A MULTIDIMENSIONAL MEASURE OF DIARRHEAL DISEASE LOAD CHANGES RESULTING FROM ACCESS TO IMPROVED WATER SOURCES IN HONDURAS

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Waterborne illnesses continue to be a major source of morbidity and mortality in developing countries. A myriad of interventions to improve both access and quality of water for household use has been used. The impact of these interventions is most commonly measured by self-reported frequencies of diarrhea, a method prone to significant reporting bias.

Here we report a multidimensional measurement of the impact of community-based water treatment facilities on diarrhea using a combination of ethnographic data, medical chart reviews, and immunoassays for known waterborne amebic pathogens.

This combination of methodologies demonstrated a clear decrease in the morbidity and amebic disease loads as a result of availability of treated water provided by community-based treatment facilities. Also, ethnographic inquiries found evidence of significant shifting of attitudes regarding water consumption and risks from untreated water.

Considering the known impact of waterborne illnesses upon the worldwide burden of diseases and the fact that already available technologies can address this problem, this study lends support to devoting additional resources into community-based water treatment facilities and similar interventions as cost effective and immediately deployable.

Introduction

A key component of the United Nations Millennium Development Goal Number 7 states "halve, by 2015 the proportion of the population (global) without sustainable access to safe drinking water and basic sanitation" (Development, 2004). Most waterborne diseases result in diarrhea that continues to be a leading cause of morbidity and mortality worldwide (Velebit, 2004; Beeching, 2004). According to World Health Organization data, approximately ten percent of the worldwide burden of disease would be removed by the water supply, sanitation, hygiene and management of water resources, making water related diseases arguably the most manageable set of health problems affecting humans using existing technologies (Annette PrŸss-†stŸn, 2008).

A great deal of work has been done attempting to measure the impact of interventions to provide improved water sources at the household level, and, less frequently, at the community level. The overwhelming majority of these studies has used either key informant or self-reporting of diarrhea (defined as three or more loose stools per day) as the measure of disease burden (Boisson S, 2009; Umesh D. Parashar E. G., 2003; Gelting & Leonard, 1998; Fewtrell L, 2005). Reliance upon non-objective measures introduces a host of potentially confounding factors casting significant doubt upon the results of such studies (Boisson S, 2009; Clasen T, 2006).

Water Missions International (WMI) is a nonprofit, nongovernment organization that works to provide sustainable water treatment capacities and sanitation facilities for people in developing countries. In 2006, WMI received a grant from the Pentair Foundation to provide improved water source access and toilet systems to all of the people in the district of Colon, Honduras, an area that contains approximately 340,000 people. The goal of 100% coverage utilizes a combination of solutions including, home based filtration systems for communities with less than 300 people, and a variety of high capacity treatment systems for larger communities. The implementation of this project is ongoing as of this writing. The project also includes a health impact study resulting in this writing.

In the baseline study phase of the project, water sources for 613 communities were identified. Various water quality tests were conducted on 100% of the water sources. Based on the standard membrane filter test, every water source was found to contain high counts of coliform bacteria.

Water treatment systems used in these communities were developed and manufactured by WMI, a nonprofit organization based in Charleston, SC. The technology uses a combination of multimedia, multistage filters and chlorination to provide treated water for drinking and cooking that meets WHO drinking water standards. In addition, WMI provides community development programs that include education and microenterprise strategies to assure sustainability of these interventions. For all households that lacked adequate sanitation facilities

and agreed to assist in installation, sanitary pit latrines with pour flush toilets were also provided. Hardware and installation costs per water treatment unit range from $14,000 to a high of $20,000. Once installed, each unit is capable of producing 37,000 liters of treated water per day at a cost of $0.25-0.50 (US) per 3,000 liters. In smaller communities where a central treatment facility was deemed unstainable, point-of-use sand filters with chlorination systems were placed in individual households. These communities with point-of-use units were not included in this study.

Methods

Twelve communities were randomly selected from the Colon district in three categories. Four communities had not yet obtained a water treatment system and were used as controls. Four other communities where water systems had been deployed were entered into the study as were four more communities where both water systems and sanitary pit latrines had been installed. A multidimensional study design employing a combination of ethnographic interviews including self-reporting of health issues, immunoassays of stool samples for known waterborne pathogens, and medical chart reviews was created to test the null hypothesis that the water and sanitation interventions had no impact upon the disease load within the communities selected.

Role of the Funding Source and Ethics Review

All participating researchers donated their services to the project and were reimbursed for actual expenses related to travel and accommodations only. The study design, collection and analysis of data and interpretation of the data were the sole responsibility of the researchers.

Prior to initiation of the study, the Colon Minister of Health gave approval and consent for the project and study, including protocols for managing positive tests for amebic diseases as well as other aspects of the study design. Furthermore, the Institutional Review Board of Water Missions International reviewed and approved the study design. Consistent with this review, no information from medical chart reviews which could identify subjects of the study was retained outside of the local healthcare facility. Under the supervision of a licensed physician, all individuals in whom potential pathologic parasites were found were given free treatment with regimens previously approved by the Colon Minister of Health. The control communities where no water treatment or sanitation facilities existed were selected from a pre-existing construction queue and intervention was not withheld as a result of this study. Verbal consent was obtained from all subjects who provided fecal specimens or who were interviewed.

Ethnographic Data

The bilingual social scientists of the research team recorded interviews with focus groups and individuals selected by convenience sampling. Four focus groups of four to five subjects and 46 individuals consented to the interviews. The results were translated by at least two bilingual researchers, transcribed, and entered into narrative analysis software (*Atlas.ti*¨). In addition to these interviews, twenty-four of the fifty-two subjects who showed immunoassay evidence of amebic parasite infection were located and also interviewed and this data was treated in a similar fashion. The interviews were semi-structured and questions were asked related to concepts of health, water, disease causations, indigenous systems of healing and health knowledge, as well as attitudes toward modern biomedical practices.

Biomarker Data

Recent advances in highly sensitive and specific rapid immunoassays for amebic diseases have made field-testing of individual fecal specimens now possible (Susan E. Sharp, 2001; Lynne S. Garcia R. Y., 2000). These devices test for species-specific antigens of common amebic parasites known to be primarily waterborne (CDC, 2008). The device chosen for this study tested for *Giardia lamblia*, *Entamoeba histolytica/Entamoeba dispar*[3], and *Cryptosporidium parvum* antigens. Previous work has shown these tests to have both specificity and sensitivity in excess of 96% for the before mentioned pathogens (Susan E. Sharp, 2001; Raymond Chan, 2000; Lynne S. Garcia R. Y., 2000).

Immunoassay of stool for these amebic parasites was used as an indicator that the subject had been exposed to waterborne pathogens and was therefore at risk of these and other infectious waterborne illnesses. Specimens were obtained from 182 consenting adults and children of consenting adults who volunteered for the study as a result of advertising in test communities. Specimens were tested within 12 hours of collection using the Triage Micro Parasite Panel¨ manufactured by Biosite Incorporated. Results are summarized in Table 1.

Medical Chart Review

As previously noted, the Colon Minister of Health (CMOH) gave written consent for the research team to review local epidemiology reports and household medical records. The community in the 12-community study group with the oldest water system was selected for this part of the study.. Medical records held in a local healthcare clinic were reviewed by selecting the most recently created records and working toward the older records until 314 charts had been inspected. Each chart represented a household. Data collected during the baseline study phase of the project indicated that the average household contained 5.4 people yielding an approximate population subject to this review of 1,700 individuals (a higher

	Summed all who had any WMI intervention (n=104)	No WMI Intervention (n-78)
Total + for any amebic parasite	25	28
Total – for any amebic parasite	79	50
% + for any amebic diseases	24.0%	35.9%

Table 1

number of individuals than the CMOH records indicated lived in the community). Charts were inspected for visits to the clinic for diarrhea, dysentery, or a diagnosis of amebic diseases and the gender, age, and date of the visit was recorded.

Previously tabulated records of total clinic visits were also reviewed and, except for a single month during a dengue fever outbreak, a less than 15% fluctuation of the number of visits per month was noted over a seven-year period. Before tabulating visits for potential waterborne illnesses, a six-month period was allowed for the system to become fully operational and water delivery stabilized. From this point forward until the time of the chart review (34 months), a total of 45 visits to the clinic were found. In the 34 months prior to the installation of the water treatment facility 92 visits to the clinic for diarrhea or dysentery were noted. These results were charted over time as seen in Figure 1. The vertical arrow indicates the date of installation of the water treatment facility.

Results

Ethnographic data suggests a high level of understanding of the causes and prevention of diarrhea among the communities studied. All of the people interviewed attributed the majority of their diarrheal diseases to water and sanitation issues.

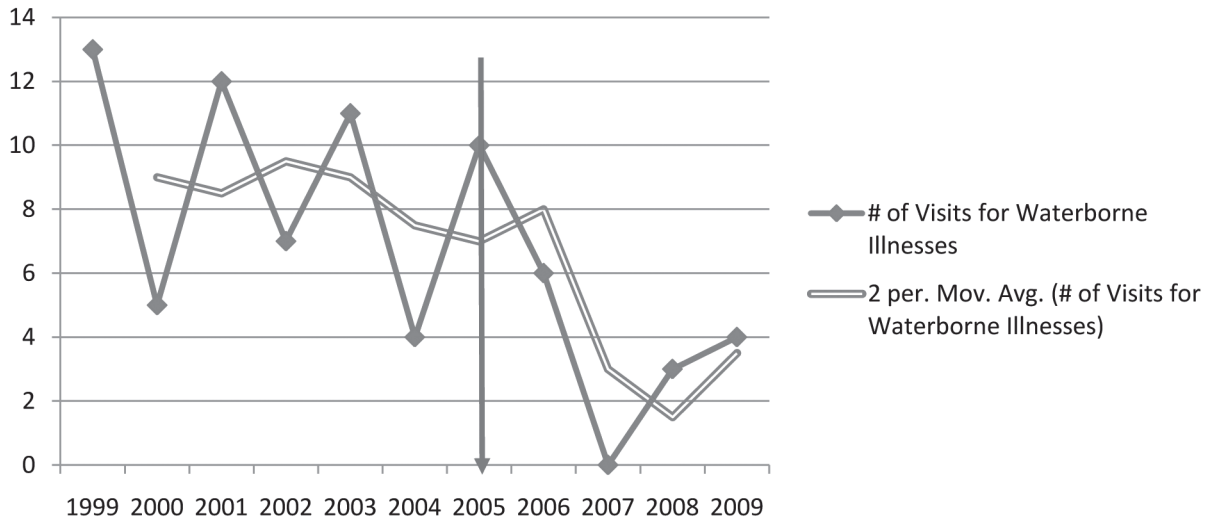

Figure 1. Trendline Based upon the Monthly Number of Visits to La Brea Health Clinic for Potential Waterborne Illnesses

"We have had it for one year, and we haven't done that bad. And we have seen the change in health between those who drink purified water and those who don't."

"The amount of children with parasites has decreased very much. Now when people go to the centro de salud, they go for problems like fevers, gripe (colds), but not for parasites."

"There is no life without water. "

"Everyone looks better. You can see it in their color and their skin, it's because of the water and the latrines."

"Look, the people have always tolerated to the maximum extent, diarrhea in young children, including even the adults. But now less with the purifier, thanks to the project by Water Missions International that came to give us the purifier."

"Many results because there are almost no children with diarrhea, nor adults because the entire community is drinking water from the purifier."

"And my family is a testimony of that. In my house, I have 3 kids, 5, 3, 2. And their problems of diarrhea and stomach inflammation is no longer a problem. It is because we stopped drinking water from the taps and we only drink water from the purifier. I am a true testimony that there has been a real change in my house."

"One day the water at my house stopped working, and so I went to work, and when I got home I drank water from the tap. And the result was that we got diarrhea, my kids, my wife and me also, everyone. From that day I learned a lesson, and we understood that clean water really is important. It's a necessity, it is not a luxury."

"We have seen a reduction in diarrhea. Before there was more. But with the purifier there is less. There is always diarrhea but not as much as before."

Table 2

Thirty-eight of thirty-nine people who expressed knowledge of diseases indicated an understanding of water as a potential vector of diarrheal diseases. Furthermore, all of the subjects reported an unspecified reduction of diarrheal episodes after they began using treated water. While four subjects reported the occasional use of herbal remedies, the rest relied almost exclusively upon the local health clinics and hospitals for their medical needs.

There were significant signs of a shift of ideations regarding drinking untreated water characterized by the quotes in Table 2. Further interviews with 26 of the subjects who tested positive to stool parasites despite having access to treated water indicated behavioral lapses, most commonly the intermittent drinking of untreated water. All but two of these subjects indicated knowledge of the potential for the untreated water to cause diseases and gave other reasons for drinking from potentially contaminated sources.

Twenty-nine percent of all subjects tested showed immunoassay evidence of stool amebas. *Entameba* (51%) accounted for the majority of species while *Giardia* (44%) was slightly less common. *Cryptosporidium* (4%) was uncommon. The prevalence of parasites decreased in subjects from communities where a water treatment system existed (26.4%) when compared to subjects from communi-

ties where water systems had yet to be installed (35.9%). A chi-squared analysis was performed on the results of the immunoassay tests. The difference between positive test rates in the communities with WMI interventions (water and sanitation or water treatment alone) and communities where such interventions had not yet occurred was significant with an alpha level of <.001.

Medical personnel from four local health clinics stated in their interviews that the numbers of diarrhea cases they treated had dropped since the WMI water systems were installed. This was confirmed by data from the chart review which indicated an approximate 52% reduction of clinic visits for diarrheal diseases in the 34 months after the community water system became fully operational and water distribution had been established. This finding is particularly significant since it occurred during a period when records from the CMOH showed an increase in diarrheal diseases in 13 of 15 nearby communities being monitored in the district.

Discussion

To our knowledge, this is the first study to combine self-reported and objective measures of diarrhea disease loads and to specifically use immunoassays as an indicator of exposure to potential waterborne pathogens. The triangulation of these methodologies provides powerful support to what otherwise are strongly subjective and questionable measures of disease loads from waterborne pathogens.

Ethnographic data found during this study strongly suggests that, consistent with other similar work (Gelting & Leonard, 1998), the availability of improved water is felt by its recipients to improve a general sense of health and well-being. High levels of knowledge related to water issues exist in this area of Honduras which could be attributed to many factors including sophisticated public health efforts, high literacy rates comparable to the region, widespread health education in public schools, and the training offered by Water Missions International and other NGO's. Local indigenous belief systems appear uncommonly and for no one were they the preferred method of treatment for diseases.

Immunoassay evidence of decreased prevalence of waterborne parasites strongly supports the contention that community-based water treatment facilities reduce the overall stool parasite load. All subjects who tested positive for either *Giardia* or *Entameba* were treated with two age and weight adjusted doses of tinidazole. A follow up study of all subjects who submitted stool samples is planned to examine the re-infection rates among the communities with and without access to water.

When parasite antigens were detected in stool samples of individuals who had access to improved water sources, ethnographic investigation revealed lapses of behavior in spite of a high level of understanding of the risks associated with drinking from untreated sources. Further analysis of the interviews of subjects whose stool was positive for potential waterborne parasites suggests that risk and time management decisions rather than cultural or knowledge base differences accounted for lapses in behavior and willingness to drink untreated water. Subjects reported that the time required to obtain treated water, sometimes a difference of only a minute or less, was too great to overcome their concerns with potential health risks associated with untreated tap water.

Multiple pathogens and inflammatory conditions cause diarrhea, making monitoring this symptom alone an inexact measure of the disease load related to water quality. Worldwide, the most common cause of diarrhea is viral infections from the rotavirus, a ubiquitous infection that may be transmitted by personal contact (Umesh D. Parashar E. G., 2003). Food contamination and non-infectious inflammatory diseases add to the diarrhea prevalence. Though not precisely known, the number of diarrhea cases unrelated to waterborne pathogens is likely substantial. This means that the 52% drop in diarrhea rates noted in the community chart reviews may represent an even greater majority of the cases that could possibly be related to potential water and sanitation issues.

This combination of qualitative data, health records reviews, and immunoassays shows compelling evidence that a community-based water treatment facility reduces the burden of diseases in the communities of Colon, Honduras. We further validate with objective measures prior work based upon self-reporting of diarrhea rates. Finally, this data suggests that interventions on a community level to provide potable water access when combined with community development efforts and sanitation can play a significant role in the reduction of mortality and morbidity from waterborne diseases and associated co-morbidities.

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A nearly universal finding of all healthcare interventions is that the benefits tend to be unequally distributed across the target population. Additional ethnographic work is needed to understand why. Furthermore, while the health benefits of improved water and sanitation access would seem obvious, there is sparse literature on the subject from which to understand the value added to the public's general health and well-being by such interventions. All of these issues are tightly interwoven with the concept of water access as a basic, universal human right.

In most wealthy Western countries where public health infrastructure is substantial, water access and quality have been assumed to possess significant value, and large-scale interventions are done with little or no public debate or input. In many of the poorer countries and within different systems of knowledge, such assumptions are often highly contested leading to uneven acceptance

of water and sanitation systems even when they are made available. This again affords anthropologists opportunities to apply their discipline in an arena of proven benefit often to the most marginalized of people. WHO data suggests that improvements to drinking water, sanitation, hygiene, and water resource management would eliminate 10% or more of the worldwide burden of disease. If ever there existed an opportunity for anthropological methodology to be meaningfully applied to save lives, this is it.

Notes

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[3]The rapid tests does not differentiate between the more clinically significant *E. histolytica* and the morphologically identical *E. dispar*, however both are likely waterborne pathogens and the differentiation for this study was not undertaken as both can indicate exposure to contaminated water.

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