2011-06-22

Water Management and Public Health: A Case Study from Rural Mexico

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WATER MANAGEMENT AND PUBLIC HEALTH: A CASE STUDY FROM RURAL MEXICO

By

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A THESIS

Submitted to the Faculty
of the University of Miami
in partial fulfillment of the requirements for
the degree of Master of Arts

Coral Gables, Florida

June 2011

UNIVERSITY OF MIAMI

A dissertation submitted in partial fulfillment of
the requirements for the degree of
Master of Arts

WATER MANAGEMENT AND PUBLIC HEALTH: A CASE STUDY FROM RURAL MEXICO

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COOPER, ANDREW (M.A., Latin American Studies)
Water Management and Public Health: (June 2011)
A Case Study From Rural Mexico

Abstract of a thesis at the University of Miami.

Thesis supervised by Professor Daniel Suman.
No. of pages in text. (73)

This study provides a look into a small rural municipality in Mexico and analyzes the association between public health and water management. While first touching on the public health aspects of drinking water distribution, the study introduces the specific case of water management in Latin America and specifically Mexico, focusing on the difficulties of distributing clean, potable water. The case study of Miacatlán, Morelos will provide the potential towards investigating how drinking water management involves more than a connection to a water faucet, and how many factors can affect the quality and potability of distributed water, such as management practices, socio-economics and larger political structures. This study will develop how certain water management practices have the potential to raise the quality of distributed drinking water, and subsequently the public health of rural municipalities in Mexico. While clear causality is not to be inferred between management and public health, this study instead underscores the potential benefits from implementing effective water management practices on the local, rural scale.

I would like to dedicate this work to my late father, Ross Cooper. From a young age he always instilled in me a desire to learn.
Thank you, Dad.

Acknowledgements

I would like to acknowledge first the members of my committee, and I also extend my gratitude to Dr. Sherri Porcelain who helped me focus my research. Special thanks to the Center for Latin American Studies who assisted my field research and to Nuestros Pequeños Hermanos and the people of Miacatlán, Morelos where the idea of this thesis was born.

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Chapter 1: INTRODUCTION

Adequate distribution of drinking water services is an essential requirement towards the protection of the public health of a society and to ensure basic living conditions, yet in the developing world this simple service has often been lacking and is a contributing factor towards mortality and illness. Almost 1 billion people in the world lack an improved connection to water supply, resulting in some level of water shortage (WHO & UNICEF, 2010). However, even with formal access, limitations to either quality or quantity can limit a household's ability to acquire daily required volumes to ensure good health. While some writers and authors (Solomon, 2010) have used water shortages to warn of the impending water crisis, a more practical, informed approach must be observed instead.

Peter Rogers (2006: 34) claims, "there is no *water crisis*; there is a clear *water management crisis*" which emphasizes not the lack of water, but lack of water management. This management crisis can explain the problems related to drinking water—of both quantity and quality—especially in countries with a high percentage of 'official' connections, while still not being able to purify and distribute this water[1]. Still, this management crisis of water resources is very serious when understood that there are over 2.2 million deaths from diarrheal diseases every year (Birn et al., 2009). The main determinants for these diarrheal bouts stem from water quality and level of sanitation as well as certain health-promoting activities, and thus are preventable. Worldwide, public health is the primary driver of drinking water distribution improvements, and indeed the

[1] While water resource management involves water services to many different sectors, including agriculture, industry and domestic stakeholders, I will only be focusing on domestic services. This decision is based upon the direct connection between domestic water services and public health. I will be referring to water, domestic, and drinking water services interchangeably and only refer to agricultural or industrial water when explicitly stated.

WHO and UNICEF have launched worldwide campaigns aimed at increasing access and quality of water supplies (Water Sanitation Health Programme; Millennium Development Goals). However, the quality of delivered water is not as easily identifiable as simply counting water faucets. This is especially true in nations which have decentralized their water systems, as individual municipalities are responsible for ensuring the quality of water access to their citizens, often without adequate oversight.

In this thesis, I will focus on the rural management of drinking water in Mexico by introducing case studies from a rural municipality. The study will serve to ask a question whether managerial practices demonstrate an association with the public health of a community. My analysis of the rural municipality will be framed around a UNESCO (2010) finding of four general factors encountered in smaller water management systems:

- Lack of institutional arrangement
- Poor infrastructure
- Lack of political will
- Socio-economic conditions

These four factors form what I will name the 'political economy of drinking water services', which frame the ability for municipal managers to adequately address the institutional, infrastructural, political and socio-economic issues of their communities.

I will open the thesis by demonstrating the crucial link between water distribution and public health in the global arena. This will specify what requirements are necessary to promote and ensure basic public health and how management systems must address these concerns, while also addressing the socio-economics of water and institutional arrangements, specifically in Latin America. I will then introduce the current situation of

Mexican water distribution, focusing on the current management crisis facing Mexico, one which centers on the inability to provide safe, drinkable water of sufficient quality for human consumption, as viewed through the lens of the 'political economy of drinking water services'.

Following the contemporary analysis of Mexican water distribution, I will explore my case study of the municipality of Miacatlán, Morelos in south-central Mexico. This case study will examine and compare five communities within the Miacatlán municipality through the various management schemes present in each community. The purpose will be to contrast and compare water management practices and water quality within these rural communities in order to determine an association between management practices and the public health of the communities. I predict that indeed certain management practices will carry weight in relation to public health, particularly management strategies in coordination with health professionals in the communities, aimed directly at the public health of the community. Still each community, being very distinct, will retain its own specific management needs, lending towards the development of a management plans based on the municipal level.

This thesis will demonstrate how the water management of one rural municipality affects the public health of its individuals. Still, I do fully understand that many externalities take place within the scope of public health. Thus, I stress that I do not attempt to create direct causality between management of water and the public health of the municipality, but instead use the case study to determine why some communities may be able to provide clean drinking water for the population, while others suffer from poor health and diarrheal diseases. I will analyze my case study to determine what association exists between certain water management practices and the public health of a region

This study, while limited to the results of one rural municipality, seeks to form a greater understanding of the connection between water management and public health and will allow for the design of management plans with public health as their primary focus, raising water quality and reducing mortality from diarrheal diseases. My studies provide an opportunity to look beyond simple water connection percentages, which often does not tell the complete story of water quality and quantity, and instead promote a novel approach towards water quality surveys by including the management of water as a key component to evaluating the public health of a region.

Chapter 2: WATER DISTRIBUTION AND PUBLIC HEALTH

Water distribution in not only involves the physical management of water, but also significant social and public health aspects that were often overlooked in previous years. Okke Braadbaart (2009) shows that as Latin America was undergoing rapid industrialization, while also struggling to provide basic services to the rapid influx of rural migrants into urban areas, the transfer of the "piped water" paradigm to Latin America from the global North brought two important questions for cities in the South: Who will be responsible for the costly undertaking of rapidly implementing piped distribution networks? And who will monitor the public health component of the water supply? The second question stresses the importance that water services holds on the level of public health, and will be explored further specifically regarding Mexican drinking water management.

Drinking water services and the imported water distribution framework must now represent the specific physical, geographical, social, and cultural characteristics of the communities which they serve. The planning and implementation of water distribution improvements does not follow a one-size-fits-all approach, but instead must involve "a greater convergence of perspectives…in order to develop the required inter-sector coordination" (Heller, 2009: 136). Heller challenges the opinion that technical solutions and management practices for drinking water services are universally valid and independent of local contexts. While this opinion has faded from contemporary systems in developed countries, this framework often still prevails in developing countries (Heller, 2009).

The implications from this assumption create problems when local socio-economic, environmental, and public health issues are ignored, or worse, when they are obscured due to the management framework. This fragmented perspective hinders the management and limits the ability for interdisciplinary and inter-sector approaches to develop. Indeed, effective drinking water management must accept that water is a complex resource containing issues of valuation, public good distribution, and allocation of the resource, as well as public health. Both human and non-human processes interact within the extraction, distribution and consumption phases of drinking water management, creating a complex network of actors, providers, users and observers, all of whom must be integrated into the water management process (Swyngedouw, 2009). If public health is to be integrated into the water management process, several inter-linkages must be explored.

Inadequate water and sanitation services are major causes of mortality and illness, especially in poor societies. The burden of disease created by poor water and sanitation often exceeds that of many major diseases (e.g., malaria or tuberculosis) (Pruss et al., 2002). For public health to be adopted as the key driver for drinking water services, several radical changes will necessarily take place. This would necessitate a reordering of priorities from a distribution-oriented (top-down) to a user-directed approach (Heller, 2009), closing the gap between management and consumer, but also leading to more equitable practices. This also includes changes to the institutional framework of management, including management practices and quality monitoring parameters. A similar reordering of the distribution framework (structured via decentralization) brings the consumers closer to the management scheme.

The management of drinking water resources is a crucial issue in addressing the public health of a region as clean water and the adequate disposal of waste are cornerstones towards diarrheal control. The linkages between public health and the basic determinants of health are as numerous as they are important. Simple mortality and morbidity statistics demonstrate the importance of clean water to healthy societies. "Water and sanitation-related illnesses kill some 3 million people each year and are among the leading causes of preventable mortality and morbidity," in fact, diarrhea alone causes 2.2 million deaths annually, mostly among young children (Birn et al., 2009: 314).

Infant and young child (children under 5) mortality are intricately connected to the water quality and often infant mortality serves as "the most sensitive indicator of a general level of 'development' and the state of health of a population" (Birn et al., 2009: 252). While admittedly health indicators are very complex with numerous influencing characteristics, high infant mortality rates "represent inadequacies in public health often involving socio-economic and sanitary conditions. Still, "many of the leading causes of infant and child morality are preventable" through sanitary and water improvements as well as public health initiatives (ibid: 252). Indeed, a 2006 survey shows access to an in-house water connection is often closely associated with infant mortality, as where water access is high, infant mortality is often low. However like any indicator outliers do exist, such as Sri Lanka which contains a low level of both connections and infant mortality, however this is primarily due to Sri Lanka's investments in maternal health and community water sources (Birn et al., 2009).

Infant and child mortality rates also serve as a strong indicator, as children are more vulnerable to environmental factors, such as contaminated water as children drink proportionally more than adults, taking in a higher concentration of toxins as well as being apt to "explore and put objects and hands in their mouths, exacerbating exposure" (Birn et al., 2009:483). Finally, poverty influences a child's vulnerability due to poor healthcare and the higher presence of toxins in the soil and water.

Mortality rates have been reduced from very high levels due to advances in purification. Indeed, almost half of the decline of mortality in the United States during the early 20^{th} century can be attributed to advances in water purification (Birn et al., 2009). However these same advances have not been fully implemented in developing countries.

The difference in mortality for developing nations exemplifies the large gap between available technologies and the implementation of these advancements in developing countries. The capital required to make large advancements and implement universal coverage curtail many efforts for developing nations to serve their population. Indeed the American Waterworks Association (2008) assesses the capital required for infrastructure projects to be great and increasingly expensive. Current cost-effectiveness analysis often show that improved water and sanitation management and regulation *without infrastructure investments*, as well as hygiene education, may have the ability to increase public health in developing countries, while also being extremely cost-effective for controlling childhood diarrhea and not being limited to strictly what can be financed and constructed (Birn et al., 2009; WHO, 2003). While infrastructure improvements must not be forgotten, cost-effective solutions hold an opportunity for developing nations to economically address water management and water quality concerns, while also remaining within the feasibility of developing nations to address water quality issues.

Water Resources in Latin America

Indeed, better management can combine with better water quality to increase public health. While water quality can change due to naturally occurring contaminants, human activity can also alter the balance of water quality, disrupting natural flows which may result in contamination (García, 2006). This disruption leads to an imbalance of water quality and presents dangers to health of those who live near and depend upon the local water system.

Because of the importance which water quality holds for the health of communities, specific criteria must be imposed for the monitoring of water quality at levels sufficient for human consumption. This is complicated by how water quality management is often lacking in developing countries, including many in Latin America. While the reasons for these shortcomings are related to economic constraints, others include managerial skills and understanding of water quality monitoring, specific to Latin America (Barrios, 2006). In this vein, specific water quality monitoring and evaluation systems must be developed while keeping financial constraints on the project in order to encourage sustainable practices.

To use the example of Mexico, in 1996, a World Bank sponsored project was launched in order to modernize the Mexican water quality monitoring network (World Bank, 1996). The main objective of the redesign was to propose a cost-effective, reliable, accessible, and useful water quality monitoring program (Biswas et al., 1997). Extensive inter-disciplinary discussions involved Mexico's Ministry of Health, Ministry of Environment, Ministry of Tourism, and many other governmental and non-governmental entities. The results, however, were mixed. While the advancements were important in that major attention was given to the subject of water quality management, the redesign did not create a functional monitoring program, which while based upon numerous expensive-to-monitor parameters, many "are rarely enforced" (Downs et al., 1999). Similarly, the Hydraulic Plan 1995-2000 (CNA, 1995) states only general objectives, instead of specific guidelines. Eugene Barrios (2006) sees oversight such as this, as demonstrating a lack of a functional, usable and reliable water quality monitoring system for its water management activities. This shortcoming is mirrored in many Latin American countries, where financial constraints have capped the ability of good intentions to result in effective solutions.

Literature is highly divided upon the economics of water. Adopted at the 1992 International Conference of Water and the Environment in Dublin, one of the four Dublin Principles, adopted by the United Nations, holds that "water has an economic value in all is competing uses and should be recognized as an economic good" (United Nations, 1992). Other authors hold a naturalist outlook with water as an inherent human right to be shared by all (Barlow & Clark, 2002). However, Vandana Shiva (2002) acknowledges the two cultures of water: one treating water as a private commodity and the other treating water as a sacred gift, and it is upon this dual opinion which drinking water management must be framed. Drinking water holds roles of both a private good (those governed by conventional market economics) and a public good. When consumed within the home, drinking water is a private good, and while it is distributed through the distribution network to the community, it is a public good (Hanemann, 2006). Still, other problems arise with scarcity issues, when coverage is not universal and when water quality is not at adequate levels.

Similarly, the cost of water and the levying of water tariffs are also very difficult. Hanemann (2006) finds that many water tariffs are not levied upon the economic value of the volume of water—volume charges are negligible in many cases—but instead upon the costs of the water distribution infrastructure. In many countries the water is even subsidized below the cost of distribution in cases where low socio-economic standings dictate. Furthermore, charges are initially established to recover the construction costs and to finance the short-run operating costs, which are minimal. Instead, as infrastructure ages "it is economically optimal to switch to pricing based on long-run [i.e. replacement] marginal cost" (ibid: 87). However, most water agencies are already tied into the current financing schemes and unable to drastically adjust the water prices for continued growth. Still, there are innovative approaches and a growing literature (Islas Cortés & Sainz Santamaría, 2007; Aguirre, 2006; Seroa da Motta et al., 2004; Jouralev, 2004) which stresses the importance of using economic instruments in the distribution schemes in order to recoup costs, offer subsidies and plan for future capital investment. Whether these solutions will be implemented is yet to be seen.

Alongside the financing and tariff schemes the essentialness of water, must be evaluated as to public health of individuals. Water expert Peter Glieck (1999) determines access to 50 liters per day per person as the minimum human requirement for water for daily drinking, basic sanitation, bathing and cooking requirements. In developing countries this 50 liters can often be difficult to obtain when water tariffs limit the ability to purchase water from the distribution network. In fact, the OECD found the willingness-to-pay for water hovered around 4% of their income towards water services (OECD, 2003). This represents the maximum value households are willing to spend on domestic water before resorting to lower daily volumes or relying on water of lower quality from untreated streams or run-off. However, in areas where sources of water are distant or non-existent, households must often purchase water from water vendors at levels much higher than 4% of household income (Castro, 2009).

Most noticeably, the ability to purchase water has important complication for public health, where as water access and water quality decrease, severe health problems arise, especially when approaching the 50 L/d per person benchmark. Not only will decreased water availability and quality affect the personal health of a household, with decreased water available for basic sanitation, further problems arise, expanding what is the double burden of disease (Pruss et al., 2002). To create an example, as water quality worsens, not only will the prevalence of water-borne diseases increase, but decreased water for basic sanitation and hand-washing will facilitate the further spread of water-borne illnesses.

It has been stated, of the importance for adequate institutions in place to manage the intricacies of water management and the important public health implications of said management (Crase & Gandhi, 2009). While using the claim that that public health drives water management, institutions must be adapted and implemented to control water extractions, purification and distribution for public health. Indeed, Elinor Ostrom (1992: 1907) claims that “for the next several decades the most important question related to water resources development is that of institutional design rather than engineering design.”

This is not to say that the current institutions and management of common resources is fundamentally flawed or doomed, as the simplistic ‘tragedy of the commons’ would lead us to believe. The tragedy of the commons (Hardin, 1968) predicts the failure of managers to sustainably use common resources as users seek to consume as much of the common resource as possible. Indeed, in a perfect chaos this failure results from inability to communicate clear objectives of use of the resource, as well as failure to communicate with other consumers. However, with adequate institutional management, the chaos retreats and order is restored, allowing for effective management of common natural resources (Ostrom, 1990).

As institutions will become crucial in the management scheme, we must determine what role institutions will hold for water management. Philip Pagan (2009) sees water institutions as organizing water management and uses North's (1990) structure, stating that "institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction." This is the breakdown of water management practices and strategies and in terms of water distribution, decentralization has appeared as the dominant implementation scheme among larger republics in Latin America, with exceptions being few and far between.

With decentralization of water management gathering support, an evaluation must follow on the objectives, purposes and results of decentralization in drinking water management. Many authors see centralized authority, decision-making and management as a hindrance to the distribution of water (Ananda et al., 2009; Namboodiri & Gandhi, 2009). A decentralized approach, not only streamlines the administrator-user interface, but also does so at a lower cost. A World Bank project for a group of developing countries, determined that per-capita water costs to be over four times higher in centralized systems than in fully decentralized systems (World Bank, 1994). Still, decentralization is not the magic solution, as the success of decentralization will lie heavily on the ability of the local government's management and planning capacity (Saade Hazin, 2006).

All developing countries must align their formal institutions with a management plan and one which is also approved by the stakeholders. Often, "the institutions created by government or bureaucratic hierarchies are not congruent with the rules and customs associated with informal indigenous institutional arrangements" (Herath, 2009: 84). However, even within non-indigenous communities, the institutions may still not line-up within culturally accepted regulations. While Herath focuses specifically on irrigation institutions, her studies also apply to drinking water institutions. Only if these institutions and their management plans are approved and agreed upon by the communities, will the institutions be successful. In many developing countries, institutional deficiencies are the root of water management problems as development lags behind those of other countries (Crase and Gandhi, 2009: 5)

Understanding the framework behind water quality and public health allows us to establish the current driver behind current water management both in the developed world as well as in the developing world. Furthermore, the economics of water management demonstrate the precarious position that water holds within the modern political economy and will determine which improvements are feasible and cost-effective. Water institutions have the opportunity to be the crucial link between the success and failure of water management, especially management on a local scale, and reforms and evaluation mechanisms will lie upon their successes. These institutions in

Mexico have a distinct history and establish the framework of analysis, upon which we may construct our evaluation of contemporary Mexican drinking water distribution.

Chapter 3: MEXICO AND WATER DISTRIBUTION

With the framework of analysis and theory of public health in place, we now are able to analyze the Mexican water distribution management and evaluate its strengths and weaknesses. In terms of average connection, water and sanitation services remain fairly low in comparison to the overall economic strength of the country. As of the last Mexican census in 2005 over 10% of the population had no access to water supply, with urban and rural zone coverage at 95% and 70% respectively (CNA, 2010), however a substantially higher percentage lacks access to safe, drinkable water (Torregrosa & Jimenez, 2009). This percentage is primarily in rural zones, but also includes much of the peri-urban slums, where although they may have 'access' to water supplies, the cost, quality, intermittency and class divides transform these 'permanent connections' into barriers to water access. Furthermore, access does not necessarily imply potable water, as according to National Water Commission (CNA), "inhabitants considered to be covered *do not necessarily* dispose of water of drinking quality" (CNA, 2010: emphasis mine). In terms of Mexico, water supplies termed as drinking water may not actually fulfill the drinking water norms.

The implications of this poor quality of water are immense for the public health of the nation. Indeed, between 2000 and 2008, intestinal infections and diarrheal diseases were the number one cause of mortality for children between 1-4 years, representing between 8-10% of all deaths within this age range (SINAIS, 2008b). Worldwide, the majority of deaths age 1-4, stem from inadequate water and sanitation services (Birn et al., 2009). For infants the situation is much graver, where the mortality rate per 1,000 live births ranges from 15 to 16 deaths between the years 2008 and 2000 according to

Mexico's National System for Health Information (SINAIS, 2008b). However, significantly higher rates for Mexico of 29-32 infant deaths per 1,000 live births were reported by the WHO during this same period (WHOSIS, 2008). To contextualize these numbers, during the same time period infant mortality in the United States per 1,000 live births was 7.0 and the percentage of deaths among children under five years of age due to diarrheal diseases was 50 times lower (WHOSIS, 2008).

As stated earlier, infant and young child mortality rates are important as they describe the general state of health of a population and indeed in terms of water quality and access, these mortality rates serve as a gauge for environmental heath in Mexico, an opinion held by experts in international health (Birn et al., 2009). Additionally, the CNA also uses child mortality as their gauge of success during the 18 years of their existence.

While the average mortality through diarrheal disease of children under the age of five has been in decline, disaggregated data across the 31 states, show several states with alarming increases between 2005-2010, including Guerrero, Colima, Hidalgo, Morelos and Campeche (CNA, 2010). Guerrero, not surprisingly is one of the states with the lowest household connections to water at 68%, however Morelos and Colima have water connections of over 90%, reaching nearly 98% in Colima (CNA, 2010). Contrary to expected trends, these health and water connection statistics demonstrate that a simple household connection does not necessarily secure public health in Mexico.

I use this discrepancy between expected and actual mortality rates to question whether there are public health issues within water management and quality within Mexico. In the absence of extreme outliers, such as sustained armed conflict or genocide, it would appear that the water currently distributed to households does not promote public health and places household members, and especially young children and infants at risk. Indeed, from personal experience and numerous academic studies, water quality is proven to not be of sufficient quality for human consumption (Cifuentes, 2002a; Downs et al., 1999; Torregrosa & Jimenez, 2009). This discrepancy also asks for a deeper investigation of water management and public health than simply a water connection. I will thus investigate the political economy of water in Mexico, specifically focusing on water management and public health on a local, municipal level.

Differences in political ideology in Mexico stratify the water debate. While water distribution is often thought of as a straightforward issue for all political parties, competing agendas have politicized the debate as each political party wants to be seen as the sole deliverer of water resources to the population. Also, the socio-economic connection to poverty and water management involves the interface between supplier and purchaser, as the 'willingness to pay' in Mexico has been shown to be a critical factor in water improvements (OECD, 2003), where if the population cannot afford to purchase water from the network, then no amount of water treatment and infrastructure improvements will reach this marginalized sector of society. Water quality issues continue to plague the country and this critical feature directly affects all aspects of Mexican water distribution, while poor infrastructure also contributes to poor water quality. While many of these political and socio-economic differences are outside the realm of water administrators, local water management practices *are* within the realm of influence to develop strategies for better distribution of drinking water resources. Still, the influences deriving from outside the water management scope (political and socio-economic) must be incorporated into the management strategy to overcome these obstacles.

These differences, institutional, infrastructural, political and socio-economic, will be analyzed in terms of the Mexican specific case, how they fit into the current state of water management and Water Plan, how they present strengths and weaknesses, and finally how they have shaped the current water management crisis in Mexico. My case studies will focus on the local level, following the decentralized viewpoint of water distribution. However, I first present the national framework in order to see the problems facing Mexico as a whole. Following both of these viewpoints I will be able to draw meaningful, educated analysis and reach conclusions.

To introduce the current situation of drinking water distribution in Mexico we will begin with the landmark 1992 Water Law (CNA, 1992), cementing the decades-long decentralization process of water resource management. As result of the 1992 water reform, authority was delegated to the municipalities, in a decentralization push, one which the World Bank decided was more efficient (World Bank, 1994), and a position supported by many prominent water researchers, (Scott & Banister, 2007; Saade Hazin, 2006). In Mexico, the CNA is the sole water authority for federal water management and is charged with the promotion and execution of federal infrastructure as well as preserving water quality of all water bodies within Mexico (Saade Hazin, 2006). The 1992 Water Law, succeeded in becoming the framework for the federal water system. This comprehensive policy reversed the historical tendency to highlight the importance of water for its agricultural use, as the 1992 law viewed water as a natural resource instead of an agricultural good (Saade Hazin, 2006). However, the law also fostered a greater participation of the private sector in the water industry, a design that many believe was a capitulation to international pressures to institute neoliberal laws into the Mexican economy (Barkin & Klooster, 2006; Schmidt, 2005). Also, under this new arrangement was the establishment of 13 administrative regions, based not on state boundaries but on water basins. This structural arrangement reflects a progressive and innovative arrangement which is at the heart of integrated water resource management.

While the most noticeable result of water restructuring was the creation of the CNA and the delegation of authority of water management to the communities, the framework connecting these two extreme sections of water management is complex and merits its own evaluation. The new institutional structure follows the federal system in place in Mexico with three separate levels: the federal, the state/basin level and local municipal. Upon this three-tiered system, authority and power is delegated, with increasing responsibility for distribution to the municipal level.

On the federal level the CNA is officially charged with administration of the national waters, management and control of the hydrologic system and promotion of social development (CNA, 2010). The CNA also establishes administrative direction and establishes water quality norms. In terms of drinking water the most important norm establishes clear limits of water quality, including levels for physical conditions (color, smell, flocculation) chemical conditions, (e.g. arsenic, a serious problem in northern Mexico, and nitrates) and biological conditions (coliform bacteria and parasites), (NOM-127-SSA1-1994, DOF, 2000). This drinking water norm, based upon WHO guidelines for drinking water quality, establishes the total levels to be applied for all drinking water across Mexico. The current National Water Plan 2007-2012, established by the Felipe

Calderón administration stresses the need to expand monitoring systems across the nation (CNA, 2008). Additionally the CNA has recently promoted integrated water resources management (IWRM), which overlays easily upon the already established watershed committees dividing the river basins of the nation (Torregrosa & Jimenez, 2009). The commitment to IWRM comes alongside the current establishment of the National System of Environmental Indicators, four of which deal explicitly with water on a national level. The success of both IWRM and Environmental Indicators will ask for a reevaluation in the coming years following their complete implementation.

While these CNA programs are established on the national scale, the CNA does not have a clear, direct impact on rural water users, aside from delegation of responsibility and funding large water projects. This is left to the state/basins and municipal users. On a state level, each state maintains its organization also charged with administration and coordination of funding projects. The management objectives are more concrete and direct, and aimed at assisting the municipalities.

Finally the direct administration of water resources falls to the municipalities themselves. While there is not one framework which the thousands of municipalities follow, most are coordinated by an Office of Potable Water, under the supervision of the municipal president. The objectives of each municipality vary widely and tasks and programs depend heavily upon each municipal president's agenda. It is here, especially in rural municipalities, where supervision and transparency is at its lowest. It is upon this local level where the government must set up management strategies instead of the federal, national level (Gooch & Stålnacke, 2010). It is when the focus on water connections and management remains solely on the big-picture that municipal-level efforts, or more dangerously, lack of efforts, may go unnoticed, while the public health suffers.

This current water management organizational structure has succeeded in many ways as noticed by the increase in the percentage of the population with access to drinking water since its restructure. As of 2007, 18 years after the creation of the CNA, 90% of the population had access to drinking water, and increase of more than 10% over those 18 years (CNA, 2007). However, while this connection appears to show significant gains, the quality of water has deteriorated over the past decades to the point where observations of bottled water consumption show that the population has lost trust in the ability to drink the distributed tap water. Indeed, it is not possible to drink the water in much of Mexico (Jimenez, 2009), and while several communities (most notably Monterrey and Tijuana [Smith, 2005; Torregrosa & Jimenez, 2009]) have managed to provide clean drinking water, this is by far the exception from the rule. There are obvious strengths as well as weaknesses of the current management, and they must be evaluated, focusing primarily on the institutional, infrastructural, political and socio-economic differences.

Institutions

Water quality remains the largest obstacle to actual water coverage as, in general, the water is not safe to drink untreated throughout the country (Jimenez, 2009). However, this again does not tell the entire story, as several communities deliver safe, drinkable water to its citizens. Monterrey is one of the success stories of Mexico where water expert Vivienne Bennett of California State University San Marcos stated that "Monterrey is the only city in Mexico where you can go and drink potable water anywhere" (Smith, 2005). Water quality in Mexico is indeed limited, but other successes exist in smaller communities with safe, drinkable water including rural Palpan, serving a population of roughly 400 households (interview with Ruperto Gonzalez, 2010). If safe drinking water can be provided to rural communities of less than 1,000 as well as those of more than 1,000,000, the institutional management of water quality may become a crucial issue facing water distribution in Mexico.

The current water plan in Mexico contains the highest water quality requirements in Latin America, however due to weakness in institutional governance, these parameters are rarely measured (Downs et al., 1999). This is also noted by Blanca Jimenez (2009) who stated that despite the existence of 52 parameters for water quality, only fecal coliform and residual chlorine are systematically measured. And even these parameters are often overlooked as noted during investigations in Mexico City (Jimenez, 2009) as well as in rural Morelos during 2010 (field research conducted by the author). With parameters governing inorganic compounds, microbiological, organic compounds, pesticides, radioactive components and other critical indicators specified within the Mexican Official Standard (Jimenez et al., 1999), it can be seen that water quality is not lacking due to the absence of parameters, but instead due to a lack of managerial enforcement and transparency of said parameters (Townsend & Eyles, 2004).

Thus, despite stringent parameters included in the 2007-2012 Water Plan, the enforcement capabilities instead must be evaluated, not only for Mexico as a whole, but for each river basin, and for each municipality. Local conditions must be evaluated by each municipality and formulated into their specific water quality management framework. Furthermore, regulations and standards must be realistic and achievable, as

Benedito Braga et al. (2006) shows that unenforceable standards undermine the trust in the rules of law. Furthermore, these standards can be gradually tightened as necessary to arrive at the desired parameters, however a long-term plan will be necessary, longer than the 5-year plan Calderón proposed in 2007 (CNA, 2008).

Infrastructure

To address the other limitation in Mexico, the infrastructure is aged and in very poor condition. David Barkin and Daniel Klooster (2006) found the state of design and repair of water mains to be in 'dreadful conditions'. While hyperbole may be in use, conditions in rural communities support their claims as the heterogeneous nature of water distribution systems hinders repairs, decreases efficiency, and allows for clandestine extractions, such as conditions found in Palpan, combining PVC, steel and concrete pipes. Furthermore, very few water extractions are metered across Mexico and in rural zones this percentage approaches zero. The lack of monitoring of water extractions complicates the abilities for water providers to know how much water flows through their system and to where it is consumed (Barkin & Klooster, 2006). This monitoring will be central to rural water developments as administrators attempt to increase the quality of water which is not currently monitored as to its volume.

Further problems include the intermittency of drinking water. As intermittency is not a requisite in determining access, access only one day a week can be categorized as a permanent connection. As a household must store large quantities of water in the house, this water is now at risk to contamination throughout the week until new resources are delivered. Such rural households are encouraged to employ point-of-use treatment, but these systems can often be well beyond the household's ability to purchase and maintain such systems (Lang et al., 2007) as costs for water can expand to 11-21% of household income.

Larger infrastructure problems, such as lack of sewerage and chlorination also affect water quality as unachievable pollution standards perpetuate public health problems as wastewater often goes untreated. In fact, of the 87 percent of industrial and domestic waste collected in sewers, only 21 percent is actually treated, while this number is significantly lower in rural areas. This low quality of sanitation is reflected in the low quality of natural water sources and measured by the high rates of diarrheal disease observed from those who consume this water (Cifuentes et al., 2002a; Cifuentes et al., 2002b). Water pollution problems around the country in both urban and rural areas are shown by numerous studies detailing high levels of pollution (Cortés Muñoz et al., 2001; Downs et al., 1999; Jimenez et al., 1999). Furthermore, actual chlorination of this polluted water is highly suspect as noted during a study of 5 rural communities, where only 2 communities reported trace amounts of chlorine (field research conducted by the author in 2010).

Politics

Within the political war, which has been waged back-and-forth since 2000, the conservative PAN has wrested control of the federal government away from the long-established PRI, but the left-leaning PRD still looms large in governmental politics with little bipartisan cooperation. To use an example from the State of Morelos, downstream (and historically PRI) villagers marched on the PAN Governor's office to demand the removal of a trash dump which threatened the quality of the community's water supply and posed a real public health threat, a problem the PAN denied (Garcitapia & Garcia, 2009). Collusion with top officials within the Federal Attorney for Environmental Protection for toxic waste permits in rural Hidalgo also suggests political corruption regarding drinking water resources (Sandoval Castañeda, 2009; Norandi, 2008). With politics so charged and dynamic, issues as widely popular such as water resources increasingly play themselves out in the *oficinas del presidente* instead of in the offices of potable water located next door.

A mojor problem in the political structure of water distribution, results from the federal government and CNA delegating responsibility to municipalities without also delegating financial resources (Saade Hazin, 2006). While municipalities have enough funds to pay current expenses, (i.e., salaries and current distribution costs), there is no capital for reinvestment in the system. Instead, the municipalities remain dependant on the federal government and CNA to continue to fund large-scale projects. Barkin and Klooster (2006) note the irony of a powerful central agency, which is reluctant to give up authority, charged as the primary facilitator of operating a highly decentralized structure of almost 2,500 local municipalities.

Schlager and Lopez-Gunn (2006) specifically note that local level institutions have become regarded as a 'new institutional messiah'. However, the authors also note the importance to distinguish between decentralization of *de jure* political authority and decentralization of *de facto* governing capacity (ibid: 56). Despite many years of reform, adequate governing capacity has still not been given to the local governments in Mexico (Saade Hazin, 2006).

Furthermore, gaps in oversight create spaces for managerial breakdown as federal and state oversight institutions are concentrated on the average public health of the state rather than the total public health of every citizen. As almost all water goes unmonitored, public health risks increase exponentially as diseases spread more rapidly as both sanitation and water supply suffers (Tortajada, 2003). In Mexico much of the oversight for the water sector is divided depending on the different categories of users—agriculture, hydroelectricity and urban-industrial—with each oversight agency creating different management strategies, convoluting the ability to provide oversight but also convoluting water quality due to effluents within each sector (Barkin & Klooster, 2006). While the focus here is not on wastewater, sanitation or agricultural effluent, they do remain important and large parts of the hydrologic cycle and cannot be trivialized or forgotten.

Also, a commonly referenced problem I encountered in Mexican towns is that due to the short three-year term of municipal leaders, the benefits of water infrastructure projects are not apparent until the next administration has taken office, and receives the praise for the project's success. Saade Hazin (2006) also counts this as a reason for the absence of long-term water planning.

Furthermore, rampant clientelism in Mexico creates the space where water connections are given in exchange for the promise of votes in coming elections (Torregrosa & Jimenez, 2009; Castro, 2006). As clientelistic practices abound, governing bodies fight amongst themselves for the ability to cater to the citizen votes, resulting in an institutional infighting that is noticed in areas where there is overlap of authority, especially among conurbated municipalities (Castro, 2006). Recently, citizens in Mexico City were informed to "join the PRI if they wanted a fairer water deal" exemplifying the coercion of citizens into political parties in order to enjoy water services

(Castro, 2006: 122). As political parties use water services as a bargaining chip, water appears to become a luxury, bestowed by administrations instead of the common public good as it is referenced in the Mexican Constitution.

Furthermore, the lack of political transparency threatens water management and public health (Townsend & Eyles, 2004), as detailed data about drinking water quality is absent apart from a few isolated academic studies.

This is, however by no means to say the politics behind water are failing. The decentralizing efforts made during the 1980s successfully paved the way for efficient water basin schemes on which the current plan is based. It also allows for the effective interaction between the administrators and actual consumers of the water, a crucial tenet for effective water resource management (Gooch & Stålnacke, 2010). Furthermore, the establishment of basin committees more effectively addresses local conditions, revealing natural arsenic contamination in the Comarca Lagunera region of northern Mexico (Schmidt, 2005).

Socio-economics

Other problems involve the distribution of wealth in Mexico, which is very imbalanced as nearly 10 million Mexicans control 80 percent of the total GDP, while the most deprived 20 percent control only 2 percent of the total wealth. Furthermore this wealth is mostly centered in the urban Federal District and the surrounding state of Mexico while smaller and more rural states concentrate much less wealth (Torregrosa & Jimenez, 2009) Furthermore, while only 25% of the Mexican population lives in rural zones, over 60% of the extreme poor lives in these zones (World Bank, 2005). This provides a clear example of the poverty which often characterizes rural zones, limiting their ability to purchase drinking water and also finance large water projects. This imbalance of wealth presents severe problems for the economic sustainability of water projects established in rural zones.

Opposed to many other resources, which may be easily governed by market-based economics, water as a resource is more crucial and thus different. As noted earlier, the minimum of 50 liters per person must be attained daily to ensure adequate health. The price for this volume, while on average is less than 4% of household income, can increase dramatically if both water supplies and income levels decrease in rural areas. This can often be the case and in some cases people connected to the distributed water network were paying between 5-10% of income for water services (Castro 2006). Also, people buying water from private vendors often pay even higher levels (Barkin & Klooster, 2006). In the case of water shortages and during the dry season, private water vendors or bottled water can raise expenses to high levels as private vendors raise prices in collusion with municipal authorities (Castro, 2006)[2].

Water is also ingrained within the Mexican culture, as it is in all cultures and water as the source for life has been adopted as the banner for many social movements. This is exemplified by the water struggles which led to the formation of a rural social movement, known as “13 Pueblos”. The social movement “provides for the defense of the water, air, and land” and supports rural communities seeking to secure water rights (Robinson & Caldera, 2008). Their presence in Morelos serves as a strong display on the part of rural communities to fight for their right to water. The 13 Pueblos ranks are largely filled by poor, rural farmers and community members, up against the wealthy

[2] While my study focused solely on water distribution from the formal supply network, further studies into water trucks would greatly benefit the study of water stress in zones of low socio-economics.

cities. One such example is of the rural community of Alpuyeca (population 7,800) up against the state capital, Cuernavaca (population over 300,000) demanding changes to ensure the continued health of the small community. 13 Pueblos allows the poor rural citizens to organize themselves when other avenues to defend their access to water have been cut off.

Water trucks are also common throughout the country where drinking water is delivered by huge tanker trucks, prominently displaying *¡Agua no Potable!* on the side of the truck. Furthermore, as water vendors are often unlicensed and apart from the official water distribution system, the quality of this water is very suspect, and often the water tanks can be seen simply pumping untreated water from streams and lakes. This practice is observed in many poor areas, but is especially prominent within indigenous zones in Mexico, possibly further marginalizing the indigenous people residing there.

Rural communities are often excluded, and the "local authorities do not have either financial or human resources that they need to meet the water requirements of rural Mexicans" (Lang et al., 2007). Wide-ranging subsidies may not reach the poor sectors that they are supposed to help. For example, when the poor are required to buy small volumes of water from water vendors in the informal sector, water subsidies do not benefit the poor, but instead subsidize the middle and high-income classes to fill swimming pools (Torregrosa & Jimenez, 2009; Barkin & Klooster, 2006). This again stems from the inability to meter and monitor water flows.

An important facilitator of future political and institutional coordination will be the Mexican Institute of Water Technology (IMTA) whose mission is to produce, instill, and disseminate knowledge and technology for the sustainable management of water in

Mexico. This government organization serves to be leaders in development of water technology while also promoting water education and capacity building within water administrators as well as with public users. In particular, Claudia Magdela Espinoza Garcia, a specialist in Water Education, designs programs for communities and water administrators to value water and promote more efficient practices. However, the efforts of IMTA are only successful if the water administrators seek help from IMTA, as their experts and specialists are not able to conduct independent research in all of the 2,500 municipalities around the country. As such, more work and emphasis will be necessary in order to remove roadblocks to universal and safe water quality.

What can be drawn from this example is that despite the appearance of high levels of connections to water access, several factors: institutional weakness, low water quality and infrastructure, politics and low socio-economics reduce the true level of connections within the country. This is backed up by the clear volumes of water present, but the inability to purify and distribute water resources to the rural Mexican population. To summarize the major difficulties facing Mexican water distribution I have summarized them into several points here:

- an institutional system which has not truly decentralized power to municipalities
- infrastructure which lacks water quality monitoring and metering
- political organization which does not adequately plan for long-term management
- lack of an economic design directed to the marginalized indigenous and poor

While issues such as gender and environmental sustainability are also presented (Ennis-McMillan, 2006; Tortajada, 2000; Robinson & Caldera, 2008), I was not able to observe these issues within my case study in rural Morelos, however they must still be reserved for an analysis of other regions.

The Water Agenda 2030 (CNA, 2010) currently being developed by President Calderón shows promise to move out of the 6-year presidential administration window. Still, whatever changes that will be instituted, must be based in the management of municipalities. Without this link, the program will fall into the decentralization trap once again of federal management without addressing local water problems. Indeed, a UNESCO study (2009) calls for a new adaptive management, one which can be designed and applied to any of the 2,500 municipalities in Mexico. This of course, will require an integrated and multidimensional approach, one which involves policy makers, water technology innovators, water administrators and most importantly the actual users of water resources.

Especially among rural and poor communities where extreme differences in quality cause increased health risks, a new evaluation must be implemented to determine actual water access in rural Mexico. The next chapter will do exactly that by visiting a rural municipality and investigating links between current management practices and the public health of the region.

Chapter 4: MIACATLÁN, MORELOS

With public health and the Mexican case of drinking water presented in the previous chapters, I will now follow the decentralized nature of the Mexican drinking water framework and focus on a rural municipality to introduce specific case studies. In order to correctly access the Mexican drinking water system, this study will focus on the local, municipal level. The following case study about the Municipality of Miacatlán will examine municipal water management and its association with the public health of the town, investigating three specific aspects of the water within the municipality: raw water quality; public health of communities; and water management practices.

Like many studies on Mexican water quality (Jimenez et al., 1999), I will include raw water quality data, focusing on the basic parameters such as the presence of coliform bacteria and residual chlorine in the water supply. I will also evaluate the public health of the communities, acknowledging the importance of clean drinking water to community health. Focusing on public health will revisit previous surveys of water quality (Khan et al., 2007; Cifuentes et al., 2002a; Downs et al., 1999) which will examine human health as an indicator for water quality problems. Finally, I will introduce a novel approach to water quality by investigating the possible association of water management practices upon water quality. I will introduce the methodology of my study following an introduction of the region under study.

Study Area

Miacatlán is a rural municipality within the small state of Morelos in South Central Mexico. The state of Morelos is situated directly south of the Federal District, with its large capital city of Cuernavaca. The state is most famous for being the home of

Emiliano Zapata, Mexico's revolutionary leader, who championed for agrarian and rural rights (*¡Tierra y Libertad!*) during the Mexican Revolution. Indeed, today just as in 1910, agriculture and water take center-stage as most of the 33 municipalities remain very rural and based in agriculture. Miacatlán was chosen as a study zone, as it resembles the average municipality both in terms of population as well as socio-economic levels. Furthermore, I am extensively familiar with the municipality from two years of living with the community, establishing connections with the local government and community members. I worked for two years as a volunteer at an orphanage located within the municipality, providing volunteer childcare and work with the water filtration system at the orphanage.

The municipality covers a total of over 220,000 square kilometers and contains over 22,000 inhabitants, mostly centered in two larger communities[3]. The municipality of Miacatlán is characterized by moderately high altitude, ranging from 1000 m in Coatetelco to 1600 m in Palpan and seasonal rainfall, typical in tropical regions. The studied population is from the 5 largest communities in the municipality: Miacatlán *pueblo*[4], Coatetelco, El Rodeo, Xochicalco, and Palpan with populations ranging from around 8,500 in both Miacatlán *pueblo* and Coatetelco to roughly 1,000 inhabitants in Xochicalco, El Rodeo and Palpan[5]. The municipality has little heavy infrastructure, centered on a main highway with smaller roads leading to Palpan and Coatetelco. The region is within the Balsas River basin, and all communities are within the Tembembe

[3] All population and housing data is from the 2005 Mexican Housing and Population Count (INEGI, 2005)
[4] The town of Miacatlán will be henceforth referred to as Miacatlán *pueblo* in order to avoid confusion with the larger municipality of the same name, which will continue to be referred to as Miacatlán.
[5] These 5 communities contain 95% of the population of the municipality, and when speaking of the municipality as a whole, it is this 95% in these 5 communities to which the study will refer (INEGI, 2005).

micro-river basin with intermittent streams and springs near Palpan. A map of the municipality can be found in Figure 3.1.

The total population of the towns included in this investigation is 21,588, of which 2,090 persons are under the age of 5 years. This important demographic is most vulnerable to waterborne diseases, and while comprising only 1/10 of the total population, local hospital epidemiological data shows that children in the area under the age of five disproportionately represent 1/3 of all hospitalizations due to water-borne illnesses (source: author). This imbalance demonstrates the need for better water quality management to address these health issues.

I have also identified a community to act as the control site for this municipal evaluation. The community is a children's orphanage with its own closed water supply system and health records, housed within an ex-hacienda directly adjacent to Miacatlán *pueblo*. This community has an extensive and well-documented history of extracting, purifying and distributing potable drinking water to the over 650 children who live within the home.

To better identify with the municipality I will briefly extend the same 'political economy of water' framework to the municipality of Miacatlán. Beginning with the institutional framework, the municipality has authority over distributing potable water to its inhabitants. The Municipal President is the head of the municipality with a Director of Potable Water serving as the head of distributing water. Further duties are carried out by the individual communities, with each community 'supposedly' having a Director of Potable Water. In terms of water quality, the municipality relies on the State Health Services (SSM) and the State Commission on Water and the Environment (CEAMA) to provide water quality testing (a function the municipality cannot perform). These water quality tests are not on file at the Municipal Government, rather at the SSM and CEAMA offices in Cuernavaca, and were inaccessible despite my repeated requests.

Water infrastructure within the towns are rather straightforward with water resources easy to acquire with deep wells furnishing most of the water for the towns and above-ground springs supplying water to the north-west of the municipality. Water connections exist within all of the towns, yet the coverage rates differ greatly, as does the consistency of water flow. For regions without household connections or without constant connections, water trucks deliver water, while households without socio-economic resources to pay for the water truck rates may be forced to acquire water via other means, such as collecting from untreated streams or irrigation canals.

The politics of water within the municipality are much more difficult to identify. However, through personal experience I have observed the politics of water distribution often polarize debate into a stalemate throughout Mexico and particularly in the municipality of Miacatlán. This is not surprising to a community where important water resources (both agricultural and domestic) hold great value during the lengthy dry season. The socio-economic value of water in the community is important because to acquire drinking water, the community members must either purchase expensive bottled water or treat (usually by boiling) distributed water before consuming. Both methods cost money and time by either walking to purchase bottles or using firewood and waiting for the water to boil. This has so moved the population in neighboring municipalities that a water-based social movement “13 Pueblos” has began to place demands upon the state and federal government to step in and protect drinking water supplies for the towns.

While the social movement has not reached Miacatlán, its progress will be important to the future of water resources for the municipality.

Methodology

The case study will follow a specific methodology in order to evaluate aspects of the five communities within the municipality of Miacatlán. The study, conducted during the rainy season in June and July 2010, was based upon the three-pronged framework of measuring raw water quality, public health of communities, and water management practices. The first two methods are well-used methods of determining water quality and are frequently combined in academic studies (Cifuentes et al., 2002a; Jiménez et al., 1999). However, by including all three aspects, I hope to reveal an association between management practices and the water quality and public health of a community. These aspects will allow for three risk factors: managerial risk, water quality risk and public health risk, which can be cross-analyzed for trends and similarities.

In order to evaluate the raw water quality, I tested the presence of residual chlorine as well as bacterial loads, a simple yet successful indicator of poor water quality (OECD, 2003). Measuring fecal coliform levels in drinking water provides an indicator for effective disinfection of drinking water and allows for a rapid assessment of water quality levels (Cole, 2002). I used 3M PetriFilm test plates to determine the bacterial loads in the water supplies of each community, with numerous tests from all of the *colonias* (neighborhoods) within the communities. Samples were taken from household tap water and incubated at 36 degrees C. for a period of 24 hours, and then measured as to the growth of fecal coliform colonies per 1ml of water sample. I also measured residual chlorine levels in the same water supplies. While the presence of chlorine does not directly indicate good or poor health, it does provide a successful indicator of water quality, as it is inversely related to bacterial growth. Adequate levels, according to the US Environmental Protection Agency, range from 0.8-1 mg/liter in water supplies. However, levels can often vary more widely without introducing severe health risks[6]. I compared both fecal coliform and chlorine levels from each studied town against one another to assess a low, medium and high water risk factor.

The OECD (2003) also admits that traditional microbial parameters are insufficient and encourages an integrated system of both traditional as well as epidemiologic data. The epidemiological method centers on measuring the burden of disease upon a population via instances of either hospitalization or poor health. Because quantitative public health data were unavailable, I used epidemiologic evaluations conducted via interviews with doctors and health professionals at four government sponsored public health clinics scattered throughout the municipality.

I coded the epidemiologic evaluations by health professionals to encourage homogeneity in their responses. I asked the following questions to the health professionals:

- Are there water-borne diseases/parasites facing the population?
- Is the water unsafe to drink as distributed?
- Does the population drink the water without adequate treatment?

Using these sets of data allows an assessment of a low, moderate, and high public health risk associated with each community determined by how many 'yes' responses are given

[6] Chlorine as monitored by the State Commission of Water and the Environment, is monitored as chlorine level leaving the chlorine station instead of residual chlorine levels at the household. This difference in methodology may explain the discrepancy between the two chlorine measurements. However, my method allows for a measurement of residual chlorine levels within the household water supplies.

from the previous three questions. Combining the quantitative (water quality) and qualitative (epidemiologic) data will create a clear picture of the health of the population, incorporating both statistics, as well as the opinion of public health officials.

The novel addition to this study is its evaluation of the institutional arrangements for water distribution and management present within the community and valued upon a series of 5 management categories through interviews with the town's Director of Potable Water. First, the staff size present in the town are judged against the rule-of-thumb that one water manager is necessary for every 1,000 inhabitants (Bhat, 2010). Education and experience in the role of water manager are also important and evaluated upon time in current position as well as knowledge of the local distribution system. According to Braadebaart (2009), domestic water serves three basic functions: source of water, domestic water and drinkable water. Each subsequent function requires a higher quality of water, and only drinkable water is determined to be fit for human consumption. I asked water directors about their perceived function of water (upon Braadebaart's three functions): source of water, domestic water, and drinking water. The reason for this was to establish the management aim for the quality of distributed water with drinkable water as the best case scenario. Integration of water administrators and public health was considered positive if the directors reached out to the public health clinics and health professionals located within the communities. Finally, the presence of water boards is an indicator that stakeholders are involved with the management of water resources (Gooch & Stålnacke, 2010).

Further aspects such as infrastructure within the communities were determined from the National Census Statistics (INEGI, 2005) and included rates of water connections and drainage (specifically if sewerage and treatment is present). Furthermore, the source of water, chlorination, and intermittency were assessed on a municipal level as to their effects on water quality.

I also briefly introduced the political economy of water for each community, how political and socio-economic data determine how water is distributed and who can purchase it. Socio-economic levels can determine whether a household can purchase water from the network or in better cases purchase safe bottled water for drinking purposes. Indicators such as high presence of homes with dirt floors, low rates of household drainage, and low prevalence of common household appliances (TVs, refrigerators, etc.) represent limitations to purchasing adequate water supplies or bottled water (Cifuentes et al., 2002a). High education levels may indicate knowledge of hygiene and altogether, these evaluations allow analysis of a community's ability to mitigate diarrheal diseases.

Before introducing the case studies, I propose several factors which I hypothesize will provide the best association with public health improvements. Firstly, chlorine should provide a clear link between water quality and public health because chlorine is a basic standard for all water quality norms. Also, integration between water management and public health will also serve to connect health professionals with the managers of community water.

Results

Miacatlán pueblo

The town of Miacatlán *pueblo* is the seat of the municipality and has slightly less than 10,000 residents, scattered among 9 *colonias*. A map of the community is located in

Figure 3.2. The town is centrally located within the municipality and along the main highway and between both Coatetelco and Palpan. The town is surrounded by fertile farming grounds and fed by an extensive water channel system from the Tembembe River near El Rodeo. The town's colonial history centers on the agricultural ex-hacienda San Salvador, which survives to this day housing the orphanage Nuestros Pequeños Hermanos that houses 650+ children and youths. A control study will revisit this community.

The current institutional arrangements and water management strategies in Miacatlán *pueblo* pose little difficulties to the management of water within the community. According to the decentralization scheme present in Mexico, the Office of Potable Water within the municipal government is responsible for water distribution. For the community of Miacatlán *pueblo*, the Office is led by a Director of Potable Water with a total staff ranging between 4 and 5 persons, a size sufficient for the population of the town. Staff experience in water management spans several decades with knowledge of the distribution network. When asked of the primary aim for water distribution within Miacatlán *pueblo,* water managers stated their role was to distribute water fit for human consumption, confirming the aim to provide water of the highest category. Furthermore, the staff was knowledgeable about new projects and future plans, verbally expressing desire to expand and update the system. Also, integration and knowledge sharing were present as I met with the directors of both Potable Water and Municipal Health in the Director of Health's office room. Coordinated outreach to community members stressed the need to boil water before drinking. I also met with the public works architects who stated they coordinate work with the Office of Potable Water when expanding both the water distribution and sewerage network. Finally, while I did not observe the presence of water boards, the water managers suggested their existence. In terms of water management practices, Miacatlán *pueblo* succeeded in establishing the groundwork for distributing clean, healthy water with a low water management risk.

Also, a strong infrastructure system within Miacatlán *pueblo* suggests high water quality and very high coverage. About 97 percent of the population claims a connection to water while 94% has access to sanitation with sewerage with primary treatment being the most common form of coverage. The municipality claimed to purify and chlorinate water supplies before distribution, utilizing both liquid and tablet chlorination. The majority of the community relied on water from two deep wells, one of 650 m and one at 900 m, with two new wells currently being perforated. Water quality is analyzed two times a year with coordination with the State Water Commission (CEAMA). However, these data were not public. In three *colonias*: Los Linares, El Mirador, and Emiliano Zapata, parts of the population were served by canal water from surface streams. Los Linares experienced reductions in water pressure with frequent gaps in service and drastic reductions of water quality.

To address the politics of Miacatlán *pueblo*, infighting between contesting political parties over voters' sympathies appears as a striking feature within the municipal seat, and while not being directly observed, may also exist within the surrounding communities as well. Large water infrastructure projects remain strongly aligned along party lines despite the emergence of a multi-party system within the municipality. Various political parties (PRI, PAN, PRD, Nueva Alianza, and Convergencia) are active in Miacatlán, like in many Mexican municipalities. However, the strength remains consolidated within the PRI. I witnessed divided support among the strong PRI and PRD for control of water resource allocation with the PRD strongly supporting building a canal system capable for distributing water for decades. PRI party members, including the current municipal president, focus efforts on drilling new wells, which may prove more expensive in the long term. The inability to evaluate long term planning and combine political forces may result in difficulties in guaranteeing water quality and promoting public health.

Economic activities in Miacatlán *pueblo* are largely agricultural-based in the large cultivable areas surrounding the town. However, the town also supports a significant service economy, hosting the *tianguis* (local markets) twice a week. The town also contains the large centers for purchasing cement and paint, as well as the one bank for the municipality. Furthermore, the Office of the Municipal President stated that the population of Miacatlán *pueblo* enjoys the highest economic levels of the entire municipality (interview with Secretary of the Municipal President). Several socio-economic features related to water quality also are prominent in Miacatlán *pueblo*. The population enjoys high education levels with only 36% of the population above the age of 15 having not completed secondary school (7th grade). This compares quite favorably to the state educational level of 32% without a secondary education, which includes both urban and rural zones in the state. Similarly, the community also enjoys high socio-economic levels as determined through a variety of indicators, such as low percentage of homes with dirt floors, low relative overcrowding of individuals within homes and high prevalence of appliances such as TVs, refrigerators and computers. These high levels of socio-economic conditions are beneficial in relation to the amount households spend on water charges. Monthly tariffs range from 32-40 pesos (roughly $2.50-3.20 USD[7]) per month. These do not pose as a limitation to water consumption, nor would bottled water be out of reach for much of the population.

I conducted several health assessments within Miacatlán *pueblo* via conversations with health professionals and through independent water quality tests. Health specialists, in Miacatlán *pueblo* confirm that water-borne diseases and parasites are present in the water supply. However, they do not pose a threat to the population which tends to purchase bottled water to meet most household drinking water demands, as stated by the local doctor. While this is not an economically efficient practice, socio-economic levels in Miacatlán *pueblo* are high enough to ensure the population receives quality drinking water. The households that cannot purchase bottled water continue to treat household water with chlorine or boil their water.

Following my epidemiologic framework, Miacatlán receives a low public health risk as indicated by positive answers to only one of the health risk questions. Individual water tests identified a health threat in the water supply with moderate fecal coliform levels. Significant fecal coliform levels were found in each of the studied *colonias* within Miacatlán *pueblo*. However, of the 15 samples taken from the community, five showed zero fecal coliform growth (33% of total) demonstrating a heterogeneity of water quality across the community. Sample locations may be found as black dots on the Miacatlán *pueblo* map. Still, tests found no presence of chlorine, which combined with the fecal coliform levels indicates a moderate water health risk. Fecal coliform and chlorine data can be found in Table 3.1.

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[7] 12.6 MXN = 1 USD, used as the average conversion rate for 2010

While Miacatlán *pueblo* faces a significant water health risk, economic levels and bottle water consumption in the town seem to offset the direct danger of consuming contaminated water. Furthermore, attempts by the water managers to distribute water for human consumption, as well as combined efforts between public health specialists may serve to mitigate the dangers of consuming contaminated water. Also, Miacatlán *pueblo* benefits from high education levels, further mitigating the danger of diarrheal diseases through education about hygiene. Still, increased chlorination of the public water supply is necessary to reduce public health risks to those citizens not able to purchase bottled water for drinking. While several water samples did not show fecal coliform growth, the heterogeneity of water quality demonstrated significant gaps in the quality of water provided across the community, suggesting infrastructural problems.

Coatetelco

The town of Coatetelco is very similar in population to Miacatlán *pueblo*, with a population of just under 9,000, across 4 *colonias*. A map of the community can be found in Figure 3.3. Similar to Miacatlán *pueblo*, agriculture dominates the landscape surrounding the town as does a large natural lagoon where water resources are diverted and used for agriculture in the surrounding area. However, Coatetelco's population is very different from the municipal seat and is categorized as an indigenous zone. While not primarily an indigenous speaking population, many of the residents do still identify themselves as indigenous. The town is also host to a pre-Columbian archeological site, further reinforcing its indigenous roots.

Within the municipality, Coatetelco has its own Office of Potable Water, led by a Director and with between 2-3 total staff members to administer water to almost 9,000 inhabitants, a staff size insufficient for the town population (according to the 1:1000 rule-of-thumb). While the Office of Potable Water in Coatetelco had its own office within the town hall with archives and its staff, the current Director has a very limited experience within water management. Furthermore, the manager of water stated that his aim was not to distribute water of a quality sufficient for human consumption, providing a major hindrance to public health of the town. Statistics and information gathered from the Director were confusing with regards to the depths of the two water wells which service the town. Furthermore, I did not observe any integration between health officials and water managers, as the head of the public clinic did not know of the existence of the Office of Potable Water despite being separated in distance by only the public square. The water management of Coatetelco presents a very different view from that of Miacatlán *pueblo* resulting in a high water management risk to the public health of the town.

Infrastructure in Coatetelco is also deficient with 12% of the population lacking access to water within their home, creating instances where the population must rely on expensive water trucks to supply the home with water. While official statistics cite 67.5% of the population with drainage, community members state that none of this effluent is treated and instead remains in the subsoil or drains towards the lagoon. According to the State Commission for Water and the Environment (CEAMA), liquid chlorine is added to the water supply. However, not one of the 4 *colonias* is listed as a CEAMA chlorine testing location. The town receives water from two wells perforated 30 years earlier, one whose depth is 80 meters contrasting greatly with the 600+ meter wells of Miacatlán *pueblo*. I was unable to acquire information about the depth of the second well. The water demands of the population require that households receive water only one day of the week, severely limiting the clean water a household can use throughout the week. This intermittence is not reflected on official household statistics, as the 'permanent' connection is only usable one day of the week.

Political parties in Coatetelco carry much less weight than in the municipal seat, and I did not observe politics positively or negatively affecting water in Coatetelco. Still, many political decisions made in the municipal seat will affect water projects and the citizens of Coatetelco.

With the natural and artificial water sources available in Coatetelco, agriculture is not surprisingly the dominant economic activity in the region. While Coatetelco enjoys a small service economy, particularly with respect to the nearby lagoon, it lacks the large businesses (cement, paint, banks) that similarly sized Miacatlán contains. Socio-economic levels are much lower than in Miacatlán *pueblo*, with roughly 50% of the population living in homes with a dirt floor, and 30% of all homes lacking drainage[8] that along with overcrowding of homes, suggests much lower socio-economic levels compared to the rest of the municipality. Further socio-economic indicators, such as prevalence of TVs, refrigerators, and washers indicate the lowest socio-economic conditions for the entire municipality. Education levels also speak of low socio-economic levels as 51% of all inhabitants over the age of 15 have not completed the 7th grade. While indigenous zones often contain high levels of drop-outs, these numbers are higher than the municipal average of 44%. In light of low socio-economic indicators, water tariff prices average 35 pesos ($2.75 USD) per month, which does not appear to

[8] Municipal averages for homes with a dirt floor and homes without drainage are 24% and 16%, respectively. State averages for these two categories are 9.2% and 5.8%, respectively.

limit ability to purchase from the distribution network, but low socio-economic levels most likely does not allow for bottled water purchases.

Health professionals in Coatetelco claim water-borne and diarrheal diseases to be very prevalent throughout the community and also list water as a threat to the public health of the population. The population is not able to purchase bottled water for drinking purposes and must treat distributed water by boiling the water or via expensive chlorine tablets. When these methods are not available, the head doctor of the town public clinic states the population drinks the water untreated. Three positive responses to the epidemiologic questions reveal a high public health risk to the town. Water tests on the Coatetelco water supply revealed bacterial loads in the majority of the water samples. Of the 6 water samples collected, 2 revealed heavy fecal coliform counts, 2 with moderate counts, and 2 found no fecal coliform growth. This disparity reveals heterogeneous water throughout the community, but still points towards contaminated water facing the community. (Not surprisingly, the homes with high fecal coliform levels received their weekly water supply numerous days before.) Furthermore, residual chlorine was not found in any of the samples, resulting in a moderate water health risk.

Coatetelco represents a similar situation as Miacatlán *pueblo* with a large population centered in an agricultural zone. However, several disparities set it apart. Firstly, the low socio-economic levels mean the quality of distributed water affects the health of the population that is unable to purchase bottled water for all household needs. Secondly, the managerial practice of not striving towards potable water represents a limitation to public health as does the lack of sewerage. Both may contribute to health risks as untreated household and nearby agricultural effluent can contaminate the water supply in the unusually shallow town water well which management does not appear to potabilize. This is further complicated from lack of chlorine and the intermittence of water delivery to the population. That the population experiences severe diarrheal diseases is not surprising.

Xochicalco

The following three communities are much smaller and only represent 12% of the entire municipal population. The three communities are very similar in population size with roughly 1,000 inhabitants each. As the largest of the remaining communities with 996 inhabitants, Xochicalco is similar to Coatetelco in that it is also an indigenous zone and contains the famous UNESCO pre-Colombian archeological site from which the town derives its name. Much of the largely indigenous community works in the agriculture fields located near the community.

Xochicalco lacks a town hall and a public health clinic (construction of a public clinic is underway), so much of the town's politics and health care have been absorbed by the neighboring communities. Without observable water management practices, the community of Xochicalco is unable to establish the aim towards providing potable drinking water, nor coordinate actions with the public health clinic, once constructed. The absence of clear water management practices places a high water management risk upon the community in terms of water health.

With water connection rates at 86.1%, this community has the lowest rates for the municipality, which causes a sizable percentage of the population to rely on alternative means for attaining water, ranging from purchasing from neighbors or water tankers. Drainage is also lacking in Xochicalco where 15% of the population lacks even a simple septic system. I was unable to ascertain the existence of water authority or manager within the town, aside from a water well and a chlorination station. Without a clear water manager, town water boards may exist as the final political authority.

Socio-economic indicators in Xochicalco are low—not uncommon in indigenous zones. Furthermore, little economic activity is present in Xochicalco. Education levels are on average with the municipality; however, they are much lower than the average for the state. Without a Director for Potable Water, I was not able to observe rates for water tariffs or management practices, but would predict them to be similar to other towns around 30 pesos ($2.40 USD), and despite low socioeconomic levels, I would predict those connected to the network would still be able to afford the relatively low tariffs. Bottled water, however, would be too expensive.

Health professionals from other communities, as well as community residents, claim a health risk to the Xochicalco population from bacteria, However, as public clinics do not exist in Xochicalco, opinions from doctors in the area were not evaluated. I do admit a certain ambiguity in the absence of health opinions. Still, the community residents' opinions place a moderate to high public health risk on Xochicalco. Furthermore, my water samples showed deplorable water conditions with the highest levels of coliform bacteria for the entire municipality. Chlorine was also not observed at any of the locations, which results in a high water health risk to the citizens of Xochicalco.

Xochicalco runs a significant health risk not only because of the existing socio-economic and infrastructure conditions but also due to the lack of monitoring and coordinated management. The community has not created a consolidated water management system nor a system for monitoring fecal coliforms or using chlorine, the two most important indicators for water quality. While many factors will affect water quality and public health, Xochicalco appears to not have a management plan in place to mitigate health risks. In this case, the municipal and state governments must step in to assist the small impoverished community.

El Rodeo

The community of El Rodeo, population 984, is situated between the Tembembe River and the man-made lagoon of El Rodeo, which is fed by a series of canals used to divert water for irrigation purposes. This illustrates the importance of not only agriculture but also water resources to the community.

While containing a small town hall, El Rodeo does not have the same institutional structure as the larger communities in the municipality. Still, El Rodeo does have a Director of Potable Water, charged with the distribution of water resources. His duties appeared to also extend to the distribution of irrigation water, a resource very important to the community. I was never able to meet with the water manager of El Rodeo, which suggests that his duties may only be a part-time attendant to the small community of El Rodeo. While a further staff was not observed, his position is adequate for a town of its size. While integration between drinking water and irrigation was observed, coordination between health professionals was not as apparent. Managerial practices in El Rodeo are not as complete as in other towns, yet for a small town the management structure presents only a moderate water management risk to the town.

El Rodeo contains one deep water well, and I was unable to acquire further details or statistics on the distribution plan for El Rodeo. Still, the coverage was quite extensive for the town, with the highest rates of water connection and sanitation services within the municipality. Chlorine is distributed at a point-source directly adjacent to the well.

Economic activity in El Rodeo is also centered on agriculture, proven by the presence of the irrigational lagoon, as well as the municipal seat for the Federal Ministry of Agriculture (SAGARPA) office. Socio-economic conditions in El Rodeo are more favorable than most small towns with higher socio-economic and educational indicator. Indeed, El Rodeo contains the lowest percentage of homes with dirt floors and the highest average grade level achieved within the municipality. Evidence of higher socio-economic levels suggests community members would be able purchase distributed water or bottled water as needed.

Epidemiologic opinions for El Rodeo were difficult to ascertain as a public health doctor does not directly oversee El Rodeo, however rough descriptions were acquired from health professionals in adjacent communities. Diarrheal diseases were stated to affect inhabitants of El Rodeo. However, similar to Miacatlán *pueblo,* a greater percentage of the population might be able to purchase bottled water suggesting that water did not pose a health threat. Due to these opinions, El Rodeo contains a low water public health risk. This was supported by the results of my testing of the water supply that did not show evidence of coliform bacteria and presented residual chlorine levels. Also, a water engineer living in El Rodeo, while preferring to drink bottled water, did not hesitate to drink water from the tap without treatment, and he claims the water is relatively safe to drink. While these tests cannot confirm the safety of the drinking water, the water appears more potable than other communities within the municipality.

El Rodeo presents an unusual case of only basic water management, yet a safe and uncontaminated water supply. Higher socio-economic and education levels allow for the purchase of bottled water and educated sanitary practices, yet these alone cannot account for low health risks. Presence of chlorine in the water supply also helps the community provide safe, clean drinking water.

Palpan

The final community in the municipality of Miacatlán, is the mountain town of Palpan. This small community of 822 is nestled in the mountains 2,000 ft. above the municipal seat. With little level ground, the landscape is not dominated by farmland as in the valley below, and the main water sources are from mountain springs in the area.

Palpan employs a Director of Potable Water with a total staff ranging from 2-3 persons for the small town of under 1,000, a staff size more than necessary. The director also had an extensive knowledge of the water system in Palpan, citing exact number of connections and inhabitants served from memory which suggests his competence. The Director stated potable water to be the principle aim as a water manager, as he steers his management towards distributing safe, drinking water. Evidence of coordination with the town health clinic corroborates evidence of public health taking precedence in the community. Management practices in Palpan are highly developed and establish a low water management risk to the public health of the community.

Infrastructure within the town is characterized by high water connection rates but low sanitation services. With no sewerage system for the town, untreated waste is distributed by septic systems in individual homes. Fresh-water springs provide water for the community as the springs provide the community with a continual source of water. Chlorination stations also introduce liquid chlorine to the town's water supply.

Being far removed from the municipal seat, Palpan's politics are heavily shaped by local politics, which is noticed by the presence of water boards. Socio-economic levels are also shaped by Palpan's isolated nature. Education levels are very low for the community, and census indicators reveal low socio-economic levels, a prediction confirmed by the Secretary to the Municipal President during an interview. Also, the water tariffs here are 30 pesos ($2.40 USD) and are lower than in any of the other communities, facilitating the purchase of water. Still, bottled water would not be affordable to the entire population.

The doctor at the public health clinic reported no presence of water-borne diseases, and did not state the water as a threat to public health. Further treatment of distributed water was difficult to establish, but the evaluations from the doctor would still reveal a low public health risk to the community. The doctor stated that during his year of service in Palpan, the water was consistently chlorinated. Examinations of water quality showed zero coliform bacteria were found in the four samples taken from the community. Chlorine was not measured, but due to evidence from the community doctor of patients describing occasional stomach irritation due to chlorine, and I would expect high levels of chlorine to exist. Both the epidemiologic and actual water quality examinations provide a low water and low public health risk to the community of Palpan.

Palpan presents a case where clean drinking water has been distributed to the population despite low socio-economic conditions. The spring-fed source of water represents a source of water not contaminated by agricultural runoff and or household wastewater. However, it is the presence of chlorine which effectively eliminates any bacteria threat from the water supply. Managerial competence is also present in levels not seen in the other small communities of the municipality. The combination of effective water management and purification are factors that account for the potable water supply in the community of Palpan.

NPH (control)

The control site for my study is an orphanage of roughly 650 children—roughly the size of Palpan—yet over half of these children are under the age of 10 and are highly susceptible to diarrheal diseases. Also, the orphanage also has its own deep-water well, treatment plant and distribution network to ensure that the community receives clean, potable drinking water. The orphanage is housed within an ex-hacienda directly adjacent to Miacatlán *pueblo*.

The orphanage water supply is managed in much the same way as a city system. The water manager, Elías Madrid, has the capacity to provide a safe water supply for the 650-person orphanage. He also maintains strict orders to deliver potable water at all times. His experience is extensive and backed by many years of water management. He coordinates directly with the medical doctor to ensure the water is of suitable standards for human consumption. This sort of water management is optimal for public health and allows for no water management risk to the orphanage.

The deep water well at the orphanage is of the same specifications as the wells in Miacatlán *pueblo* and extracts water from the same water table. However, the chlorination at the orphanage is more consistent than of the other communities I examined. Furthermore, the entire site is connected to an extensive sewerage system with complete on-site primary treatment.

However, being a private community, the water system is not contingent upon local politics but instead is geared towards the overall public health and wellbeing of the children at the orphanage. Thus politics do not hold sway over the community. Also, the orphanage benefits from fundraising offices to raise capital for the orphanage and its water management system. The institution is run by well-educated directors with a medical doctor on site. These socio-economic benefits mean that the high costs of a private water system is funded by the orphanage.

I also conducted health assessments at the orphanage and found no health risks from water-borne diseases, no threat to the community from the water and no need for additional treatment of the water. Water samples further corroborated this assessment as did the presence of residual chlorine in the water samples. Due to very well documented health assessments and frequent coliform bacteria tests, it is safe to say that no water-related public health risks exist within the orphanage.

As the control site for the municipality, the orphanage confirms the ability to purify groundwater within the municipality and distribute it a surrounding community. The orphanage community understandably has many advantages, including access to foreign capital, yet its extensive management practices also serve to promote potable drinking water.

Analysis of Communities

The 5-part case study of Miacatlán allows for an analysis of the communities in terms of their drinking water. Following the results of the study, significant differences were found throughout the study, with extreme variances in fecal coliform counts and chlorine levels, public health evaluations and managerial practices. Additionally, socio-economic and educational levels differed greatly, with the lowest socio-economic levels in the indigenous communities and in the mountain town of Palpan. Access to health clinics was limited to Miacatlán *pueblo*, Coatetelco, and Palpan as inhabitants in the other towns had to travel up to 5 km for the nearest clinic. I do not interpret these distances as a barrier to health care, but instead a small hurdle for the populations of El Rodeo and Xochicalco.

In terms of raw water quality, the indigenous communities of Coatetelco and Xochicalco faced the largest degrees of contaminated water, while Miacatlán *pueblo* resulted in moderate bacterial contamination. In terms of public health, the same three communities possess health problems related to diarrheal and water-borne diseases. However, due to high socio-economic levels and progressive public health strategies, inhabitants from Miacatlán *pueblo* were able to mitigate these health problems by purchasing bottled water or treating distributed water.

This study does not masquerade as a definitive assessment of medical health nor of managerial compliance, but instead can be used as an exercise to investigate the associations between water management and public health for a municipality in Miacatlán, Morelos. Table 3.2 includes relative risk factors for the communities within the municipality, in terms of managerial, public health, and water quality risks. These risk factors allow for a comparison between the different communities' water management and an evaluaton of whether an association exists between water management and public health of the Miacatlán municipality.

By analyzing the risk factors, we see that the two communities with a high managerial risk, those with little institutional and infrastructural frameworks in place to manage drinking water resources, also have the highest water quality risks and public health risks. Again, this is not stating causality as numerous factors combine to affect the public health of a community. However, it is telling that the three communities with low or moderate managerial risks also have low to moderate health and water quality risks.

Still, more important than associating health risks to communities, will be to evaluate which management strategies are the most beneficial towards public health. My predictions suggest that two strategies would be most beneficial towards public health: adequate chlorination of water supplies and coordinated work between water managers and institutions of public health.

Chlorination of water supplies is indeed difficult, as it requires capital to purchase chlorine as well as consistent monitoring of chlorine addition. This especially poses a difficulty to impoverished rural communities. However, despite this, two of the municipal towns demonstrated adequate chlorination of water, Palpan and El Rodeo, and these communities also reported small health risks among the population.

While Miacatlán *pueblo* sampling did not demonstrate residual chlorine in the water samples, extensive interconnection between the water managers and the town's two public health clinics served to educate households, and in particular new mothers, of the dangers of diarrheal disease and poor water, a link also found in Palpan. Similar health relationships were not found in either Xochicalco or Coatetelco, despite the existence of a readily-accessible public health clinic in Coatetelco. In Coatetelco, the public health clinic created its own diarrheal education programs, but the Office of Potable Water was not involved in this process. Neither Coatetelco nor Xochicalco participated in the health clinics efforts to educate the community as to the dangers of contaminated water.

Additionally, the role water holds within a community also proved important to how a community is able to manage its water. Water managers in Miacatlán *pueblo* and Palpan stated their role was to deliver potable water to the inhabitants of their town. Palpan succeeded in this while Miacatlán *pueblo* was able to deliver water of dubious quality. More important, however, is that Coatetelco only stated its water was to function as a source of water, not suitable for drinking purposes, and indeed, Coatetelco's water is not potable. However, not setting potable water as the goal will hinder the management from ever approaching potability.

Other management practices proved less decisive in their role on public health. Staff size, socio-economic indicators, and water boards were less definitive in their benefits towards public health. Sewerage undoubtedly is a strong benefit with relatively little drawbacks in terms of public health, yet it was not a necessary requirement for public health as El Rodeo was able to succeed despite its lack of formal sewerage. Furthermore, socio-economics did not prove a large influence on public health of the communities. Despite similar low socio-economic levels and populations in both Xochicalco and Palpan, public health data was dynamically different, demonstrating that low socio-economic levels are simply a hurdle to be crossed rather than a permanent barrier to public health.

Chapter 5: CONCLUSIONS

Mexico faces many obstacles in order to deliver safe potable water to its population, which are present in large cities such as Mexico City as well as rural zones. A major difficulty that small municipalities in Mexico have in water resources management lies in the decentralization scheme, which has not delegated actual power or financial resources to rural municipalities. This creates instances where municipalities must themselves create their own management strategies to overcome what socio-economic, infrastructural or political difficulties they face in order to provide clean drinking water to their citizens. Still, several municipalities have shown the ability to rise above these limitations as they strive towards providing safe drinking water, by framing their management strategies in the way to maximize public health.

These case studies demonstrated how various communities attempted different management strategies, and suggest how certain management patterns appear to parallel high water quality and improved public health. While admittedly numerous factors affect both public health and water distribution, as I explored in Chapters 2 and 3, water administrators are in the position to implement equitable and efficient practices for their communities, directly affecting—and hopefully improving—water quality.

First, coordination between health professionals and health clinics is a beneficial step in order to stress public health as the primary driver for water services. Indeed, in both Miacatlán *pueblo* and Palpan efforts to coordinate health professions succeeded by directly involving those trained in public health into the management of water services. In examples from the towns, water managers were alerted to increases in diarrheal diseases, marking a possible contamination to the supply network. In addition, health clinics were able to educate community members to hygienic practices and necessary household treatment of distributed water.

This study also explored the necessity for increased chlorination within the municipality of Miacatlan. In the two communities with adequate chlorination, El Rodeo and Palpan, the health clinics did not report a threat to the community from the water supply nor was bacterial growth present in the water supply. This again stresses a simple and cost-effective measure. While the communities will need to purchase sufficient chlorine, the infrastructure of chlorination stations is already present. Furthermore, chlorine is much more cost-effective than perforating new wells and installing new water mains, an approach currently being pursued by Miacatlán *pueblo*. Instead, existing technology will allow for the most cost-effective benefits towards public health.

Also, Xochicalco will soon receive a public health clinic of its own, yet as noted by the Coatetelco example, without water manager-health professional coordination, prevalence of diarrheal diseases in Xochicalco may not change. Thus it becomes imperative that municipalities create management strategies which take use of their abilities and design their own management plans and direct themselves towards increased water quality and better public health. Evidence from Chapter 2 stresses the need to align water distribution strategies with a focus on public health, to eliminate water-borne diseases and reduce diarrheal mortality.

We have also seen that specific management practices should be tailored to the needs of each community. To return to Coatetelco, undoubtedly a formal sewerage system would immensely benefit the town and indeed improve public health. However, if the town cannot afford a water administrative staff larger than 2 or 3 persons, a formal sewage system would appear to be well beyond their financial abilities. A focus on practicality must pervade all talks on improvement to water systems in the developing world, where obvious solutions for the global 'North,' such as sewerage and new wells, may not be practical. Indeed, to encourage unattainable solutions only serves to discourage advances (Braga et al., 2006). Coatetelco can take the first step by increased chlorination of their water supply, a solution indeed attainable for a dense population, (9,000 living within 4 *colonias*) where residual chlorine would remain in the water supply for a longer time than in more dispersed Miacatlán *pueblo*. However, commitment on the part of water managers will be necessary to implement continual addition of chlorine.

Even with progressive municipal management, more assistance must also be given from above, as the Federal and State water commissions appear to have forgotten rural municipalities. Rural municipalities have not been delegated the financial and managerial power they require to ensure safe potable water, a sentiment held by numerous Mexican water experts (Saade Hazin, 2006; Tortajada, 2003). This serves to further isolate the rural municipalities which lack sufficient capital that is often concentrated in urban zones. Decentralization is the first step, but rural zones require oversight and may not be as financially autonomous as larger metropolitan areas. Federal and state institutions such as the CNA and CEAMA must promote proactive relations with the municipalities, encouraging future collaboration with health agencies and water quality monitoring. The greatest benefit for the municipality of Miacatlán is coincidentally also located within the state of Morelos. Both the National Institute of Public Health (INSP) and the Mexican Institute of Water Technology (IMTA) are headquartered in the state capital of Morelos, and specialize in studies of public health and water quality. These federal institutions can combine with municipal administrators to carry out studies on diarrheal mortality and water quality. However, the municipalities must take initiative and reach out to these institutions to make such outreach a priority.

This study illustrates the many challenges that face Mexican water distribution, due to environmental or socio-economic factors, limiting their ability to deliver safe, potable water. However, poor management also is a major challenge. As seen from Miacatlán, municipalities can succeed in the face of these challenges if the water managers and administrators address the managerial problems facing effective water distribution. Mexico must focus efforts on the small-scale municipal level in order to make any positive changes in current water management. While much of the focus is being placed on large cities, such as exploring private-sector involvement (Barkin, 2004; Tortajada & Castelán, 2003), a focus on rural zones, where 60% of the poorest Mexicans live, must also draw the attention of the government in order to reach equitable water solutions for the entire population.

An emphasis on public health, demonstrates what should be a priority for water resource managers, and in terms of distributing domestic water for human consumption, this must be the ultimate goal. With advantages to public health deriving from advances in water management and regulation, encouraging improved management can be just as effective as investing in improved water connections and sanitation, especially in locations where ‘improved access’ still does not translate into clean, potable water. Furthermore, in cases such as rural Mexico which is overwhelmingly impoverished, large, capital-heavy public works projects may be impractical due to financial constraints and other solutions explored.

By looking back on the Miacatlán example, we can see both gains and losses among the five studied communities. Not one community has developed the perfect plan, but yet each community does offer individual strengths to use to its benefit. Whether it is naturally clean spring water or the presence of a government-sponsored public health clinic, each community has the ability to deliver clean water. It is a matter of placing public health benefits as the end result of water management, which will propel water management into delivering safe, potable water.

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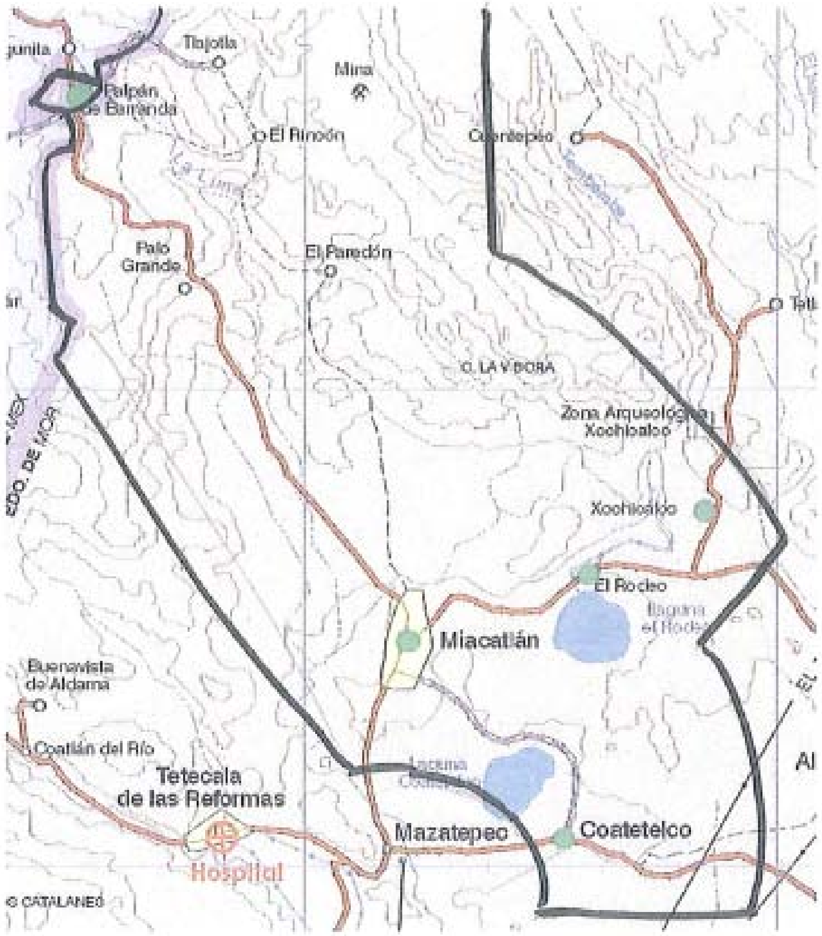
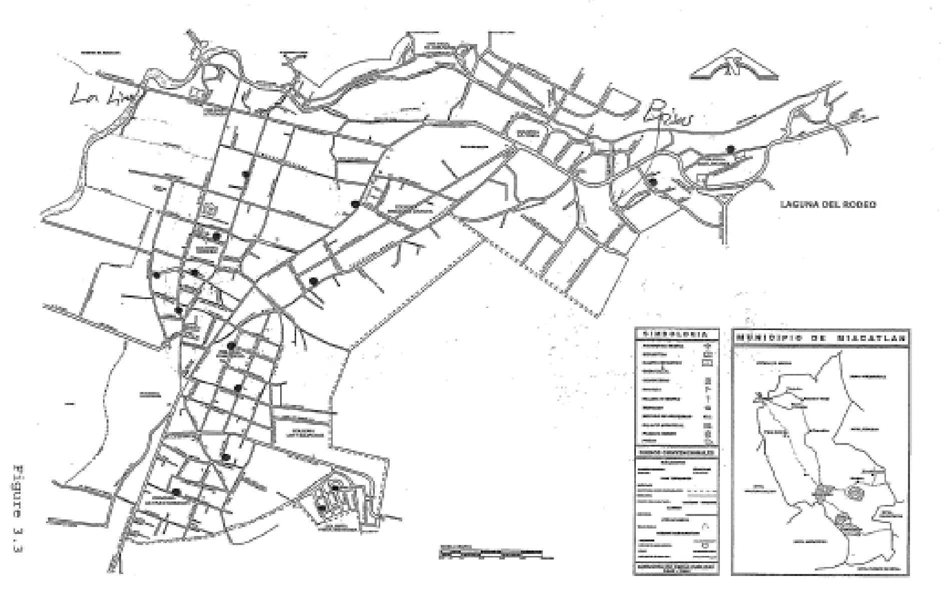
FIGURES

Figure 3.1



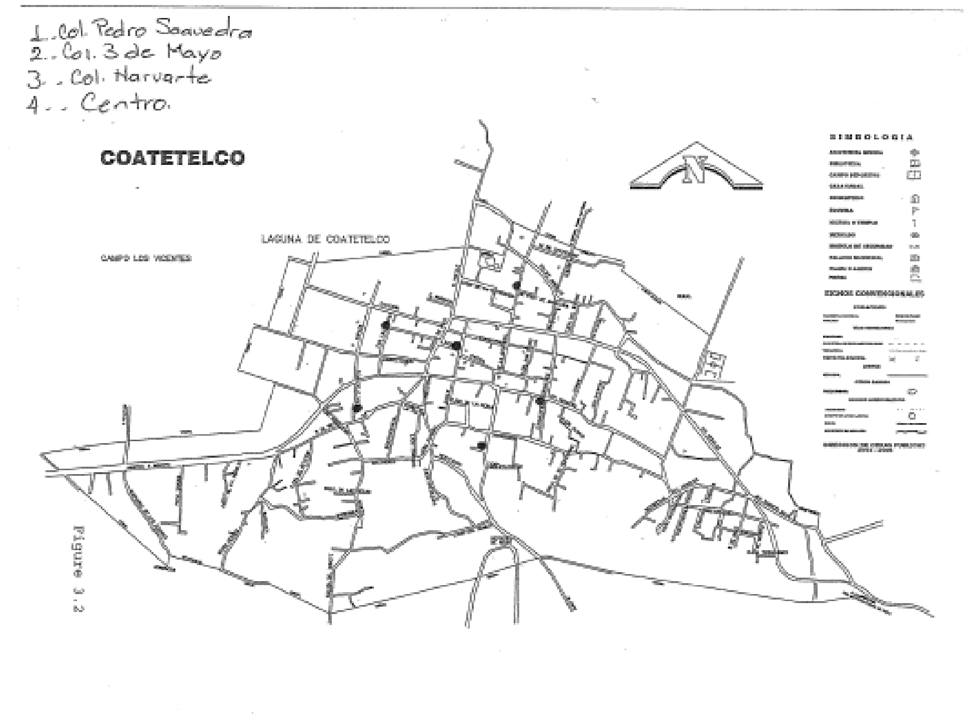
Municipality of Miacatlán, outlined in Black.
Five Communities under study located at green dots.
Regional hospital in Red.

Figure 3.2



Community of Miacatlán *pueblo*. Black dots represent water testing locations.

Figure 3.3



Community of Coatetelco. Black dots represent water testing locations.

TABLES

Table 3.1

	Coliforms (colonies/1ml test)	Chlorine (mg/l)
Palpan	<2	High
El Rodeo	<2	.1-.5
Miacatlan[1]	15.08	0
Coatetelco	18.16	0
Xochicalco	40.33	0
NPH (control)	<2	2.75
Ideal (EPA reg.)	<2	.8-1

1. refers to Miacatlán *pueblo*

Table 3.2

Risk Factor	Managerial Risk	Water Quality Risk	Public Health Risk
Miacatlan[1]	Low	Moderate	Low
Coatetelco	High	Moderate	High
Xochicalco	High	High	Moderate/High
El Rodeo	Moderate	Low	Low
Palpan	Low	Low	Low
NPH (control)	Low	Zero	Zero

1. refers to Miacatlán *pueblo*