Meeting the Need for Safe Drinking Water in Rural Mexico through Point-of-Use Treatment

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DSFLGKFDLG;KDF;LGK

EXECUTIVE SUMMARY

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Millions of rural Mexicans are at risk because of unsafe drinking water. In a 2002 report on the state of water quality in the world by the United Nations Development Programme, Mexico ranked 106th out of 122 countries, while the United States was ranked twelfth (UNAM-CNA 2004). Moreover, gastrointestinal diseases were estimated to cost Mexico US$3.6 billion in health care expenditures in 1990 (Margulis 1992) and continue to be one of the most serious health problems today (CNA 2001; Fox 2004; Iberia Sánchez 2005; Tortajada 2001). In addition, potable water coverage in urban (95 percent) and rural (68 percent) areas are grossly unequal.

II. Point-of-Use Water Treatment: A Promising Option for Rural Communities

The construction of centralized treatment systems is not an adequate response to the immediate and urgent task of protecting public health against water-related infectious diseases. Decentralized, low-cost, and proven point-of-use (POU) technologies such as the Safe Water System, solar disinfection (SODIS), and UV disinfection are promising alternative approaches to meeting the urgent water quality needs of rural Mexico.

III. Trends in Mexican Water Policy: Decentralization Leaves Rural Residents Behind

Decentralization under the National Waters Law (Ley de Aguas Nacionales—LAN) has taken the form of devolution of authority from the National Water Commission (CNA) to municipalities without being accompanied by other essential changes that are necessary for decentralization to work. Local authorities do not have the financial or human resources to meet the water needs of rural Mexicans. At the same time, people in the rural communities are unprepared to take on the burden of building and maintaining their own centralized water treatment systems.

IV. Point-of-Use Water Treatment and Federal Agencies: Decentralization that Works

Mexico is fortunate to have a number of capable federal institutions with strong networks that extend into local communities across the country, including the Secretary of Health (SSA) and the Secretary of Social Development (SEDESOL). Outreach workers in these organizations are well positioned to implement solutions to rural water quality problems, including POU treatment systems. In support to federal agencies, states and municipalities have key roles to play in coordinating the implementation of rural water and development programs.

V. Recommendations

A. Prioritize Rural Drinking Water

Rural water management decisions at the municipal, state, and basin levels should reflect Article 13.3.II of the National Waters Law, which states that water for domestic consumption has priority over all other uses.

B. Encourage Institutional Cooperation Across Scales and Sectors

In order for the drinking water situation in rural Mexico to improve, there will need to be inter-institutional cooperation at the local, regional, and national level. Given the inherent limitations of single institutions, cooperative programs need to be designed to take advantage of the individual strengths of actors in the private, public, and nonprofit sectors.

C. Disseminate POU Technologies

Given the low costs and proven effectiveness of point-of-use technologies in improving water quality and human health, it is urgent that Mexican states, municipalities, and federal institutions, in conjunction with the civil society and private sector organizations, develop programs to make POU technologies available to rural residents.

I. DRINKING WATER IN MEXICO: RURAL RESIDENTS AT RISK

Millions of rural Mexicans are at risk because of unsafe drinking water. The seriousness of this problem became painfully clear when a cholera[1] epidemic swept through Latin America in the 1990s, claiming tens of thousands of lives (Borroto 2000). Despite the success of programs created by Mexican health authorities in response to the epidemic, including Vida Suero Oral (Oral Rehydration Therapy) and Agua Limpia (Clean Water), water quality related illnesses remain a serious problem for many of Mexico's rural residents today. In a 2002 report on the state of water quality in the world by the United Nations Development Programme, Mexico ranked 106th out of 122 countries, while the United States was ranked twelfth (UNAM-CNA 2004).

Throughout Mexico, rural residents collect untreated water from unprotected sources. In the home, family members obtain drinking water by dipping a common cup into an open storage container. As a result, the risk of contracting dangerous waterborne illnesses such as intestinal parasites, amebiasis, salmonella, shigella, leptospirosis, and cholera is unacceptably high in rural areas (Cortés Muñoz 2001; personal communication with Edgar Ruiz Mercado, MD, 10/30/05). Children are especially vulnerable to waterborne diseases, which can cause stunted growth and death by dehydration. Moreover, gastrointestinal diseases were estimated to cost Mexico US$3.6 billion in health care expenditures in 1990 (Margulis 1992) and continue to be one of the most serious health problems today (CNA 2001; Fox 2004; Iberia Sánchez 2005; Tortajada 2001).

Currently, potable water and sanitation coverage in urban and rural areas are grossly unequal. Two common indicators of the state of drinking water quality are (1) the percentage of the population served by piped water, and (2) the percentage with access to working sewage systems, shown for Mexico in Table 1. In 2000, 94.6 percent of people in urban areas had access to potable water, while the coverage in rural areas was only 68 percent (INEGI 2000). With regard to sanitation, the situation is even more disparate, with coverage at 89.6 percent for urban and 36.7 percent for rural areas (INEGI 2000). The lack of improved water supply and sanitation facilities increases the risk that water will become contaminated with disease-causing agents.

Table 1. Coverage of Centrally Distributed Piped Water and Sewer Systems in Mexico, 2000

Population Group	People Living in Individual Homes (Millions)	Piped Water		Sewer System	
		Millions of People	percent	Millions of People	percent
Urban	71.1	67.3	94.6	63.7	89.6
Rural	24.2	16.4	68	8.9	36.7
Total	*95.3*	*83.7*	*87.8*	*72.6*	*76.2*

Source: INEGI 2000; Note that the census counted 97.4 million people. Data on service coverage was not available for the 2.1 million who lived in shared.)

II. POINT-OF-USE WATER TREATMENT: A PROMISING OPTION FOR RURAL COMMUNITIES

"Approaches that rely solely on time- and resource-intensive centralized solutions will leave hundreds of millions of people without access to safe water far into the foreseeable future." —Eric Mintz, MD, MPH, U.S. Centers for Disease Control

High initial costs put centralized water treatment and piped distribution systems out of the immediate reach of much of Mexico's rural population (Mintz 2001; Reiff 1996). The Inter-American Development Bank estimates that water supply projects in Mexico cost nearly US$700 per family served for infrastructure alone (BID 1998). In addition, the maintenance requirements of centralized supply and treatment systems are often unmet in both rural and urban settings for a variety of social, economic, and institutional reasons (Mackintosh 2003; Mintz 1995).

Since the mid 1990s, prominent health organizations including the Pan American Health Organization (PAHO) and the U.S. Centers for Disease Control (CDC) have been arguing that the construction of centralized treatment systems is not an adequate response to the immediate and urgent task of protecting public health against water-related infectious diseases. Instead they advocate providing individual households with the capacity to disinfect their own water through household or point-of-use (POU) technologies (e.g., Mintz 1995; Quick 1996; Tauxe 1995). In contrast to centralized source improvements, which have only a small impact on health, household-level interventions have consistently resulted in reductions of diarrheal disease by 35–39 percent in a range of cultural contexts (see Table 2). A variety of POU systems have been implemented around the world, leading the World Health Organization (WHO) to establish a new international network dedicated to POU technology development, evaluation, and dissemination.[2] Unfortunately, Mexico has thus far not taken advantage of the potential of POU technologies to improve the quality of life for its rural citizens.

Given the low costs and proven effectiveness of point-of-use technologies in improving water quality and human health, it is urgent that Mexican states, municipalities and federal institutions, in conjunction with civil society and private sector organizations, develop programs to make POU technologies available to rural residents.

Table 2. Reduction in Diarrhea Morbidity by Intervention

Intervention	percent Reduction in Diarrhea Morbidity
Water Supply Improvements	6–25
Sanitation Improvements	32
Hygiene Education	45
Point-of-use Water Treatment	35–39

(Source: WHO 2004)

Two of the most well-known household water treatment methods are boiling and adding chlorine in the form of tablets or bleach. Unfortunately, boiling water is time consuming and very energy intensive, limiting its potential to be a widespread and long-term solution to water quality problems. Chlorine pills and bleach require that complicated dosing procedures be followed and may dramatically alter the taste of the water. Several approaches to treating water at the point-of-use have been developed to avoid the problems associated with boiling, chlorine tablets, and bleach. Two of the most highly promoted and well-studied are the Safe Water System (SWS) and solar disinfection (SODIS). An emerging POU technology with which the authors have experience uses ultraviolet light (UV) as a disinfectant. Each technology has a unique set of advantages and limitations, making it extremely important to pay careful attention to the particular needs of the local context in choosing an appropriate intervention. These technologies are compared in Table 3 and described in detail in Appendix A.

Table 3. Comparison of water treatment technologies including centralized treatment and three point-of-use approaches (Safe Water System, SODIS, and UV Tube).

	Point-of-Use (POU) Treatment Technologies			Centralized Treatment
	Safe Water System	SODIS (Solar Disinfection)	UV Tube	
Means of Disinfection	Low-concentration chlorine solution distributed in bottles and applied by user	Transparent water bottles exposed to solar radiation for six hours to two days, depending on sunlight availability	Ultraviolet light produced by a germicidal lamp inside a treatment chamber controlled by user	Concentrated chlorine dissolved in water at central plant operated by technicians
Advantages	• Small initial costs ($4–$6 per family)[III] • Small ongoing costs ($1–$4 per family per year)[3]	• Virtually zero initial and ongoing costs	• Large quantities of disinfected water can be obtained quickly • Minimal behavior change required • Small ongoing costs ($1-$3 per family per year)[IV]	• Large quantities of disinfected water can be obtained quickly • Minimal behavior change required
Limitations	• Considerable behavior change required • Very stable distribution channel required	• Considerable behavior change required • Sunlight availability	• Electricity required • Moderate initial cost ($40–$80 per family)[4]	• High initial ($100–$700 per family)[5] and ongoing costs • Requires trained operators
Ideal Situation	Communities with an established store where users can continuously purchase disinfectant bottles	Communities outside the cash economy, with presence of an institution that can provide promotion of the technology	Communities with solar or grid electricity and financial ability to cover most of initial costs	Communities with higher densities with enough economic and human resources to implement and maintain infrastructure

III. TRENDS IN MEXICAN WATER POLICY: DECENTRALIZATION LEAVES RURAL RESIDENTS BEHIND

The trend toward decentralization has not positioned the institutions and policies governing water services in Mexico to effectively address the needs of rural communities. Decentralization became the guiding principle behind the management of water in Mexico beginning in 1992, when the Mexican government passed a new National Waters Law (Ley de Aguas Nacionales—LAN) in an attempt to reverse the course of the country's decaying water infrastructure and to more efficiently allocate water between competing uses. The LAN relieved the National Water Commission (CNA) of its duty to provide water services for Mexico's urban and rural residents, passing along the responsibility to states and municipalities. The CNA remains the lead regulatory water authority, but states and municipalities are increasingly given more responsibility for providing drinking water and sanitation to both urban and rural areas (Tortajada 2001). Unfortunately, decentralization under the LAN has taken the form of devolution of authority from the CNA to municipalities without being accompanied by other essential changes that are necessary for decentralization to work. Local authorities do not have the financial or human resources that they need to meet the water needs of rural Mexicans. With pro-active local leaders, rural communities can sometimes secure the financial and technical assistance necessary to successfully implement central water treatment and piped distribution systems.

Under the LAN, the provision of drinking water in rural communities can become the responsibility of municipal operators, where they exist. In an evaluation of the status of local control of water resources in 2004, however, the Inter-American Development Bank found that municipal operators are not able to serve rural areas given limited human and capital resources and because their first priority is trying to meet the needs of underserved urban populations (Gómez 2005).

The example of Baja California Sur (BCS) illustrates that even relatively successful decentralized water programs fall short of meeting rural needs. The BCS state government implemented a program that allowed rural families to receive gasoline powered pumps and hosing at no cost, enabling dispersed households to pump water from a water source to the home. This was a cost effective alternative to constructing centralized water distribution systems for low population density communities. However, the program failed to provide its beneficiaries with a viable means to make the water safe for drinking. This highlights the pressing need for a comprehensive national program to implement POU technologies in order to improve water quality in rural communities.

IV. POINT-OF-USE WATER TREATMENT AND FEDERAL AGENCIES: DECENTRALIZATION THAT WORKS

While municipalities and states are encountering numerous difficulties in providing rural areas with water services under the current iteration of decentralization, Mexico is fortunate to have a number of capable federal institutions with strong networks that extend into rural communities across the country. Outreach workers in these institutions are well-positioned to implement solutions to rural water quality problems, including POU treatment systems. For example, with a constant presence in most communities across the country, rural health workers of the SSA are in an excellent position to promote POU technologies, together with educational modules that create a value for clean water and adequate hygiene practices.

A nation-wide program to promote and implement POU water treatment in rural communities could be led by the Mexican Institute of Water Technology (IMTA), the Secretary of Social Development (SEDESOL) and the Secretary of Health (SSA), with the local support of states and municipalities. Such a nationwide program could be based on already existing expertise, resources, and infrastructure. IMTA[6] researchers have the capacity to develop POU technologies and dissemination strategies for the Mexican context, as well as to provide training and technical support to other institutions responsible for the promotion and implementation phases of the program. SEDESOL, with its more than 22,000 Diconsa community stores, would be a natural distribution channel for POU products, systems, and replacement parts. Federal programs targeting marginalized communities, such as Oportunidades, can provide a subsidy on the price of POU systems to ensure that the poorest and most vulnerable groups are reached. When necessary, state governments and municipalities could also provide economic assistance. Local representatives of state government—the *delegados* and *sub-delegados*—can play an essential role in coordinating support at the community level.

Decentralization should not become a program in which the government simply transfers the burden of responsibility for water and sanitation services to the poor. Decentralization should be a national movement of working with communities to design and implement solutions that are appropriate for their needs.

V. RECOMMENDATIONS

A. Prioritize Rural Drinking Water

Rural water management decisions at the municipal, state, and basin levels should reflect Article 13.3.II of the National Waters Law, which states that water for domestic consumption has priority over all other uses.

B. Encourage Institutional Cooperation Across Scales and Sectors

In order for the drinking water situation in rural Mexico to improve, there must be inter-institutional cooperation at the local, regional, and national level. Given the inherent limitations of single institutions, cooperative programs need to be designed to take advantage of the individual strengths of actors in the private, public, and nonprofit sectors. Nongovernmental organizations are often well-positioned to serve as liaisons between community members and external agencies and could be incorporated into hygiene education or water quality testing programs. Local businesses could be contracted to build POUs for a government program or could be given incentives to sell devices directly to rural communities.

C. Disseminate POU Technologies

In order to make POU technologies available to rural Mexican communities, we recommend that a nationwide program be created to promote and implement POU water treatment in rural communities, in which:

(1) The Mexican Institute of Water Technology (IMTA) develops POU technologies and dissemination strategies. Local universities and technical colleges can also play an important role in technology development and are currently critical, but underused resources. In addition, it is imperative that universities begin to train future water managers in interdisciplinary curricula that prepare them for working in issues that affect rural communities.

(2) The Secretary of Health, through its rural health workers, promotes the use of POUs, coupled with hygiene education.

(3) The Secretary of Social Development disseminates POU products, systems, and replacement parts through its Diconsa stores, and provides special assistance to ensure that the poorest and most vulnerable groups of the population receive access to clean water.

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APPENDIX A: THE POU APPROACH AND DESCRIPTION OF TECHNOLOGIES

POU Approach

The three crucial elements of POU water treatment are the treatment technology itself, safe water storage containers, and education to motivate and promote behavioral changes. The treatment technology must be affordable, culturally acceptable, and easy to operate. To minimize the cost and effort involved in maintenance and to reduce the risk associated with dependence on long supply chains, the technology should also be made using locally available materials. Safe water storage containers are necessary because of the well-documented risk of recontamination of treated water within the household (Wright 2004). Narrow-mouthed containers fitted with a spigot are ideal, but must also conform to local cultural standards (Makutsa 2001; Mintz 1995; Ogutu 2001). Approaches to hygiene education vary in content and structure but are also important in reducing the incidence of diarrheal disease (Esrey 1985; Esrey 1986; Esrey 1991; Fewtrell 2005).

Chlorine—The Safe Water System

As part of their response to the Latin American cholera epidemic, the CDC, PAHO, and other organizations joined together to develop a new point-of-use chlorination system called the Safe Water System (SWS). This approach is based on the mass production of an inexpensive sodium hypochlorite (chlorine) solution and plastic bottles with measuring caps. The solution is then distributed in plastic bottles to individual households within a community, who use it to treat their personal water. Yearly costs are estimated at US$1–4 per family served (Reiff 1996). This method has been implemented in several countries around the world, and epidemiological studies have linked it with substantial reductions in diarrheal disease (Quick 2002; Quick 1996). The advantages of SWS include low recurrent costs, the use of local labor and materials, and the provision of a residual that protects the water against recontamination following treatment.

There are at least two potential drawbacks to the Safe Water System. One limitation is that even when the dosage is correct, chlorine changes the smell and taste of the water, which may decrease its acceptability to users. A second limitation is that SWS depends on a system of continuously manufacturing, distributing, and properly using the plastic bottles and chlorine solution. Each family's constant need for chlorine solution under the SWS system makes its supply of safe water vulnerable to supply chain interruptions. Safe Water System is ideal for communities with an established store where users can continuously purchase the chlorine solution.

For more information on SWS, see http://www.cdc.gov/safewater/

SOLAR DISINFECTION—SODIS

The lowest cost POU water treatment system is solar disinfection. This method was developed and tested by Swiss Department of Water and Sanitation for Developing Countries (SANDEC) in the early 1990s. Solar disinfection is accomplished simply by placing transparent water bottles in sunlight for several hours. A combination of natural ultraviolet light and heat is responsible for destroying pathogenic organisms in the water (McGuigan 1998). A number of studies have shown that SODIS can reduce diarrheal disease (Conroy 1996; Conroy 1999, 2001). Advantages of the SODIS system include the fact that the water is already contained in a safe storage vessel, the low initial and recurrent costs, and the ease of use. One limitation of SODIS is that the treatment process is slow and depends on the availability of sunlight. In addition, the quantity of bottles necessary to supply a household's need may be awkward to manage (Lantagne 2006). SODIS also does not leave a residual to protect the treated water against recontamination. SODIS is an ideal clean water solution for communities that are outside of or on the fringe of the cash economy, but with the presence of institutions that can provide training on the technology.

For more information on SODIS, see http://www.sodis.ch/

Ultraviolet Light—The UV Tube

Although the use of ultraviolet light to disinfect water has been known for over a century, its potential as a low cost, point-of-use technology has only recently emerged. Over the past several years, researchers in the Renewable and Appropriate Energy Laboratory, directed by Professor Daniel Kammen, and the Civil and Environmental Engineering Department, focused on the laboratory of Professor Kara Nelson, of the University of California, Berkeley, have developed an ultraviolet disinfection system that can be constructed using common materials available at most hardware stores in Mexico for US$40–80. Called the "UV Tube," this system delivers a dose of ultraviolet light to water that is approximately double the standard established by the National Sanitation Foundation and the American National Standards Institute (NSF/ANSI Standard 55). It disinfects water at rate of five liters per minute and requires only 15 watts of electricity (equivalent to a small compact fluorescent lamp) that can be drawn from a grid connection, solar panel, or electricity generator. A typical household can disinfect their daily drinking water requirements in less than 10 minutes[7].

Major advantages of the UV Tube include its speed of operation, ease of use, and low ongoing costs. Another advantage is that the UV Tube does not change the taste or temperature of the water. Finally, the use of UV light enables the UV Tube to inactivate protozoan pathogens like *Cryptosporidium* and *Giardia* against which chlorine is ineffective. Disadvantages of the UV Tube include its dependence on electricity, need for a reliable device manufacturing facility, and inability to provide a residual disinfectant in treated water. Since UV light does not provide residual protection, the UV Tube needs to be coupled with a safe storage container and a hygiene education program. Pilot studies of the UV Tube are underway in the states of Baja California Sur and Morelos, Mexico. The UV Tube is ideal for communities that have access to electricity through the grid or solar panels, and in communities that have the financial means to cover most of the system costs.

For more information on the UV Tube, see http://rael.berkeley.edu/uvtube/

APPENDIX B: LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
BCS	Baja California Sur
CDC	U.S. Centers for Disease Control
CNA	Comisión Nacional del Agua (National Water Commission)
IMTA	Instituto Mexicano de Tecnología del Agua (Mexican Institute of Water Technology)
LAN	Ley de Aguas Nacionales (National Waters Law)
NSF	National Sanitation Foundation
PAHO	Pan American Health Organization
POU	Point-of-Use
SANDEC	Swiss Department of Water and Sanitation for Developing Countries
SEDESOL	Secretaría de Desarrollo Social (Mexican Secretary of Social Development)
SODIS	Solar disinfection
UV	Ultraviolet light
WHO	World Health Organization

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ENDNOTES

1. Cholera is caused by the bacterium *Vibrio cholerae*. Cholera is spread in water and food contaminated with the bacteria and by people who have the disease, making it particularly dangerous in poor areas with shared, contaminated water supplies and where hospital care and patient isolation is rare.

2. The International Network to Promote Household Water Treatment and Safe Storage, http://www.who.int/household_water/en/.

3. Reiff, F. M., M. Roses, L. Venczel, R. Quick, and V. M. Witt. 1996. Low-cost safe water for the world: A practical interim solution. *Journal of Public Health Policy* 17, no. 4: 389-408.

4. Unpublished field research conducted in part by authors Kaser, Lang, and Reygadas in Baja California Sur and Sri Lanka, 2005

5. Smaller value: unpublished field research conducted by authors Kaser, Lang, and Reygadas in Sri Lanka, 2005. Larger value: BID. 1998. *Programa para la sostenibilidad de los servicios de agua potable y saneamiento en comunidades rurales*. Banco Interamericano de Desarrollo, ME-0150.

6. IMTA has experience with various POU technologies, including SODIS, and the UV Tube.

7.This estimate assumes the need for ten liters of water per person, five people per household, and a disinfection rate of five liters per minute.

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