A Collaboration of Statistics and Engineers Without Borders: Health and Water Survey in Belize

William Fripp[1], Marina Hanna[2], Krisztina Filep[3], Jon Fripp PE.[4]
[1]Stephen F. Austin State University (SFA-EWB)
[2]Texas A&M University (TAMU-EWB)
[3]Statistics Without Borders (SWB)
[4]Technical Advisor (TAMU-EWB)

Abstract
The Texas A&M University chapter of Engineers Without Borders (EWB-TAMU) conducted a comprehensive analysis of health conditions and water quality in the community of San Mateo, Belize. Statistics Without Borders (SWB) was contacted to aid in the appropriate evaluation and reporting of data. This paper describes the project with some of the findings, as well as the collaboration between the two volunteer organizations and the challenges encountered.

Key Words: water survey, statistical practice in developing countries, health assessment, water quality, inter disciplinary cooperation

1. Introduction

Statistics Without Borders (SWB) is an Outreach Group of the American Statistical Association. Comprised entirely of volunteers, it provides free statistical consulting to organizations and government agencies, particularly from developing nations, which do not have the resources for statistical services. In support of non-partisan and secular activities, SWB promotes the use of statistics to improve the health and well-being of all people (SWB, 2009).

Engineers Without Borders USA (EWB-USA) supports community-driven development programs worldwide by collaborating with local partners to design and implement sustainable engineering projects. It focuses on smaller scale infrastructure projects within an overall community project framework and strives to provide practical engineering solutions. EWB-USA programs are full partnerships with the host community and local organizations. The goal is for communities to successfully monitor and maintain projects in order to assure that basic infrastructure needs are met and will remain sustainable without further support (EWB, 2013).

The Engineers Without Borders Texas A&M University chapter (EWB-TAMU) approached Statistics Without Borders for help with their project. In January 2013 The EWB-TAMU team consisted of 7 students and an engineer advisor. The SWB team consisted of three statisticians with various backgrounds.

2. EWB Project Overview

The community of San Mateo, Belize, is characterized by extreme poverty and inadequate water and sewage infrastructure. Although the neighboring San Pedro Community is a popular tourist area, many of the low wage support population live in the neighboring slum area of San Mateo. This area was built on a mangrove swamp and is

frequently inundated by minor storms. The area is characterized by extreme poverty, inadequate housing as well as sewage and water supply infrastructure. A photograph of one of the residences is provided in Figure 1. In addition, the poor drainage results in standing water that is frequently contaminated with sewage. Many residents must utilize substandard wooden pedestrian bridges (Figure 2) that are in constant state of near collapse (locally referred to a 'London Bridge' because they all fall down). Disease bearing mosquitoes are a constant issue as well. As a result the residents of San Mateo are at risk to water born diseases.

Figure 1: Typical San Mateo residence

Figure 2: Pedestrian Bridge

A 2012 report by an EWB-TAMU team documented dangerous coliform contamination in the water supply. This conclusion was based upon water quality grab samples at five taps and two cisterns in San Mateo. The primary contaminant was sewage related. Due to the nature of this dangerous condition, the team identified this issue to the authorities. The results of this initial analysis identified the problem and led to the implementation of point-of-use Sawyer water filters in many homes. Some local repair and improvement of infrastructure has also occurred since this 2012 trip and may be a result in part of the publicity generated by this initial effort.

In early 2013, another EWB-TAMU team returned to San Mateo in order to attempt to quantify disease and water problems, identify any 'hot spots' and provide a baseline assessment that may help local officials and cooperating NGOs evaluate conditions and focus future efforts. This assessment included health indexes, water measurements and infrastructure assessment. All tools were adapted from existing WHO guidance. Waterborne diseases can be manifested in a variety of ways, and an accurate assessment requires a multidisciplinary approach. This effort was conducted in cooperation with other NGOs present during the trip, particularly a University of Mississippi Sociology team led by Kim Shackelford.

Health issues can result from many causes and can be manifested in a variety of ways so a multi factor analysis was utilized. This included a water quality assessments, health evaluations, and infrastructure assessment. Reporting all of the data as discrete readings would potentially obscure a useful assessment of conditions. Therefore, the data collected during the evaluation was to be compiled to produce an aggregate score to indicate 'Dangerous' (3), 'At Risk' (2), or 'Satisfactory' (1).

1.1 Survey Frame and Sample Design

The team estimated that the community contained 247 structures. Of these it was estimated that 220 were occupied or could be considered to be residential units (homes). A complete evaluation was conducted on 26 of these residential units. Partial data was obtained for a number of other households. The team attempted to select homes randomly, but there was some bias in the analysis due to residents who were not at home or unwilling to speak with the team. In addition, residential units that were unsafe to approach were not chosen, eliminating some behind very long "London bridges". Efforts were also made to assure that there was a balance of the visited sites in terms of house condition, location, and resident identity.

1.2 Water Quality Assessment

The local Ministry of Health has limited on-site water analysis capability. The standard practice is to ship water samples to Belize City for analysis, which could result in delays and sometimes corrupt samples. Since bacteria levels can vary greatly, delays make water analysis highly inaccurate. Therefore, all water sampling and analysis had to be conducted in the field by the TAMU-EWB team. Due to the limited time for this trip, analysis needed to be conducted quickly and with recognition that all samples were temporally and spatially limited. Therefore a multi factor analysis which included observations and measurements of indices of water quality impairment was used in conjunction with the water quality sampling.

As noted earlier, the 2012 EWB-TAMU team conducted water quality grab samples at five taps and two cisterns in San Mateo. In 2013, the EWB-TAMU team returned and was able to conduct over 200 discrete water quality samples. The water quality tests measured pH, free and total chlorine, total dissolved solids (TDS), fecal coliform contamination, and general coliform contamination. These tests together provide some of the most important indicators for the safety of water and whether it can be effectively treated.

Table 1 provides the scoring assignment categories for water available to particular households. Read down the left column and when one or more issues can be checked, the score in the right-hand column was assigned.

Table 1: Water Quality Assessment

Measured or observed indices	*Rating Risk Score*
No pressure at spigot Bacteria present Strong odor	3
Chlorine present but too low or pH too high Trace bacteria TDS above 1000 Cloudy or turbid water	2
Uses bottled water	1

All water sources tested provided a pH reading that matched the recommended level of 6.5 – 8. The relationship between chlorine and pH is very important because for the chlorine to work effectively, the pH level must be lower than 8. Otherwise the chlorine becomes bound as a salt and loses significant disinfecting effect.

Free chlorine is most important when testing chlorine as it does the work of sanitizing water. It is "free" because it has not yet reacted to organic material and is therefore ready to act. The EPA recommends maintaining free chlorine at 0.4 g/L. The results came back scattered from 0 – 1.4 g/L. Residents from the community are wary of chlorinating the water, believing that the smell of chlorine indicates the water is not safe to drink. It is recommended that a resident should chlorinate stored water every 3 to 6 months, but it was discovered that some residents had only chlorinated once or not at all if they were storing rainwater. The taps that ran from the city were all chlorinated, with some resulting in a reading of over 1 and others between 0.4 and 0.6. There seemed to be some irregularity in chlorination, as levels varied significantly over the course of a day. Most of the storage water showed no traces of chlorine.

Water tested for TDS showed that most households presented a value of less than 400 parts per million (ppm). The EPA recommends that drinking water have below 500 ppm. It is worth noting that the TDS results from the recently deployed Sawyer Water Point of Use Filters ranged from 12-24 ppm, showing that they were eliminating almost all particulate matter. However, although Sawyer water filters were made available, it was found that 80% were not functioning adequately. This includes filters that were producing contaminated water, were not assembled correctly or not assembled at all.

Water is tested for coliform bacteria (both hazardous and benign) using several different types of tests. A photograph of some of these samples being evaluated is shown in Figure 3. Appropriate use of these techniques requires a firm understanding of sampling protocols. Training of team members was conducted prior to collecting samples and several spot checks were made to assure a minimal sampling error.

Figure 3: Samples undergoing evaluation during study.

One of the most useful and important tests conducted was the Patho Screen that tested whether water contained hydrogen sulfide producing coliform bacteria, which are found almost exclusively in human fecal matter. These bacteria are not directly harmful but their presence means that other dangerous bacteria are almost certainly present. These latter organisms are difficult to test for in the field, making the Patho Screen the most effective way to check water safety in the field. All tap water came back negative, whereas stored rainwater generally came back positive for coliform bacteria.

Approximately 60% of cisterns tested positive for general coliform and about 8% positive for fecal coliform. All open water tested positive for fecal contamination, but authorities have warned the population against consuming that water. While there are still standing areas of sewage, many of the inadequate and leaking water lines running through these pools have been replaced.

Water pressure was low, inconsistent or off at many locations. This puts the pipe system at high risk to intrusion of contaminated water. Many pipes have been repaired; however, lack of backflow preventers and protection taps places water at additional risk for contamination.

1.3 Infrastructure Assessment

The infrastructure of dwellings was based on observation. This provides an assessment of future risk conditions and how susceptible a resident unit is to contagion and infection..

Table 2 provides the scoring assignment categories. Read down the left column and when one or more issues can be checked, the score in the right-hand column was assigned.

Table 2: Infrastructure Assessment

Measured or observed indices	*Rating Risk Score*
Standing water around spigot Broken or damaged water lines No pressure at spigot Shared or no privy	3
Spigot outside but otherwise secure Residents report bad smells or taste in water Poor or fair house condition Outside toilet but in decent condition No effective place to wash hands near food prep and bathroom area No sawyer filter present or not in working condition	2
Bathroom	1

All of the open water pools are contaminated with fecal coliform bacteria. Many of these areas are adjacent to yards and walking paths between homes which places people at risk for disease. Many of the houses have dangerous structural and electrical conditions.

1.4 Health Assessment

A health assessment includes measures of current health and recent health issues. This provides an indication of past problems as well as on going or chronic issues. The health assessment was conducted on any household member who was willing to participate. The EWB-TAMU team realizes that this was the highest source of bias as people with better health were largely not home as they were out working, and those with very poor health would not answer the door. A photograph of EWB team member conducting part of the health assessment is shown in Figure 4.

Figure 4: Health assessment being conducted.

Table 3 provides the scoring assignment categories. Read down the left column and when one or more issues can be checked, the score in the right-hand column was assigned. In each household, the person with the worst health was used to assign the score for the household.

Table 3: Health Assessment

Measured or observed indices	*Rating Risk Score*
High blood pressure Skin disease present Currently sick Recent death	3
Moderate blood pressure High BMI Report being recently sick with diarrhea Moderate to low use of local medical facilities	2
Understands basic health issues	1

The health assessment showed that 70% of households had at least one member who exhibited basic health concerns (high BMI, high blood pressure, skin rash, etc.).

1.5 Overall Findings

The data collected during the evaluation was compiled to produce an aggregate score to indicate 'Dangerous', 'At Risk', or 'Satisfactory'. This was created by adding the values from the previous tables. Table 4 provides the summary scores and assignments.

Table 4: Aggregate Score

Score	*Rating*
3 to 4	Satisfactory (green)
5 to 6	At Risk (yellow)
7 to 9	Dangerous (red)

A map of the showing identified sample locations and rated houses is provided below in Figure 5. This mapping shows that the At-Risk and Dangerous homes are uniformly distributed throughout the community. This indicates that there is not an easy fix to the health issues. A summary of the records are provided in Table 5.

Figure 5: Risk Assessment rating of homes assessed.

Table 5: Summary of Health/WQ Assessments

Rating	*Percentage*	*Confidence interval (at 90% level)*
Satisfactory (Green)	20%	12.3%
At Risk (Yellow)	24%	13.1%
Dangerous (Red)	56%	15.2%

Evidence of dangerous fecal contamination was identified in all open water tested. Possible sources were identified including standing sewage and inadequate water supplies. Water lines that were in direct contact with standing pools of sewage were broken or had inadequate connections. Fortunately, multiple NGOs, as well as local government officials, are interested and working towards reducing the risks.

2. Challenges and Collaboration

2.1 Engineers Without Borders

Going out to a community for any type of assessment is never easy. The EWB-TAMU team encountered several challenges that exist in many, if not, most surveys.

The first challenge was time. The team was only in San Mateo from January 5 to 13, 2013. During that time, they had to learn how to conduct health assessment and water quality tests, as well as visit homes to obtain the data.

The availability of respondents was also a challenge. There was non-response for various reasons – either due to non-contact (people at work, or simply not at home) and refusal to respond.

There was also concern for the safety of team members. Team members had to contend with people who were not always welcoming, animals on the loose and simple access to dwellings.

Finally, there were the more subtle political issues. San Mateo is home to three ethnic groups and no single group could be favoured in terms of the number of dwellings included in the sample and the treatment of respondents, even if some dwellings were deemed to be more at risk. Publishing the data is also sensitive in this regard. In general, the quality of water is a politically sensitive issue in San Mateo.

2.1 Statistics Without Borders

The main challenge for Statistics Without Borders is always the timing of the request for help. In this case, the EWB-TAMU team was already in the field when SWB was contacted. The first discussion between SWB and EWB-TAMU took place after EWB-TAMU team members had returned from the field in Belize. This left SWB with no input on sample size and sample selection and raised an initial concern about what exactly SWB could provide. There was some worry that EWB-TAMU was simply looking for statisticians to vet their data collection and results. However, it turned out that this was not the case at all.

SWB reviewed the analysis done by the EWB-TAMU team. The final written report describing the project and findings, written by EWB-TAMU team members, was excellent and SWB felt that nothing further was needed. SWB did help EWB-TAMU team members understand how confidence intervals worked, how to calculate them properly and the nuances of using a pre-packaged confidence interval calculator. There was also guidance on the use of the finite population correction factor, which needed to be applied in this small sample.

One concern that remained was how biased the sample really was. Although it was not possible to quantify, EWB-TAMU team members took basic notes on the non-respondent

households. They did conduct the sampling to the best of their abilities as they made every effort to select a heterogeneous group of households in terms of location, infrastructure and residents of the household. In the end, SWB confirmed that although the sample was not random, it was realistically close to it. For future efforts, the EWB team learned to document these issues more clearly and consistently.

Although SWB had dreams of large data sets with possibilities of extensive analyses, the sample size (26) was really too small to do any type of modelling. In order to improve the sample and the potential for analysis, SWB would suggest a larger sample (with the realization that this is not always feasible), as well as a well-documented status for each dwelling to help determine proper stratification, estimate bias and possibly compensate for non-response.

3. Conclusions

While the San Mateo area is still at risk, the EWB-TAMU team made recommendations for the community to reduce water contamination (including improved sewage treatment and drainage of standing water, installation of Sawyer filters and education on the use of chlorine for household water disinfection). As well, they recommend increased health education for the community.

This collaboration worked very well. The communication lines between the SWB team members and the EWB-TAMU project leader was good. Unfortunately, due to the final sample size, no additional analysis was performed. By far, the most useful outcome of the collaboration was the realization by the EWB-TAMU team how important it was to consult the statistics "gurus" before collecting the data.

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