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Waterborne Disease-Related Risk Perceptions in the Sonora River Basin, Mexico

Agustin Robles Morua,[1] Kathleen E. Halvorsen,[2,*] and Alex S. Mayer[2]

Waterborne disease is estimated to cause about 10% of all diseases worldwide. However, related risk perceptions are not well understood, particularly in the developing world where waterborne disease is an enormous problem. We focus on understanding risk perceptions related to these issues in a region within northern Mexico. Our findings show how waterborne disease problems and solutions are understood in eight small communities along a highly contaminated river system. We found major differences in risk perceptions between health professionals, government officials, and lay citizens. Health professionals believed that a high level of human-waste-related risk existed within the region. Few officials and lay citizens shared this belief. In addition, few officials and lay citizens were aware of poor wastewater-management-related disease outbreaks and water contamination. Finally, aside from health professionals, a few interviewees understood the importance of basic hygiene and water treatment measures that could help to prevent disease. Our results add to the literature on environmentally-related risk perceptions in the developing world. We discuss recommendations for improving future human-wastewater-related risk communication within the region.

KEY WORDS: Mexico; risk perception; waterborne disease

1. INTRODUCTION

The World Health Organization (WHO) estimates that about 10% of diseases globally are attributable to water-quality-, sanitation-, or hygiene-related problems.(1) Only 53% and 80% of the global population has access to basic sanitation and a reasonably safe and adequate supply of water, respectively.(2) Access to adequate sanitation and quality drinking water is even lower in rural areas, particularly within the developing world.(1,2) The poor state of water supply and sanitation systems in rural communities is often caused by cultural, economic, and political barriers to constructing and maintaining these systems. These barriers include disagreements between community members, local government officials, and funding agencies over responsibilities for constructing and maintaining facilities. For example, the Joint Academies Committee on the Mexico City Water Supply(3) and Ingram *et al.*(4) report that many Mexicans believe that water should be free. This situation makes it difficult for water agencies to collect revenues to pay for operations and maintenance expenses.(3–7)

Many governments and aid organizations have funded water supply and sanitation projects to correct these problems. Unfortunately, many of these systems have failed.(3,4,8–15) These failures may have occurred because the systems followed the build-operate-transfer (BOT) model, where external contractors were hired to build the system.(8,16) Communities were usually left out of the design and decision-making process, but left in charge of the

[1]Arizona State University, AZ, USA.
[2]Michigan Technological University, MI, USA.
*Address correspondence to Kathleen E. Halvorsen, Michigan Technological University, MI, USA; tel: 906.487.2824; kehalvor@mtu.edu.

system's operation and maintenance. The prevalence of poverty and political instability in rural communities in developing countries can reduce the perceived importance of water supply and sanitation to community governments and inhabitants.[8–10,17,18] Prior work suggests that a lack of understanding of basic human waste management problems and solutions may also be a key factor.[19]

Finding sustainable solutions to water and sanitation problems requires addressing not only technical and financial challenges, but also the political and cultural beliefs and attitudes that prevent solutions from being implemented successfully.[20,21] Understanding how people impacted by and involved in managing water and sanitation problems perceive the risk associated with waterborne diseases may help to solve at least part of this puzzle. We use Slovic's definition of risk as "a concept that humans invented to help understand and deal with the dangers and uncertainties of life."[22–24] We also draw on his usage of the term "risk perception" as judgments that exist in people's minds and are used to characterize and assess the severity of a particular problem.[22,24,25] In our study, we focus on the judgments in people's minds regarding the severity of waterborne diseases, as well as the causes of and solutions to these diseases.

Slovic and others argue that perceptions of risk are "inherently subjective,"[26] interrelated with culture, and often different when public and expert perceptions are compared.[27] Differences in risk perception can cause disagreements about the best course of action to solve a problem.[24] Risk perception assessment can therefore provide critical information for the development of programs that effectively manage water-related and other risks.[28,29] Since risk perceptions are affected by geographic and cultural contexts,[30,31] it is important to conduct studies that are sensitive to this context.

For instance, one of the most important predictors of risk perception is direct and indirect experience with the risk.[24,25,31] Direct experience can provide feedback on the degree of risk along with the success of specific reduction strategies and is likely to vary by location.[24,32] People who perceive a relatively high likelihood of an adverse event in their locale are more likely to take steps to reduce that likelihood or minimize negative impacts and to support government policies to do similarly, even if it requires an economic sacrifice.[33]

Understanding key risk perceptions related to waterborne disease requires the assessment of many beliefs related to the problem and its causes and solutions. Knowledge of the problem itself affects individuals' understanding of whether and how much they and members of their community may be at risk. For example, exposure to information regarding local waterborne disease outbreaks may vary among community members. It is also important to understand what individuals know about the underlying causes of these diseases. For example, awareness that contaminated drinking water is a local problem and that the contamination is caused by poorly managed or treated wastewater is likely to affect risk perceptions. Finally, it is important to assess understandings of solutions to waterborne diseases. These include basic hygiene practices; the treatment of drinking water at the community or household level; better choices regarding or protection of, water sources; the purchase and consumption of bottled water; and the construction and maintenance of sanitary latrines or community-level sewage treatment systems.

2. PERCEPTIONS OF RISKS ASSOCIATED WITH WATERBORNE DISEASES

Our study analyzes the complex set of interrelated risk perceptions associated with waterborne diseases in rural communities in northern Mexico. We therefore begin our literature review with risk perception research conducted in Latin America and border or urban U.S. regions where Latinos were a targeted study group. In particular, they focused on understanding community members' judgments related to problems and causes associated with drinking water quality and waterborne disease, and to a lesser extent, solutions to these problems.

Ingram *et al.* conducted one of the few waterborne-disease-related risk perception studies comparing U.S. and Mexican populations in the Nogales, U.S.–Mexico border region.[4] They found that, although Mexicans were more at risk from waterborne diseases, they were less likely to perceive this as a risk than U.S. residents on the other side of the border. A potential explanation for this difference was that health professionals on the Mexican side downplayed the local risk of waterborne disease, emphasizing instead problems such as respiratory disease.

A number of studies have assessed perceptions regarding the causes of waterborne disease. The results have been mixed with most studies finding that individuals did not understand that their

contaminated drinking water was putting them at great risk of waterborne disease and a few studies finding high degrees of perceived water-related risk. For instance, Poblete-Davila *et al*.[34] found that few of the Costa Rican community members they surveyed were aware of the connection between local drinking water contamination and disease. Similarly, the Nogales study[4] found that Mexicans, including community health professionals, underestimated the risk from local water contamination, while community members and health professionals on the U.S. side of the border overestimated local risk from water contamination. Another study with Latino populations in the El Paso region of the United States found little awareness of their risk from contaminated drinking water.[35]

On the other hand, some studies have found that Latino populations were well aware of their risk from water contamination. For example, a study in the Tucson area found that poor Latinos believed themselves at risk from water contamination, particularly in comparison to wealthier neighborhoods with better water quality.[36] Research conducted in Hermosillo, Mexico, close to our study region, found that residents rated water contamination and associated health problems as one of the greatest risks they regularly encountered.[37] A study conducted in the Dominican Republic[38] found that a majority of individuals knew that they were at risk of disease from their contaminated local drinking water supplies.

While a number of studies have assessed risk perceptions regarding water-contamination-related causes of waterborne diseases, fewer have assessed understandings of the problems' causes. One of these is Byrd *et al*.'s study in El Paso, Texas,[35] which found that residents in poor neighborhoods were well aware of health risks associated with poorly treated wastewater. Additionally, researchers in the Nogales study found that Mexican health professionals believed that most waterborne diseases in their community were caused by poor hygiene practices rather than drinking water contamination.[4]

Several studies have investigated Latin American attitudes toward risk reduction, including support for improved wastewater treatment, household-level drinking water treatment, and hygiene practices. The results of studies have been consistent. Researchers found little support for wastewater treatment improvements in locales with low levels of household-level treatment of drinking water and inconsistent practice of basic hygiene measures. For instance, scientists conducting a study in Costa Rica found that only 5% of interviewees recognized the need for basic hygiene measures or adequate wastewater disposal practices such as ensuring sufficient distances between latrines and drinking water wells.[34] Similarly, researchers in Guatemala found little support for a new wastewater treatment plant that subsequently closed.[14] Although, as mentioned earlier, a majority of individuals in the Dominican Republic study knew they were at risk from contaminated drinking water, only a few treated their drinking water through boiling it or adding chlorine.[38] On the other hand, researchers in the El Paso study found that a majority of individuals on the Mexican side of the border refused to drink water from the tap and instead spent 3–5% of their income on bottled water.[35]

Two of the factors that may explain these risk perception gaps are beliefs about neighbors' risk perceptions and levels of trust in risk-related information. For example, Fessenden *et al*.[39] found that individuals' risk perceptions were shaped by beliefs about how others in their community perceived the risk. Some studies suggest that the level of trust individuals have in an agency can greatly influence their willingness to believe information provided by that agency.[35,39] For instance, if officials are viewed as proactively responding to a risk, community members are more likely to trust future information issued by these officials about the risk.[39] On the other hand, if officials are viewed as having been forced by community members to deal with a risk, these members are less likely to trust the officials and their information. This situation can affect agencies' abilities to communicate about important risks. For instance, in the El Paso study, only a third of interviewees trusted the information provided by the local health department, while 56% trusted information on television.[35]

Studies of risk perceptions have shown that women are generally more concerned about environmental risks than men.[40,41] A number of studies of risk perception targeting Latinos have used gender, income, and educational levels to describe differences in risk perceptions in the population studied.[35–38] For example, the case studies conducted in El Paso and Tucson[35,36] were designed to elicit risk perceptions specifically from men and women, and people with different income and educational levels. Other studies of Latinos focused on understanding the risk perceptions of children's caretakers in poor neighborhoods.[34,38] These researchers

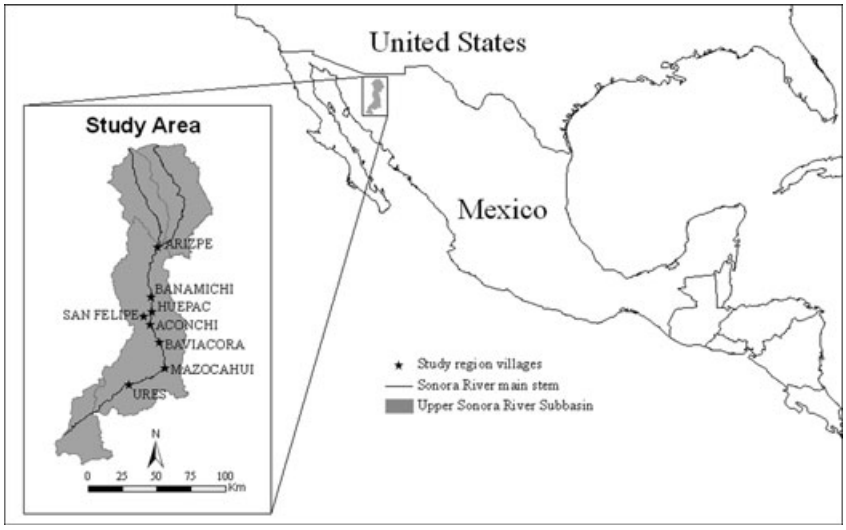

Fig. 1. Study region.

found that respondents with lower incomes believed themselves to be more at risk from waterborne disease than wealthier community members.

These studies provide valuable insights into waterborne-disease-related risk perceptions. However, by tending to focus on just one or two risk perception dimensions related to waterborne diseases, the studies may have missed key relationships between perceptions of the problem, its causes, and its solutions. There is a need for research that assesses perceptions of all of these dimensions in the same region at the same time. We therefore set out to study perceptions related to all three in one area of the world experiencing high levels of waterborne disease, much of it tied to poor sanitation systems and inconsistent hygiene practices.

3. WATERBORNE DISEASE, HUMAN WASTE MANAGEMENT, AND THE SONORA RIVER BASIN

We chose the upper Sonora River basin (USRB) in northern Mexico as our study area (see Fig. 1 for location) because of the significant water-related risks present in this rural region. Also, two of the authors conducted prior wastewater-related research in one of the communities within the region, providing a basis for understanding many key elements of area waterborne disease problems, including high poverty levels and poor interactions between rural communities and state agencies.[19] The work we describe in this article is part of a larger study that includes an engineering analysis of solutions to wastewater contamination problems in the USRB. Thus, our risk perception study was preceded by fieldwork with the purpose of assessing the actual risks related to water quality and its relation to wastewater management issues within the region. The following is a brief description of key factors related to the region's geography, waterborne disease prevalence, drinking water, and wastewater treatment system performance.

There are about a dozen small communities with 500–3,500 residents along the 200-km-long main stem of the Sonora River. Although a number of these communities have drinking or wastewater treatment systems built under past state or national initiatives, many are not fully functional and some are completely abandoned. Some have no system at all. Due to the variable nature of the regional climate and inadequate water supply management, all of the communities suffer from periodic drought and water shortages. Most of the drinking water systems were built during the 1950s while the sewage collection systems and some of the current wastewater treatment lagoon systems were constructed in the 1970s and 1980s. In 1983, Mexico decentralized its water and sanitation sector, giving municipalities responsibility for their management with most funding and technical advice coming from state and federal agency officials.[6,7]

All of the households in the county seats are connected to sewage collection systems. The majority of the towns outside the county seats dispose of their household wastewater in either septic tanks or

simple pit latrines. The majority of the communities with sewage collection systems discharge their wastewater into lagoons or ditches adjacent to the floodplain of the Sonora River. All of the lagoons in these rural communities were built in the early 1980s at the same time as the construction of the sewage systems. Lagoon systems are the most typical form of waste-water management practice in this region, due to minimal operational and maintenance costs. The lagoons were built without any protection against seepage of wastewater to groundwater, such as plastic membranes or compacted clay. Most of these lagoon systems are currently abandoned. Access to the sites is very difficult, which makes inspections and maintenance problematic.

Because of the current state of the wastewater treatment infrastructure, it is difficult to determine if any of these lagoons were designed using conventional treatment design guidelines. However, based on the dates when these lagoon systems were built, most, if not all, of these systems are old enough to have exceeded design lifetimes. None of the lagoons have been evaluated for their performance in removing contaminants or to determine if they meet the Mexican standard for discharging wastewater into water bodies.[8,19] Like many other developing countries, responsibility for meeting national standards lies in the hands of local officials. Unfortunately, a few files required reports, perhaps due to a lack of funding to pay for lab tests.[6–8]

Most of the lagoons appear to be working as containment ponds, without any engineered discharge point. In these cases, wastewater losses occur via infiltration and evaporation. It is also possible that during storm events, these lagoons overflow and wastewater flows directly into the Sonora River. The lagoons in the towns of Arizpe and Baviacora have direct discharge outlets into the Sonora River. As of summer 2008, the town of Aconchi, which is currently building a new facultative lagoon, was temporarily diverting untreated wastewater to the Sonora River. The town of Ures does not have any type of formal wastewater treatment system. This town discharges its untreated sewage into a drainage field located adjacent to the Sonora River.

In Mexico, communities ranging in size from 2,500 to 20,000 residents are required to monitor wastewater effluent twice a year.[42] However, national wastewater standards are rarely met, particularly for wastewater treatment. One reason is that agencies struggle to meet operating costs. While communities receive some state and federal funds toward these costs, they are usually insufficient, particularly because local residents frequently fail to pay their water and wastewater treatment bills.[5,19]

The Mexican National Water Commission monitors the surface water quality throughout the country. Historic results of the monitoring pertaining to the Sonora River were requested through official channels[43] and were denied on the basis of threats to national security. As part of our multidisciplinary studies conducted in the USRB, we therefore did our own field studies[44] to determine the fecal waste loads from unlined wastewater lagoons located adjacent to the Sonora River. We found that significant fecal waste loads emanate from the communities of Arizpe, Aconchi, and Baviacora. *Escherichia coli* (*E. coli*) concentrations, a typical indicator used to quantify contamination from human wastes, ranged from zero in the sections of the river upstream of the rural communities to 20,000 CFU/100 mL in regions downstream of known wastewater discharge zones. These results indicate that contact with surface waters at several sites could pose a public health risk, since *E. coli* concentrations at these sites exceeded by one to three orders of magnitude the criteria established by the U.S. Environmental Protection Agency (EPA) for recreational contact.[45]

Drinking water standards are established and monitored by the Mexican Secretary of Health.[46] Municipal authorities also have responsibility for compliance with drinking water standards. However, health departments monitor drinking water disinfection system performance using residual chlorine and pH levels. The presence of residual chlorine is an indicator of the performance of the disinfection process in the drinking water system. The Mexico drinking water standard establishes the minimum and maximum residual chlorine as 0.2 and 1.5 mg/L, respectively. The levels reported in all of the towns in our study region were zero. Also, although not required by law, regional health departments test drinking water wells sporadically for microbiological contamination. Two of these tests in our study region found unacceptable levels of microbiological contamination.

The State of Sonora Office of Health reports frequent outbreaks of waterborne, human-waste-related diseases[47] in the USRB and classifies the area as an "endemic Giardia Lambia region."[48] Several measures of regional waterborne disease incidence over the past 5 years are included in Table I. "Acute diarrheic diseases" is a general term for symptoms that may be caused by drinking water contaminated with human wastes or poor hygiene practices. Health clinic visits related to waterborne diseases are classified as such by health clinic

Table I. Incidence, Type, and Number of Health Clinic Visits Associated with Waterborne Diseases by Year in the Upper Sonora River Watershed[47]

Year	Acute Diarrheic Disease (Cases per 1,000 People)	Amoebiasis (Cases per 1,000 People)	Giardiasis (Cases per 1,000 People)	Shigellosis and Helminthiasis (Cases per 1,000 People)	Typhoid (Number of Outbreaks)	Hepatitis A (Number of Outbreaks)	Health Clinic Visits Due to Waterborne Diseases
2002	64.5	12.8	19.1	2.4	0	1	15%
2003	205	65.9	38.5	0	2	2	22%
2004	34.5	7.1	7.6	0.9	0	1	10%
2005	34.9	4.6	12.7	0.4	2	2	11%
2006	29.7	2.2	8.5	0.3	0	4	11%

[a]Health records shown in this table are exclusively for the clinics in the towns visited. The total population served by the clinics in the USRB was 14,832 based on the 2005 census data.[58]

workers. Amoebiasis, giardiasis, shigellosis, helminthiasis, typhoid, and hepatitis A are diseases associated either with drinking water contaminated with human wastes or poor hygiene practices. The information was obtained from the yearly records submitted by all the rural health clinics in the USRB to the State of Sonora Health Department. The number of outbreaks reported per year in the USRB was obtained from the Sonora Health Department Epidemiological Center. The tally of all waterborne-related diseases was normalized against the population census of 2005 for all of the communities in the USRB (pop. 14,832) and is reported in Table I as incidences per 1,000 people. The incidences and outbreaks of waterborne diseases and percentage of total health clinic visits related to waterborne diseases shown in Table I indicate that waterborne diseases are a major problem in these communities.

All households in the USRB communities are served by centralized water supply systems supplied by drinking water wells located adjacent to the Sonora River. Although the high incidence of waterborne disease may be due at least partially to drinking contaminated water, avoiding this by boiling water or buying bottled water is difficult and expensive. An informal survey of stores and water purveyors in the region indicates that bottled water prices range between $US 0.05 and $US 0.11/L if bought in bulk. Assuming an individual needs at least 5 L of drinking water per day[49] and an average regional family size of four individuals per household, purchasing bottled water would amount to about $US 400–$800/year. Since the average regional daily household income is $US 5.66,[50] avoiding drinking contaminated water through the purchase of bottled water is impractical for many.

Given the condition of USRB drinking water and wastewater treatment systems, potential pathways for exposure to waterborne diseases include (a) ingestion of contaminated or untreated drinking water; (b) contact with untreated wastewater in lagoons or ditches; (c) contact with untreated or partially treated wastewater transported to the Sonora River through direct discharges or through infiltration into groundwater flowing toward the river; or (d) contact with untreated or partially treated wastewater that has contaminated groundwater and wells. Although it is difficult to estimate the degree to which community members are exposed to pathogens through each of these pathways, there is significant potential for exposure to waterborne, disease-causing microorganisms via improper disposal of wastewater and improper drinking water treatment within our study region.

4. RESEARCH DESIGN

The goal of this study was to explore the beliefs or judgments in people's minds regarding the severity of, and causes and solutions to, waterborne-disease-related problems.

Our study took place in the eight rural communities along the main stem of the Rio Sonora indicated in Fig. 1. We developed and pretested a semi-structured interview guide (see the Appendix) with researchers familiar with the region. Qualitative interviews can provide exploratory, in-depth information regarding attitudes and beliefs related to topics where little research has been performed, such as waterborne disease risk perceptions in the developing world.[30,51–54]

We conducted 72 interviews. Table II shows the breakdown of interviews by key categories. The

Table II. Breakdown of Interviewees by Category ($N = 72$)

Interviewee by Category	Number of Interviews	Percentage of Interviews
Lay citizens	38	53
Local government officials	11	15
State and federal government officials	5	7
Health professionals	15	21
Academic	1	1
Priests	2	3

majority of interviewees (92%) were residents of the rural communities along the upper Sonora River. The remaining interviewees included state and federal officials with water management responsibilities in the state capital, Hermosillo. We also interviewed health professionals, including doctors and nurses in local health clinics, along with a few officials in the State of Sonora Epidemiology Laboratory. Finally, one academic who had conducted relevant studies in the region and two local priests were also interviewed. We refer to community members who are not professionals or government officials as "lay citizens."

Because we believed that gender and income would be important variables influencing waterborne-disease-related risk perceptions, we aimed at interviewing a group of individuals roughly representative of the USRB in terms of gender and income level.[51] Thirty-eight of our interviewees were lay citizens and 18 (47%) of them were female. We used the standard qualitative methods technique of identifying key demographic characteristics expected to affect interviewees' views with respect to waterborne-disease-related risk perceptions, and worked to interview enough people with these characteristics to be able to find patterns in their views.[52]

We expected that gender, income level, and occupation, in particular, being a lay citizen versus a state or local official or a health professional, would affect these perceptions. Like most qualitative methods, our research was not designed to be generalizable to a larger population, especially in terms of making statements about the distribution of particular findings within that population.[52,55] Rather, we focused on finding key patterns likely to be present in the larger population. In order to find these key patterns, we had to make sure that our sampled interviewees represented the breadth of views likely to be present in the larger population. We therefore focused our selective sampling to ensure that a representative range of income levels was present in our interviewees.

Table III. Estimated Lay Citizen Income Levels ($N = 38$)

Estimated Lay Citizen Income Levels	Monthly Income[a]	Number of Interviews	Percentage of Interviewees	Regional Income Percentages[b]
Low	< $4,000	11	29	37
Middle	$4,000–$15,000	23	61	55
High	> $15,000	4	10	8

[a]Monthly income was estimated based on interviewee's job description and the minimum wages established by profession by the Mexican National Commission of Minimum Wages (CONASAMI)[56] and the State of Sonora Official Government Employee Salary tabulator.[57] The estimates are in Mexican pesos.

[b]Regional monthly income levels were estimated using the results of the Mexican National Income and Expense Survey (ENIGH, 2005) extracted only for our study region.[50]

However, our concern that income would be a highly sensitive subject kept us from asking direct questions about income. Instead, we asked interviewees to name their occupation and those of any other adults in their household. We used the Mexican federal wage statistics by occupation[56] and the State of Sonora government salary list[57] to generate estimates of interviewees' monthly incomes. To make sure that our sample was representative of the regional income levels, we compared our estimates to income levels in the 2005 Mexican National Income and Expenses Household Level Survey[50] for our study region. Observations recorded during the interviewing process provided additional information (such housing and vehicles). Based on this approach, we divided our lay citizens into three income classes: low, middle, and high. Table III shows the estimated monthly incomes of lay citizen (in Mexican pesos).

Our criterion for selecting lay citizens focused in choosing adults from areas of the communities with different income levels. Interviews with local authorities and state and federal government officials were conducted by requesting formal appointments. Health professionals were also approached in the same manner. Potential lay citizen interviewees were approached in public areas, such as streets and plazas, and through local chains of referral.

Our interview protocol included questions about local waterborne disease problems, the causes of these problems, and practices that could be used to reduce their prevalence. We also asked about the

value of information provided by local officials and health departments. The interviews were conducted by the first author, a native of this region, experienced in both qualitative methods and the technical dimensions of wastewater management. A research assistant took notes during each of the interviews.

The interviews were conducted in Spanish, tape recorded, and transcribed verbatim into Word documents. Interview transcriptions were then sorted by question. The files containing the responses to a specific question were carefully coded, using standard qualitative analysis methods, and identifying common answer patterns and quantifying the numbers of interviewees providing these answers to each question.[53,55] For example, one of the questions asked interviewees to describe any local problems associated with water resources. After gathering together responses to this question into one file that included a label for the interviewee number, we found that their answers tended to fall into the following categories: water quantity, water quality, and a lack of wastewater and drinking water treatment. Additionally, some people believed that there were no significant water-related problems. We recorded the "subpatterns," for instance, that people worried that a lack of water quantity would lead to economic patterns. The interview number for individuals providing a response that fit a certain broad and "sub" pattern was recorded. This allowed us to count up numbers of people responding in a particular way and to fairly easily compare responses from subgroups, such as officials, health professionals, and lay citizens. Analysis was conducted using the Spanish transcriptions, while quotes presented in this article have been translated into English. The next section presents our results. Please note that we include numbers and percentages of interviewees offering a particular response to a question as an aid to the reader in seeing the prevalence of various response patterns. Our research was not designed to be generalizable to the basin population per se, but rather to be exploratory work aimed at beginning to understand waterborne-disease-related risk perceptions. The inclusion of percentages is not intended to suggest that a similar percentage of responses would emerge from a larger, randomized study of the general population.

5. RESULTS

Our results indicated that awareness of area waterborne disease risk was low. Twenty-four (33%) interviewees did not believe that waterborne diseases posed a serious local health threat. Only one lay citizen and two local government officials knew that waterborne disease outbreaks, including those listed in Table I, regularly occur in the area. Nineteen (80%) interviewees of the group that did not believe that waterborne diseases posed a serious health threat told us that getting sick from contaminated food or water was a common, but not serious, problem. Also, 21 (88%) interviewees from this group explained that waterborne diseases were only a problem for particularly sensitive people, while most develop an immunity to the disease organisms in tap water. As one stated: "Getting sick is no big deal. Stomachaches are common. It is only some people, such children and the elderly, who are very sensitive to contaminated tap water" (interview 20). These views stood in stark contrast to those of the health professionals, all of whom stated that several serious waterborne diseases were an ongoing problem in the region.

Lay citizens also tended to believe that the risks associated with upstream communities' wastewater discharges were not serious. When asked about the effectiveness of local wastewater treatment facilities, 36 (50%) interviewees explained that sewage was discharged into wastewater lagoons, and that these lagoons were effective in preventing the contamination of the nearby Sonora River. Only 18 (25%), including all of the state and federal government officials, were aware that wastewater from most of the riverside communities was regularly discharged directly into the river without prior treatment. Twenty (28%) interviewees told us that they did not know how human waste was currently managed within their community; however, 27 (38%) believed that wastewater was not a serious problem in the region. Twenty-three of the interviewees (85% of the group that who believed that wastewater was not a serious problem) believed that wastewater was not a serious problem were lay citizens. As one lay citizen interviewee reasoned: "If there were serious [waterborne disease] problems, community members and officials would be talking about it, and we have not heard anything" (interview 54).

Regarding how safe the drinking water was in the communities, 41 (57%) interviewees believed that local tap water was safe, including 74% of the lay citizens and 91% of the local officials. However, just one of the 16 health professionals we interviewed shared this belief. More female than male lay citizens believed that water quality was a problem and could describe in detail techniques for avoiding

waterborne disease. Forty-four (61%) interviewees stated that drinking water treatment processes in their communities were inadequate. This apparent paradox implies that some interviewees thought that the water supply was safe enough to drink without treatment. As one local government official said:

> *We do not chlorinate very consistently. We definitely need to make improvements. If the water was making people sick, people would be complaining to us and we have not received any complaints. I believe that water in this region is okay to drink even without proper treatment.* (interview 23)

When interviewees were asked how they could avoid getting sick from waterborne diseases, 31 (43%) interviewees stated that they drank bottled or boiled water. All of the health professionals stated that they drank bottled water. Only nine of the lay citizen interviewees (24% of lay citizens) told us that they always drank bottled or boiled water. Thirty-two (44%) interviewees said that they always drink tap water while 18 (25%) told us that they drink both tap and bottled water. Four (6%) interviewees stated that they drink bottled water only during the rainy season when they believe that tap water is more contaminated. Twenty-one (29%) offered examples of people they knew who became sick from drinking contaminated tap water.

Forty-one (57%) interviewees did not believe that drinking water quality was a problem in their communities. Twenty (28%) said that no one they knew had ever gotten sick from drinking tap water and 19 of these 20 people were lay citizens. In addition, a local government official stated that, despite inconsistencies in drinking water treatment, waterborne diseases were generally not caused by unsafe drinking water. The local officials tended to attribute these diseases to poor hygiene practices.

One hundred percent of the lay citizens and local government officials interviewed stated that they had received information from health clinics about preventing waterborne diseases and that they trusted this information. However, they told us that they did not usually receive this information until after becoming sick and visiting a clinic. All of the lay citizens told us that local government officials or water managers never issued warnings regarding potential water quality problems. They explained that the information released by local water management offices focuses on water conservation and the need to make timely payments, rather than water quality problems.

None of the interviewed health professionals believed that the information they provided to lay citizens and local government officials about waterborne disease risk was effective. For instance, one health professional stated:

> *Despite showing them measurements of chlorine levels that indicate that drinking water is not treated consistently, people still feel their water is safe. Some people even complain that adding chlorine changes the taste of natural water.* (interview 60)

Although all the interviewees reported high levels of trust in the information provided by health clinics, only 18 (25%) believed that community members were following the recommendations. Most believed that the information either was completely ignored or only followed for a short period of time. On the other hand, only 14 (19%) interviewees trusted information provided by local government officials. Fourteen (19%) interviewees, including a number of state officials and health professionals, said that local government authorities did not want people to find out about tap water problems because they would then have to fix them.

6. DISCUSSION

Prior knowledge of the situation regarding poor sanitation, inadequate protection of drinking water, reports of local health clinics regarding waterborne-related diseases, and statements made by health professionals allowed us to determine that there is in fact a high level of risk associated with waterborne diseases in the USRB. We concluded that many interviewees were unaware of this problem. This finding is consistent with findings from studies conducted in Latin America or in Latino populations.[4,14,34,35,38]

There was a major gap between the risk perceptions of health professionals and those of lay citizens and government officials with respect to waterborne diseases. The latter were much less likely to be aware of the prevalence and seriousness of these diseases and tended to believe that the symptoms of these diseases were a normal part of everyday life.

With respect to the causes of local waterborne disease problems, a few interviewees could explain how wastewater was managed in their community or elsewhere in the study region. However, most lay citizens were nonetheless confident in the effectiveness of local wastewater treatment facilities and believed that the health risks associated with wastewater discharges were minimal. There were major differences in the drinking water safety perceptions of health professionals versus lay citizens and government officials. Lay citizens and local government officials

were much less likely than health professionals to believe that local drinking water was unsafe. Local government officials tended to attribute human-waste-related diseases to poor hygiene practices, as was found in the Nogales study,[4] but a majority of lay citizens and government officials believed that drinking water treatment in their communities was inadequate. Regardless, they tended to believe that tap water was reasonably safe and the waterborne disease problems it did cause were simply viewed as a normal part of everyday life that did not pose a serious health risk.

The interviews revealed that most common methods used to reduce the waterborne disease problem were boiling tap water or buying bottled water. The consistency in applying these measures varied greatly. Forty-three percent of interviewees reported drinking bottled or boiling water while another quarter reported applying these measures only intermittently. This finding is consistent with other work that found that people were not regularly following disease prevention recommendations.[38]

With respect to their trust in and exposure to disease prevention information, all of the lay citizens and local officials said that they had received related information from health clinics, usually only after going to the clinic with a waterborne disease. Unlike participants in the El Paso study,[35] all of the lay citizens in our study trusted health department information. However, this trust did not necessarily translate into following health department recommendations. Lay citizens also reported that they never received information from local government agencies about water quality problems. At least some took this as an indication that there was not a problem. Perhaps if health departments and local officials joined forces to provide one message regarding waterborne disease risks and prevention strategies, people would be more likely to follow health department recommendations.

Overall, the picture created from our results is one of confusion and fatalism. Low-level waterborne disease exposure that causes stomach problems and diarrhea was seen as normal even though it was known to create significant problems for vulnerable people, especially the young and elderly. In a region with high poverty levels, governance that is not particularly dependable, and inadequate basic wastewater and drinking water treatment systems, residents may not expect a great deal of human welfare protection from local governments. On the other hand, there are basic and inexpensive measures that residents could take on their own, such as hand washing with soap and household treatment of drinking water with chlorine (i.e., bleach), that would likely reduce the incidence of regional waterborne disease even without changes in drinking water or wastewater treatment.

Our findings contribute to the risk perception literature by demonstrating that in a poor area with chronic exposure to noncatastrophic risk, many residents did not perceive themselves at risk from waterborne disease even when professionals deeply involved in reducing it believed that it is serious. Additionally, they enhance our understanding of how risk is constructed within the third world where few risk-related studies have been conducted. With regard to the broader theory of how risk is constructed, our results support the finding that expert constructions of risk are often very different from lay citizens,[24,39] while extending this finding to the developing world.

Given these findings, we make some recommendations. First, since most of the interviewed population tends to underestimate the risk associated with waterborne diseases, a broad-based disease prevention campaign is needed. This campaign should clearly describe the prevalence and seriousness of waterborne diseases within the area. Since most of the interviewees knew someone who had been sick with waterborne disease, using information about community-level prevalence might increase the effectiveness of communication campaigns. State and local government, health officials, and lay citizens should collaborate on designing and implementing these campaigns, in an attempt overcome the issue of distrust of information originating from government sources. Since, at this time, the routes of exposure to the diseases are not well established, the campaign should provide information on the full range of personal and household disease prevention strategies. Second, an integrated study should be undertaken to determine the routes of disease exposure and transmission, consisting of (a) determination of where contact with human wastes are taking place; (b) prioritization of technical interventions, such as improved wastewater treatment or improved drinking water treatment, for each town in the USRB; and (c) a plan for securing popular support for these technical interventions.

7. CONCLUSION

Our findings add to the very limited understandings of waterborne-disease-related risk perceptions

in the developing world. They suggest that misunderstandings of the problem, its causes, and its solutions are common. This is unfortunate in an area where waterborne diseases are prevalent, serious, and relatively easily preventable. Our findings suggest that, in a region where low-level waterborne diseases are a daily occurrence, many people come to see them as a routine part of life, perhaps because other problems, such as feeding their families, are more pressing. Waterborne disease prevention campaigns should focus on clearly explaining why these diseases are a problem and how they can be prevented, especially without resorting to constantly boiling water or buying expensive bottled water. They should clearly and honestly describe the cause and effect of poor drinking water and wastewater treatment in combination with the need for basic hygiene practices, such as washing with soap after using the bathroom. Our findings are limited by the fact that we conducted our work in a fairly small region and did not conduct a large scale quantitative survey. Future work should focus on similar regions and, when possible, move toward implementation of larger-scale surveys to determine the distribution of the risk perceptions we found.

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APPENDIX: INTERVIEW QUESTIONS

1. Including yourself, how many people live in your household?
2. How many children live in the household?
3. What do you do to earn a living?
4. In your opinion, what are your community's biggest problems?
5. How important are water-related problems in your community?
6. Who is in charge of managing water-related issues in your community?
7. Can you tell me about the water you use in your house? Do you ever have too little? If so, when?
8. Is your drinking water safe? If not, why?
9. Do you drink water from the tap? If not, why?
10. What kinds of sicknesses can people get from drinking contaminated water?
11. Has anyone in your family/friends in town gotten sick from drinking tap water? If so, please tell me what you remember/heard about this?
12. Can people do anything to keep from getting sick from drinking tap water?
13. How did you learn about these sickness prevention practices?
14. In your opinion, do people in your community follow these practices?
15. What happens to the wastewater from your house and the community?
16. Do you think that improper wastewater management is causing problems in your community?
17. Do you know what is being done with the wastewater in upstream communities?
18. Do you think that wastewater from upstream communities may be causing problems here in your community?
19. Do others communities on the Sonora River have any wastewater management problems?
20. What is your opinion about the quality of the Sonora River water?
21. Has anyone given you information about local water quality problems?
22. How does the local water treatment and management office inform residents about water quality problems?
23. Was the information you received from them useful to you?
24. Do you trust the information local health officials have given you regarding public health problems and illness prevention practices?
25. Do you think the distribution of this information has had positive results? Do you feel people have adopted their recommendations?
26. Do you know of any local group that has tried to address local water quality problems? If yes, please explain.

27. Have people in your community ever asked local government to fix water quality problems?
28. What, if any, water treatment improvements do you believe should be done in your community and in the Sonora River region? If none, why?
29. Would you support these improvements? If not, why?

REFERENCES

1. Prüss-Űstün A, Bos R, Gore F, Bartramm J. Safer Water, Better Health: Costs, Benefits and Sustainability of Interventions to Protect and Promote Health. Geneva, Switzerland: World Health Organization, 2008.
2. World Health Organization (WHO). Water and sanitation data query tool, 2004. http://www.wssinfo.org/en/ watquery.html. Accessed January 15, 2009.
3. The Joint Academies Committee on the Mexico City Water Supply. Mexico City's Water Supply: Improving the Outlook for Sustainability. Washington, DC: National Academy Press, 1995.
4. Ingram H, Laney NL, Gillian DM. Divided Waters: Bridging the U.S.–Mexico Border. Tucson, AZ: University of Arizona Press, 1995.
5. Pineda N. La Busqueda de la Tarifa Justa. El Cobro de Los Servicios de Agua Potable y Alcantarillado en Mexico. Hermosillo, Mexico: El Colegio de Sonora, Instituto Mexicano de Technologia del Agua, 2006.
6. Simonelli J. Defective modernization and health in Mexico. Social Science & Medicine, 1987; 24:23–36.
7. Pineda N. La política urbana de agua potable en México: del centralismo y subsidies a la municipalización, la autosuficiencia y la privatización. Región y Sociedad 2002; 14:24.
8. Tortajada C. Policy failures prevent water quality progress in Mexico. Water and Wastewater, 2003; 18:25–26.
9. Alvarez-Vigil J. Principales problemas que limitan la participación comunitaria en los proyectos de abastecimiento de agua y saneamiento. Educación Médica y Salud, 1982; 16:404–417.
10. Carter RC, Tyrrel SF, Howsam P. Impact and sustainability of community water supply and sanitation programmes in developing countries. Journal of Chartered Institution of Water and Environmental Management, 1999; 13:292–296.
11. Foster M. New Approaches to Development Co-Operation: What Can We Learn from the Experience of Sector Wide Approaches. Working paper 140, Center for Aid and Public Expenditure, Overseas Development Institute, London, UK, 2000.
12. Hamner S, Tripathi A, Mishra RK, Bouskill N, Bradway SC, Pyle BH, Ford T. The role of water use patterns and sewage pollution in incidence of water-borne/enteric diseases along the Ganges River in Varanasi, India. International Journal of Environmental Health, 2006; 16:113–132.
13. Mackintosh G, Colvin C. Failure of rural schemes in South Africa to provide potable water. Environmental Geology, 2003; 44:101–105.
14. Ratner B, Rivera A. Reasserting community: The social challenge of wastewater management in Panajachel, Guatemala. Human Organization, 2004; 63:47–57.
15. Pena S, Cordova G. Public participation and water supply. The case of two communities on the USA-Mexico Border. Water International, 2001 26:390–399.
16. Tam CM. Build-operate-transfer model for infrastructure developments in Asia: Reasons for successes and failures. International Journal of Project Management, 1999; 17:377–382.
17. Biswas AK, Tortajada C, Braga B, Rodriguez DJ (eds). Water Quality Management in the Americas. Berlin, Germany: Springer, 2005.
18. Graham W. Mex Eco? Mexican attitudes toward the environment. Environmental History Review, 1991; 15:1–17.
19. Robles Morua A, Mayer AS, Durfee MH. Community partnered projects: A case study of a collaborative effort to improve sanitation in a marginalized community in northwest Mexico. Environment, Development and Sustainability, 2009; 11:197–213.
20. Downs TJ. Sustainable health risk management and the role of cross disciplinary professionals in developing countries: The Mexican experience. Environment, Development and Sustainability, 2001; 3:61–81.
21. Downs TJ. Making sustainable development operational: integrated capacity building for the water supply and sanitation sector in Mexico. Journal of Environmental Planning and Management, 2001; 44: 525–544.
22. Slovic P. The Perception of Risk. London and Sterling, VA: Earthscan Publications, 2000.
23. Slovic P, Weber EU. Perception of Risk Posed by Extreme Events. Conference on Risk Management Strategies in an Uncertain World. New York, April 12–13, 2002.
24. Slovic P. Perception of risk. Science, 1987; 236:280–285.
25. Kasperson RE, Renn O, Slovic P, Brown HS, Emel J, Goble R, Kasperson JX, Ratick S. The social amplification of risk: A conceptual framework. Risk Analysis, 1988; 8:177–187.
26. Slovic P. Trust, emotion, sex, politics, and science: Surveying the risk assessment battlefield. Risk Analysis, 1999; 19(4):689–701.
27. Weber EU. Decision and choice: Risk, empirical studies. In Smelser NJ, Baltes PB (eds). The International Encyclopedia of the Social and Behavioral Sciences. Oxford, UK: Elsevier Science Limited, 2001
28. McDaniels TL, Axelrod LJ, Cavanagh NS, Slovic P. Perception of ecological risk to water environments. Risk Analysis, 1997;17: 341–352.
29. Granger M, Fishoff B, Bostrom A, Lave L, Atman C. Communicating risk to the public. Environmental Science and Technology, 1992; 26:2048–2056.
30. Bennet P, Calman K. Risk Communication and Public Health. Oxford, UK: Oxford University Press, 1999.
31. Bontempo RN, Bottom WP, Weber EU. Cross cultural differences in risk perception: A model based approach. Risk Analysis, 1997; 17:479–488.
32. Alhaki AS, Slovic P. A psychological study of the inverse relationship between perceived risk and perceived benefit. Risk Analysis, 1994; 14:1085–1096.
33. O'Connor RE, Bord RJ, Fisher A. Risk perceptions, general environmental beliefs, and willingness to address climate change. Risk Analysis, 1999; 19:461–471.
34. Poblete-Davila S, Bennett V, Nieves-Rico M (eds). Opposing Currents: the Politics of Water and Gender in Latin America. Pittsburg, PA: University of Pittsburg Press, 2005.
35. Byrd TL, VanDerslice J, Peterson SK. Variation in environmental risk perceptions and information sources among three communities in El Paso. Risk—Health Safety and Environment, 1997; 8:355–372.
36. Williams BL, Flores Y. Do Mexican–Americans perceive environmental issues differently than Caucasians?: A study of crossethnic variation in perceptions related to water in Tucson. Environmental Health Perspectives, 2002; 110:303–310.
37. Corral-Verdugo V, Frias-Armenta M, Gonzalez-Lomeli D. Percepción de riegos, conducta proambiental y variables

demograficas en una comunidad de Sonora, Mexico. Región y Sociedad, 2003; 15:49–72.
38. McLennan JD. Prevention of diarrhea in a poor district of Santo Domingo, Dominican Republic: Practices, knowledge, and barriers. Journal of Health, Population and Nutrition, 2000 18:15–22.
39. Fessenden-Raden J, Fitchen JM, Heath JS. Providing risk information in communities: Factors influencing what is heard and accepted. Science, Technology, and Human Values, 1987 12:94–101.
40. Flynn J, Slovic P, Mertz CK. Gender, race, and perception of environmental health risks. Risk Analysis, 1994; 14:1101–1108
41. Greenberg MR, Schneider D. Gender differences in risk perception: Effects differ in stressed versus non-stressed environments. Risk Analysis, 1995; 15:503–511.
42. Norma Oficial Mexicana NOM-001-ECOL-1996. Límites máximos permisibles de contaminantes en las descargas de aguas residuales en aguas y bienes nacionales, 1996. Available at: http://www.semarnat.gob.mx/leyesynormas/. Accessed on July 31, 2009.
43. Ley Federal de Transparencia y Acceso a la Información Pública Gubernamental. 2002. Available at: http://www.ifai.org.mx/, Accessed on July 31, 2009.
44. Robles Morua A. Integrated water and sanitation solutions for the upper Sonora River basin (northwest, Mexico). Unpublished doctoral dissertation, Michigan Technological University, 2010.
45. Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report. Washington, DC: U.S. Environmental Protection Agency, EPA-823-R-03–008, June 2003.
46. Norma Oficial Mexicana NOM-127-SSA1–1994. Salud Ambiental. Agua para uso y consumo humano. Límites permisibles de calidad y tratamientos a que debe someterse el agua para su potabilización, 1994. Available at: http://portal.salud.gob.mx/. Accessed on July 31, 2009.
47. Secretaria de Salud del Estado de Sonora. Anuarios estadísticos de salud, 2005. Available at: www.saludsonora.gob.mx. Accessed July 15, 2008.
48. Comisión Estatal del Agua, Gobierno del Estado de Sonora. Saneamiento en el Rio Sonora. Reporte de actividades 2003–2004, 2004. Available at: www.ceasonora.gob.mx/articulos.aspx?id = 39. Accessed August 1, 2008.
49. Howard G, Bartram J. Domestic Water Quantity, Service Level and Health. Geneva, Switzerland: World Health Organization, 2003.
50. Encuesta Nacional de Ingresos y Gastos de los Hogares (ENIGH-INEGI). Información sobre la infraestructura de las viviendas, la composición familiar de los hogares, así como de la actividad económica de cada uno de sus miembros, 2005. Available at: http://www.inegi.org.mx/est/contenidos/espanol/soc/sis/microdatos/default.aspx. Accessed on July 14, 2009.
51. Bernard HR. Research Methods in Anthropology: Qualitative and Quantitative Approaches. Lanham, MD: Rowman Altamira Press, 2005.
52. Becker HS. Tricks of the Trade. Chicago, IL: University of Chicago Press, 1998.
53. Miles MB, Huberman AM. Qualitative Data Analysis. Thousand Oaks, CA: Sage Publications, 1994.
54. Patton MQ. Qualitative Evaluation and Research Methods. Thousand Oaks, CA: Sage Publications, 1990.
55. Denzin NK, Lincoln Y (eds). Collecting and Interpreting Qualitative Materials. Thousand Oaks, CA: Sage Publications, 2003.
56. Comisión Nacional de los Salarios Mínimos (CONASAMI). Información de la fijación de los salarios mínimos legales de acuerdo con la Constitución Política de los Estados Unidos (salario mínimo general, áreas geográficas y salarios mínimos profesionales), 2007. Available at: http://www.conasami.gob.mx. Accessed on July 14, 2009.
57. Gobierno del Estado de Sonora. Secretaria de Hacienda. Dirección General de Recursos Humanos. Información acerca del catalogo de puestos para empleados del gobierno del estado en todos los niveles, 2008. Available at: http://www.sonora.gob.mx/transparencia/. Accessed on July 14, 2009.
58. Instituto Nacional de Estadistica y Geografia. Information estadistica para Sonora, 2009. Available at: http://inegi.org.mx.