical patterns, a majority of warning events will be followed by near normal diarrhoea rates. It would likely therefore prove difficult to define a threshold level of risk for diarrhoeal disease in Suva with sufficient specificity (i.e. avoiding false positives). A proposed mechanism for such an EWS is outlined in Figure 8.

**Table 2. Key components of an early warning system for public health** (Source: Ebi & Schmier, 2005)

<table>
<thead>
<tr>
<th>Component of EWS</th>
<th>Key considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meteorological identification and forecasting</td>
<td>Type of event, Risk of event (probability versus impact), Accuracy, Timing</td>
</tr>
<tr>
<td>Prediction of possible health outcomes</td>
<td>Modelling functions of climate factors and disease risk (e.g. diarrhoea risk index, as described above)</td>
</tr>
<tr>
<td>Response plan</td>
<td>Where will intervention be implemented?, When (including thresholds for action)?, What interventions are to be triggered?, How will the actions be implemented?, Implemented by whom and communicated to whom?</td>
</tr>
<tr>
<td>System evaluation</td>
<td>Monitoring and evaluation of system components and overall effectiveness?, Cost-benefit analysis/economics effectiveness</td>
</tr>
</tbody>
</table>
If the meteorological identification and forecasting components may be assumed to be sufficiently accurate and timely, the next questions are whether or not the forecast can be communicated effectively to the target community, and whether or not effective responses are feasible. Caution must thus be advised when considering such EWSs as health sector-led strategies in developing country settings such as Fiji where, typically, the health system is already at or approaching maximum capacity. Following the flooding disasters in Fiji in early 2012, public and environmental health staff in one of the most affected subdivisions commented that an EWS would be of little or no practical value if adequate/increased resourcing was not also provided to enable the intervention.

It must also be recognised that EWSs based on the models above must take into account the potential sources of error and bias of this study. This include, but are not limited to, systematic errors in data collection, reporting and analysis; intrinsic differences in data validity and/or public health practice between the two study sites; and the inability of the models above to incorporate non-climate factors contributing to disease activity. Future lines of inquiry relevant to this work could, inter alia, include finer spatiotemporal analysis and ecological testing of microbial contamination of water supplies, and the socio-environmental contributors to this process.

At the most basic level, an operationally effective EWS might be achieved by the improved communication of existing weather or climate forecasts to a community that is already willing and able to take appropriate action.

In the case of diarrhoeal disease, such actions may range from temporary relocation to avoid a storm surge, to intensive health promotion campaigns (e.g. targeting household water, sanitation and hygiene measures to reduce the risk of diarrhoea), in addition to alerting health professionals of the likelihood of increased presentations during periods of increased risk.

The evaluation of such systems is, of course, critical to their viability and effectiveness. Along with cost-benefit analyses, a fundamental process is that of information feedback. An “iterative management” approach, which uses monitoring and evaluation to incorporate information feedback to improve the efficiency and effectiveness of such initiatives as an EWS, would be necessary to enhance, over time, the accuracy – in terms of both sensitivity and specificity – of the mechanism (Ebi, 2014). There is also an emerging body of work related to the statistical evaluation of EWS models (Chaves & Pascual, 2007).

With respect to the generalizability of climate-based EWSs as potential climate change and health adaptation measures for other climate-sensitive diseases in Fiji, and comparable risks in other Pacific island countries, it is suggested that EWS development should be attempted initially for the most important health risks. Weighing up the relative importance of different climate risks to health is a difficult task. This is the case even under a steady-state assumption, but even more so if the past is seen to be an unreliable guide to the future, given climate change trends. This is beyond the scope of the present guide to provide detailed advice on this aspect, however, such guidance is available elsewhere (Lindgren et al., 2012).
In many cases, the groundwork will have been done as part of a vulnerability and adaptation assessment, in which case these established priorities should be the starting point for EWS development, as was the case for this project in Fiji.

It is not possible to be definitive in a general sense about the appropriate priority for EWS in the wider context of policy responses to climate change, since such decisions will depend upon local circumstances, and the priority climate-sensitive health risks. Thus a “horses for courses” approach is recommended for climate and health modelling, such as that required for EWS mechanisms (Ebi & Rocklov, 2014).

It is also clear that EWSs should not be seen as a stand-alone response to climate-health risks, but as part of a comprehensive policy response, which combines adaptation measures with, inter alia, mitigation, promotion of health co-benefits and improvements in health systems efficiency and resilience. Integration of EWSs into other, broader primary health care and public health surveillance and response systems will be vital to optimise their effectiveness (Grasso et al., 2012). In Fiji, such integration may be possible in the context of disaster preparedness and response: infectious disease surveillance; food and water safety testing; and the emergency capacity-building activities of bodies such as the Pacific Humanitarian Team. Other opportunities for integration include the potential to use existing meteorological forecast systems, such as the seasonal forecasts provided by the FMS for the agriculture sector, in application to specific disease models (e.g. providing a three month ‘diarrhoea risk outlook’ for the wet season in Fiji).

It is pertinent to note that, in Pacific SIDS, including Fiji, there are many challenges involved in devising and implementing such EWSs as adaptation strategies. These challenges include, but are not limited to, the incompleteness and variable accuracy of both climate and disease datasets; the geographic remoteness of many islands and/or communities; and the lack of physical, human and financial resources for additional health sector activities.

Nevertheless, Fiji and other Pacific island countries also have some inherent advantages which could, theoretically, enable such systems. Such advantages relate primarily to social networks within small populations, whereby information can be relatively easily transmitted between actors and agencies, given the often close ties between individuals and communities. This combination of “bonding” and “bridging” types of social capital which have emerged from the nascent literature on climate change and health governance (Bowen et al., 2014; Bowen et al., 2013) may prove to be particularly relevant in the Pacific.

Such social capital could also be considered to extend across the Pacific region, giving rise to the possibility of a regional network integrating meteorological and environmental determinants of infectious disease risk, along with demographic, socioeconomic and spatial factors, to provide a more comprehensive understanding of the epidemiology of health risks in the region. A potentially very useful example of such multi-disciplinary, trans-border collaboration along these lines is the European Environment and Epidemiology Network*.

Conclusion

EWSs such as that proposed for diarrhoeal disease in these pilot sites in Fiji appear to be a promising adjunct to contemporary public health practice, and a potentially useful innovation in the context of climate change and health adaptation. The analysis described in this paper suggests that an index of diarrhoea risk could be used to determine appropriate thresholds to trigger proactive public health actions aimed at reducing the impact of diarrhoeal disease in Fiji.

While recognising that these are potentially powerful tools to reduce the current and future burden of disease due to climate variability and change, EWSs must nevertheless be employed sparingly and accurately. To paraphrase eighteenth century French philosopher Montesquieu: “Useless warnings weaken necessary warnings.”

Finally, it must be remembered that, in the long term, the most cost-effective response to climate change, including in relation to its detrimental effects on human health, is likely to be mitigation – reducing global greenhouse gas emissions to protect the health of our population and planet.

Acknowledgements

The authors’ sincere thanks go to Ms Kelera Oli and Ms Jyotishma Naicker – respectively, the current and former PCCAPHH Project Coordinators. The authors also wish to acknowledge the invaluable contributions of Mr Steve Iddings and Mr Kamal Khatri (both formerly of WHO South Pacific) and the ongoing support of senior members of the Fiji Ministry of Health, especially Dr Eloni Tora, Chair of the PCCAPHH Project Steering Committee.

References


Investigating vulnerability to climate-sensitive diseases in urban, rural and remote sites in western Fiji


Abstract

The health impacts of climate change are a pressing concern for developing Pacific island countries such as Fiji. Four climate-sensitive communicable diseases have been identified as priorities in Fiji: typhoid, diarrhoeal disease, dengue fever and leptospirosis. This study assessed community vulnerabilities to these diseases in five disease ‘hotspots’ on the western side of the island of Viti Levu. The assessment sought survey information about water and sanitation, shelter, food hygiene, waste management, drainage, and practices relevant to the transmission and prevention of the priority diseases. The findings showed that sanitation, shelter, water quality, mosquito control and hygiene-related behaviours are areas of vulnerability, particularly in rural and remote communities. The needs identified by the assessment will inform adaptation priorities and disease prevention activities tailored to community needs.

Introduction

Climate change threatens the ecological and environmental systems that support life, and thus human health is susceptible to climate change (McMichael AJ et al., 2004). Indeed, connections are increasingly being made out between weather, climate and health challenges such as disease outbreaks (McMichael AJ et al., 2003). Pacific island countries such as Fiji are acutely vulnerable to the health impacts of climate change, due to their exposure to extreme climate events, existing disease burdens and poor economic capacity. Designing and implementing effective adaptation strategies to prevent diseases that are sensitive to climate is a pressing challenge in Fiji, and requires an in-depth understanding of the ways in which communities are vulnerable to climate-sensitive disease. This paper reports the findings of a community risk assessment of 1040 households undertaken in five ‘disease hotspots’ in the western subdivision of Fiji, which aimed to establish a baseline in relation to community vulnerabilities to four communicable, climate-sensitive diseases identified by the Fiji Ministry of Health as priority: dengue fever, diarrhoeal diseases, typhoid and leptospirosis. The assessment investigated water and sanitation, shelter, food hygiene, waste management, drainage, and practices relevant to the transmission and prevention of the diseases in communities variously classified as urban, rural and remote. The assessment findings identify risks and will inform adaptation priorities and disease prevention activities.

Methods

The four target diseases are considered priorities due to disease burden, potential correlations between disease incidence and factors such as temperature, humidity and rainfall, and history of outbreak after extremes of rainfall or temperature, drought, or hydro-meteorological disasters (Technical Working Group, 2011). The sites where the assessment was conducted were identified by the Fiji Ministry of Health as target disease ‘hotspots’. A ‘hotspot’ was defined as a site where two or more of the four priority diseases occurred at higher than average incidence, or in two or more ‘clusters’ (patterns of unusual disease activity) between 1995 and 2009 (Technical Working Group, 2011). The five ‘hotspot’ sites, which represented urban, rural and remote communities, were selected on the west side of the island of Viti Levu. Historically, typhoid, diarrhoeal disease and dengue have accompanied both drought and heavy rain or flooding, and leptospirosis has also occurred in some sites after heavy rain or flooding. Information about the five sites is captured in Table 1 below.

Table 1: Sample characteristics: sites, classification, numbers surveyed

<table>
<thead>
<tr>
<th>Site</th>
<th>Classification: Location</th>
<th>Number of households surveyed</th>
<th>Population surveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>Urban</td>
<td>585</td>
<td>2649</td>
</tr>
<tr>
<td>Site 2</td>
<td>Rural</td>
<td>284</td>
<td>1373</td>
</tr>
<tr>
<td>Site 3</td>
<td>Rural</td>
<td>133</td>
<td>783</td>
</tr>
<tr>
<td>Site 4</td>
<td>Remote</td>
<td>32</td>
<td>180</td>
</tr>
<tr>
<td>Site 5</td>
<td>Remote</td>
<td>6</td>
<td>33</td>
</tr>
</tbody>
</table>

The authors applied International Federation of the Red Cross and Red Crescent Societies Vulnerability and Capacity Assessment Guidelines (IFRC, 2006) to the modification and testing of the 78-question survey tool, which was adapted from an existing Fiji Ministry of Health vulnerability and capacity analysis survey tool. Respondents were first asked for demographic details, and then asked a series of questions about shelter and household characteristics, sanitation, water sources, drainage and surroundings, waste management, food hygiene and behavioural practices. The authors trained 25 Red Cross volunteers living in or close to the sites to be interviewers. The majority of interviewers trained had completed secondary school, all spoke English competently, and a number were able to translate survey questions into either Fijian or Hindi if required. They were trained during a two-day workshop that included sessions about climate change, climate-sensitive diseases, communication techniques, and questionnaire delivery and recording.

During site visits, the interview team aimed for as close to complete coverage as possible and put in place various measures to achieve this: site visits were planned using satellite photos, teams visited sites multiple times and at different times during the day, and interviewers left stickers on dwelling doors that had been surveyed in order to minimise duplication and to highlight households yet to be surveyed. It was difficult to get a clear sense of coverage as records of total numbers of households in each site are either approximate or non-existent, however we estimate that a minimum of 85% of households in each site were surveyed.

Responses were grouped into common themes for analysis. The data was entered and analysed by three trained project staff and volunteers using Epi Info™ software. Regular meetings and problem reporting ensured that data entry staff entered data in a uniform and consistent manner.

Keywords: Climate-sensitive diseases, rural, remote sites

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1 Fijian Red Cross Society

Volume 4, Issue 1, 2015
Results
Sample characteristics

Table 2: Sample demographics

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>50.5</td>
<td>51.6</td>
<td>49.5</td>
<td>53.3</td>
<td>45.5</td>
<td>50.0</td>
</tr>
<tr>
<td>Female</td>
<td>49.5</td>
<td>48.4</td>
<td>50.4</td>
<td>46.7</td>
<td>54.5</td>
<td>50.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fijian</td>
<td>75.1</td>
<td>77.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>30.5</td>
</tr>
<tr>
<td>Itaukei</td>
<td>23.6</td>
<td>21.9</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>69.1</td>
</tr>
<tr>
<td>Others</td>
<td>1.3</td>
<td>0.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Households with at least one member who completed indicated education level

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>96.0</td>
<td>87.0</td>
<td>97.0</td>
<td>93.8</td>
<td>100.0</td>
<td>94.8</td>
</tr>
<tr>
<td>Secondary</td>
<td>83.0</td>
<td>64.0</td>
<td>80.5</td>
<td>56.3</td>
<td>66.7</td>
<td>70.1</td>
</tr>
<tr>
<td>Tertiary</td>
<td>24.0</td>
<td>18.0</td>
<td>9.0</td>
<td>0.0</td>
<td>0.0</td>
<td>10.2</td>
</tr>
<tr>
<td>Vocational</td>
<td>11.0</td>
<td>8.0</td>
<td>24.8</td>
<td>0.0</td>
<td>0.0</td>
<td>8.8</td>
</tr>
</tbody>
</table>

Weekly household income (FJD)

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 100</td>
<td>28.7</td>
<td>65.5</td>
<td>50.4</td>
<td>87.5</td>
<td>83.3</td>
<td>63.1</td>
</tr>
<tr>
<td>100 - 200</td>
<td>35.9</td>
<td>23.3</td>
<td>33.1</td>
<td>12.5</td>
<td>16.7</td>
<td>24.3</td>
</tr>
<tr>
<td>200 - 300</td>
<td>14.0</td>
<td>4.9</td>
<td>8.3</td>
<td>0.0</td>
<td>0.0</td>
<td>5.4</td>
</tr>
<tr>
<td>300 - 400</td>
<td>5.0</td>
<td>1.1</td>
<td>3.8</td>
<td>0.0</td>
<td>0.0</td>
<td>9.9</td>
</tr>
<tr>
<td>400 - 500</td>
<td>3.2</td>
<td>0.4</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>500 +</td>
<td>5.3</td>
<td>1.4</td>
<td>1.5</td>
<td>0.0</td>
<td>0.0</td>
<td>1.6</td>
</tr>
<tr>
<td>Don’t know</td>
<td>7.9</td>
<td>3.5</td>
<td>1.4</td>
<td>0.0</td>
<td>0.0</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Demographic information is reported in Table 2. Ethnic majorities across the sites are markedly different; the populations of the two remote sites and one rural site are wholly Itaukei (ethnic Fijian) whereas over three-quarters of the populations of the two remaining sites are Fijians of Indian descent. The percentage of households that had at least one member that had completed secondary education was high across the five project sites, but the range was broad in relation to secondary education completion: from 56.3% in remote Site 4 up to 83% in urban Site 1, and generally low in relation to tertiary education (from 0.0% in the two remote sites up to 24.0% in the urban site). Across the five sites, 87.4% of households earned $200 FJD or less per week, and of these, 72.1% earned $100 FJD or less. Respondents from urban Site 1 reported earning considerably more than respondents from the sites classified as ‘rural’ or ‘remote’.

Shelter
Findings related to shelter vulnerabilities are reported in Table 3. Approximately one quarter (27.9%) of respondents live in houses that are set at ground level rather than raised off the ground. More than half (between 53.4% and 100%) of the households in the four sites that are classified as rural or remote reported that their shelter was mainly constructed from non-concrete materials, namely wood, corrugated iron, bamboo or grass. An average of 22.6% of households reported having insufficient space for occupants, and the two remote sites led this count at 34.4% and 33.3% respectively.

Table 3: Shelter vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total Sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>House not raised off</td>
<td>15.7</td>
<td>20.4</td>
<td>25.2</td>
<td>28.1</td>
<td>50.0</td>
<td>27.9</td>
</tr>
<tr>
<td>the ground</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>House has insufficient space</td>
<td>5.5</td>
<td>14.4</td>
<td>25.2</td>
<td>34.4</td>
<td>33.3</td>
<td>22.6</td>
</tr>
<tr>
<td>House mainly</td>
<td>38.9</td>
<td>73.2</td>
<td>53.4</td>
<td>100.0</td>
<td>83.3</td>
<td>69.8</td>
</tr>
<tr>
<td>constructed from</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sanitation
Survey findings related to sanitation vulnerabilities are reported in Table 4. Approximately a fifth (19.2%) of households using a flush or water seal toilet reported that it was not connected to a concrete septic tank, most notably in remote Site 4 (43.8% of households). A quarter (26.1%) of households did not have their septic tank connected to a proper soakage pit, and again remote Site 4 reported this issue the most (62.5% of households). Overall, 28.1% of households reported using pit toilets, and in remote Site 5 100.0% of households relied on pit toilets. A majority (82.1%) of households in the five sites reported having no sink near the toilet for hand washing, ranging from 55.4% of households in urban Site 1 up to 100.0% of households in the two remote sites, with the two rural sites sitting between.

Table 4: Sanitation vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit toilet only</td>
<td>4.1</td>
<td>23.2</td>
<td>13.0</td>
<td>0.0</td>
<td>100.0</td>
<td>28.1</td>
</tr>
<tr>
<td>Flush/water seal toilet: Plumbing not working</td>
<td>4.1</td>
<td>27.1</td>
<td>31.3</td>
<td>28.1</td>
<td>N/A</td>
<td>18.1</td>
</tr>
<tr>
<td>Flush/water seal toilet: Not connected to concrete septic tank</td>
<td>4.6</td>
<td>32.4</td>
<td>15.3</td>
<td>43.8</td>
<td>N/A</td>
<td>26.1</td>
</tr>
<tr>
<td>Flush/water seal toilet: Tank not connected to a proper soakage pit</td>
<td>4.3</td>
<td>39.8</td>
<td>23.7</td>
<td>62.5</td>
<td>N/A</td>
<td>26.1</td>
</tr>
<tr>
<td>No sink near toilet</td>
<td>55.4</td>
<td>61.3</td>
<td>93.9</td>
<td>100.0</td>
<td>100.0</td>
<td>82.1</td>
</tr>
</tbody>
</table>

Water supply
Water supply findings are captured in Table 5. Three out of the five sites relied upon tap water almost exclusively, whereas a notable proportion of households in two sites - Site 5 (33.3%) and Site 2 (15.5%) - reported relying exclusively on an unprotected water source, namely river water or spring water. Overall, an average of three-quarters (76.7%) of the households in the five sites did not own a water tank. A majority of households in all five sites (96.6% and 95.1%) reported that both water availability and quality were affected by hydrometeorological disasters and heavy rain, and although few households reported water quality being affected by drought in the urban and rural sites (0.0%, 20.4% and 1.5% of households in Sites 1-3, respectively), 93.8% and 100.0% of households in the two remote sites reported water quality during drought as a problem.

Table 5: Water supply vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 n=100%</th>
<th>Site 2 n=100%</th>
<th>Site 3 n=100%</th>
<th>Site 4 n=100%</th>
<th>Site 5 n=100%</th>
<th>Total sample N=500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household relies on unprotected water source only</td>
<td>4.1</td>
<td>23.2</td>
<td>13.0</td>
<td>0.0</td>
<td>100.0</td>
<td>28.1</td>
</tr>
<tr>
<td>Household relies on tap water only</td>
<td>95.2</td>
<td>51.4</td>
<td>99.2</td>
<td>100.0</td>
<td>66.0</td>
<td>82.4</td>
</tr>
<tr>
<td>Household does not own water tank</td>
<td>65.0</td>
<td>50.7</td>
<td>84.7</td>
<td>100.0</td>
<td>83.0</td>
<td>76.7</td>
</tr>
<tr>
<td>Water availability affected during HMD</td>
<td>99.0</td>
<td>85.6</td>
<td>98.5</td>
<td>100.0</td>
<td>100.0</td>
<td>96.6</td>
</tr>
<tr>
<td>Water quality affected during heavy rain</td>
<td>97.4</td>
<td>78.2</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>95.1</td>
</tr>
<tr>
<td>Water quality affected during drought</td>
<td>0.0</td>
<td>20.4</td>
<td>1.5</td>
<td>93.8</td>
<td>100.0</td>
<td>43.1</td>
</tr>
</tbody>
</table>

Drinking water practices
Households were asked whether they practised water safety measures such as boiling, filtering or purifying, and about storing drinking water. Findings are captured in Table 6. Across the sites, 11.2% of households reported that they never practised water safety measures. Notably, all of the households in remote Site 4 reported that they always practised water safety measures. An average of 10.2% of respondents reported storing water in containers without covers or lids, although all households in remote Site 4 reported storing water in covered containers. Urban Site 2 had the most households reporting never practising water safety measures (21.1%) and storing water in uncovered containers (21.8%).
Food hygiene
Table 7 captures responses related to hygiene and food preparation. Overall, 62.2% of households reported having no sink in the kitchen for washing dishes, hands and fruits and vegetables, although the range was large: from 6.2% in urban Site 1 to 100.0% in Site 5. Approximately half (49.4%) of households reported having no running water connected to the kitchen area, and when urban Site 1 (at 3.8%) is excluded the percentage in the rural and remote sites is considerably higher at 60.8%. All sites reported a high presence of rats in the kitchen (72.9%), particularly rural Site 3 (88.5% of households), which may be explained by the higher percentage of households in Site 3 that report not having an enclosed kitchen (33.6%, compared to the average of 16.5%). Approximately one-fifth of the households (21.7%) reported that they did not store food in cupboards or sealed containers, and the households that reported preparing food on the floor (i.e. not having a kitchen bench for food preparation) ranged from 3.8% in urban Site 1 up to 99.6% in remote Site 4.

Mosquito control
The findings of questions relating to mosquito breeding risks: stagnant water not covered in water seal toilets, water stored in uncovered drums, poor drainage around the home, rubbish disposal within house boundary, and rubbish/debris around the house, are captured in Table 8.

The two rural sites (Sites 2 and 3) had the highest percentages of households reporting poor drainage around the house (51.4% and 68.7% respectively), and that they routinely left stagnant water for flushing water seal toilets uncovered (53.3% and 57.7%). Site 2 also had the highest percentage of households that kept water in uncovered drums (44.7% compared to an average of 24.5%). Remote Site 5 had a high percentage of households (83.3%) that disposed of rubbish in a pit within the house boundary, and over half of the households in all sites (57.6%) had rubbish or debris around the house.

### Table 6: Drinking water storage and safety vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 (n=100%)</th>
<th>Site 2 (n=100%)</th>
<th>Site 3 (n=100%)</th>
<th>Site 4 (n=100%)</th>
<th>Site 5 (n=100%)</th>
<th>Total sample (N=500%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household never practices water safety measures</td>
<td>18.1</td>
<td>21.1</td>
<td>7.6</td>
<td>9.4</td>
<td>0.0</td>
<td>11.2</td>
</tr>
<tr>
<td>Household stores water in uncovered containers</td>
<td>7.7</td>
<td>21.8</td>
<td>4.6</td>
<td>0.0</td>
<td>16.7</td>
<td>10.2</td>
</tr>
</tbody>
</table>

### Table 7: Food preparation and hygiene vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 (n=100%)</th>
<th>Site 2 (n=100%)</th>
<th>Site 3 (n=100%)</th>
<th>Site 4 (n=100%)</th>
<th>Site 5 (n=100%)</th>
<th>Total sample (N=500%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No sink in kitchen</td>
<td>6.2</td>
<td>33.8</td>
<td>74.0</td>
<td>96.9</td>
<td>100.0</td>
<td>62.2</td>
</tr>
<tr>
<td>No running water to kitchen</td>
<td>3.8</td>
<td>30.3</td>
<td>58.8</td>
<td>87.5</td>
<td>66.7</td>
<td>49.4</td>
</tr>
<tr>
<td>Evidence of rats in kitchen</td>
<td>68.5</td>
<td>58.8</td>
<td>88.5</td>
<td>65.6</td>
<td>83.3</td>
<td>72.9</td>
</tr>
<tr>
<td>No food preparation bench</td>
<td>3.8</td>
<td>17.6</td>
<td>51.9</td>
<td>90.6</td>
<td>66.7</td>
<td>46.1</td>
</tr>
<tr>
<td>Kitchen not enclosed</td>
<td>5.0</td>
<td>8.5</td>
<td>33.6</td>
<td>18.8</td>
<td>16.7</td>
<td>16.5</td>
</tr>
<tr>
<td>Food not stored properly</td>
<td>6.2</td>
<td>13.7</td>
<td>28.2</td>
<td>43.8</td>
<td>16.7</td>
<td>21.7</td>
</tr>
</tbody>
</table>

### Table 8: Mosquito control vulnerabilities

<table>
<thead>
<tr>
<th></th>
<th>Site 1 (n=100%)</th>
<th>Site 2 (n=100%)</th>
<th>Site 3 (n=100%)</th>
<th>Site 4 (n=100%)</th>
<th>Site 5 (n=100%)</th>
<th>Total sample (N=500%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water seal toilet: Stagnant water not covered</td>
<td>0.9</td>
<td>53.3</td>
<td>57.7</td>
<td>N/A</td>
<td>N/A</td>
<td>22.4</td>
</tr>
<tr>
<td>Water kept in uncovered drums</td>
<td>26.5</td>
<td>44.7</td>
<td>34.4</td>
<td>0.0</td>
<td>16.7</td>
<td>24.5</td>
</tr>
<tr>
<td>Poor drainage around house</td>
<td>32.6</td>
<td>51.4</td>
<td>68.7</td>
<td>37.5</td>
<td>33.3</td>
<td>44.7</td>
</tr>
<tr>
<td>Household dispose of daily rubbish in a pit</td>
<td>37.6</td>
<td>64.1</td>
<td>25.2</td>
<td>53.1</td>
<td>83.3</td>
<td>52.7</td>
</tr>
<tr>
<td>Rubbish/debris around house surroundings</td>
<td>43.9</td>
<td>52.5</td>
<td>68.7</td>
<td>56.3</td>
<td>66.7</td>
<td>57.6</td>
</tr>
</tbody>
</table>
Discussion
The findings offer detailed insights into conditions and practices associated with vulnerability to climate-sensitive diseases in the survey sites.

Demographic data gives insight into site language needs, cultural expectations, economic capacities and education levels, essential for tailoring adaptation initiatives. The different ethnic minorities in the five sites will impact upon approaches to adaptation planning. In addition, the more remote sites have relatively low levels of secondary education, which should be taken into account in the design of health promotion interventions and messages. An understanding of income levels and disparities is also relevant to adaptation measure design. As incomes are generally low, particularly in remote sites, the affordability of adaptation and disease prevention measures must be considered.

The data shows that the majority of households report that their shelter is vulnerable to extreme weather. However, specific shelter vulnerabilities vary: ground-level housing can be flooded in low-lying sites; overcrowding is more prevalent in the two remote sites than in the other sites; and all sites apart from urban Site 1 have a majority of shelters constructed out of non-concrete materials like wood, tin and woven grass that may be more vulnerable to strong winds or heavy rain than concrete houses. A variety of adaptation measures can be planned to respond to the highlighted shelter issues that could impact upon health. Promoting ways to stop water entering homes and to strengthen shelters is relevant to communicable disease prevention: reducing exposure to flood waters and minimising stays in evacuation centres, where conditions can become unsanitary, are potential outcomes. Where overcrowded housing is reported, adaptations that emphasize healthy behaviours such as promoting hand washing and good hygiene can help reduce the risk of diseases related to unsanitary conditions such as diarrhoea and typhoid.

Sanitation is particularly relevant to two of the target diseases (typhoid and diarrhoea) which can spread through contaminated water and food, and insects such as flies. A considerable number of households in the two rural sites and one remote site report that their toilets are not connected to concrete septic tanks; anecdotal evidence collected by interviewers suggests that steel drums, which have small capacity and may overflow, deteriorate or collapse, are widely used instead. The data also shows where septic tanks are used, proper soakage pits are often not installed, a particular problem in remote Site 4. Septic tank and soakage pit systems are generally not considered appropriate for areas that are prone to flooding, and poor soakage pit construction can contaminate the surrounding environment. Two sites, rural Site 2 and remote Site 5, report a considerable amount of pit toilet use. Pit toilets are an effective way to dispose of human waste if constructed properly, but can present an obvious health risk in flood-prone areas and for diseases such as typhoid as they can encourage flies. More information is required about use of pit toilets in both sites, such as whether they are routinely covered, in order to better understand disease risk that may be related to flies. Ensuring safe water and hygiene practices in conditions where pit toilets pose an environment contamination risk, such as during floods, is an important adaptation measure.

The sanitation data shows that there is a clear need to assess the viability of improving toilets and waste disposal systems in the rural and remote sites, and to address potential risks associated with environmental contamination (water, food, soil and/or flies) through health promotion. The assessment revealed that there is a distinct lack of hand washing facilities near toilets in all five sites; an important barrier to consider in the design of health promotion interventions to encourage hand washing after toilet use. Vulnerabilities revealed by the findings in relation to water supply are relevant to the target diseases, which are variously sensitive to both the abundance and scarcity of water. A high majority of respondents in all five sites report that water availability is affected during hydro meteorological disasters. Three sites rely on tap water almost exclusively, leaving them vulnerable to water shortages where mains supplies are disrupted, particularly where they do not own secondary supplies such as tanks for rainwater harvesting. The high proportion of households that report that water quality was likely to be affected by disasters or heavy rain, and/or drought shows that achieving widespread safe water storage and purification practices is essential to disease prevention. Further, support in the form of water storage facilities or water source protection may be necessary to assist vulnerable sites, such as the two remote sites, where a third of households report relying on an unprotected surface water source. The proportions of households that report never practising water safety measures and storing water in uncovered containers are not insignificant, and reveal a need for education around safe drinking water and waterborne disease prevention.

The findings revealed a number of risky practices and conditions related to food hygiene, which are relevant to the prevention of target diseases like typhoid and diarrhoea. Hand washing prior to food preparation, washing eating utensils, and washing fruits and vegetables that are not cooked are key preventive actions in disease control, and having a kitchen sink and a water connection to the kitchen facilitates these important behaviours. The data shows that nearly two-thirds of households do not have kitchen sinks, and approximately half of households report not having a direct water connection to the kitchen; the two remote sites stand out in relation to these factors. Lack of kitchen sinks and running water to kitchens and sinks are likely to pose barriers to hygienic food preparation, and these conditions should have bearing on the design of disease prevention interventions. In one rural and both remote sites, more than half of households do not have benches in the kitchen for food preparation: instead, food is prepared on the floor. Overall, a fifth of households report not storing food properly in containers or cupboards, which may increase the risk of food being exposed to rats and flies. Target disease prevention interventions clearly require elements of food hygiene education, particularly in the remote sites. Vector control is relevant to preventing dengue fever and the findings related to mosquito breeding reveal a number of risks. Routinely leaving stagnant water used for flushing water seal toilets uncovered occurs in a majority of households with water seal toilets in the two rural sites. Storing water in uncovered drums is a pervasive risky practice across nearly all sites, and adaptations to ensure consistent covering of stored water are necessary.
Rubbish left exposed to collect rainwater can breed mosquitoes; over half the households in rural Site 2 and remote Sites 4 and 5 dispose of rubbish in a pit within the household boundary. More than half of households in all sites have rubbish or debris in surrounding the house. There is a clear need to encourage appropriate rubbish disposal and tidy environments across all sites to reduce the potential for dengue mosquito exposure.

The findings related to leptospirosis bacteria exposure risk in domestic settings show a high presence of rats (a leptospirosis carrier) in kitchens across all sites, and particularly in the rural and remote communities. Practices like not storing food properly, preparing food on the floor, and not disposing of kitchen waste in a rubbish bin with a lid may encourage rats into the kitchen, and these practices are generally reported in all sites, although less so in urban Site 1. The data suggests that interventions that disease prevention measures should focus on rat control and safe food preparation/storage and kitchen waste disposal practices.

Conclusion
The findings highlight both general areas of risk and specific risks in ‘hotspot’ communities in relation to the four target diseases, including food hygiene, water supply and safety, sanitation, shelter vulnerability and mosquito control. They also reveal that certain communities, particularly the remote communities, are especially vulnerable to a number of risk factors related to the target diseases. Acknowledging that it appears that the four target diseases are set to become a greater disease burden for Fiji as the climate changes, tailored, appropriate adaptation measures are urgently needed. Identifying the different areas of vulnerability in communities is the first step in designing fitting adaptation measures to minimise health risks associated with climate-sensitive diseases.

Acknowledgements
The authors wish to acknowledge that this data was collected as part of the Piloting Climate Change Adaptation to Protect Human Health project, a United Nations Development Programme and World Health Organization project funded by the Global Environment Facility, jointly implemented with the Fiji Ministry of Health.

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The use and effect of papaya (Carica papaya) leaf juice for the treatment of dengue fever

Muller, S 1, Downes, M 1 and Cordell, G. A 2

Keywords: Dengue fever, Carica papaya, papaya leaves, platelets

Dengue fever (DF) is one of the fastest emerging arboviral infections transmitted by the bite of infected Aedes aegypti mosquitoes. The maximum burden of the spread of dengue fever caused by the dengue virus is in the Asia Pacific region and outbreaks most commonly occur in populated urban and residential areas of tropical countries. The prevalence of dengue has grown dramatically in recent decades and is now endemic in more than 100 countries (Gubler, 1998). An estimated 2.5 billion people (36% of the world population) are at risk globally and the Asia Pacific countries alone include 70% of the cases (WPRO, 2014a). The annual incidence of dengue fever cases is estimated to be 50-100 million globally with a report of 500,000 hospitalizations and 25,000 deaths (WHO). Dengue outbreaks are now arising more frequently in the countries of the Pacific sub-region where it was normally contracted off-island (WPRO, 2014a).

Dengue infection in Fiji:
Fiji is one of the countries in the Pacific region where a high level of dengue activity has been observed and since 1885 has had a long history of dealing with dengue (Deo, 2014). Table 1 and Figure 1 show the dengue fever cases reported in Fiji from the year 1971 to the present year 2014. The five-year period histogram depicts the resurgence of dengue fever as occurring three times in the years 1971 to 2014 with reported high incidence levels of 16,203, 24,780 and 20,000 cases in the years 1975, 1998 and 2013 respectively. In Fiji, the recent outbreak (2013) shows the number of suspected cases to be 20,000 with a total of 13 confirmed deaths was reported where the majority of the cases were from the Central Division (70%), followed by the Western Division (20%) and the remaining 10% from the North and East (WPRO, 2014b, 2014c).

Table 1: Dengue fever cases reported in Fiji from 1971-present including outbreak years and number of cases. (source: The Fiji Ministry of Health 2010-2013; WHO, 2000; WHO & TDR, 2009)

<table>
<thead>
<tr>
<th>Yearly period</th>
<th>Total number of cases</th>
<th>Outbreak year</th>
<th>Outbreak cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971-1975</td>
<td>19766</td>
<td>1975</td>
<td>16203</td>
</tr>
<tr>
<td>1976-1980</td>
<td>145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1981-1985</td>
<td>1153</td>
<td></td>
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<td>4409</td>
<td></td>
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</tr>
<tr>
<td>1991-1995</td>
<td>415</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996-2000</td>
<td>24794</td>
<td>1998</td>
<td>24780</td>
</tr>
<tr>
<td>2001-2005</td>
<td>3046</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006-2010</td>
<td>2416</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011-2014</td>
<td>20833</td>
<td>2013</td>
<td>20000</td>
</tr>
</tbody>
</table>

Figure 2 shows the rapid increase of global dengue fever cases from the year 1955 according to a report from WHO from various countries with dengue cases (WHO & TDR, 2009).

Alarmingy, with population and climate changes, the number of dengue cases projected for 2085 is around 5-6 billion people (at least 50-60% of the projected global population) (Hales, 2002). There is an expectation of rapid evolution of epidemiology with increased frequency of dengue outbreaks and spread to new geographical areas that were previously unaffected mainly due to global climatic changes which will favour a suitable climate for dengue fever transmission where a significantly larger human population would then be at risk (Hales, 2002).

Figure 1: Dengue fever and dengue haemorrhagic fever cases reported in Fiji from 1971 - present. Blue bars = 5 year periods, red bars = major outbreaks years (1975, 1998 and 2013). Figure compiled from several sources (Ministry of Health Fiji, 2010, 2011, 2012, 2013; WHO, 2000; WHO & TDR, 2009).

Figure 2: Average annual number of dengue fever (DF) and dengue haemorrhagic fever (DHF) cases reported to WHO and of countries reporting dengue, 1955 - 2007. Image source (WHO & TDR, 2009).

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DENV serotypes and the incidence in the Pacific:

Dengue virus is a positive sense, single-stranded RNA virus, approximately 11kb in length, composed of four antigenically distinct serotypes (DENV-1 to -4) that belong to the genus Flavivirus in the Flaviviridae family (Tang & Ooi, 2012; Westaway & Blok, 1997; WHO & TDR, 2009). Dengue virus was first isolated from Japan in 1942 by Hotta (1952).

A patient infected with a particular serotype attains lifelong immunity against that specific serotype but not to the other three (Tang & Ooi, 2012). The January 2014, a WHO report indicates that dengue virus serotype 3 has re-emerged in many countries in the South Pacific after nearly 20 years of relative dormancy (WHO, 2014). People develop immunity to a particular strain of dengue virus which they encounter however the re-emergence of the same serotype in new generations may be common.

Patients who are affected with dengue show a wide spectrum of flu-like symptoms that last for 2-7 days (40°C/104°F). These symptoms typically include headaches, body pain, malaise and other non-specific symptoms such as nausea, vomiting, swollen glands, diarrhoea, and body rashes. More severe clinical symptoms typically include headaches, body pain, malaise and flu-like symptoms that last for 2-7 days (40°C/104°F). These symptoms show the potential lethal disease manifestations that lead to dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Senthilvel, 2013). Those who have been previously infected are at greater risk of developing more severe disease upon reinfection with a different dengue serotype.

In the first instance, dengue infection diagnosis is mostly clinical, relying on self-reported patient symptoms (Idrees & Ashfaq, 2012). However, these symptoms can be non-specific and frequently overlap with other febrile illnesses (Tang & Ooi, 2012). Therefore, laboratory confirmation tests are needed to confirm dengue infection. Laboratory diagnosis of dengue can be made by detection of the virus or the viral genome, viral antigens or antibodies (Idrees & Ashfaq, 2012).

Infected patients can progress from stable to severe over a short period of time therefore early laboratory diagnosis is critical treatment and community public health issue. Often a primary diagnosis can be suspected using a whole blood count test looking for increased haematocrit and decreased platelet levels (Figure 3). During the acute phase of the infection, laboratory tests can detect viremia (up to 5 days after onset of the infection) (Vaughn et al., 2000), viral RNA and viral antigens/proteins. Towards the end of the acute phase serological tests are widely used to confirm dengue infection. The two serological tests that can be performed are dengue IgM and dengue IgG. IgM antibodies can be detected 3-5 days after onset of the illness and peak at two weeks. IgG antibodies slowly increase from the end of the first week of illness and are detectable for several months (WHO & TDR, 2009).

Although the disease has brought a highly significant mortality rate in many countries there is no vaccine or any specific therapy or pharmaceutical medications for dengue infection (Dharmaratne, Wickramasinghe, Waduge, Rajapakse & Kularatne, 2013).

The treatment of dengue in Fiji:

The current dengue treatment options in Fiji include fluid replacement, paracetamol and rest. There is no prescribed medicine or vaccine to specifically treat dengue fever in Fiji. However, Fijian reports indicate that it is commonly practiced belief that papaya (Carica papaya) leaf juice can be used at the onset of dengue as a form of plant-based, self-medication regimen, instead of going to the hospital (Ahmed, 2014).

A new approach for the treatment of dengue:

To date, there has been no research carried out in Fiji to support whether papaya leaf juice is effective for dengue fever treatment. However, there is research evidence from other countries such as Malaysia (Afzan, 2012; Subenthiran, 2013), India (Deepak, 2013; Patil, 2013), Indonesia (Yuninta, 2012), Sri Lanka (Dharmarathna, et al., 2013; Hettige, 2008) and Pakistan (Ahmad, 2011; Idrees & Ashfaq, 2012) that provide emerging support for the use of papaya leaf extract as a treatment for dengue fever. There are also encouraging preliminary results of tests by clinical trials that show the mix of neem leaf (Azadirachta indica) and papaya leaf juice was effective in the prevention and management of dengue fever as a plant based therapy (Narayan, 2012). A combination of neem leaf and papaya leaf juice has also been recommended as a traditional Siddha medicine in India and showed remarkable results in dengue patients by increasing the platelet count during dengue virus infection (Staff Reporter, 2012). An interesting observation was also reported in a study by the Indian Institute of Forest Management in 2012 which showed an increase in the platelet count within 24 hours in dengue patients who drank papaya leaf juice (Kala, 2012).

A team in Malaysia reported an accelerated increase in platelet count in dengue fever and DHF patients taking Carica papaya leaf juice (Subenthiran, 2013). The study parameters included full blood count, haematocrit levels, renal profile and liver function tests to ensure the safety of the use of papaya leaf juice. Murine models also showed that administration of papaya leaf juice increased platelet count (Dharmaratna, et al., 2013; Sathasivam, Ramanathan, Mansor, Haris, & Werndorfer, 2009).

A clinical trial study in Sri Lanka (Hettige, 2008) showed that dengue patients who were given papaya leaf extract recovered completely, without the need to be admitted to hospital. This is an indication that this natural traditional medicine may help to repair the liver damage caused by dengue virus. It has also been suggested that it is essential to take papaya leaf extract at the early stages of the illness to control the progression, and also prevent damage to vital organs. If dengue infection is not diagnosed and treated the course of infection may lead into bone marrow suppression, resulting in low platelet count. This may lead to more serious and possibly fatal phases of the illness such as dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Deepak, 2013).

Physico-chemical studies show that young Carica papaya leaves are rich in flavonoids and alkaldoids and possess medicinal properties such as anti-inflammatory, wound healing, anti-hypertensive and anti-tumour activities (Anjum, Ansari, Naqvi, Arora & Ahmad, 2013; Oloyede et al., 2011/12). Research reports from the US and Japan indicates that enzymes found in papaya leaf have cancer fighting properties against a wide range of tumours including cervical, breast, liver, lung and pancreatic cancers. The study indicated that papaya leaves have no known toxic effects and side effects in their clinical use (Otsuki et al., 2010).
Other parts such as the fruit, seeds, latex, roots and peel of the Carica papaya plant have also been studied for their medicinal benefits (Aravinda, Bhowmik, Duraival, & Harish, 2013). Such studies on the medicinal properties of the leaves of Carica papaya and their effective use in the treatment of dengue infection provides a new avenue for dengue research in Fiji in order to find a naturally available plant to be used as a traditional herbal medicine for dengue therapy that is cost-effective, with no major side effects and is sustainable and readily available to all patients as a home remedy without the need for hospitalization.

Dengue infection in Pacific countries has emerged as a major health concern and a serious health issue in Fiji with the recent outbreak in 2013. Developing a tetravalent vaccine against all four known serotypes is very challenging and to date there is no licensed vaccine available for dengue virus. Costs and adequate access for the provision of a developed vaccine are also a concern from a public health perspective.

Keeping this mind, there is an urgent need to assess whether the use of papaya leaf juice is effective in treating the symptoms of dengue infection or preventing the more severe forms of the disease. If proven, this can be an alternative medicine to combat this endemic infection as there is an expectation of increased frequency of dengue outbreaks. Papaya leaf juice has showed to play a significant role in recovery from dengue fever. It will be very exciting and challenging to develop a research study in Fiji to study the effect of papaya leaf juice for the treatment of dengue infection.

In response to this need, the Medical Research Laboratory (MRL) and Research Center of the College of Medicine, Nursing and Health Sciences, Fiji National University has initiated lab-based research at Tamavua to study the important compounds present in the leaves of Carica papaya and a clinical trial at the CWM hospital to test the various serological and immunological parameters such as platelet counting by flow cytometry, hematocrit level, antibody profile etc. in dengue infected patients.

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Introduction

Typhoid fever is a systemic infection caused by Salmonella Typhi, a gram negative facultative rod-shaped bacterium that belongs to the family Enterobacteriaceae known as enteric bacteria (Todor, 2014). Humans are the only natural host and reservoir for S. Typhi and the infection is transmitted to a person through the fecal-oral route by ingestion of food or water contaminated with faeces (WHO, 2003).

Typhoid fever is a global health problem. The World Health Organization (WHO) conservatively estimates there are 21 million cases of typhoid fever and 216,000 deaths each year predominantly among children of school age or younger (Coalition against Typhoid, 2013) and a major problem in least developed and developing countries. Buckle, et al (2012) estimated regional typhoid fever incidence rates in 2010 ranged from <0.1/100 000 in Central and Eastern Europe and Central Asia to 724.6/100 000 in Sub-Saharan Africa.

Generally, typhoid is endemic in impoverished areas of the world where the provision of safe drinking water and sanitation is inadequate and the quality of life is poor. Contaminated food and water have been identified as the major risk factors for typhoid prevalence as well as poor sanitation and close contact with typhoid cases and carriers.

In Fiji the incidence of typhoid fever has risen drastically from the year 2004 (Kumar, et al, 2000). Typhoid is endemic in Fiji as indicated by the 1,847 laboratory-confirmed cases reported between January 2008 and July 2012 (Greenwell, 2013). Analysis of the laboratory confirmed cases reported to Fiji Centre for Disease Control at Mataika House from 2000 to 2013 showed that the northern division reported increased cases of typhoid over the years 2005–2008 and gradually decreasing from 2009 – 2013, followed by the western division between the years 2007 – 2013 and the central division from 2005 – 2013 with increasing trends and a minimal number of cases from the eastern division (Ministry of Health Fiji, 2013). It is considered as one of Fiji’s “Three Plagues”, along with dengue fever and leptospirosis (Fiji’s Piloting Climate Change Adaptation to Protect Human Health, 2011). Unhygienic practices have been the common cause of typhoid fever outbreaks in Fiji following mass food distribution such as during family gatherings and cyclones (Jenkins, 2010).

Reducing confirmed typhoid cases by 75 per cent, from 40 per 100,000 in 2009 to 10 per 100,000 in 2015 is a priority for the Fiji Ministry of Health as outlined in its strategic plan 2011 – 2015. In order to achieve this, well coordinated prevention and control activities are therefore necessary including improved surveillance, early recognition and prompt and well-coordinated response to any disease outbreak.

Chronology of events:

On June 16, 2014, the infection control nurse at the colonial War Memorial (CWM) Hospital in Suva reported a 16 year old girl from Marata Settlement in Wailoku, Tamavua, Suva admitted with laboratory-confirmed typhoid fever. One week later, a cluster of probable typhoid cases from Wailoku area but from different settlements were admitted at CWM Hospital. From May 24, 2014, which corresponds to the date of onset of illness for the above case to June 25, 2014, total of 22 typhoid cases were reported of which 13 were laboratory confirmed and 9 were probable cases. All these cases attended and ate at a mass gathering held at Ki Settlement on May 17, 2014.

Upon receipt of the first typhoid case notification, the Suva Subdivisional Outbreak Response Team (SORT) was activated. The objectives of outbreak investigation were as follows:

1. To determine the source of infection;
2. To search for other family members and close contacts who might be suffering from the same illness;
3. To conduct environmental inspection; and
4. To conduct typhoid awareness and other public health interventions to halt and prevent further outbreak from the immediate source.

Methods

The investigation followed the ten steps as outline in Communicable Disease Surveillance and Outbreak Response Guidelines (Fiji CDC, 2010) illustrated in Figure 1.

Results

Investigation of cases.

The cases were interviewed using the standard Typhoid Case Investigation Form. Close contacts were searched by visiting the places the cases visited within the two weeks of having the illness. Additional cases were identified using the following case definitions:

• Probable active typhoid fever – A case living in Wailoku, Tamavua, Suva suffering from fever and other signs and symptoms of typhoid fever such as diarrhea, abdominal pain, headache, loss of appetite, etc. from May 1, 2014 to July 30, 2014.
• Confirmed active typhoid fever – A probable case as above plus isolation of Salmonella Typhi in blood culture.
A total of 22 active typhoid fever cases, 13 confirmed and 9 probable cases were identified from four settlements in Wailoku, Tamavua, Suva – Marata, Biliwai, Ki and Savura settlements with an incidence rate of 38 per 10,000 population. Of the 22 active cases, two were from outside Wailoku area. All the cases attended and ate at the gathering held at Ki Settlement on May 17, 2014. The first confirmed case developed signs and symptoms one week after the mass gathering. All of the cases presented with fever of more than 3 days, headache and body weakness. Other signs and symptoms the cases presented were loss of appetite (92%), chills (92%), diarrhea (21%), abdominal pain (21%), constipation (13%) and confusion (13%). None of the cases presented with rash.

The number of cases by place of residence is presented in table 1.

Table 1. Distribution of cases by place of residence

<table>
<thead>
<tr>
<th>Place of Residence</th>
<th>No of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marata Settlement</td>
<td>3</td>
</tr>
<tr>
<td>Biliwai Settlement</td>
<td>3</td>
</tr>
<tr>
<td>Ki Street</td>
<td>14</td>
</tr>
<tr>
<td>Savura Settlement</td>
<td>2</td>
</tr>
<tr>
<td>Outside Wailoku*</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

* 2 confirmed typhoid cases from outside areas who attended the gathering on May 17, 2014 at Ki Settlement

All the cases were i-Taukei, 12 males and 10 females. Majority of the cases were in the age group 20 – 39 years. The distribution of the cases according to age group is presented in Figure 2.

The Epidemic curve.
The epidemic curve for this typhoid outbreak is presented in Figure 3.

The first case reported has a date of onset of May 24 which is seven days after the mass gathering. The last case reported for this outbreak was on June 26 which is almost one month after the first case.

This epidemic curve suggests a point source outbreak. In a point source outbreak, persons are exposed over a brief time to the same source, such as a single meal or an event; the number of cases rises rapidly to a peak and falls gradually; and the majority of cases occur within one incubation period of the disease. (CDC, 2012).

Environmental Investigation

The environmental investigations conducted include house to house inspection on accommodation, rubbish disposal, water and sanitation facilities. Water samples from where the households get their water supply including the tap water, rain water receptacles, wells and creeks were collected and sent for bacteriological analysis. All the affected households have well maintained dwelling houses and compound, flush toilets, rubbish pit and treated water supplied by Water Authority of Fiji. Most houses have rain-water tanks and use wells and nearby creek for bathing and washing clothes. All the water samples collected tested negative for the presence of any coliforms or E. coli.

Discussion

Wailoku, Tamavua, Suva which is composed of several small settlements have a total population of 5,244 where 55% are i-Taukei, 40% Fijians of Indian descent and 5% Fijian of other descent of whom majority are former Solomon Islanders. The area is endemic for typhoid fever with two to three cases reported every year.

In June 2014, twenty two typhoid fever cases (13 confirmed and 9 probable cases) were seen and admitted at CWM Hospital all of whom attended and ate at the one year death anniversary held at Ki Settlement in Wailoku, Tamavua, Suva. Three weeks after the gathering, the first case was admitted at CWM Hospital for laboratory confirmed typhoid fever. The infection control nurse immediately notified the Divisional Medical Officer (DMO) Central who notified the Suva Subdivisional Outbreak Response Team (SORT) to investigate. The Suva SORT composed of the Subdivisional Medical Officer (SDMO) Suva, environmental health officers and zone nurse Wailoku was mobilized to investigate in order to identify the cause of the outbreak, look for other cases and implement public health interventions to halt and prevent further spread of the disease. The ten steps in disease outbreak response as outlined in the Fiji Communicable Disease Guidelines were followed.

As presented in the results, 22 cases were identified, 13 confirmed and 11 probable active typhoid cases all of whom were admitted at CWM Hospital and tested for the presence of S. Typhi in the blood and stool samples. Twenty cases came from the settlements in Wailoku and two cases were from the outside area but linked to the Wailoku cases. All were treated and responded well to Ciprofloxacin. There was no death from this outbreak.

Public Health Interventions

The Suva SORT implemented the following public health interventions to control the typhoid outbreak and prevent its further spread:

1. House to house inspections were conducted to interview cases including all their contacts and to conduct awareness on typhoid prevention and control.
2. Symptomatic contacts of confirmed typhoid cases were treated with oral Ciprofloxacin antibiotics as per the Fiji national typhoid fever treatment guideline 2010 and referred to CWM hospital for blood and stool cultures.
3. Hand washing soaps were distributed to residents of affected households with onsite hand washing demonstrations conducted by the environmental health staff.
4. Supervision and monitoring of mass gatherings held at Wailoku.
5. The subdivisional outbreak team conducted a series of community meetings to present on typhoid prevention and control in all affected settlements in Wailoku.
6. All food handlers during the mass gathering at Ki Settlement in Wailoku where all the typhoid cases were linked were identified, interviewed and their stool samples sent for stool culture.
7. Community medical outreach and shift clinics were organized to provide general outpatient services and health promotion activities to the affected and neighbouring communities.
8. Follow-up of cases on a weekly basis.

Limitations

This typhoid outbreak investigation has the following limitations:
1. Case control study on the food eaten during the mass gathering and the risk of acquiring typhoid fever from attending the said mass gathering were not done due to staff, resource and time constraints.
2. Not all of the close contacts of the typhoid cases were screened or tested for S. Typhi. Only the symptomatic contacts detected were screened and treated with oral Ciprofloxacin.

Conclusion

This typhoid fever outbreak in Wailoku, Tamavua, Suva is a point source outbreak linked to a mass gathering at Ki settlement most probably caused by a healthy carrier (although this was not confirmed by evidence due to limitations in screening for healthy carriers).

The most important lesson learned in this outbreak is the efficient and well coordinated response by the Subdivisional Outbreak Response Team. Guided by the Fiji Communicable Disease Surveillance and Response Guidelines, the team was able to contain, control and prevent further spread of the typhoid outbreak in Wailoku, Tamavua to surrounding areas.

The challenge remains on how to detect healthy typhoid carriers and a cost-effective screening test for health typhoid carrier is recommended.

Reference


Community-based approach to improving rural water supply and sanitation in Taveuni

Matadigo P. K1*, Kumar. V1, Raikoso. J1

Keywords: Community base approach rural water supply, rural sanitation

Abstract
The implementation of the Masters Apprenticeship Programme began with the initiatives or partnership between the Taveuni Rural Local Authority, Northern Health Services, Jeff and Karen Weigel of the Redondo Beach California Rotary, Norman Hantzche of Questa Engineering and Taveuni Rotary which initially began on the summer of 2011.

The Masters Apprenticeship Programme compromises of selected Village Health Workers (active) and Village Headmen or T uraganikoro’s. The programme is a practical, hands on, adult learning, and vocational philosophy of empowering the use of local available materials to address, rectify and solve the on-going problem of unsafe, unhealthy rural drinking water. Thereby adopting an action oriented approach.

At the end of the programme Bio Sand Filters, Springbox Protection or Coverings and Rainwater First Flush Systems were completed. Additional Toilet Blocks, Soakage Pit/Leach field system and Grey Water, Slop Water treatment system were also completed. Thus improving Rural Water Supply, Community Sanitation and intercepting/eliminating the spread of typhoid and leptospirosis on the Island of Taveuni.

Method
Initially it started off as a Community Awareness Programme (CAP) for Water and Sanitation for the communities of Qarawalu and Delai Vuna/Southern Taveuni. The Local Authority Grant was utilised for this programme.

This first community meeting was more of an awareness gathering rather than the hands on practical approach or action oriented that later eventuated. Lessons learnt were that the typical community mentality, were clearer when hands on demonstrations were conducted rather than the dissemination of theory through black board or power point presentations.

Thus the formulation of the Masters Apprenticeship Programme, where the selected Village Health Workers (active) and Turaganikoro’s were nominated. The Masters Apprenticeship Programme began with the practical, hands on, adult learning, vocational philosophies ofempowering the use of local available materials to address, rectify and solve the ongoing problem of unsafe, unhealthy rural drinking water. It was more of an action oriented approach, where at the end of the programme clean, safe water and improved sanitation was achieved through the Ministry of Health mission statement, ‘To provide a high quality Health Care Delivery Service by a caring and a committed workforce working with strategic partners…….’

Discussion
The Clay`s Handbook on Environmental Health (19th Edition) describes the principle of water as a colourless, tasteless, odourless liquid and one of the greatest solvents known to science. Water has many physical features that make it unique. It is naturally found as a liquid, a solid and a gas. The term ‘pure water’ nowadays is accepted as meaning water that is dietetically pure.

It is a known fact that most of Fiji’s Rural Water Sources are termed as untreated and are not extensively purified as that of the planned, civil, town, urban areas. The public health requirement of continuance quality water supply is of critical importance. Most of the sources are captured then distributed to communal standpipes. Others have a reservoir tank for distribution and the universal public health message of boiling water for drinking is oftenly stressed.

The burdens of the Curative Services are lessened when Public Health interventions or infrastructures are strategically addressed. This is critical for the prevention of gastrointestinal diseases, diarrhoea, shigellosis, leptospirosis and typhoid.

The partnership of the Local Authority/Taveuni Rural Local Authority, Northern Health Services, Jeff and Karen Weigel of the Redondo Beach California Rotary and Norman Hantzche of Questa Engineering began on the summer of 2011.

Introduction


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Initial Planning
Without proper planning, the required results would not be achieved. Amat Victoria Curano, in Latin means Victory Loves Preparation! The preparation of the MAP Programme began earlier with continuous Skype conversations, email correspondences, meetings that were exchanged between the Taveuni Rural Local Authority and our strategic partners four to six weeks prior to the following agreed, respective implementing dates.

2012(27/08/12 to 07/09/12); 2013(21/10/13 to 31/10/13); 2014(21/07/13 to 31/07/14)

Areas of importance covered were Logistics; the availability of transportation for the carting of materials, the Master Apprentices and other needed runs, Catering; provided by the host community with financial assistance from the Taveuni Rural Local Authority and strategic partners.

Worth noting that the strategic partners were also responsible for the refund of bus fares for the Master Apprentices’ travelling daily to and from the host village or community and the taking of Water Quality Samples with the use of a petri dish water test for bacteriological presence done at room temperature and the use of a reagent that shows colouring of the different strains present.

Testing Method known as Coliscan Easygel.

The Taveuni Rotary also helped out through local grape vine knowledge on the best person to contact when initiating a programme such as this.

The targeted communities for the implementation of the MAP Programme were specifically targeting the following the Communicable Disease prevalence during such years; for Typhoid, Leptospirosis and Dengue (the least importance of the three).
Results
The 2012 Master Apprenticeship Programme achievements are the following:

Vuniwai settlement Springbox

DURING

AFTER

Vurevure settlement Toilet Block/Septic Tank/Soakage Pit, Leach Field System

Figure 6: The Grey Water/Slop Water Plan—Source Questa Engineering

Figure 7: The Rainwater First Flush System

Figure 8: Vuniwai settlement Springbox covering

Figure 9: Location of Vurevure settlement and Concept Plan—Source Questa Engineering
Figure 10: Toilet Block I

Figure 11: Toilet Block II

Figure 12: Toilet Block III
Salialevu Primary School Biosand Filter and Rainwater First Flush System

Figure 13: Toilet Blocks Septic Tank and Soakage Trench

Figure 14: Master Apprentices’ constructing the Biosand Filters

Figure 15: Master Apprentices’ constructing the Rainwater First Flush System
Navakau Primary School Rainwater First Flush System

DURING

AFTER

Figure 16: Master Apprentices' constructing the Rainwater First Flush System

Wairiki/Holy Cross Primary School Rainwater First Flush System

DURING

AFTER

Figure 16: Safe Drinking Water for the School Community
2013 Master Apprenticeship Programme achievements are the following:

**Lavena Primary School & Lavena Lodge Biosand Filter**

![Figure 17: Safe Drinking Water for the School Community](image1)

![Figure 18: Protected Water source for the Community](image2)

![Figure 19: Master Apprentices’ completing the protected Water source for the Community](image3)
FIELD NOTE

Vidawa Village Springbox

Figure 20: Protected Springbox completed

Lavena Village Springbox

Figure 21: Protected French "V" trench Springbox in completion

Villa Maria settlement Springbox

Figure 22: Protected Springbox trench in completion
Bouma Primary School Biosand Filter

**Figure 23:** The complete Biosand Filters for the School Community


**Figure 24:** The impact of the Masters Apprenticeship Programme in addressing safe, wholesome rural water supply-Source Questa Engineering
The 2014 Master Apprenticeship Programme achievements are as follows;

Vurevure settlement Grey Water/Slop Water System

**BEFORE**

![Before Image](image1.png)

**DURING**

![During Image](image2.png)

**AFTER**

![After Image](image3.png)

_Figure 25: The complete Grey Water/Slop Water System-Source Questa Engineering_

Vurevure settlement Grey Water/Slop Water System

**BEFORE**

![Before Image](image4.png)

**DURING**

![During Image](image5.png)

**AFTER**

![After Image](image6.png)
Figure 26: The Protected Springbox-Source Questa Engineering

Qila settlement Springbox

Figure 27: The Master Apprentices’ complete the Protected Springbox-Source Questa Engineering
Discussion
The involvement of the partnership strategy or team strategy is of utmost importance in forecasting or predicting the required results of a clean, safe, wholesome rural water supply and sanitation.

Solutions by using the available sand, pebbles, river or creek gravel for construction of the Biosand Filters, Spring boxes and Rainwater First Flush Roof Catchment system are practical, affordable, time bound and easy to construct, and maintain with the least technical expertise. The programme started small then grew to what it is today through the intact consultations between the Taveuni Rural Local Authority, Ministry of Health, Northern Health Services, Questa Engineering, Taveuni Rotary and Redondo Beach California Rotary.

The Community, Village Health Worker and Turaganikoro’s of Village Headman involvement of the construction of Biosand Filters, Springbox Protections, and Rainwater First Flush Roof Catchment system are the practical solution for a safe, wholesome Rural Water supply.

Furthermore the introduction and use of the Water Sample testing method known as Coliscan Easygel is suitable or reliable. The need for an incubator for a bacteriological growth sample is not needed. Making it reliable to take and monitor water samples at room temperature or the Office surrounding. The different colour changes shown in Fig. 24 reveal the presence of pink pigments for coliforms and dark blue pigments for e coli. This is in contrast to the Hydrogen Sulphide Test Kit where the grey, black colour changes show the presence of contamination. Fortunately the Questa Engineering and Redondo Beach California Rotary were responsible in supplying this revolutionary Water Test Kit.

Reference

Figure 28: The Master Apprentices Programme 2013 Recipients’
The Lazarus Redemption Experience!-Resurrecting the Public Health Protection strategy towards the reported Dengue Cases for the Cakaudrove Subdivision

Journal Entry on building a Public Health Case on Mosquito Control conducted by the Nasavusavu Rural Local Authority/Savusavu Health Office 2014

Matadigo P. K1, Matebalavu. K2 and Ragata. S3

Keywords: Dengue, mosquito control, Public Health Act

HEALTH INSPECTORS JOURNAL
10th February, 2014
Monday 1400-1930hrs

Senior Assistant Health Inspector Samuela Ragata EDP No 93053 were involved in a Public Health proactive measure by adopting the source reduction “destruction” strategy for the Hot Spot Area known as NAQERE. A Business known as Savusavu Tyre Centre was inspected and there was evidence of the presence of mosquito larvae present in the discarded tyres lying randomly around the compound. Through diplomacy(first point of dialogue or entry) the Business owner was warned and told to keep the area free from mosquito larvae.

14th February, 2014
Friday 1720-1900hrs

A re-inspection of the Tyre Centre Business was conducted by Senior Assistant Health Inspectors Samuela Ragata and Kolosa Matebalavu EDP No. 91477. Greatful through innovation and technology with what the digital camera can capture for the 21st Century Area Inspectors can achieve. Surely compliments the statement that a “picture portraits a thousand words”.

Figure 1 Hot Spot Area I NAQERE

Figure 2 Positive Tyres with Mosquito Larvae present at the Tyre Centre
Even though there were drastic changes of the non-presence of mosquito on the re-inspection of 14/02/2014, the Tyre Centre continued to neglect the heed advice when inspecting the area on alternative dates. Especially when given an INTIMATION NOTICE to carry out the necessary works.

23rd April, 2014
Wednesday 1030hrs

Visit to the Savusavu Court-Court Clerk for relevant information on the following documentations; Charge Sheet, Statement of Offence, and Particular of the Offence. (Building a Case without reasonable doubt towards a Public Health Offence; The mere presence of the immature stages of a mosquito (mosquito larvae), Part XI Mosquitoes, Section 109 of the Public Health Act Cap 111, 1936.)

Fortunate to have digital camera to capture the evidence of the mosquito larvae present in the tyres.

Greatful for the two Area Inspectors in documenting important evidence relevant to the Public Health Offence.

25th April, 2014
Friday 1034hrs

Lodged the Charge Sheet, Statement of Offence, Particular of the Offence and Summons to the Savusavu Court for the Resident Magistrate endorsement. Also attached were the documented digital pictures that were captured during that particular moment. Revealing the presence of mosquito larvae.

14th May, 2014
Wednesday 0800hrs

Used the Savusavu Hospital vehicle to transport Mr Samuela Raga to hand deliver the Summon and Chargesto the owner/occupier of the Bussiness premises known as Savusavu Tyre Centre. (Case No 93/14)

26th May, 2014
Monday 0900hrs

First Call at the Savusavu Magistrate Court. Offender pleaded guilty in writing. Case No 93/14 sets a precedence for the Public Health Act risk management on the control of mosquitoes especially Aedes species Dengue Mosquitoes in Savusavu.
Prosecutor’s would agree that building towards a Case takes the skill of preparedness where as to state “all stones were uncovered” thus relating to the Charge and Particulars of Offence. Such action must always be the last resolution where all other avenues of diplomacy have been extensively covered.

Our Communities (we are also included) must know and understand that it is a Public Health Offence for breeding or having the presence Mosquito larvae amongst us. The basic message of daily source reduction strategy is oftenly emphasised.

When delivering the sentence for Case 93/14 at the Savusavu Magistrate Court, the Resident Magistrate asked for some time in the Chambers to verify and look into our 1936 Public Health Act Cap 111. (As the Court was accustomed to mainly Criminal and Civil Cases)

Even though our Public Health Act was archaic or outdated with unreasonable fines and penalties, it was in two folds; complimented by the Sentencing and Penalties Decree 2009 and the fact that a simple system was already in place—it was a matter of enforcement that needed to be resurrected!

The following Offices must be mentioned in making Case 93/14 a precedence for our 1936 Public Health Act Cap 111:
- Provincial Development Office/Cakaudrove
- SDMO/Cakaudrove-Administration
- DMO/Northern
- DHI/Northern
- Senior Managers/MOH
Brief Summary

With the Leptospirosis being endemic in Ba subdivision the Environmental Health Officers from the Ba Health Office continued with the Prevention and Control program from last year to improve the knowledge about the disease.

The beginning of the year reported in 10 cases confirmed cases which were between the months of January – February, 2014. With early confirmed cases the expectancy of more cases being reported in the consecutive months would be high hence the decision to continue the program of awareness and rodent control to intervene the transmission route. The World Health Organization recommends interventions that aim to control at the level of infection source (i.e. rodent control, animal health) and interrupt the transmission route (e.g. Wearing PPE’s).

This program is part of a strategy to help the community in Ba to reduce their risk of acquiring leptospirosis.

This report outlines the activities undertaken for two weeks during the program from the 10th July to 1st August, 2014 which also explains the risk factors associated with the disease and makes practical suggestions on how to reduce the risk of leptospirosis in the Ba Subdivision.

Objectives
1. To raise awareness within the hotspot areas of Ba through community outreach that would target all possible communicable diseases as well.
2. To conduct rodent control measures through distribution of rat baits/traps.
3. To mobilize the community in the undertaking of preventative actions to eliminate further spread of bacteria.
4. To create a baseline data through assessment of the cattle and pig farms in Ba Subdivision and create awareness amongst farmers.
5. To issue intimation notice to individuals who are found to have premises that is conducive to harboring rodents and keeping of livestock that are capable of infecting humans via contact from infected urine.

Overview of Leptospirosis Activities

The following describes the key activities undertaken for the two weeks which commenced at the Varavu Settlement on the 10th of July, 2014 whereby the individual residents were visited and the nearby dairy farms were assessed to establish whether they meet the Public Health requirements.

The areas visited are as follow:

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Settlement</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10/07/14</td>
<td>Varavu</td>
<td>For awareness snd distribution of rats baits in the cane belts areas and assessment of dairy farms in the settlement</td>
</tr>
<tr>
<td>2.</td>
<td>14/07/14</td>
<td>Rarawai, Vaqila</td>
<td>For awareness and distribution of rat baits in the cane belts areas</td>
</tr>
<tr>
<td>3.</td>
<td>15/04/14</td>
<td>Vatulaulau</td>
<td>For awareness and distribution of rat baits in the cane belts areas</td>
</tr>
</tbody>
</table>

4. 17/07/14 Namau, Koronobu For awareness and distribution of rat baits in the cane belts areas
5. 18/07/14 Bulabula, Navoli, Navatu For assessment of dairy farms and distribution of rat baits
6. 20/07/14 Nadhari, Vatiyaka, Khalsa Road, Lavuci, Bilolo For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement
7. 21/07/14 Bilolo For awareness session with community and distribution of rat baits. Water issues in the community also discussed after recent water sampling.
8. 22/07/14 Tavarau For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement
9. 23/07/14 Veisaru, Busabusa For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement
10. 24/07/14 Varadoli, Rarawai For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement
11. 31/07/14 Yalalevu, Miha, Mahajan, Ba Methodist School For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement. Awareness conducted with Ba District scouts gathering
12. 01/07/14 Waivuka For awareness and distribution of rat baits in the cane belts areas and assessment of dairy farms in the settlement

Community Awareness

The awareness programme included the following topics for the 3 Communicable Diseases:
1. Definition of the disease: Leptospirosis, Typhoid and Dengue
2. Causative agent/animal hosts
3. Mode of Transmission
4. Signs & Symptoms: what to look out for
5. Possible risk factors
6. Treatment and prevention

The awareness session was conducted in the evenings to educate the public especially the targeting the farmers, sardars and community leaders such as District Advisory Councillors. This method ensured a faster mode of delivery of the message the team wanted to get across to all members gathered in relation to the communicable diseases and open discussions lead to people enquiring about the disease as for some it was the first time to hear about the Leptospirosis Disease. Some communities also raised issues regarding the keeping of animals near the water sources as it might also be polluted with animals waste.

1 Ba Sub-Division, MOHMS, Fiji
2 Address of Correspondence: sanjeetprasad@yahoo.com
The team also conducted house to house awareness in some parts because the settlements in Ba are scattered apart and transportation is a problem especially in the evenings. Hence the team visited the houses made an assessment and based on that the risk could be evaluated individually and controlled by means of awareness and through issuance of intimation notices with those that require immediate intervention to prevent the people from getting infected.

Creating a Baseline Data for Livestock farmers
The team also visited the farmers that are involved on the dairy farm or piggery industry to create a baseline data and assess the current status of each farms in terms of how well the farms are kept, adequate water supply, distance of animal yard from dwelling houses etc. These factors have to be considered as Leptospirosis is associated with infected animal urine and transmission can occur directly or indirectly.
Graph 1: These farms mainly consist of dairy farms as these have large scale animals. These areas are also inclusive of cases from past year such Varavu, Natoli and Vatiyaka.

Graph 2: indicates the approximate distance of dairy sheds from the residence whereby only 2 sheds meet the requirements of the Public Health Act.

Graph 3: The farms were assessed on where the animals were tied and the location of cow yard from the residence, nearby river etc. Majority of the animals (37.5%) are kept on a higher ground and near the residence.
Graph 4: shows the percentage of houses that have rat infestation with 87.5% reporting of rat problems at home.

Graph 5: shows the vastly used water source and whether the supply is enough for carry out cleaning processes.

Graph 6 & 7: shows that 75% of the sampled farmers having access to personal protective equipments with majority i.e. 65.6% having some knowledge of the disease Leptospirosis.
Discussion
The Leptospirosis infection occurs from direct or indirect contact with infected animal urine. Since the Serovar most likely to be prevalent in different types of animals in Fiji is still unknown, thus the best practice would be to create mass education amongst the farming communities that disrupts the transmission. As studies have shown that with increased education level the prevalence of the disease goes down, hence with that in mind the Ba team had to work with Advisory councilors, Local Authority Members and school organization to conduct awareness in the hotspot areas of Ba. The knowledge amongst the farmers had been assessed as indicated in graph 7 with 65.6% of the sampled farmers having some form of knowledge on Leptospirosis whereby it is called by a different name in vernacular language. The education of the communities was carried out in languages appropriate i.e. in vernacular where the technical aspects of the disease itself was described in the simplest way possible and with situations or case scenarios that may be applicable in each settlement.

The rodenticiding method was continued from the previous year as disease investigation reports indicated high presence of rats. The sampled farmers this year also indicated the presence of rats with 87.5% (graph 4) reporting of infestation in the residence. The houses in the farming communities are located very close to the agricultural activities such as sugarcane and vegetable farms, hence during the sugarcane harvesting season the farmers have reported the movement of rats from farms to the nearby dwellings to looking for food. Thus the communities were provided with rat baits to help them eliminate the rat population and reduce the risk of infection.

Along with rat baits the members of the public were further informed on how to prevent rats from entering the residence by keeping it in good repair and conditions that will prevent access and potential breeding sites. The food storage that are also potential food sources for the rats was recommended to be stored in pest proof containers and stacked above the ground. The public have been asked to keep the inside and the outside of their dwellings as clean as possible to prevent harborage of rats and regularly examine for evidence of infestation.

Moreover the importance of a proper waste disposal system in the settlements is vital whereby the community members were advised to dispose waste responsibly and not allowed to accumulate so that it doesn't attract the rats and become a nuisance in their own homes.

Furthermore the secondary aspect of the program was to establish a baseline data of the animal farms in the Ba Subdivision. This was mostly concentrated on the dairy farms currently being carried out by the Agriculture/Animal Health Department in Ba whereby milking sheds and cow yards are being setup to assist farmers in supplying raw milk to a locally based company SC Foods. The total number of farms assessed was 32 with only two of the sample farms (graph 2) meeting the requirements of the Public Health Act Cap 111 whereby under Section 136 & 137 of Part XI of the Public Health Regulations which states that no animals to be kept within two hundred feet of any residence which also includes the site of buildings for animals.

Thus the 30 dairy milking sheds that has already been construct- ed or are under constructed is in fact in breach of the Public Health Act & Regulations. Another risk factor associated with the location of dairy sheds was the location of the cow yards from the residence. This was found to be on a higher ground (37.5% as indicated in graph 3) then the residence and during the evening they livestock's were tied close to the residence mainly due the fear of theft. As these methods of animal keeping are practiced today the risk of infection increases amongst not only the farmers but the entire community as well as rain would cause the effluents from the cow yards to flow downwards and also pollute the nearby rivers or water sources.

The design of these dairy sheds was also scrutinized and found most of them to be flawed in terms of carrying out basic hygienic practices and cleaning of sheds. Some sheds are still without any water but the milking is still being conducted and supplied, hence a constant water supply should be present to cater for the hand washing and also the cleaning of the sheds as cows tend to urinate during milking. If urine is not cleaned at the work area the risk of infection amongst the farmers is quite high with farmers as most have access to PPE's but practicing the use of PPE's occasionally.
Conclusion
Leptospirosis is predominantly known as an occupational disease and as such the two weeks program targeted the most vulnerable group i.e. the community in the rural settlements, hotspots areas of Leptospirosis, farmer and sardars whereby these groups of people can identify the risk factors in their daily lives and implement mitigating factors to prevent the spread of Leptospirosis.

The assessment of dairy farms has revealed that the design and construction of these new dairy sheds are not up to par with standards that protect the public health because as such the risk factors associated with Leptospirosis has not been taken into consideration, rather poorly planning amongst government departments and lack of information to the farmers is a major contributing factor to its downfall.

However there is ample time to improve the future projects in Ba if the two major departments of Health and Animal Health can liaise with each other first before commencement of any projects then farmers and communities would have a farm that can control the risk factors.

Finally this program has come about in time as sugarcane harvesting season had begun and farmers are out in the farms where they are most at risk. The program had been well received by the communities and with anticipation; the precautionary measures emphasized during the awareness would be practised.

Recommendations
The following recommendation has been suggested after the completion the program:
1. The Animal Health Department to cease all new dairy shed and cow yard projects in Ba to immediately liaise with Ba Rural Local Authority as the developments that is being conducted is illegal as no approval has been granted from relevant authorities.
2. The designs, site requirements, water supply, waste and effluent management of these dairy farms and also other animal farms such piggeries to be to the satisfaction of the Ba Rural Local Authority, thus with proper planning the risks associated with Leptospirosis can be minimized.
3. To follow up on those farms issued with notices for improvements and implementation of mitigating factors.
4. To continue with the annual rodenticiding to reduce the rat population that can spread the bacteria rapidly.

Limitations
The program had encountered some factors that had limited the full potential of the program such as:
1. Firstly the budget had been reduced whereby the coverage of the program had to be scaled down.
2. The transportation was an issue as Ba Subdivision has only one fully capable vehicle which caused the late arrivals and delay in programs
3. Some farms could not be assessed as due to time constraints and transport delays.

Acknowledgement
The Leptospirosis Awareness Campaign was initiated by the Environmental Health staff of the Ba Health Office and would like to acknowledge the contribution and support of the following people:
• The Deputy Secretary Public Health: Dr. Eric Rafai
• The Chief Health Inspector: Mr. Dip Chand
• The Divisional Western team of DMO Dr. Susana and DHI Mr. Rakesh Kumar
• The Sub divisional team leaders SDMO Ba Dr. Ana and SDHI Ba Mr. Josefa Tabua
• The Ba Subdivisional Drivers

And finally the ever hardworking staff of Ba Health Office for their sacrifice and support during the campaign:
• Senior Assistant Health Inspector: Mr. Hetesh Chand
• Senior Assistant Health Inspector: Mr. Jackson Mar
• Senior Assistant Health Inspector: Mrs. Repeka Vueti.

These are the images showing the activities that were carried out during the Leptospirosis Program.

Image 8: shows SAHI Hetesh conducting awareness session with Sardar group.
Image 9: shows SAHI Sanjeet presenting at the Varavu Primary School which included the students, teachers and the parents.
Image 10: The rat baits were also distributed along with awareness program to the community members to help in the elimination/reduction of rat population that are posing a major Leptospirosis threat in the farming communities.
Image 11 &12: The above images show two of the community awareness at Vatulaulau & Namau with explanation on the three LTD’s and having open discussion with the community members, highlighting the risk factors in their own settlement.
LAUTOKA CITY COUNCIL PROMOTES HOME COMPOSTING

Summary
Lautoka City Council established the home compost subsidy programme under the “Waste Minimization and Recycling Promotion Project in Fiji” referred to as the “3Rs Project” to encourage citizens to use compost bins for organic waste composting at homes. The subsidy is available to all citizens of Lautoka District including the rural residents where by the compost bin is sold for only $30.00 whilst the normal price is $60.00. It has been realized that home composting is an easy and fun way for the whole family to take part in an environmentally friendly solution. Presently total of 250 residents in Lautoka City are using the compost bins for composting. Findings reveal that an average of 107g/person/day of organic waste is composted. This accounts for 25% of the household waste which is not entering the waste stream. Hence, home composting is the most cost effective means of minimizing waste.

Introduction
Base line surveys conducted in Lautoka City Council under the “Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands” referred to as the “3Rs Project” in 2008 revealed that 1.1kg of waste was generated/person/day which amounted to municipal waste generation rate of 48.1 tons of waste/day. The waste management costs accounted for 20% of the total council budget and it was also revealed that 60% of the waste generated was of organic in nature. In addition, the open burning of waste and littering was concern for the council and the citizens as it posed serious public health nuisance, caused environmental pollution and fire risk to properties. Home Compost subsidy programme was therefore adopted by the council to encourage the citizens to recycle organic waste by practicing home composting.

The Approach Taken
Since home composting was a fairly new concept in Fiji, the citizens and the counterpart staffs lacked the practical knowledge to practice composting at home and deal with the challenges. Counterpart staffs were given capacity building opportunities like 3R Promotion training in Kitakyushu and Shibushi City in Japan and other local site visits to composting sites. In addition, Pilot Project on home composting was implemented whereby 100 residents and 20 counterpart’s staffs from LCC and NTC were given compost bins to practice home composting. Series of awareness programs on promotion of home composting were launched via media, house to house visits, displays, schools visits and community meetings. Based on the validity, viability and success of the pilot project, the council adopted the home compost subsidy programme as a core activity under the Solid Waste Management Plan and expanded the activity to the whole municipal area. The subsidy programme is available to all citizens of Lautoka District including the rural areas where by the compost bin can be purchased for only $30.00 whilst the normal price is $60.00. The application forms are available at the health department and citizens are required to provide basic information like name, number in family, residential address and phone contacts.

Results and Lessons Learnt
Home composting is an easy and fun way for the whole family to take part in an environmentally friendly solution. It is envisaged that composting will lessen the waste amount being disposed at the disposal site. This contributes to reduction in landfill management costs, increases the lifespan of landfills and ultimately reduces the leachate generation, smell and fly nuisance at the disposal site. Organic waste like grass and garden cuttings, vegetable waste, fruit peelings, papers, leftover food like cassava, bread, rice etc can be composted. Hence, littering, backyard accumulation of refuse, waste scattering of garbage by stray dogs, breeding of disease vectors, open burning of waste and the associated smoke nuisance and the health hazards can be avoided by noble practice of home composting. More so, the final compost product can be used to promote organic vegetable and flower gardening. It has been noted that it takes around 4 – 6 months for the compost to be ready (matured) depending on the amount and size of organic waste added initially, the moisture content and frequency of turning the compost pile. Presently, total of 250 residents in Lautoka City are using the compost bins for composting. Findings reveal that an average of 107g/person/day of organic waste is composted. This accounts for 25% of the household waste which is not entering the waste stream

Sustainability
Strengthening of human and capital resources, sustainable financing, awareness raising, supportive legal framework and policies all contributes to effective implementation of waste minimization initiatives like the noble practice of home composting. For instance the commitment and initiative of the council in adopting the home compost subsidy program has ensured the promotion and sustainability of home composting in Lautoka. In addition, the council has sustained the awareness activities especially in schools through the clean schools programs to motivate children who are excellent agents of change to practice composting.

References
1. 3R Action Plan of Lautoka City Council developed in November 2011 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands.
2. 3R Promotional Manual developed in 2012 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands.
MARKET WASTE COMPOSTING IN LAUTOKA CITY COUNCIL SUMMARY

Summary
This case study was implemented in Lautoka City, Fiji, under the “Waste Minimization and Recycling Promotion Project” which was implemented through JICA’s technical cooperation since October 2008. The project focused on strengthening the capacity of local staffs to promote waste minimization. The base line surveys revealed that it was crucial to decrease the amount of organic waste which accounts for 60% of waste generated in Lautoka. The local counterpart staffs were dispatched to number of similar composting sites as part of capacity building to adopt the best practices which could be applicable in Lautoka. After a series of trial and error method, the counterpart staffs in consultation with the JICA Experts adopted the heap method which was proven to be cost effective and practical. The council managed to sell 11 tons of compost since 2011 at a subsidized rate of $3/10 Kg. The council has managed to establish a sustainable market for the compost. This waste minimization initiative can be useful for any of the PICs intending to minimize market organic waste.

Introduction
Lautoka City like any other urban center in the PICs is particularly concerned about Solid Waste Management with the potential to cause negative impacts on the fragile environment, tourism, trade, food supplies, public health and severely place constraint on the existing limited resources. Thus, implementation of waste minimization is indispensable towards addressing these challenges and ensuring a sustainable Fiji. Hence, Lautoka City Council in partnership with Department of Environment and other municipal councils implemented 3R initiatives under the technical cooperation project of JICA namely the “3R Project”, “J-PRSIM” and “Shibushi Model Project”. Since organic waste accounts for more than 60% of waste generation in Lautoka City, market waste composting was conducted to recycle the organic wastes as more than 85% of market waste generated is organic in nature. Hence, average of 1ton/day of market organic waste is unloaded at the compost yard located at disposal site for composting.

The Approach Taken
The inception of the “3Rs Project”, the counterpart staffs had limited knowledge and skills to implement any composting activity. Hence, the local counterpart staffs were dispatched to number of similar composting sites as part of capacity building exercise to adopt the best practices which could be applicable in Lautoka. After a series of trial and error method, the counterpart staffs in consultation with the JICA Experts adopted the simple heap method which was proven to be cost effective and practical. Series of awareness activity was organized for market vendors to separate organic waste and the council also modified the market cleaning contract so the contractor is also responsible to separately store organic waste on the collection truck and unload at the compost yard. At yard, the 3R workers also cut bigger organic materials into smaller pieces using a knife to decompose faster. Wood chips shredded from green waste (partly decomposed) are used as base material and for covering.

This assists in moisture control; eliminate flies and odor; and also introduce microorganism so it acts as catalyst for the compost. In addition wood chips or brown are excellent source of Carbon whilst the fresh organics have high Nitrogen content. Thus by mixing the fresh organic waste with dried organic waste, it helps to maintain a desirable C:N ratio which is very important for good quality of compost. The excavator for landfill maintenance is used to turn the heap of compost on a fortnightly basis until the compost matures. Once the compost is fully matured, it is sieved, weighed and packed in 10 kg bags for sale at subsidized price of $3.00. The actual price is subject to review depending on the actual production costs.

Results and Lessons Learnt
The Vunato Disposal Site (VDS) at LCC has been effectively used for composting of market organic waste as such composting cannot be done at other public, residential or commercial zones. The council managed to sell 11 tons of compost since 2011 at a subsidized rate of $3/10 Kg. The success of composting depends on various factors and one of the important factors is right moisture content in the pile. It is vital that 50-60 % of moisture is required for optimum composting process. Less moisture will reduce microbial activity and thus slowing the composting process and on the other hand excessive moisture will result in foul smell and generation of leachate which becomes undesirable. Hence old stock of partly decomposed shredded chips (browns) used as base and covering material effectively acts as moisture controls, eliminates fly and odor nuisance and helps maintain the C:N ratio which is essential for good quality of compost. The presence of excavator at the site also enables effective turning of the heaps whereby oxygen is introduced into the heap and assist in breaking down the particle size to accelerate the fermentation (composting process). Home composter is also set up at the compost site for demonstration purposes. Both the market compost yard and simple home composter acts as excellent means of education for the visitors who frequent the VDS especially students. This is more interesting to visitors as they are able to see all the process of composting from receiving, turning, sieving and packing of the final compost product at one place. Market waste composting is an effective means of recycling market green waste provided that organic waste is effectively segregated from other wastes. This waste minimization initiative can also be very useful for any of the PICs intending to minimize market organic waste.

Sustainability
It was noted that amount of compost sold from January to March 2014 for three months accounts for 39% of total compost sold in the year 2013. This indicates that council has managed to establish a sustainable market or demand for compost sales amongst the citizens of Lautoka City and other area including business people such as hotels. The council sells the compost from the council office and keeps record of sales including the customer information. This has become convenient for the customers to purchase the compost material. Records reveal increasing number of repeated customers returning to buy more compost having used and realized the value and importance of compost for gardening. The council has amended the contractual agreement of market cleaning contractor whereby it has become the responsibility of the contractor to create awareness on waste separation for vendors, separately collect and store organic waste on the collection truck, carry out remaining separation work and transport the organic waste to the compost facility at Vunato Disposal Site. This has ensured sustainability of the composting activity.
FIELD NOTE

References

1. 3R Action Plan of Lautoka City Council developed in November 2011 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands.

2. 3R Promotional Manual developed in 2012 under the Waste Minimization and Recycling Promotion Project of the Republic of Fiji Islands.