FROM EMERGENCY TO FIX: POINT-OF-USE WATER FILTRATION TECHNOLOGY IN *COLONIAS* ALONG THE UNITED STATES-MEXICO BORDER

A Thesis

by

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ABSTRACT

Small-scale decentralized facilities and technologies are rapidly becoming a dominant technological fix to deliver water to underserved populations in developing nations. This project examines the case of a university partnership with government agencies seeking to roll out new POU (point-of-use) and POE (point-of-entry) devices in *colonias* – low-income, rural and peri-urban subdivisions commonly defined by their proximity to the US-Mexico border. This study critically evaluates the role of POU and POE devices as a substitute for community-based water governance, leading to self-managed systems. I measure whether these technologies will advance overall household water security, evaluate the program's overall costs and benefits, and analyze the process by which the implementation of POU devices is institutionalized as a water governance strategy in El Paso *colonias*.

The study uses data collected from household surveys with *colonia* residents in order to measure household water security using a novel Guttman scalogram method. The household water security assessment is compared with interviews and other data on the technology to assess whether POU and POE devices can improve residents' current water security status. In addition, I used data from semi-structured interviews in order to analyze the process by which POU technologies have been decontextualized from emergency response uses and repurposed as a technological fix to poor water services in the *colonias*.

Findings indicate that the technological fix for the socio-environmental problem of acceptable drinking water will likely add more financial and labor burdens on already vulnerable populations. Consequently, the rollout of these technologies shifts the costs of acceptable and secure drinking water from collective efforts to low-income individual households. I argue that the driver of this governance shift is the formation of a neoliberal discourse coalition which mobilizes and legitimizes soft-technologies as a solution to water insecurity, thus resulting in EPAs support of an epistemic community of technical and behavioral experts determined to disseminate the technologies in the US. As the state and experts roll out these technologies as cost-saving devices they exert incredible power to re-enroll people in mediating water-society relations and reproduce hierarchies of power in water management systems.

DEDICATION

To those with uneven access to water and those who intend to fix it with a straw.

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NOMENCLATURE

AWWA	American Water Works Association
BSF	Biosand Filtration
CDC	United States Center for Disease Control
CF	Ceramic Filter
EPA	United States Environmental Protection Agency
GAC	Granulated Activated Carbon
HWTs	Household Water Treatment Technologies
IRB	Institutional Review Board
MDG	Millennium Development Goal
MF	Microfiltration
NMSU	New Mexico State University
PAHO	Pan American Health Organization
POE	Point-of-Entry
POU	Point-of-Use
SDWA	Safe Drinking Water Act
STS	Science and Technology Studies
SWS	Safe Water System
UF	Ultrafiltration
UTEP	University of Texas at El Paso
WHO	World Health Organization

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CHAPTER I

INTRODUCTION

Small-scale decentralized facilities and technologies are becoming a dominant technological fix to deliver water to underserved populations and reduce the risk of waterborne diseases in developing nations. Development and emergency management institutions have also widely adopted them as a means of treating household water in disaster relief response contexts (Loo et al., 2012). One example of these technologies is point-of-use (POU) or point-of-entry (POE) household water filtration technologies (HWTs).

Small-scale, low-cost, decentralized systems are referred to as “soft” technologies or the water “soft-path”, where responses to the global water crisis involve the roll out of soft technologies to deliver water services and qualities matched to users’ needs (von Meier, 1994; Gleick, 2003). Scholarship engaging theoretical insights of critical geography and science and technology studies (STS) identify these as “mediating” technologies to refer to, “the way technologies are intended to dampen the environmental, economic, and technological consequences of water supply by reworking the relationships between the technical network, the user, the environment, the institutions responsible, and society at large” (Furlong, 2011). This study also recognizes the potential influence of soft technologies on socio-technical relations, where individual users are purposefully enrolled in the management of water provision to replace other community or collective efforts in water governance. Drawing on critical geography and science and technology studies, this research builds a case study to explore the intimate politics at the intersection of technology, water privatization, and water governance and the role of water technologies in reshaping the lives of its' users. Close examination of this case empirically substantiates scholarship identifying the processes through which particular socio-hydrological configurations continue to reproduce social and environmental injustice.

This study examines the case of El Paso, Texas, where the US Environmental Protection Agency (EPA) has committed $500,000 for a pilot program to investigate the feasibility of POU and POE water treatment systems for rapidly mitigating unsanitary drinking water conditions in the *colonias* in El Paso County (Page 2011), where water services remain precarious. *Colonias,* or unincorporated rural subdivisions, are predominantly Mexican-American communities located along the US-Mexico border and are often characterized by high poverty rates and poor infrastructure (Ward 1999; Dolhinow 2010; Jepson 2012; Parcher and Humberson 2009). Approximately 50,000 Texans living in about 1,800 *colonias* lack access to safe drinking water and sanitation, health care, electricity and paved roads (Korc and Ford 2013, pg. 80).

In August 2011, the EPA supported and promoted POU devices in a regional conference ("BienESTAR") attended by stakeholders and researchers at the University of Texas – El Paso (UTEP). At the conference, a representative from Vestergaard Frandsen, a Europe-based international company specializing in complex emergency response and disease control products, marketed their POU water filtration products, the "Lifestraw® Family," to the conference participants. As a result of the conference, the

EPA committed $500,000 for the pilot program. The current EPA pilot project (December 2011 to November 2014) has contracted engineers from UTEP and public health scientists from New Mexico State University (NMSU) to examine a range of POU and POE devices, including Lifestraw® in El Paso County *colonias* (ibid).

This study interrogates the mechanisms, actors, discourses, and politics within this process that enabled the materialization of the EPA-funded project. Through the lens of political ecology, I aim to understand the power relations in decision making, how water governance is enacted, and to what means and ends water becomes available to residents through the institutionalization of POU/POE technologies in the *colonias*. To this end, this study offers three major assessments. First, I review the development of POU devices in order to contextualize how the technologies fit within a global political-economy. Second, I conduct a household water security assessment as a means to analyze how POU/POE technologies may improve water security in individual households. Finally, I investigate the discourses of key actors and informants in order to highlight the gap between neoliberal discursive framings and *colonias* realities.

Findings reveal that the neoliberal political-economic context of POU technologies plays a key role in their institutionalization process domestically, as it influences the range of technologies available for application, mechanisms of capitalization, and their social construction. Results of the household water security assessment reveal weaknesses of the technology as a solution to poor water service, with marginal improvement to household water security as well as the poor likelihood of adoption by household residents. Furthermore, findings suggest that household adoption of POU/POE technologies will likely add more financial and labor burdens on already vulnerable populations. Analysis of qualitative interviews of key actors engaged on the project identified the partnerships and discourse coalition which legitimizes the application of low-cost, quick-fix water filtration technologies in the *colonias*. In sum, as POU technologies are rolled-out in *colonias,* this short-sighted fix re-enrolls residents in mediating water-society relations and provides a technical mechanism for the state to evade responsibility for lack of basic services. This process generates socio-hydrological conditions that are inequitable, where individual households are forced to bear the burden of water service provision and management.

Prior to proceeding to the following chapters, it is necessary to discuss the underlying assumptions about the human right to water that is inherent to my analysis and theoretical framework. In the last decade, scholars and activists have highly regarded and marshaled to fulfill people's right to the life-giving and non-substitutable substance that is water in light of the millions of people across the globe without access to it. In September 2010, the UN Human Rights Council confirmed that it was legally binding upon states to respect, protect, and fulfill the human "right to safe and clean drinking water and sanitation that is essential for the full enjoyment of life and all human rights" (Sultana and Loftus 2013). While this shift in international policy represents a major victory for these activists in the process of achieving universal access to safe drinking water, many have since brought attention to what this shift means for the politics of water governance, equity and justice (see chapter II of this thesis). Indeed, "the human right to water says little about how people might be provided with water and who will provide it" (Sultana and Loftus 2013).

From a political-ecology perspective, scholars analyzing the materializations of this shift posited that it has so far accomplished little beyond sustaining the individual as a healthy organism (Linton 2012). In this sense, the human rights doctrine assigns water to be little more than a fixed quantity and quality, as critical scholars assert that water is processual in nature – and that the ability to access part of this cycle for consumptive or hygienic purposes is necessarily social. Therefore, a critical eye must be maintained towards the materialization of the human right to water and must understand water access schemes to be "a function of social and economic circumstances" that are contextually dependent (Linton 2012). Adopting this perspective, this analysis is predicated by the notion that in order for water systems and services to be effective and sustainable they should be in accordance with the cultural as well as the environmental particularities of place. Technologies of water supply, however appropriate in one social and environmental context, may not be appropriate within another.

I understand that the right to water must be defined not only as so much water at a particular quality, but also as the ability of its users to participate in decisions about the delivery of their rights. In this, the human right to water defines a rule of governance which implies that the basic questions of how water is allocated and managed should be decided by democratic processes rather than market principles. In short, I believe that the right to water means the right to be democratically involved in the making and re-making of the hydrosocial cycle.

As an author and researcher, it is important for me to make clear that I carry a deep appreciation for the efforts of the experts engaged with this intervention, and in no way intend to dismiss their efforts towards improving water security for water poor populations in the United States. My purpose is not to condemn, but to understand the rationale behind this intervention – what experts seek to improve, what discourses and assumptions mobilize particular ways of doing things, and the calculations that are applied by the experts that carry them out. I also seek to understand the potential effects of the technological intervention, as it is embedded within politics that shape current and future hydro-social configurations. With a broadly critical view I am able to analyze the project itself. In doing so I do not make suggestions toward how to improve this specific intervention or technology, yet I feel that my analysis provides opportunities to think critically about more just water futures for *colonias* residents.

CHAPTER II

BACKGROUND AND SIGNIFICANCE

This chapter reviews recent literature from three theoretical areas in human-environment geography that informs the approach to my case study. First, I address the broad development of the hydro-social cycle as a framework to understand how technocratic considerations are influenced by broader social and political forces. Second, I focus on the rich literature on neoliberalization and water's privatization that provides the epistemological framework for which to demonstrate the ways that the state shifts water management to the subjects of technological interventions. The third literature narrows to an analysis of current work on science and technology studies as it intersects with political ecology in order to understand how expert's assumptions, visions, and techniques are circulated and imposed on others through technological interventions.

Political Ecology and Social Water

The critical attention to water has emerged as a distinct sub-field within political ecology in order to examine the reproduction of environmental inequalities and injustice. Over the past decade, research on the political ecology of water specifically analyzes the enrollment of water into broader political economic processes. In particular, scholars have addressed the, "economic and political power relations through which access to, control over, and distribution of water is organized", which illuminates the conflicts inherent to the process of environmental change (Budds and McGranahan 2003; Bakker

2004, 2007, 2010a; Norman and Bakker 2009; Swyngedouw 2009). Scholars argue that choices made by social actors to determine whether technologies are 'appropriate' on the basis of physical, cultural, and economic sustainability, have immense implications for water access in low-income settings (Swyngedouw 2009). This decision-making process is decidedly political and "should be analyzed as such" (ibid.).

Swyngedouw calls for scholars analyzing hydro-social transformations to give particular attention to material, economic, political, and cultural power relations. Hydro-social interactions understand water's physical flows as embedded and co-produced within political economic, cultural, and social power regimes and these interactions saturate water with meanings and values (Bakker 2003; Swyngedouw 2004, 2009; Budds 2008, 2009). He writes, "It is these power geometries and the social actors carrying them that ultimately decide who will have access to or control over, and who will be excluded from access to or control over, resources or other components of the environment" (Swyngedouw 2009, pg. 57). Moreover, scholars have highlighted how water discourses are enlisted to defend or legitimate particular strategies of water use and allocation, because they determine or frame who will have access, who will benefit from water's flow, and who will be excluded (Shiva 2002; Kaika 2003; Bakker 2007; Swyngedouw 2009; Bustamante et. al. 2012). For example, Bakker (2007) and Kaika's (2003) work demonstrates the ways that powerful arguments, or environmental discourses, are mobilized or enlisted to frame water as a fundamentally "scarce" resource, but also highlight how these discourses are embedded in broader social conflicts over water distribution and management. Recent work argues that discourses of scarcity have become hegemonic in global water politics (Harris et al. 2013).

Political ecology of water examines the way the world water crisis is produced in order to understand how power changes water's flow. New avenues of research and theorizations of water-society relations have been studied by critical geographers who use political-ecological research in order to explain hydrological and hydrosocial cycles and the ways in which they reproduce each other (Bakker 2010a; Swyngedouw 2009; Loftus 2009). In recent years, scholars have shifted their focus to move beyond the study of how water management is shaped by power relations to include analysis of how water itself shapes those relations in return. (Linton 2010; Loftus 2009; Swyngedouw 2004; Swyngedouw 2007). Using the case study of the city of Guayaquil in Ecuador, Swyngedouw (2004) identifies the social, economic, and political mechanisms through which water flows, while identifying how power relations simultaneously transform urban water. To illustrate the co-productive aspects of hydro-social relations we can look to critical geographer Jamie Linton. Linton (2012) draws on this relational, co-production paradigm to assess water activism for the right to water. He writes, "proclaiming a specific human right to water fixes humans and water in a certain kind of relationship…by redefining the right, the identity of both 'human' and 'water' are changed" (Linton 2012, p.45).

Karen Bakker argues that this co-productive framework "provides the ability to demonstrate the mutual causality between human societies and landscapes, or how human activities shape landscapes and waterscapes: and, simultaneously, how the water cycle shapes human societies" (Bakker 2009). Findings from this framework lend scholars to question how decisions in water management are influenced by broader social and political forces. Political economy and political ecology approaches to the hydro-social cycle have also been engaged to explore the relations between social, ecological, political, and economic forces behind particular water issues rising with urbanization, modernization, and industrialization.

Bakker (2010a) successfully engaged and demonstrated the role of power relations, subjectivities, historical geographies, and ecological differences in the ways that water comes to influence political, social, economic, cultural and environmental transformation across scales. In her recent book *Privatizing Water, s*he identified three models of water management that exist in cities today: private, state, and community managed, and explored how they overlap and interact with one another. These models are discussed with respect to concepts of market failure, state failure, and governance failure, and the ways in which these failures have collectively contributed to the contemporary urban water crisis, i.e. the exclusion of communities from access to equitable, sustainable water supply. In her examination of urban water, Bakker concluded that urban water can no longer be treated as a technical issue or "fix", as it is riddled with issues of poor governance, including political processes, social power, collective deliberation, and the mediation of competing interests. This understanding can inform the analysis of the advantages and shortcomings of public, private, and community governance. She looks at the entirety of hydro-social relations to describe how the creation of large-scale, integrated, modern technical networks is far from complete in lower and middle income countries, where community control (small-scale, decentralized, and reliant on alternative or artisanal technologies) remains widespread. Replacement of these models of water management is necessary, Bakker posits, if we are to formulate adequate responses to the failure of both conventional government and private sector models which seek to provide ‘water for all’ (Bakker 2010a).

Aligning with the argument put forward by Loftus (2009), much of the scholarly work on the political ecology of water focused primarily on the enrollment of water into broader political economic processes. This has been demonstrated through discussion of Swyngedouw (2009), who focused on the transformation of water flows into global capital, and Bakker’s (2010, 2008) work on neoliberalization and market environmentalism to describe the myriad ways the private sector influences decision making within new governance arrangements. It is to these scholarly engagements with the commercialization of water and the role of the private sector in shifting governance arrangements that I will now turn.

Neoliberalism and Water’s Privatization

Geographers have found themselves broadly unsympathetic to forms of market rule of natural environments and biophysical resources that characterizes neoliberal policy. Landmark articles by scholars such as Castree and Bakker systematically review and provide meta-analysis of recent geographical literature on neoliberal approaches to governing human interactions with the physical environment (Bakker 2009; Castree 2008a, 2008b; Heynen et al. 2007). Subsequently, there is no shortage of attention from geographers to the role of neoliberal policies in reshaping the water sector, (Bakker 2007; Harris 2009; Ahlers and Zwarteveen 2009; Bakker and Furlong 2011; Birkenholtz 2009a, 2009b; Perreault 2005) in changing gender relations, (Coles and Wallace 2005; Laurie 2005; O'Reilly et al. 2009; White, Bradley, and White 1972) and in changing individual human bodies (Meehan 2013; Bakker 2012; Guthman 2011; Lemke 2011; Jepson and Lee 2014). This section will review the vast literature on neoliberalism and water privatization which analyzes the ways in which neoliberal policies shift water governance schemes, alter gender dynamics, and discipline individual human bodies.

Literature regarding water privatization has assessed the role of the private sector’s ability to meet the targets set by the Millennium Development Goals (MDGs) since the 1980s. As the development process ventured into the for-profit market through the Washington Consensus and an increasing number of water privatization schemes received funding from the World Bank, anti-corporate globalization protests followed suit, as well as geographers engagement with such conflicts (Bakker 2010a; 2010b; 2013; Hall and Lobina 2007; Budds and McGranahan 2003; Page 2005; Bakker 2013, 2004; Goldman 2007). Jessica Budds (2004) posits that privatization is broadly situated within neoliberal reforms as multilateral financial institutions have tapped into the water sector with the support of development agencies. Water privatization involves many linked, yet distinct, variegated forms: privatization, marketization, and commodification. Privatization assigns full ownership of water service provision to the private sector. However, full privatization models are rare. Hybrid models are much more common, where ownership is unaffected but some responsibilities are transferred to the private sector through public-private partnerships (Bakker 2010a; 2010b). Marketization refers to the construction of markets for trading and selling, where commodification refers to the process of converting a non-market good to one subjected to market rules (Harris et al. 2013).

David Harvey (2003) theorized that this shift in ownership of natural resources to the private sector represents what he calls 'accumulation by dispossession'. Harvey argued that the global crisis of over-accumulation necessarily lends itself to the privatization of water in order for capitalism to survive. In this sense, capitalism must exhaust every opportunity for spatial and temporal fixes to the crisis, where water has become the new common resource sector for a new round of capital accumulation for a powerful few through privatization (ibid.). Political ecologists such as Swyngedouw (2005), Heynen (2006), Hall and Lobina (2007), and Loftus (2006a, 2006b) have adopted this theory and have further examined the role of water privatization in shifting hydro-social relations. Hall and Lobina (2007), in their empirical analysis of private mechanisms to supply water to the poor in developing countries in African and Latin America, demonstrate the limits of the market's ability to provide equal water services to those provided through the public sector.

Despite the validity of this thesis examined by these scholars, analysis by Budds and McGranahan (2003), Bakker (2010, 2004, 2013), and Page (2005) acknowledged the limits to these arguments due to the fact that "only 5% of the world's population is currently served by the formal private sector", pointing to the reality that "privatization has achieved neither the scale nor benefits anticipated" (Budds and McGranaham 2003).

Budds and McGranahan (2003), through review of debates regarding water privatization and its conflicts in Africa, Asia and Latin America, put forward that the private sector offers minimum improvements to basic water service provision in these cases. Further, Budds and McGranahan stated that, “neither publicly nor privately operated utilities are well suited to serve the majority of low-income households with inadequate water and sanitation…because many of the barriers to service provision in poor settlements can persist whether water and sanitation utilities are publicly or privately operated” (Budds and McGranahan 2003). This work made a strong argument against private sector mechanisms for universal water provision while also pointing out that unreformed public mechanisms are equally as precarious. In the same vein, Bakker’s work on water in England and Wales similarly shifts the debate away from the opposing binary views against and for private mechanisms of water provision (Bakker 2010a).

Other political ecologists have contributed to this literature on privatization with theoretically informed approaches to analyze case studies of water privatization and commodification in various locations. Ben Page’s work on the process of commodification of water in Cameroon challenges geographers to think beyond whether or not water users should pay for their water and ask ‘how should water users pay for their water and how will the bill be divided’ (Page 2005, 2003). Jepson’s work combines historical and legal geography of water governance with extensive field study in South Texas’s rural and peri-urban communities in order to demonstrate the ways that the legal process has transformed residents from active political agents to consumers, effectively stripping their ability to resist the poor public services provided to them by regional water management institutions (Jepson 2012). This work also challenges the polarizing positions between privatization and public provision in its analysis of the way that politics determined the fate of inadequate water and sanitation services for the rural poor.

Water Governance

Critical scholarship in geography has also looked to the ways in which neoliberal reform policies involve a shift in the state's role in managing water from a top-down 'command and control' model to a more flexible, 'demand-driven' one through privatization and commercialization of water (Bakker 2002). Authors such as Bakker (2007), Bakker and Furlong (2011), Perreault (2005), and Birkenholtz (2009a) each examine the implications and contradictions of neoliberal reforms such as full cost recovery, efficiency, and the user-pay principle, as these mechanisms embody a shift in governance of water resources. Bakker and Furlong (2011) argue that governance restructuring has had profound effects on market-oriented water conservation at the municipal scale through examination of 18 municipalities across Canada. Perreault's (2005) case study of rural water management in Bolivia identified that private concessions by the state directly undermine the livelihoods of peasant irrigators through economic liberalization. Uniquely, however, Perreault focused on social movements in response to struggles over resources, which helps to illuminate the ways that water governance is altered by neoliberal ideologies (Perreault 2005). Through a case study in Rajasthan, India, Trevor Birkenholtz (2009a) examined the conflicts surrounding state subject-making. Birkenholtz concluded that the state's relationship with donor agencies mobilizes outreach and coercion in order to gain public consent for their project proposals. For Birkenholtz, this demonstrated the ways that the state shifts control to the subjects of neoliberal groundwater conservation practices, if they are willing (ibid.).

Gender and Water

Neoliberal influences lending to water privatization, water's commodification, and the transfer of water management to communities have increasingly been analyzed by critical geographers as they introduce new gender dimensions. Beginning with White, Bradley and White's work in 1972, gender-water relations have gained increasing attention from geographers engaging with the ways that "experiences, discourses and policies of water are gendered, and how gender is created through processes of access, use and control of water resources" (White, Bradley, and White 1972). Following this, Coles and Wallace's publication of *Gender, Water and Development* called attention to the ways in which gender relations have determined access to and use of water over centuries, showing from historical evidence that gender relations vary between cultures and identifies how gender beliefs affect water ownership, control, use and value of water (Coles and Wallace 2005). In 2009 a themed section in the journal *Gender, Place and Culture* included work by several feminist political ecologists investigating gender-water relationships and demonstrates the evolution of this subfield as well as its shortcomings to date (O'Reilly et al. 2009; Ahlers and Zwarteveen 2009; Walker and Robinson 2009; Sultana 2009; Harris 2009; Bull 2009). In short, all five of the articles call for the need for scholars to consider gendered politics in their attempt to understand water's production, consumption and management, arguing that people's lives are situated in a broader political-economic context that has specific implications for gender roles in the household. Ahlers and Zwarteveen (2009) concluded that, "a feminist analysis of water security needs to place politics and power at the center of its framework", suggesting that this can be achieved as scholars, "link local water struggles to larger historical and economic trends and forces". This work, as well as that of Bull (2009) and Walker and Robinson (2009), effectively observe changes in gender roles as a result of the "far-reaching influence of neoliberal economic policies" (O'Reilly et al. 2009). This claim is also echoed in Harris' contribution (2009) as she identified the need for gender-water theorists to engage more heavily with theories of neoliberalization and the simultaneous need for discussions of neoliberalized natures to include more feminist theory approaches to inequality. Some gaps in gender-water relations scholarship are simultaneously identified in Walker and Robinson and in Ahlers and Zwarteveen's work in their conclusion that gender dynamics may not always contest, and that past scholarship has overlooked relationships of assistance. Similarly, Nina Laurie conducts research in men-water relations, providing unique contributions to this literature that have yet to be developed (Laurie 2005; Laurie 2011).

Biopolitics

Most recently we have observed political ecologists using a "biopolitical" approach to analyze nature-society relations, and of course there is no shortage of interest in employing this approach to water-society relations. This body of work is informed by the theories of Foucault; he describes biopolitics as, “the entry of phenomena peculiar to the life of the human species into the order of knowledge and power, into the sphere of political techniques” (1980). Lemke has synthesized these ideas, and describes biopolitics as the “transformation of politics, where life is not only the object of politics and external to political decision-making, but that it also affects the core of politics, the political subject” (Lemke 2011). As he so precisely states, “the notion of biopolitics refers to the emergence of a specific political knowledge and new disciplines such as statistics, demography, epidemiology, and biology. These disciplines make it possible to analyze processes at a population scale, and to ‘govern’ individuals and collectives by practices of correction, exclusion, normalization, disciplining, therapeutics, and optimization” (Lemke 2011). In effect, life has become something that is measurable and definable, and must succumb to averages and normalized standards. In this sense, reality is separated from the actual living body and experiences of single individuals.

It should be no surprise that in Bakker’s (2012) most recent work, she discusses and adopts an analysis that assumes that water is simultaneously political and biopolitical as “modern governments seek to optimize both water resources and our individual water-use practices in order to secure the health and productivity of the population.” Bakker argues that formal regulations enact government control, but also that cultural norms of health and hygiene of water bodies and individual human bodies act in the same way (Bakker 2012). Following this suggestion, Meehan’s work (2013) engages a biopolitical approach in an ethnographic case study of water illegality in Tijuana, Mexico to demonstrate how illegal forms of water provision are used by the state to control and regulate certain populations of people and not others (Meehan 2013).

Water Technologies

The topic of water technologies in the context of development has gained an increasing amount of attention by critical geographers, as water technologies are integral components in water management, flow, and allocation. Water technologies shape and moderate the myriad ways people intervene, divert, tap, stop, and control the flow of water. Large-scale infrastructures including urban piped networks, connected meters, dams, and irrigation systems are often the focus of such critical geographical scholarship investigating the ways in which technological mediation of water use can affect social interactions and relations at a variety of scales. Following the work of Bakker (2004, 2010), von Shnitzler (2008), Birkenholtz (2009a), Loftus (2006b), and De Laet and Mol (2000) on such technologies, Sultana (2013) investigates the role of smaller water technologies in the processes of development. Sultana examines the political ecologies of development by investigating the ways that power relations and tubewell technologies implemented through development interventions in the Bengal Delta further co-produce water insecurities (ibid.). Small-scale water technologies play a significant role in the processes of development and management in underdeveloped nations. These technologies influence political, social, economic, cultural, and environmental transformations across scales and simultaneously produce new social spaces and waterscapes. Sultana writes, “water technologies, integral components in the management of water, are saturated with power dynamics and institutional processes that are historical and geographical, particularly in the context of development” (Sultana 2013, pg. 341).

Political Ecology and Science and Technology Studies

In order to understand the politics of development interventions, political ecologists necessarily must engage in how experts’ assumptions, visions, and management techniques are imposed on others (Goldman and Turner 2011). Political ecology and science and technology studies (STS) are relatively new fields of interdisciplinary academic inquiry that show great promise in their ability to reach beyond conventional boundaries of their individual subfields in order to analyze broader environmental politics. Over the past several decades, global interests in local environments have increased significantly. Subsequently, knowledge claims regarding natural resources and technologies emerge from different locations around the world. The reality is, however, that these knowledge claims are produced elsewhere and travel through a number of institutions before they are adapted to the realities of the local place of interest. Political ecology and STS is particularly interested in understanding the mutual influences of production, application, and circulation of knowledge on environmental politics and practice, and is one that inherently carries significant policy and on-the-ground implications. Literature in this discipline identifies the influences and politics that shape environmental knowledges as they circulate and are applied in conservation and development activities (Goldman and Turner 2011).

Recent studies argue for the integration of the following: 1) geography's critical stance on the production of nature 2) STS's engagement with actors and institutions involved in the production, circulation, and application of technology, and 3) approaches to scale within each discipline to analyze the influences of knowledge production on environmental politics in local situations (Furlong 2011, 2013; Lave 2011; Lave 2012a; Phadke 2011; Zimmerer 2011). Rebecca Lave, Mirowski, and Randalls (2010) call for scholars to explore "how the external political-economic forces of neoliberalism are transforming technoscience." Following this, Rebecca Lave's (2011; 2012a, 2012b) work demonstrates the profound interconnected character of the production, circulation, and application of stream restoration packages in the United States by integrating approaches in political ecology and STS.

Similarly, Furlong (2011) analyzed the potential impact of water efficiency technologies on urban infrastructure in Canada. Furlong deploys the term "mediating technologies" to open analytical space for critically and closely interrogating changes in urban infrastructure through the lenses of critical geography and STS. Mediating technologies refers to, "the way technologies are intended to dampen the environmental, economic, and technological consequences of water supply by reworking the relationships between the technical network, the user, the environment, the institutions responsible, and society at large" (Furlong 2011). Furlong identifies a critical need in both geography and STS to acknowledge the potential influence of small technologies on the relationships between society and infrastructure in collectively meaningful ways. Resulting from this critical need, my project seeks to empirically substantiate the process through which technologies rework the relationships between the technical network, the user, the environment, the institutions responsible, and society at large.

No critical scholarship has yet examined POU and POE water treatment technologies as mediating technologies capable of re-working hydro-social relations in meaningful ways. Renewed awareness and application of POU water treatment systems within the last 20 years in international development contexts and disaster relief contexts has resulted in a number of technical studies evaluating the technologies' ergonomics and efficacy (Tiwari 2003; Elsanousi et al. 2009; Enger 2012; Rosa and Clasen 2010). Yet, no scholar has taken a critical lens to these specific devices as mediating technologies through development interventions globally and, in this case, domestically.

Border Colonias and the Hydro-Social Cycle

"The task, already begun, is to put the hydrosocial cycle to work in helping promote social equity and environmental sustainability… wherever human intervention in the hydrologic cycle has produced inequitable or uneven access to water and water services"-Jamie Linton (Linton 2010, pg. 68)

This review has outlined current scholarship from three critical areas in human-environment geography employing political-ecological approaches to water management. I have followed the literature through the development of the hydro-social cycle as a theoretical framework to understand the social and political forces driving water management, to deep critiques on the role of neoliberal reform on water governance shifts, as well as to close examination of scholarship at the intersection of science and technology studies with political ecology.

This study contributes to this literature as it builds a case study to explore the intimate politics at the intersection of technology, water privatization, and water governance and the role of water technologies in reshaping the lives of its' users. Literature on water's privatization helps frame the rise of POU water technologies as a solution to chronic water insecurity in the *colonias*. I draw on this scholarship to broaden Furlong's (2011) definition of 'mediating technologies' to empirically investigate POU technologies as they emerge as a technological fix in U.S. border *colonias* through a critical geography optic. This approach leads me to pay attention to the question of labor and cost on individuals to further interrogate the multiple ways that technological fixes are not necessarily solutions to precarious water services.

Following this, I focus on the role of POU water treatment technologies in improving household water security and restructuring the lives of residents who receive this device for use in the household. Further, I specify the multi-scalar discourses and practices necessary to roll out new water governance schemes through technical solutions in households and communities. Moreover, I examine the political and social processes that shift the burden of responsibility for providing quality drinking water from community efforts to individual households in the *colonias* along the United States-Mexico border. Close examination of the EPA-funded pilot project seeking to demonstrate implementation of POU/POE technologies in the El Paso *colonias* enables me to assess how the state effectively transfers the burden of water governance to self-managed systems, and shifts the responsibility for operations and maintenance of infrastructure to individuals (e.g. Jepson and Lee 2014; Meehan 2013; Ahlers and Zwarteveen 2009).

CHAPTER III

OBJECTIVES, STUDY REGION, DATA AND METHODS

Scholarly literature evaluates the process through which political economic power relations fuse the hydrologic cycle with water management in socially uneven ways (Swyngedouw 2009, Linton 2010). My research specifically analyzes the production, circulation, and application of small-scale water technologies as a technological fix to water insecurity. This study frames the technology in broader political economic processes to address how power shapes access to, control over, and distribution of water even at the household or individual scale. I employed a mixed-methods approach, integrating qualitative and quantitative research methods, to critically examine the process by which POU/POE technologies have been decontextualized from their role in disaster relief and repurposed as a technological "fix" to poor water services in the *colonias* of El Paso County. In this chapter I outline research objectives, describe the study region, and specify the methods used to collect and analyze data.

Research Objectives

My project follows current scholarship on the interaction between the state and market actors to enroll decentralized solutions as technological fixes for the lack of water infrastructure (Meehan 2013). My major research question is: What is the role of POU devices in the transfer of water governance to self-managed water systems? To address this question, I examine a pilot project of POU technology implementation in the El Paso *colonias*.

I draw on existing scholarship on water governance, political ecology, and STS to analyze the gap in POU research. I focus on the role of POU household water technologies (HWTs) in restructuring the everyday lives of *colonias* residents who receive this device for household use. A political ecology framework allows me to specify the multi-scalar discourses and practices necessary to roll out new forms of water governance to households through technical devices. In this way, I document the processes of current governance roll out, implementation and uneven uptake or rejection by residents. Moreover, I describe the political and social processes that shift the burden of responsibility for providing quality drinking water from the state to individuals in the *colonias* using this framework of analysis.

My study aims to accomplish three Objectives:

Objective One

To determine the political economy of POU household water treatment technologies through an analysis of the production and circulation of POU technologies globally. I describe the evolution and current state of POU implementation. I also review technologies currently available on the market by summarizing the characteristics, cost, and functionality of each respective technology.

My rationale for this objective is that this review will provide the historical and geographical context of POU development and transfer as they have entered the development agenda and increased the market to 18 million new users in the past two decades. It should be noted here that numerous POU HWTs have been developed for emergency preparedness, disaster relief, and for consumers in developed countries; I will not analyze this use unless the technology has been implemented for use in low-income and undeveloped settings. This objective is integral because this knowledge will contribute to the understanding of the ways that POU water technologies, institutions, economies and power are co-produced and the ways in which this technology is embedded in social relations as they are implemented as solutions to poor infrastructure domestically.

I collected data through web research and comprehensive review of scholarly articles regarding POU technologies. This allowed me to identify the key players involved in the POU water filtration market including corporations, governmental agencies, non-governmental agencies, and international development organizations. Several phone interviews were also conducted with marketing representatives to gather further information that was not accessible online.

Objective Two

To determine the process by which the implementation of POU devices is institutionalized as a water governance strategy in El Paso colonias. This objective identifies the interrelations between the larger political-economic context of POU technology and the implementation of this particular technology as a technical fix for poor infrastructure. Empirical focus on the roll out for *colonias* allows for careful attention to the micro politics and discourses related to water access, technology, poverty, and intervention strategies. This objective is integral in order to understand the networks between actors and institutions formed in order to determine the implementation of such low-cost, decentralized technologies to achieve access to potable drinking water in domestic contexts.

I conducted eight semi-structured interviews with deliberately selected key actors involved in the UTEP pilot project in addition to conducting document analysis of EPA reports regarding the agencies involvement in the determination of particular technologies for implementation in the study. Key actors were identified through the snowball method. I received IRB approval to conduct such interviews on the campus of UTEP and selected actors have agreed to fully participate in the interviews purposed.

Objective Three

To analyze responses of POU HWTs among *colonia* residents and assess costs and benefits of adoption to colonia households. My strategy was to identify the interactions between residents and the POU technologies through field study in order to produce reliable accounts of the role the technology plays in terms of costs and benefits to residents (Robbins 2010). This objective is integral to the study because it identifies and analyzes residents' responses to these technologies. This is necessary because it provides insight into how these technologies are situated in the everyday lives of residents, and how they reproduce processes of self-governance in domestic settings. This objective is feasible because collaborations with UTEP researchers had been established prior to conducting the interviews. Data collection included 66 household surveys where the households selected for distribution of surveys were derived randomly within *colonias* that UTEP plans to engage in their study. Survey responses were coded and analyzed in Atlas.ti software.

Study Region

The study included twenty-three *colonias* in El Paso County and one *colonia* in Doña Ana County (New Mexico) identified from the El Paso County *Colonias* database. Within this database, *colonias* are classified into three categories based upon the level of infrastructure and potential health risk to residents regarding the availability of adequate public resources by the 2005 State of Texas Senate Bill 827 (Parcher and Humberson 2009). Classifications include Red, Yellow, Green, and Unknown, where *colonias* classified as Red incur high health risks, Yellow *colonias* incur medium health risk, Green *colonias* incur low health risks, and Unknown *colonias* do not have enough data to be classified (Appendix B-1). Additionally, several *colonia* communities were simply not present in the database.

Colonias were selected purposefully based their color classification in order to be comparable to the sample distribution followed by Jepson (2014) and in consultation with the *promotora* and local informants based on safety and previous knowledge of *colonia* characteristics. All household surveys were conducted with a *promotora*, or community-based bilingual health worker, who is also a *colonia* resident in El Paso County. We tried to select communities spread across the county and across *colonia* communities in order to capture the varied experiences across the relatively large county and into those of southeastern New Mexico. The total household sample size was 66 (n=19 in Red, n=18 in Yellow, n=6 in Green, n=23 in Unknown), which yielded data on 230 residents within the two counties. Table 1 (Appendix B-1) lists *colonia* subdivisions included in the survey.

Residents included in the survey experience living conditions characterized by substandard housing and poor access to basic services such as paved roads, street lighting, public sewer and water distribution, natural gas, public transportation, health care services, public schools and building codes (see Appendix A-2) (Ward 1999; McDonald and Grineski 2012; Kord and Ford 2013). These predominantly Hispanic subdivisions of West Texas are among the poorest of the nation and are of low socio-economic status, characterized by substandard housing, high poverty rates, low population densities in peri-urban and rural subdivisions, larger households, and low educational attainment (see Appendix A-3 and 4) (McDonald and Grineski 2012; ACS 2007-2011).

Access to reliable, affordable, and adequate drinking water is limited and highly variable between *colonias* both for those that are connected to a community water service and those that are not (Jepson 2014). Of the 78,000 residents living in 302 colonias in El Paso County, 4,500 residents living in 60 of these colonias have not been connected to a community water system. Instead, residents rely on water delivery trucks to fill 1,500 to 2,500 gallon plastic storage tanks outside the home. It is well known that the water delivered to these storage tanks is not potable and most residents rely on water vending machines for drinking water. Eighteen of the household surveys were conducted in eight different *colonia* subdivisions lacking the connection to community water service in order to capture the varied experiences across the waterscape.

If homes are connected, *colonias* residents face service interruptions due to lack of payment, experience poor water service reliability, and have concerns over tap water quality (Jepson and Lee 2014; Jepson 2014). Subsequently, most of these residents also rely on water vending machines for drinking water (Jepson and Lee 2014). Forty-eight of the household surveys were conducted in sixteen different *colonia* subdivisions with access to community water service in order to capture the varied experiences across the waterscape.

Data Collection

This study employs a novel mixed-methods approach using a Guttman scalogram method developed by Jepson (2014). This approach considers a "critical environmental epistemology" (CEE) argued for by Tim Forsyth, in order to explain environmental problems in a way that makes social and political framings a key part of inquiry to achieve more situated ways of explaining environmental problems that are more socially representative (Forsyth 2008; Forsyth 2011). Survey development and qualitative research are therefore acute to the critical environmental epistemology and hence, a central component of the Guttman scalogram method. The research plan included two major phases, informed by the three research objectives: 1) semi-structured interviews with key actors engaged in the EPA-funded pilot project and 2) household survey development and administration.

Participant Selection

Subject selection for interviews involved the perceptions of the decision makers or key stakeholders as well as key informants (elites) involved in the EPA-funded pilot project as opposed to those of the general population. Therefore, purposive and snowball sampling are effective ways to identify key stakeholders to engage as interview subjects. Snowball sampling involves making initial contacts that then provide reference to others whom are relevant for the researcher to contact. Stakeholders were initially defined in consultation with the PI of the pilot project as well as with a former colleague of the PI with prior knowledge of the key actors involved. When initial contact was made for preliminary interviews stakeholders were asked whom they perceived as other key actors or stakeholders associated or who have contributed to the project. These key stakeholders may have not been included in the study without the input from preliminary stakeholders who are familiar with those involved and who should be engaged. Adhering to confidentiality policies is particularly important with Snowball sampling, as the informant who made the initial referral was left unknown to the referred contact unless otherwise approved.

Interviews

Interviews allow the researcher to collect individual's opinions, perceptions, and discourse from those individuals who are creating and experiencing the social phenomenon under study (Klofstad 2009) – as objective two of this study aims to determine the process by which POU technologies are institutionalized as a water governance strategy in the *colonias* along the US-Mexico border. Personal interviews, or one-on-one conversations, produced a substantial amount of in-depth description and information from one respondent for discourse analysis and is often used as supplementary to survey or archival research in human-environment research (Robbins 2010). Discourse is defined here as, "a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer 1995). Interviews are often used for studies in which participants are "experts" from whom the researcher hopes to learn how certain practices, experiences, knowledges, and institutions work or *how the participants talk about* these things. The goals of the interviews are to answer questions about the ways in which particular events, practices, or knowledges are constructed and enacted within particular contexts.

Following this, an interview schedule was created to obtain information on particular topics that were deemed significant from previous literature and preliminary research and interviews. The interviews conducted in this study are considered to be semi-structured because un-scripted questions were asked throughout the interview process for further clarification, as I reflected back on my own understandings to the participants and referred to the interview schedule. The interview schedule provided a reference to the important topics and questions that I wanted to address while allowing for flexibility in the progression and order of dialogue. This flexibility allows for the person who is being interviewed to elaborate or discuss other important issues that are relevant and/or unexpected by the interviewer, but that may not have been covered by the questions in the interview schedule.

The first questions of the interview schedule (Appendix C-1) consisted of general questions to establish background information about the role of the interviewee in the implementation of the pilot project. The next question was to describe the motivation for the participant's involvement in the project and how they became involved as an actor, including whether or not they were in attendance of a key research meeting held by the Center for Environmental Research Management in August of 2011 and his or her understanding of this meetings intentions. These questions were used to identify the process of involvement of key actors and their stake in the projects outcomes.

The next section included in the interview schedule was a set of questions related to the participants view on the available technologies' strengths and weaknesses, the day-to-day implications for families adopting the technology in terms of costs and benefits and the ideal outcome or goal of the study. These questions were used to determine the perceptions and views of key informants engaged in the pilot study.

The third section of the interview schedule was composed of a set of questions related to the contentious nature of the rollout of POU/POE technologies as a permanent solution for current *colonia* residents. This set of questions included the way the participants regard the technology as a permanent or temporary solution, the cause of the lack of water infrastructure in the *colonias* of the region, and the projects contribution to mitigating the environmental or social injustice of poor water services.

The final section of the interview schedule was composed of a set of questions related to the broader context of public-private partnerships in the provision of drinking water in the household for low-income areas. This section was included based on the literature referring to water governance in low-income contexts.

As I conducted the interviews, I adapted the interview schedule, reordered, and restructured questions to be more appropriate. As interviews progressed they became more structured and were shorter, as I collected and recorded information I needed with a smaller set of questions. However, most questions were asked of all interviewees to provide opportunity for a range of perspectives on subjects that could capture strong opinions and varying viewpoints.

The first major phase of research began in September 2012 with a general search and review of peer-reviewed literature and publically available information on POU devices. This provided a broad understanding of the global political economy of the devices and the material and scholarly worldview of the devices costs and benefits to users. Additionally, preliminary interviews were conducted in March 2013 in order to gather information on the study area, to select subjects for the remaining semi-structured interviews, and determine the questions to be asked in the interviews. The interview process began in March 2013 with preliminary interviews and was completed in August

2013. The study involved interviews with the five agency staff and university professors (See Appendix B-2).

Reflexivity

The interview process involved a continuous reflection process referred to as reflexivity. Reflexivity is the process of examining my own assumptions and preconceptions as a researcher and reflecting on my relationship to respondents, particularly how that relationship may influence responses to questions asked in the interview. The interview process sought to understand perceptions of individual social actors, but does not assume that meanings are fixed and stable, that my questions are completely objective, or that respondents' answers have definitive meanings that reflect a singular reality. When developing the interview schedule and conducting the interviews I understood that individual meanings held by social actors are socially constructed, which shapes the construction of meaning in any given conversational context. Additionally, the preliminary interview process established relational contexts with interview subjects prior to the interview itself. I recognize the interview as a relational context that may produce and reproduce meanings held by social actors. Therefore, interpreting interview data required reflection on the entire research context, making the research process a focus of inquiry and recognizing the situational dynamics in which the respondent and I are jointly involved in knowledge production.

Transcripts and Coding

I transcribed interviews as they occurred exactly from beginning to end, and included the questions asked of the participant. I coded the text transcriptions using Atlas.ti software. Following transcription and coding of interviews, I chose coded statements according to three criteria: the interview question, association with a specific topic, or a strong opinion. I chose statements based on the interview question that was deemed significant during the data collection process. I also selected statements based on categories of the semi-structured interviews and according to the preliminary code-list that was generated based on literature and preliminary research. This is known as strategic sampling, where statements were chosen based on the codes generated for each topic or category (Webler et al. 2009). Initially, five topics were developed to organize the coding of statements: 1) process of involvement, 2) resident perception, 3) lived reality, 4) technology, and 5) governance. The process of selecting statements from interview transcripts was based on the objectives of the study with careful consideration for those statements that received strong emphasis by the interview subject or were unexpected.

Survey Development and Administration

The initial household survey questionnaire administered in phase two of this research was acquired from Jepson (2014). This set of questions was developed and employed to explore the relationships between socio-demographics, cost of water, water storage practices, water consumption habits, and water security. The household survey, offered in English and in Spanish, included five domains: 1) household demographics, 2) water usages and practices, 3) series of yes/no questions related to water security dimensions, and 4) income and wealth. An additional domain of the survey was added on water filtration technologies, which was used to identify resident's perception of small-scale water filtration technologies, their willingness to adopt particular technologies, and willingness to pay for devices out of pocket for use in the home. A pilot version of the survey in both English and Spanish was drafted and revised in consultation with the *promotora* to ensure the word choice and translations were appropriate and clear for the local community. This input, in combination with a pilot survey conducted with a neighbor of the *promotora* living in a *colonia* contributed to a final revision of the survey instrument. Additionally, the pilot ensured that the survey was operable and flowed in an effective manner for the interviewer and the respondent. The consent forms were received from Wendy Jepson (2014) and adapted as appropriate for the study. The Spanish language version of the survey was used for 81% of the surveys conducted and the survey took between 30 and 45 minutes to be conducted in each household.

Survey Domains

The survey instrument developed for this research built upon and modified that of Jepson (2014), as well as incorporated additional questions to explore the relationship between society and water filtration technologies. All domains were asked of the male or female adult of the household and he/she subsequently answered a sub-set of questions about all household members. This subset of questions included: the person's relationship to the respondent, age, sex, ethnicity, country of birth, education, employment status, marital status, length of residence at current address, and insurance status.

The domain of water usage and storage practices collected data that was used to construct variables for overall cost related to water storage, the frequency of water delivery, type of storage, and water storage cleaning practices based upon seasonality (i.e. spring/summer and fall/winter). This domain also included questions on water purchasing habits, location of water storage, and size of storage containers. The domain of household demographics captured data to characterize the population of residents in the *colonias* on the base of ethnicity, class, age, gender, insurance status, and age. The third domain of the survey of water filtration technologies included questions regarding the perception of water filtration devices, previous experience, willingness to pay, and the costs and benefits to users by residents. The fourth domain of water security included a series of yes/no questions within the three dimensions of water security (physical access, acceptable water quality, and water affect) of which were to be answered according to water purchasing and storage practices. These binary responses were specified as having occurred within the last year, six months, or previous month. Redundancies in questions were built into the survey to insure the consistency of responses as well as provide follow up questions about other members of the household to be answered by the respondent. The final domain of income and wealth included questions that were used to calculate the official poverty level of each household.

Survey Sampling Method

Phase two of the research plan included the development and implementation of household surveys that I conducted. I made contact with 66 households across the four *colonia* classifications (including unknown) with the *promotora*. She was able to establish rapport, translate Spanish responses into English, and to gain support within the study areas. We conducted the household surveys between July 9, 2013 and August 12, 2013. We followed a similar schedule to conduct surveys, limiting ourselves to weekdays between the hours of 9am and 4pm, excluding holidays. Households were contacted in consultation with the *promotora* according to safety, road conditions, and whether or not there was a car in the driveway. However, no two surveys were conducted that were within two households from each other in order to avoid selection bias. I selected households from each *colonia* classification category through a stratified random sampling method. The unknown group as well as the red group was disproportionately large, however, following the stratification in Jepson (2014).

Data Analysis

For data analysis, I coded and entered the data gathered from the 66 household surveys into a Microsoft Excel spreadsheet. This dataset included all household members (n=230). I compiled a second database aggregated at the household level and included variables at the household level (n=66). I compiled a third database at the household level and included responses to the binary (yes/no) questions to be analyzed through the Guttman scalogram analysis in order to classify households along a scale of water security, following the novel mixed-methods approach developed by Dr. Wendy Jepson (Guttman 1944; Jepson 2014).

Water Security Classification

Based on the notion that gaps in water reliability, quality, and access erode the functioning necessary for basic human services, Jepson (2014) developed a measure for water security that is more robust and experience-based than previous methods assessing security. In this way, water security is defined as adequate, reliable, and affordable water for a healthy life. The Guttman scalogram analysis develops household water security classifications for each household surveyed which addresses three dimensions of water security: water access, water quality acceptability, and water affect. Water access is defined as the capacity to access water for consumptive purposes, including physical access, affordability, and reliability. Water quality is understood to be the broad range of biophysical characteristics of water quality (taste, color, smell, biochemical, etc.) that influence water usage in the household. Water affect is defined as the emotional, cultural, and subjective experiences of water, where respondents define the terms of security relevant to their lives. An absence or lack of any of these three dimensions would contribute to water insecurity, although the degree to which would be variable and cumulative along a scale, based on household experiences of water deprivation. The Guttman scalogram orders responses such that the individual who positively responded (yes) more frequently will have a higher rank than an individual who responded negatively (no). Each household can then be assigned a scaled value for each dimension of water security (access, quality acceptability, and distress), yielding a rank order of individual households.

Based on this approach, a series of questions on the survey addressed each of the three dimensions of water security. Reponses were entered as either 0 or 1 into a respondent-by-item matrix for each dimension of water security. Each row of the spreadsheet represented one household and each column represented the indicators included in each water scale. Absent or negative responses were indicated with a “0”, and “1” was entered if the household indicated presence or positive response for one, many, or all of the survey questions corresponding to each specific indicator of security. A baseline of indicators included in each water dimension to be scaled was created using those chosen by Jepson (2014). My qualitative research further informed selection and elimination of indicators used for each scale in order to reflect unidimensionality. Unidimensionality holds that a positive response to a given indicator predicts the answers to all previous indicators in the scale to be positive, but not necessarily for a later indicator. The final experience-based indicators that corresponded with survey responses used in scale development are described in the idealized Guttman scales (Appendix B-2).

Three conventional measures of reliability for each dimension’s scale were calculated: coefficient of reproducibility (CR), minimal marginal reproducibility (MMR), and coefficient of scalability (CS). The CR measures the scale’s deviation from perfection, and is defined as the empirical relative frequency with which the values of the indicators correspond to the proper intervals of a quantitative variable (Guttman 1944). The CR should be equal to, or greater than 0.9, as this may be used as an efficient approximation to a perfect scale (Guttman 1944). The CS measures predictability of the scale relative to the level of prediction afforded by consideration solely of the row and column marginal, and should be greater than or equal to 0.6 (Guest 2000). The MMR must be less than 0.90, measuring the frequencies of the least popular answer (Guest 2000). Several iterations were run for each dimension and revaluated based on reflection of survey results and resident's experiences. Scales for each dimension of water security met the conventional measures of reliability (Appendix B-3).

Each household was then statistically clustered into water security classes based on the cumulative scaled scores for each dimension of water security. Using the three scales for each dimension (access, quality acceptability, and affect), households were divided into four groups of different levels of water security. S+ software was used to cluster the households into groups and to create a dendrogram applying the centroid method and squared Euclidean distance measurement. Qualitative data and the dendrogram were used to cluster the households into four groups: 1) Water Secure; 2) Marginally Water Secure; 3) Marginally Water Insecure; 4) Water Insecure.

Differences among the four groups were also tested using multi-response permutation procedure (MRPP), a non-parametric procedure to test the hypothesis of no difference between two or more groups (Biondini et al 1988; Mielke and Berry 2001). MRPP, calculated in R software, provides a measure of effective size and *p*-value of significance. In this case, Euclidean distance as a measure of average within-group distance was used. The *p*-value evaluates how likely the observed difference is due to chance, but we needed a measure of effect size that is independent of the sample size. The agreement statistic *A* describes within-group homogeneity compared to random expectation. This is called the "corrected within-group agreement" statistic; an *A*-statistic greater than 0.3 is considered fairly high. For the household water security indicator groups, the agreement statistic *A* is 0.457 and the *p*-value is 0.001. Therefore, we can reject the null hypothesis of no difference among the groups.

The household water security measurement established a baseline assessment of water security in the *colonias* of West Texas. This measurement informed the qualitative evaluation of POU and POE technology's ability to improve household water security and efficacy in providing more adequate, reliable, and affordable water to these households.

Conclusion

In this chapter I have outlined research objectives, described the study region, and specified the methods used to collect and analyze data. This research employed a mixed-methods approach which engages qualitative and quantitative research methods in order to critically examine whether POU and POE technologies can improve household water security, as well as the process by which POU technologies have been decontextualized from their role in disaster relief and repurposed as a technological "fix" to poor water services in the *colonias* of El Paso County. I discuss the results of these analyses in chapter V and VI.

CHAPTER IV

POLITICAL ECONOMY OF POU DEVICES

In this chapter I will synthesize and review the evolution and dissemination of POU technologies globally. First, I review the development and transfer of POU technologies as they have entered the international development health agenda and led to 18 million new users in the past two decades. Next, I provide an overview of the technologies available for implementation and discuss key participants in the POU economy, while providing the case of a global distributor of POU devices. Finally, I evaluate POU efficacy and note the emerging paradigm of POUs in the U.S.

While this chapter includes an extensive and technical review, the information is required to contextualize how the technologies fit within a global neoliberal political economy and to understand the production of POU technologies available for circulation and application. Further, it determines that public-private partnerships and social entrepreneurship business models mobilize the application of POU technologies in developing countries, despite the lack of rigorous evaluation of adoption and sustainability of the devices in the household.

Background

Approximately 1.1 billion people in the world lack access to potable drinking water, forcing them to utilize potentially contaminated surface and groundwater sources for drinking water supplies. This lack of access to potable water accounts for nearly 10%

of illnesses, diseases and deaths resulting from infectious diarrhea across the globe, as well as their indirect health effects such as neurological syndromes, reactive arthritis, malnutrition, and arrested growth and development (Sobsey et al. 2008; Rosa and Clasen 2010). According to the World Health Organization (WHO), 1.8 million people die of diarrheal diseases annually, most of which are children under five years of age in developing countries (WHO 2005). Despite recent completion of the Millennium Development Goal (MDG) target of "halving the portion of the population without sustainable access to safe drinking water by 2015" (WHO 2005), even those who have been provided with improved water provision measures may still not have microbiologically safe water at of the point of consumption in the household. Scholars assert that improved supplies are commonly contaminated with infectious disease causing pathogens due to inadequate treatment at the point of distribution and poor water quality regulations, subjecting many to the risk of cholera, enteric fever, dysentery, and hepatitis (Sobsey et al. 2008). Even when water may be safe at the distribution point, drinking water may become contaminated during collection, transport, and storage due to poor hygiene conditions or failing infrastructure characterizing most poor households (Boisson et al. 2010).

Over last 20 years, several methods and technologies to treat water have been promoted in low-income contexts, including the treatment of water in the home using household water treatment technologies. These decentralized water treatment technologies have been developed and widely adopted as a means to treat water at the household scale or at the point of use in order to reduce the risk of waterborne disease for vulnerable populations (considered to be those under the age of 5). Development agencies have sought to alleviate the burdens associated with poor access to safe drinking water by implementing POU devices to improve water quality in the household (Sobsey et al. 2008). Although lauded as a cost-effective intervention for achieving MDGs, HWTs do not improve water access nor do they increase the quantity of water reaching the home (Rosa and Clasen 2010). Since 1990, numerous POU technologies have become developed, endorsed, manufactured, and implemented. A technical study in 2010 suggests that, "it is likely that the actual number of people from low- and middle-income countries who practice some form of HWT may exceed 1.5 billion" (Rosa and Clasen 2010). Long before recent POU technologies were disseminated, HWT typically occurred through the practice of boiling, which has been widely promoted by health-care providers, international development organizations (INDOs), and governments (Boisson et al. 2010).

Various POU technologies are available to policy-makers, development institutions, emergency management agencies, and users. Several development organizations and research agencies are investigating strategies to further disseminate HWTs and are scaling-up existing programs that institute POU devices with more rigorous laboratory demonstrations of effectiveness: solar disinfection, biosand filtration, ceramic filtration, and flocculation/chlorination (Lantagne et al. 2009). A review in 2008 estimated that over 18 million of the 1.1 billion lacking access to potable water specifically use POU devices to treat water at the household (ibid.). Although many of the technologies have been designed, tested in laboratory settings, and implemented, few are demonstrative to offer effective and sustained use in the home. Various reviews of decentralized HWTs have evaluated these technologies for effectiveness and sustainability and assert the need for peer-reviewed research to investigate the determinants of sustained, long-term, consistent use of POU technologies once adopted. (Sobsey et al. 2008; Peter-Varbanets et al. 2009; Loo et al. 2012).

Overview of Available POU Technologies

This section provides an overview of available POU HWTs, generally categorized by methods of filtration: membrane- and non-membrane-based technologies. Tables B-4 and B-5 provide detailed information on key characteristics of these WTs, while figure A-5 provides images of select devices. This information provides an intricate understanding of the labor requirements, costs, efficacy, and health benefits of various POUs available for application in the low-income households. Understanding of these characteristics is pertinent to qualitative analysis conducted in this study which determines how adoption of these devices impact the lives of *colonias* residents and whether these devices can improve household water security in West Texas.

Non-Membrane-Based Water Technologies

Non-membrane based POU HWTs can be classified as follows (Appendix B-4):

- Physical treatment- biosand and novel filtration
- Chemical treatment- chlorination and combined coagulation/disinfection

- Thermal or light-based treatment- pasteurization, SODIS (solar disinfection), and solar distillation

Physical Treatment

Biosand filters (BSF) are built using crushed granite, gravel or sand and include a layer of bioactive soil for the removal of pathogens. This method employs gravity to drive water through the system with no pre-treatment or post-treatment requirements. BSFs can last up to 8 years or more, requiring regular maintenance of the top few centimeters of sand throughout its lifetime (Loo et al. 2012). These filters have high potential for sustained use in households, as they only require an initial purchase and do not require replacement parts (Sobsey et al. 2008).

Chemical Treatment

With development of the Safe Water System (SWS) in the 1990s, free chlorine (hypochlorite) treatment has been widely promoted as an effective means for water treatment by the U.S. Center for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO) (Sobsey et al. 2008; CDC 2012). Chlorine is supplied in several forms, including concentrated liquid or tablets and requires no pre- or post-treatment (Loo et al. 2012). Chlorine methods were "designed for treatment of large quantities of water with a small volume of chlorine" as long as 30 minutes of mixing time is allowed (Peter-Varbanets et al. 2009). The CDC, however, notes that drawbacks of this solution include its reduced effectiveness in waters with high turbidity and relatively low protection against protozoa. In effect, chlorination has been suggested for "low turbidity water in urban, rural, and emergency situations where educational messages can reach users to encourage correct and consistent use" (CDC 2012). Maintenance for this method of filtration includes keeping the water treatment and storage containers clean in order to reduce contamination and regular purchases of these chemicals must be made in order to obtain sustained use of these methods (Sobsey et al. 2008).

Commercial technologies have been developed since the early 2000s, which combine chlorination methods with dry coagulant-flocculant for disinfection. Procter & Gamble developed a portable coagulation-based HWT known as PuR™ in conjunction with CDC and UNICEF (CDC 2012). "The product combines ferric sulfate, bentonite, sodium carbonate, poly(acrylamide), chitosan (flocculating aids), potassium permanganate (oxidizing agent), and calcium hypochlorite (disinfectant) into a sachet for treating 10 L of water" (Loo et al. 2012). To treat water with PuR™, users must add the contents of the sachet to a bucket containing 10 L of water, stir the contents for 5 minutes, strain the water through a cotton cloth into a second container, and wait 20 minutes for the hypochlorite to inactivate the microorganisms. PuR™ sachets are unique in that the technology has the ability to remove heavy metals and chemical contaminants from water, such as arsenic (up to 99.8%) and pesticides, respectively (CDC 2012). The sachets have a long shelf-life and are transported easily, however they are relatively higher in cost per liter of water treated, they are only available from a few manufacturing locations, and the multiple steps for decontamination yield low risk continued acceptance post intervention (Sobsey et al. 2008).

Thermal or Light-Based Treatment

Thermal pasteurization employs heat at moderate temperatures to pasteurize water. Water is purified as it passes through a clay cooking stove called the *Chulli* purifier which contains an aluminum coiled tube that generates heat (Islam and Johnston 2006). The water disinfection stove, known as WADIS, operates similarly to the *Chulli*, but uses the "Lorena-stove" featuring chimney ventilation (Loo et al. 2012). Solar water heaters may also be used to deactivate pathogens thermally, but cost around $220/unit, disinfecting 125 L/hr, and are typically used in emergency response situations for small communities (Kang 2006).

Under severely limited conditions solar disinfection (SODIS) methods can be employed to disinfect water. This method involves filling transparent polyethylene terephthalate (PET) bottles with water and exposing the bottle to UV rays by placing them on a roof or rack for at least six hours or two days for cloudy conditions (Tamas et al. 2009). The "combined effects of UV light-induced DNA damage, thermal inactivation, and photo-oxidative destruction inactivate disease-causing organisms" (Clasen et al. 2009). Although developed in the 1980s, the Swiss Federal Institute for Environmental Science and Technology implemented SODIS in developing countries in 1991. SODIS is simple to use at minimal cost if PET bottles are accessible, however it has reduced effectiveness in highly turbid waters and takes long amounts of time to purify very small quantities of water (CDC 2012).

Solar distillation technology employs single stills using direct solar radiation for desalination in remotely located areas where water demand is less than $50m^3$/day (Loo et al. 2012). Solar stills successfully remove non-volatile contaminants and bacteria if a-priori contamination of the raw water source does not take place. A portable pyramidal still made from poly(vinyl chloride) delivers 0.5L of water per day at lower costs than bottled water, however, the solar still has not been widely adopted due to its drawbacks: high cost, high maintenance requirements, and low portability (Wassouf et al. 2011). The Watercone™ is an example of a portable solar distillation still that was invented in the early 2000s and has been employed by a German aid and relief organization known as CARE to fisherman in Yemen (Watercone 2008).

Membrane-Based Water Technologies

Membrane filtration processes use a semi-permeable film membrane, and can be categorized by their driving force as such (Appendix B-5):

- Pressure-driven membrane processes: microfiltration, ultrafiltration, and reverse osmosis
- Temperature-driven membrane processes: membrane distillation
- Osmotically-driven membrane processes: forward osmosis

Most membrane processes are pressure-driven. POU devices currently only involve membrane filtration processes, with the exception of one POU technology that applies forward osmosis for water treatment (Peter-Varbanets et al. 2009). In 2009, it was documented that 531 entities including governmental and nongovernmental organizations, utility companies, and engineering consultants are working in the membrane technology market in developing countries such as Mozambique, Ethiopia, Bangladesh, Vietnam, Uganda, Kenya, Nicaragua, Guatemala, and Pakistan, where "at least a quarter of them produce, import or provide services involving POU membrane-based systems" (Peter-Varbanets et al. 2009). These POU HWTs are discussed in the following section.

Pressure-Driven Membrane Processes

The ceramic filter (CF) is the most widely implemented small-scale microfiltration (MF) system and is a traditional method for treating water in the household (WHO 2005). The ceramic filter is composed of porous ceramic that filters microbes through size exclusion in pores spaces and can be made using locally available materials (Loo et al. 2012). The CF pot is filled with water and gravity pulls the water through filter into a separate storage container. Treated water can then be accessed through a spigot at the bottom of the storage container. There are numerous locally made and commercially available ceramic filters currently being implemented for use in developed and developing countries. Currently, the most widely implemented CF is a flowerpot shaped design or "Rabbit" brand created by Potters for Peace that stores and filters about 8-10 liters of water at a time. Other designs include candle filters that fill a hollow core with granulated activated carbon (GAC), such as the Tulip™ filter created by Basic Water Needs India Pvt Ltd. Ceramic filters may also be lined with colloidal silver to add to their bacteria removal capacities (CDC 2012). The CDC notes that this method of treatment has been proven effective at removing bacterial pathogens and larger protozoans, but not at removing viruses (CDC 2012). Filters must be cleaned regularly, have no chlorine residual protection, a low flow rate, and have the potential to break over time, but one-time purchase costs allow for it to be widely accepted (Sobsey et al. 2008).

MF is increasingly being used by travelers from more developed countries. One of the most employed commercial systems is the Katadyn Mini Ceramic filter produced by Katadyn, Switzerland. The filter is composed of a ceramic 0.2µm membrane and is operated by gravity or a hand pump. The lifetime of this technology is limited to 20,000 – 100,000 L of filtered water and the initial costs are relatively high (Peter-Varbanets et al. 2009; Katadyn 2012).

The FilterPen created by the FilterPen Co of New Zealand and Filtrix Co of the Netherlands has applied microfiltration in the form of a straw-like device. In this microfiltration device water is sucked through the device and filtered through the microfilter with pore size of 0.15µm. According to the manufacturer, this device only last about four weeks or 100 L of treated water. This technology has been developed for travelers and military uses (Peter-Varbanets et al. 2009).

The LifeStraw Personal® is a product very similar to the FilterPen™ and was developed by Vestergaard Frandsen for individual travelers (LifeStraw 2008). With a lifespan of 700 liters, engineers posit that this device demonstrates highly effective reductions of bacteria and viruses in laboratory settings, but is ineffective against small protozoan parasites (Peter-Varbanets et al. 2009).

Currently, uses of ultrafiltration (UF) systems for treating household water remain elusive (Peter-Varbanets et al. 2009). UF membranes completely remove pathogens and require significantly lower pressures than reverse osmosis membranes.

One of the few effective UF-based POU systems is LifeStraw Family® developed by Vestergaard Fransden in 2006 (LifeStraw 2008). The device is composed of a pre-filter and a chlorine chamber to reduce turbidity, where the water then flows through a hose into an UF module with 20nm pore size. The hose connecting the storage reservoir and the filtration module extends about 4.5 feet, therefore the unit must be elevated by mounting it on the wall or ceiling (ibid.). Additionally, the module must be manually backwashed once every 1-2 days (Peter-Varbanets et al. 2009). Clasen et al. write that, "independent laboratory testing showed that LifeStraw® was effective in producing microbiologically safe water to EPA standards and reducing diarrheal lapses by 15%" (Clasen et al. 2009; Boisson et al. 2010).

Reverse osmosis systems are generally unrealistic for applications in developing countries, as they have extremely high initial costs, are complex, and have high maintenance requirements. Most commercially available POU HWTs in developed countries use RO membranes and are installed under a kitchen sink in order to further treat water provided by a public utility (Peter-Varbanets et al. 2009). Maintenance requirements for RO systems includes replacement of pre- and post- filters once per 6-18 months, their initial costs range from US$200-700, and cost between US$85-135 per year to operate (Peter-Varbanets et al. 2009).

Osmotically-Driven Membrane Processes

Forward osmosis membrane technology in POU devices has been employed in the hydration bag created by Hydration Technology Innovations for use in emergency situations and military applications. In this system a bag composed of a semi-permeable

FO membrane is packed with a consumable solution. The system is immersed in the source water that diffuses through the membrane, causing the package to swell while diluting the consumable solution cased inside the bag. The purified water for consumption is sweet and contains minerals and nutrients. Engineers argue that this system has limited applications because it produces low quantities of sweet water for one individual and bacterial re-growth is likely (Loo et al. 2012).

Key Participants in the POU Economy

POU water treatment products represent a small segment of the multi-billion dollar global water treatment industry, generating $15 billion per year with an expanding market expected to grow 16.5% each year (POUZN 2007). As discussed previously in this chapter, this global sector is primarily driven by targets set by Millennium Development Goals to improve water security in developing country markets. Most efforts to scale-up POU dissemination specifically target developing countries and are employed by non-governmental agencies, international development organizations, and governmental agencies. Conversely, the industry also targets countries with significant middle- and higher-income segments on a for-profit basis in the retail market.

Most POU HWTs are unavailable to families in low-income settings due to high initial costs, even where financing mechanisms attempt to minimize this issue (Heierli 2008). Nevertheless, major organizations and corporations manufacturing, distributing, and employing POU technologies in low-income communities can be identified. TableB-6 indicates key characteristics of these major organizations and corporations including the technology manufactured, the location of their headquarters, the year established, and whether patented rights to the devices are held by those organizations.

Efficacy and diarrheal disease reduction has been demonstrated for five inexpensive POU HWTs, which subsequently have been the most widely disseminated POU systems with promotion by the CDC and Pan American Health Organization (PAHO) (Parker Fiebelkorn et al. 2012). These include chlorination, combined coagulant-chlorine disinfection, SODIS, ceramic filters, and the biosand filter. Of these five filtration mechanisms, three major developers of the technologies do not have patented rights (Synder 2008). Each are NGOs promoting water filtration solutions to improve access to safe drinking water and reduce poverty and often work in conjunction with the governmental agencies, international development organizations (WHO, USAID, UNICEF, World Vision, and The World Bank), and non-governmental agencies (Population Services International) to fund development research, market their products, manufacture and purchase HWTs, and distribute them globally. They also educate families on their use and maintenance on a not-for-profit basis. The remaining HWTs are all manufactured by a commercial company that owns the rights to their technology and operates under a business model that generates revenue for their company.

Public-private partnerships play a significant role in the large-scale distribution of household items to urban and rural markets, as product distribution to low-income, rural areas is often challenging. Most POU devices implemented in developing contexts have been disseminated by NGOs or government programs outside a private sector supply chain (Heierli 2008), as “large partner NGO volunteer or community-based distribution networks can assist with product promotion and distribution". In these partnerships, the initial cost of the POU device, cost for transport, dissemination, and community education is fully subsidized by donations to the NGO and provided to residents free of cost. If the full cost for dissemination cannot be acquired through NGO donations, microfinance institutions facilitate a financing model, which provides microcredit, or small-scale loans, to low-income families and potential distributors of POU HWTs that manage start-up costs. In the case where commercial products are implemented through market penetration, the user could be required to pay for the entire cost of the product, often preventing the user from the ability to pay for a new filtration mechanism (Heierli 2008). In the case of for-profit industries developing and manufacturing their POU technologies, these companies traditionally market their products for emergency relief or for use in developed countries for hiking, camping, and backpacking. Additionally, corporations often market their low-cost solutions to NGOs who will then purchase the technologies from the manufacturer. In these situations, the industry is supported by private investors in developed countries.

Carbon credits are also a mechanism for financing the purchase and dissemination of POU WTs. One of the mechanisms to provide a cheaper, less complex alternative to emission reductions is carbon trading, a concept that emerged through the Kyoto Protocol. Carbon emission trading is a market-based approach, which permits organizations in industrialized countries to purchase emission reduction credits in order to meet emission reduction targets or to voluntarily compensate for their greenhouse gas emissions (Bumpus and Liverman 2008). Emission reduction credits are provided and regulated by the Clean Development Mechanism (CDM) through emission-reduction projects conducted in the developing world such as afforestation and reforestation, biofuels, methane capture, energy-efficient wood stoves, and renewable energy (ibid.). Emission-reduction projects through the CDM has opened up new space for funding to conduct development and conservation projects in the Global South, and have become a "rapidly growing business opportunity for those firms which develop and broker projects and credits" (Bumpus and Liverman 2008). I will briefly turn my attention to carbon finance as a funding mechanism for the distribution of POU technologies in the Global South.

Carbon and Clean Water

Carbon finance has become a mechanism for financing the purchase and dissemination of water treatment technologies that are manufactured and patented by private corporations. Vestergaard Frandsen™ is a Swiss-based company that manufactures POU technologies with "potential to improve the health and lives of up to 4 million people." These devices are known as LifeStraw® and the LifeStraw Family®. The LifeStraw Family®, in particular, has been demonstrated to produce microbiologically safe water to US EPA standards and reduce diarrheal lapses by 15% (Clasen et al. 2009; Boisson et al. 2010).

In the Spring of 2012 an initiative known as "Carbon for Water" was launched as the first program of its kind – leveraging carbon financing to fund a commitment to bring clean and safe drinking water to Kenya's Western Province for a period of at least ten years (Vestergaard 2012). Vestergaard Frandsen™ delivered 1 million free LifeStraw Family® water filters to nearly every family in the region (nearly 4 million people), and funded the training, maintenance, and support staff to insure that the products are used correctly and efficiently. By replacing traditional purification in the region in which fossil fuels are burned to boil water, at least 2 million tons of carbon are predicted be retained the local forests each year. The environmental "benefits" (or elimination of expected deforestation) from the LifeStraw Family® are then exchanged for carbon credits. This exchange launches the company into the carbon market, which generates revenue to self-sustain the program. Industries and governments in the Global North purchase the carbon credits generated by the offsets in this project, through the CDM. As revenue is generated from the sale of carbon credits, investment in new filter units and repairs keeps the business running sustainably.

Vestergaard Frandsen™ operates under what it calls a "Humanitarian Entrepreneurship business model" where "this 'profit for purpose' approach has turned corporate social responsibility into (their) core business of creating life-saving products for the most vulnerable" (Vestergaard 2012). According to Vestergaard, LifeStraw® has the potential to reduce disease, help the environment, and improve the health and strength of communities, as well as to *save the lives* of 4 million people, while being sustained through the CDM's carbon finance mechanisms.

The company has gained significant public attention in the United States as well as in Europe and is lauded in the media for its innovative business plan. The New York Times states, "Vestergaard Frandsen plans to provide clean water to some of the world's poorest people and charge them nothing" (McNeil 2009). In 2012, a documentary film was released, titled "Carbon for Water: Life is precious. Water shouldn't be"©, which subsequently received 11 awards in numerous film festivals for environmental and development films. The film provides information for non-governmental organizations and philanthropists to purchase and implement development projects employing Vestergaard's technologies and encourages consumers and agencies to invest in this "socially responsible" and "environmentally sustainable" business (Vestergaard 2012).

Vestergaard Frandsen provides one example by which public-private partnerships are mobilized through carbon finance, where POU technologies are circulated and applied in developing countries on a for-profit basis. As social marketing campaigns bolster support for the private industry to tap into POU markets, humanitarian entrepreneurship business models are expected to shift the paradigm for international development projects globally.

POU Efficacy and Human Health

The development and implementation of POU HWTs has rapidly increased despite its inability to be proven as an effective long-term solution to improve household drinking water quality and reduce diarrheal disease risks for those who lack access to a clean drinking water source. Proponents of the technologies claim that "HWT significantly reduces diarrhea in poor areas and is among the most effective of water, sanitation, and health interventions, is highly cost effective, and can be rapidly deployed and taken up by vulnerable populations" (POUZN 2007). Yet, these interventions so far have been short-lived. Some contend that public health efforts often scaling up benevolent technological interventions that are then quickly abandoned after rigorous evaluation is conducted (Heierli 2008). There are numerous critiques of clinical trials which inform policy makers and private industries. For example, Schmidt and Cairncross (2099) argue that, "the private sector can have a role in biasing evidence toward finding an effect and in influencing public health policy in the wrong direction" (also, Schmidt 2009).

More revealing is that behavior change to adopt POU HWTs has not occurred at a sufficient scale in developing country communities to permit large-scale epidemiologic studies that assess their health impact (Parker Fiebelkorn et al. 2012). Scientists in engineering and public health also call for more studies to evaluate the sustainability of POU technologies and longevity of their adoption after their implementation (Sobsey et al. 2008). Sobsey et al. (ibid.) posits that evaluations of sustainability must include five criteria: 1) the technology's ability to consistently produce sufficient quantities of microbiologically safe water to meet daily household needs; 2) prove effective for treating many water sources and quality levels; 3) require relatively small user time to treat water, low cost (allowing for continued affordability throughout its lifetime); 4) have reliable, accessible and affordable supply chain for replacement parts, and; 5) maintain high post-implementation use levels after the cessation of intensive surveillance and education efforts as in field trials and marketing campaigns. Yet, thus far, a rigorous evaluation is elusive. There are many questions about HWTs that remain unanswered. More studies must be conducted as these technologies are implemented in order to better understand behavior change and sustainability of the technological intervention.

POU and the US

Recently, we have observed a newly emerging paradigm where POU devices are being considered for implementation in the US for uses other than disaster preparedness or retail sale. Within this new paradigm, water utilities are considering decentralized and unconventional approaches to water service provision domestically (Raucher et. al. 2004). The Safe Drinking Water Act (SDWA) requires that the use of POU and POE technologies employed for regulatory compliance must be controlled by the utility, although installation and servicing can be outsourced to local vendors, POU is not allowed for microbial compliance purposes due to concern of exposure from taps untreated by the device. In 2004 the American Water Works Association (AWWA) Research Foundation in collaboration with the US EPA, US Bureau of Reclamation, and the Association of California Water Agencies, conducted a study to examine a range of "unconventional devices" and technologies for neighborhood and household-scale water provision in the United States. The project assessed the use of POU and POE devices as cost-effective solutions to regulatory compliance for utility water provision and to provide supplemental services to customers that have expressed demand. In sum, the research suggested that the POU and POE devices piloted in the study were technically and economically feasible for utility providers and well aligned with customer preferences. But they identified that the biggest barriers to utility application of these approaches are institutional. As US federal agencies consider these alternative approaches to water service provision it is no surprise that interest and investment into the use of these devices domestically continues (Raucher et. al. 2004).

Conclusion

Despite the lack of rigorous studies identifying the reduction of the diarrheal disease risks promoted by POU HWTs and their capabilities for sustained use requiring behavioral changes in communities employing these technologies, the market for these technologies is expanding rapidly. Numerous private industries have tapped into this market in order to meet the MDGs since the early 2000s, developing and marketing their products to government agencies, development agencies, humanitarian aid agencies, and non-governmental organizations. Governmental agencies, non-governmental agencies, and private industries are scaling up efforts to expand into the narrow markets of developing countries, while federal agencies in the US consider the technology for regulatory compliance domestically. Globally, social marketing and entrepreneurship business models have shifted the paradigm for dissemination of POU technologies to low-income communities lacking access to potable drinking water that have been traditionally reached by not-for-profit non-governmental organizations. The identification of these key actors and technologies identifies the broader political economy of soft-path technologies, the mechanisms of their circulation and application in developing contexts, and the sustainability of use of these products as they are implemented directly into individuals' daily practices.

CHAPTER V

TECHNOLOGICAL UPTAKE AND HOUSEHOLD WATER SECURITY

In this chapter I will describe current water use, costs and storage practices of the households surveyed, classify each household into a water security class for each dimension of water security, and identify to what means and ends water becomes available to residents through the institutionalization of POU/POE technologies in the *colonias*. Together, this analysis provides a baseline measure with which to assess whether POU and POE technologies can improve the level of household water security with ideal adoption of the devices. Further, I will discuss potential barriers to household adoption and analyze resident's responses to suggested implementation based on survey results. Findings reveal a weakness of the technology as a solution to poor water service, with marginal improvement to household water security, as well as the poor likelihood of adoption by household residents. In sum, this analysis advances our understanding of how soft technologies potentially alter everyday lives of the poorest Americans living in *colonias* along the US-Mexico border.

Water Uses, Costs, and Storage Practices

Of the 66 households surveyed, 18 homes (or 27%) are not currently connected to a public water supplier or community water supply (See Appendix B-8). These households' primary source of water for hygiene and household chores are private water haulers that deliver water to an outdoor (often black) tank that ranges in size between

1,500 gal and 2,500 gal and must be maintained by a tenant. 28% of these homes also deliver water to their tanks by hauling it themselves from a water vending point located at a local municipal water district. This requires that residents obtain a 1,500-gallon storage container to be placed in the bed of a truck and a water pump to pump water from the municipal storage container into the resident's container, not to mention the expenses for gas to reach these vending points and labor required for this process (Jepson and Lee 2014).

Residents of these homes spend an average of $144 per month in the Spring/Summer and $127 per month in the Fall/Winter, depending on the number of household members and consumption patterns. This equates to 16% of monthly income spent on water in the Fall and 18% of monthly income spent on water in the Spring for these households, when the US EPA standard for water affordability is considered <2.5% of monthly income. All households surveyed cannot afford the water according to the US EPA standards. Water delivered to the outdoor storage tank is "potable" at the point of delivery; however, the storage tanks are often contaminated due to poor maintenance and long standing times. These tanks are also subject to algal growth, which increases the organic content of the water, causes discoloration and odor, and can lead to skin rashes with continuous contact. Therefore, all residents rely on bottled or purified water from water vending machines (*molonitos*) which require storage in 5 gallon containers (*garrafones*) transportation to the local grocery market or water vending machine, and physical labor to transport the containers to and from the home (Jepson and Lee 2014). Residents without a connection to a community water service spend between \$35 and \$42 per month in the Fall and Spring, respectively on purchasing drinking water for their home – again, which ranges due to household size and consumption patterns. Further, these 5-gallon storage containers must be cleaned with Clorox (and more water) after each use and should be replaced twice per year.

The remaining 48 households (or 73% of families surveyed) are connected to some community water service provider. Tap water is the households' primary source of water for hygiene and household chores. Residents spend an average of \$78 per month in the Spring/Summer and \$65 per month in the Fall/Winter on total water expenses. This equates to 11% of their average monthly income spent on water in the Fall and 13% spent on water in the Spring. Using the EPA standard for water affordability, 88% of these homes did *not* meet the affordability standard. Residents most commonly reported having distrust of the water quality due to unpalatable taste or smell, report that it is visually unclean water at the tap (black specs, or murky/brown color), is unreliable, experience low water pressure, and have concerns over tap water quality. The experiences of residents pertaining to different characteristics of water security are captured through the Household Water Security Classifications (HWS) to be discussed in the next section. Identified as the "no-win" waterscape by Jepson (2014), these residents retain a water service connection yet water quality remains precarious and relatively expensive. Indeed, 66% of the homes surveyed rely on more than 50% of their drinking water from water vending machines and bottled water. These residents spend between \$23 and \$27 per month in the Fall and Spring, respectively on purchasing purified drinking water for their home. The cumulative experiences of residents pertaining to different characteristics of water security are captured through the Guttman scalogram.

Household Water Security

The Guttman scalogram method developed by Jepson (2014) yielded household water security classifications for each household surveyed, addressing each of the three dimensions of water security (water access, water quality acceptability, and water affect) (See Appendix B-2 for results described in section that follows).

Considering water access, most households in the study cannot afford water (91%) and conserve water usage to save money (74%). Over half (56%) consider it a physical burden to clean their water tank (*garrafones*) and over one third (35%) reported that they lacked money to pay for water or missed a bill in the last year. Over 33% experienced difficulties buying or hauling water while 30% experienced difficulties buying water due to transportation problems. Over one-fourth (27%) reported that they share a water meter with another household or have received water for free from someone else. Only 5 households (8%) experienced adequate water access, 33 homes (50%) experienced marginal water access, 9 homes (13%) experienced low water access, and 19 homes (29%) experienced very low water access on the water access scale.

Considering water quality, 76% reported drinking more than 50% of their water from bottles or vending machines, which indicates some dissatisfaction with tap water. A large majority (71%) of homes reported that the tap or trucked water has an unpalatable taste or smell while 42% of respondents experience tap/tank water that is visually unclean. Over one-third (36%) do not disinfect *garrafones* after each use with Clorox and 24% of residents use *garrafones* older than 6 months. Based on their scaled scores, thirteen households (20%) experienced acceptable water quality, 8 (12%) experienced marginal water quality acceptability, 20 (30%) experience low water quality acceptability, and 25 (38%) experienced very low water quality acceptability.

Considering water affect (water distress), over half (58%) of respondents reported dissatisfaction as the most common emotion related to water quality. Many respondents (53%) reported that they felt troubled or uneasy related to its use, quality, and service. 47% of residents reported worry related to water quality, access, cost, and expenditure of time and effort. Similarly, 47% of residents reported disgust with the water quality, while 45% of respondents admitted to arguing or complaining about water to family members or neighbors. Finally, 42% of residents reported feeling frightened or scared. Scaled scores revealed that 23 homes (35%) experience low water distress, 10 homes (15%) experience marginal water distress, 8 homes (12%) experience high water distress, and 25 (38%) experience very high water distress.

A cumulative score was developed for each household for each dimension of water security for each household. Scores indicate the level of security for each dimension according to several indicators chosen for the respective dimension. Cumulative scores based on these three dimensions yielded water security classifications for each household in the following categories: (1) water secure (2) marginally water secure (3) marginally water insecure and (4) water insecure.

The analysis determined that only 6 households (9%) were identified as water secure, 15 homes (23%) experienced marginal water security, 21 homes (32%) experienced marginal water insecurity, and 24 (36%) of homes were water insecure (Appendix A-1). Mean scale score values and socio-economic information by water security classification shown in Appendix B-9 and B-10. This reflects the cumulative experience of water access problems, water quality acceptability, and water distress. So the question is: can POU and POE technologies improve household water security for 91.9% of the households surveyed?

Technical Waterscapes

If we are to consider technology's ability to alter the everyday lives for these *colonia* residents, one must qualitatively assess the aspects of water-society relations within the households that *ideal adoption* would modify. Indeed, one must consider the devices at face value- disregarding the devices potential to be rendered inoperable and assuming that the family will accept the device as a solution to their precarious water services. I examine costs and benefits of the technologies according to cash expenditures, labor by household members, and health benefits in order to determine how household water security might change with adoption. Costs and benefits to users accrue differently, of course, according to the water service providers (no service or connected to community water system).

Considering expenditures, the initial cost for the devices ranges between \$67 and \$139 depending on the POU unit purchased by a family. Initial costs for the POE unit researchers are considering are $849. Installation of these devices would eliminate the need to purchase purified water for drinking, providing an average monthly savings for homes without water between $38 and $45 in the spring and fall, respectively. With these savings it would take one family between 18 and 22 months of savings to offset the initial cost for a POU unit and about 3 months for a POU device.

Other costs from POE installation include those associated with properly preparing the water storage tank for the installation of the filter. It would cost about $80 per household to clean, disinfect, and remove algae from the tank, which has potential to foul the filter membrane if not removed before the device is installed. If the water storage tank is not black, residents' could purchase paint from the local hardware store to paint the tank in order to prevent algal growth, adding around $100 to the initial cost.

Although there is a substantial monthly reduction in cost for users, it was determined that only two households (11%) surveyed of those with no water service would experience a large enough reduction in monthly water expenditure for water to be considered affordable to US EPA standards (<2.5%). This was determined by recalculating the percentage of monthly income spent on water for each household (without community water service) in the absence of vended water costs, assuming that the initial cost of the unit was paid in full at time of purchase.

Homes that do have a community water service connection could expect to save $23 to $27 in the spring and fall, respectively based on the survey data. Additional costs for preparation and installation would not be required for these homes, allowing adoption of the devices to much more feasible for those households connected to a water provider. However, only 4 households (8%) with water service would experience a large enough reduction in monthly water expenditure to then be considered affordable to US EPA standards (<2.5%). This was determined by recalculating the percentage of monthly income spent on water for each household (with water service) in the absence of vended water costs.

Labor in this study refers to the amount of time and work the user must invest in order to prepare, install, operate, and maintain the device and water storage containers necessary for the filtration process. Regular maintenance of the POU devices would not be required, as there would be no need to replace the filter cartridge on the device with a lifespan of >100 years. But *garrafones* would still need to be cleaned after each use and lifted or carried as needed in the home. With POU devices, the use of *garrafones* is still necessary; therefore the device does not eliminate the potential for contamination via storage container. Nor does it eliminate the need to purchase and replace *garrafones*, and the physical effort to clean and maneuver/carry the containers remains necessary, all of which were determined to be major indicators of water insecurity in the HWS assessment.

Conversely, POE devices would eliminate this need, but would inherit time and effort needs as replacement of the filter cartridge is necessary twice per year. As previously mentioned, homes with no water service connection must prepare their water storage tank for installation of the device by cleaning the tank. This involves exceptionally difficult work and a considerable amount of time (about a full day). Installation of POE devices could take from 6 to 12 hours, including the time it takes to construct a small casing or shelter around the device for environmental protection. Finally, the expenses, time, and labor required to procure water to fill the storage tank would not be affected with installation of POE devices for these homes – also all major contributors to water insecurity indicators. In sum, the total labor costs increase with installation, operation, and maintenance of POE devices.

Considering health benefits, POU and POE devices deliver biological filtration that removes bacteria and protozoa to EPA standards for drinking water. POU and POE devices deliver a variety of filtration capacities as discussed in Chapter IV, however most offer appropriate removals of all bacteria like Salmonella, E. coli, Vibrio cholerae and Salmonella typhi (which cause Cholera and Typhoid); and of all protozoa such as Giardia and Cryptosporidium. However, the devices do not remove viruses to EPA standards for drinking water, although these contaminants are not likely.

Drinking water that does not meet EPA guidelines for free residual chlorine has been linked to gastrointestinal illnesses causing diarrhea, stomach cramps, stomach pain, and a bloated stomach (Rose et al. 2001; MacKenzie et al. 1994). Because POU and POE devices remove coliforms to safe levels, their application could eliminate the potential gastrointestinal illnesses associated with water contamination as well as the practice of maintaining chlorine levels in storage tanks for homes not connected to a community water system. However, it remains a best practice to do so, as this also reduces the risk of algal growth in the storage tank. Algal growth adds stress to the POE systems which could reduce the longevity of the device and increase the risk of filter membrane fouling, a result that would subject household members to high risk for waterborn contaminants and illness. With this, homes without a community water service are likely to experience positive health benefits with installation of a POE unit to the home; however, they may be subject to risk of contamination due to membrane fouling. Homes that are connected to a community water service are likely to experience positive health benefits with utilization of a POU device.

Based on this analysis, we can assess how adoption of these devices can change household water security with two important assumptions: willingness to pay and complete trust in the technology (See Appendix B-11). For homes connected to a community water system, we can expect minimal improvement in water access, as implementation eliminates the need to purchase vended water for residents, but labor costs increase with operation and maintenance of the filter, and water is still not considered affordable for 92% of the households surveyed. We could expect marginal improvement in water quality acceptability for homes with a connection, as implementation eliminates the need to purchase vended water, and the device may improve physical water characteristics, but it will not improve taste, nor does it not eliminate the need to maintain and use *garrafones*. Finally, we could expect marginal improvement to water distress for these homes, as the devices may improve quality acceptability, but labor and monetary costs exacerbate strain on resources.

For homes with no service connection, we would expect a decrease in water access security, as the devices do not eliminate the need to procure water for the storage tank, labor costs will increase considerably with preparation, operation, and maintenance, and water is still not considered affordable for 89% of the households surveyed. We may expect marginal improvement in water quality acceptability, as implementation eliminates the need to purchase vended water, the device may improve physical water characteristics but will not improve taste, and it does not eliminate the need to maintain and use *garrafones*. Finally, we may expect no improvement to water distress for these homes. The devices may improve quality acceptability but labor and monetary costs exacerbate strain on resources.

In conclusion, adoption of these devices may provide marginal improvement, if any to household water security with minimal improvement to each of the three water security dimensions. Further, implementation of the devices in these homes may add new financial and labor burdens to families required to purchase and maintain their device.

Household Adoption

Considering the costs and benefits to devices with complete technological uptake by residents, we must consider the apparent barriers to adoption of the devices as well as the concerns for the sustainability of the technology. The initial cost of the device is considerable, especially including expenditures incurred to prepare a water storage tank for those communities without water. This is a major barrier for uptake by residents, as there is no mechanism in place to subsidize the cost of the devices for residents. Additionally, there is no mechanism for governance in place to monitor or provide support to families that are required to purchase and maintain their water filter unit. In order to prevent membrane fouling, a concerning health implication if not properly managed, filters must be used correctly, maintained properly, and infrastructure must be rid of algal growth to ensure longevity. This process in itself is costly in terms of time, labor, and money. Considering that 47% of residents worry about their water quality in their current situation, distrust of filtration technologies ability to provide safe water – enough to invoke a behavior change in the way that water is purchased- is not likely. Further, extensive community outreach (and cost to do so) would be required in these households in order to provide pertinent information and training to residents regarding the maintenance and operation of their water filter, and this pilot project is currently the only mechanism to do so (targeting ~30 households).

All things considered, the survey results depicting resident's responses to device implementation are discussed below. According to the survey, 19 (29%) of families surveyed indicated having prior experience with a water filter. Only 12 homes (18%) of the 66 homes surveyed indicated willingness to pay over $100 for a water filter. 23% of homes indicated willingness to pay between $10 and $100 for a filter for their home and 59% indicated that they would not be willing to pay for the device based on their understanding of the devices benefits. 29 households (44%) felt that the device could replace current practices to obtain drinking water and were willing to use it in their homes (Appendix B-12), leaving 66% of those surveyed unwilling to implement the technology in the home.

Conclusion

The results reveal a weakness of the technology as a solution to poor water service with marginal improvement to household water security as well as the poor likelihood of adoption by household residents. Findings suggest that the technological fix for the socio-environmental problem of acceptable drinking water might instead add more financial and labor burdens on already vulnerable populations. While ideal adoption will reduce water expenses for some households and may potentially deliver health benefits to users with reduction of bacteria and viruses, water will still not be affordable for 91% of the households surveyed (<2.5%/month) based on monthly savings the device would incur. Further, residents (who are among the poorest of Americans), will have the burden of the technology without training or technical support, as they would be solely responsible for installing and maintaining the filter for their home.

The rollout of these technologies shifts the costs of acceptable drinking water from community and collective efforts to low-income individual households. In sum, these results advance our understanding of the impacts of soft technologies on the everyday lives of many poor residents living in *colonias* along the US-Mexico border. In spite of these dubious benefits, one is left asking the question, "Why is the state investigating and investing $500,000 in a technological means to solve the socio-economic problem of water insecurity in *colonias* of the United States?" In fact, this amount of money could provide the cost to connect nearly 500 households to a community water system.

CHAPTER VI

FROM EMERGENCY TO FIX

Despite the dubious benefits and barriers to adoption of POU technologies in the household, I raise the question: Why is the state investigating and investing $500,000 in a technological means to solve the socio-economic problem of water insecurity? Part of the answer lies in the practices of the participants and institutions involved in the project: the partnerships, workshops, and discourses that brought the project to life. Thus, this chapter presents findings from qualitative interviews conducted with key actors and informants of the EPA-funded pilot project to document the process by which POU/POE technologies have been decontextualized from their role in disaster relief and repurposed as a technological "fix" to poor water services in the *colonias*. Key questions to ask include: What collaborations enabled POU technologies to gain the EPA's interest? What partnerships allowed for the identification of research objectives? What discourses were mobilized to legitimize POU/POE technologies as a de facto alternative to community water supply infrastructure in El Paso?

To answer these key questions I follow work at the intersection of political ecology and science and technology studies (STS), which advocates for an analysis of the combinations of techniques, actors, and institutions, which embody types of knowledge that proffer and institutionalize technologies (Furlong 2011, 2013). With this approach, I first introduce key actors and institutions engaged in the project. Second, I investigate the formation of translational and operational partnerships providing the institutional arrangements necessary for the circulation and application of knowledge and expertise in this context. Finally, I analyze the formation of discourse coalitions among key actors suggesting POU technologies as a techno-institutional fix for the present problem of water insecurity.

Key Participants in the Project

Most actors involved with the EPA-funded pilot project are actively engaged in the implementation of the project, others contributed to the early stages of proposal development but are no longer active participants, and yet another set of participants have never been engaged in the project but have been informed of its objectives by others and provided their perspectives and expectations of the process and its outcomes. Because all these groups' practices and discourses are discussed in the chapter that follows, I will introduce them in this section. Participants and informants are separated into university and agency-based scientists, federal and state regulatory agency staff, and private industry staff.

Scientists at universities, federal research agencies, and public health agencies make up a crucial sector of participants in the project. They are civil engineers, public health workers, environmental resource managers, and experts in sustainable development who work for the University of Texas at El Paso (UTEP), New Mexico State University (NMSU), the Center for Environmental Resource Management (CERM), and the Pan American Health Organization (PAHO). University scientists in civil engineering and public health sciences serve as the principal investigators for the project, where scientists affiliated with CERM and PAHO primarily served to support the university scientists in the proposal development process. In general, these actors are primarily responsible for the implementation of the project, where their practices and discourses are discussed in the subsequent section.

Federal regulatory agencies refer to those organizations charged with enforcing compliance with federal environmental legislation. The US Environmental Protection Agency (EPA) awarded 11 EPA STAR grants in 2011, totaling $5.5 million, to support treatment technologies for small drinking water systems. One such grant provided $498,906 to the university scientists. Agency staff actively involved in the project primarily includes the EPA Project Officer and Grant Officer, where EPA Region 6 agency staff continues to be informed of the projects progress and remain available to support university scientists in the implementation of the project if necessary. In general, these actors are primarily responsible for the financial support of the project and assure regulatory compliance of university scientists throughout the process. State regulatory agencies (e.g. Texas Commission of Environmental Quality and Texas Water Development Board) had not been engaged or informed of the project to the best of my knowledge.

Although private industry staff members are not currently engaged in any way with the project’s implementation or progress, the private industry played a key role preceding the university proposal. As mentioned in the introductory chapter, the Regional Director of the Swiss corporation Vestergaard Frandsen (VF) attended a university workshop in August 2011 to market his POU product to university scientists.

The practices and partnerships of university scientists, federal regulatory agency staff with VF played a role in determining which technologies were selected for study in the project and point to the broader interests of the EPA, which also will be discussed in the subsequent section.

Building Partnerships

Collaborations and partnerships between university staff, agency staff, and industry staff cultivated through meetings, workshops, and the university proposal process resulted in successful grant acquisition by UTEP and NMSU scientists to determine the feasibility of POU devices matched to communities needs and to promote adoption of the technologies within households. Examination of these partnerships demonstrates how social actors form networks across space to project influence in order to produce desired local techno-social and environmental relationships (Furlong 2011, 2013; Lave 2012b). By adding POU/POE filtration technologies to *colonia* waterscapes in the water delivery system, present and future socio-technical and environmental relationships are altered. In short, the way that knowledge claims and expertise is circulated enables their application, and must be understood in order to determine the forces that play a role in water governance shifts in the *colonias* through this project (e.g. Lave 2012b).

Based on my interviews with academics and agency staff members, there are two major partnerships that lead to UTEP and NMSU obtaining the EPA STARR grant: translational and operational. Here, translational partnerships are defined as two processes unfold. The first involves key actors defining or framing the problem and solution; and second, when actors seek alliances and construct networks. Where translational partnerships define a problem and construct networks, operational partnerships encompass key actors consolidating networks to define and execute operations within the partnership.

Public-Private Partnerships as Translational Partnerships

According to one EPA staff member, in May 2011 several first level EPA headquarters officials including the Director for Environmental Health, Director for Children's Health, as well as the Environmental Justice Advisor visited the *colonias* of El Paso in order to identify communities lacking basic services within the region. About the same time, EPA Administrator Lisa Jackson made a trip to Africa where a United Nations (UN) group demonstrated a development project where POU technologies produced by Vestergaard Frandsen were implemented in the local communities. Over 1 million individuals received LifeStraw Family® units between March and May 2011, where VF supplied filter units to 90 percent of the homes in Kenya's Western Province (Vestergaard 2013). EPA's visit to the El Paso *colonias*, coupled with Lisa Jackson's new relationship with the CEO of Vestergaard Frandsen resulted in a recommendation from the EPA Administrator for the Office of International Affairs and the Environmental Justice staff of the EPA to meet with the Regional Director of Vestergaard Frandsen in Washington, DC. One interview subject states,

> This group of private sector and for-business companies with the end-use technologies [POUs] saw the first-level EPA Headquarters report and saw that conditions that you usually see in developing countries or third-world situations are the conditions of some of these US communities known as colonias. In that case, through a recommendation of the Administrator of the EPA, they put [EPA Region 6] and [EPA Region 9] in contact with them.

Indeed, several meetings with stakeholders resulted in commitments where a group of scientific, technical, official and community members in the El Paso region would collaborate with the Regional Director of VF to institute POU technologies in the *colonias*. Interestingly, a listed achievement of the Regional Director of VF during his time with the company states that he “secured EPA registration and waiver to develop a US retail distribution channel for LifeStraw exceeding over $1 million in first year sales” (User Profile, Linkedin.com).

A major outcome of this commitment to collaborate was the presence of VFs Regional Director and EPA officials at a regional scientific research conference hosted by CERM in August of 2011. The regional conference (“BienESTAR”), attended by local stakeholders and university scientists, was intended to bring together multi-disciplinary experts in order to draft an operational research agenda of community-based participatory research in the *colonias*. During this conference the Regional Director of VF gave a presentation of the LifeStraw® technology, supported by a microbiologist who had conducted previous research with POU membrane filtration. However, the VF representative who attended the conference expected that the entire conference was centered on Lifestraw®, given the nature of his invitation. Several conference participants noted their confusion and the odd presence of this corporation at the conference, as well as local EPA staff members who seemed to support the presence of VF. One interview subject states,

> [The Regional Director of VF] had his own agenda, rightfully so, and came [to the conference] under false notions. He centered his talk around how we can implement a project that we know can be effective to some degree and with user acceptability and integrate it into these communities…If the objective of the (conference) is about a company coming in and saying 'here's a product that I have that can make a difference', then how can we (as scientists) conduct a study that could help behavior change, could promote behavior change and could assess community needs and identify certain communities that could benefit from it, etc..?

The odd presence of VF indicates the tension felt by university scientists as the ideas and notions carried by VF and the EPA's alliance was translated through this presentation.

Subsequent events and relationships bridge the gap between translational partnerships formed prior to the CERM conference and operational partnerships that formed as a result of conference attendance. Those operational partnerships ultimately led to the EPA funding a project employing POU technologies, including, but not limited to those of VF.

University Partnerships as Operational Partnerships

While at the conference, VF developed a relationship with a university scientist affiliated with UT Houston. She describes the result of those interactions: "So when I met [the Regional Director of VF] I thought, 'Oh! Here is a great opportunity for all of us; including UTEP and UT Houston, to work together on something'…I spent these two-hour power sessions coming up with a proposal to the EPA." This partnership continued for a year and a half with the understanding that the EPA was going to fund the project proposal generated at the CERM conference, and that all that is necessary on the part of the university is to "go through the motions" for the university proposal with a lawyer at EPA. Although this was unknown to the university researcher writing the proposal, funding for this proposal was soon removed due to a conversation that a PAHO staff member had with Lisa Jackson's secretary following the CERM conference. Through this conversation, the ethical implications of VFs relationship with the EPA was brought to the attention of the EPA, as the EPA was supporting and marketing a particular company's product at the CERM conference. Following this, VF's Regional Director continued to pursue other funding sources for several months following this fall out.

Although this operational partnership between actors at UT Houston, VF, and the EPA failed to acquire funding, a separate, but related research proposal resulted from the CERM conference. Civil engineers at UTEP and public health scientists at NMSU developed a proposal to study not only VFs POU devices for uses in the *colonias*, but a range of POU devices available on the market, or even to develop a new POU or POE system that could be better suited to their understanding of the community's needs. The principal investigator's idea to apply for EPA funding to research POU technologies was not solely a result of the CERM conference. He was motivated to study POU devices for use in the US, as he had previously volunteered with an international development project where POU devices were distributed to families to improve the health of low-income families in Ecuador. The CERM conference facilitated the formation of the alliance between civil engineers and public health scientists at NMSU, resulting in the integration of a behavioral component to the proposal. Hence, two public health scientists from NMSU were acquired as investigators on the project. The proposal was drafted primarily by a graduate student of the principal investigator where the research team gathered input and advice from local experts including PAHO, CERM, UTEP colleagues, and the EPA to inform the proposal process.

As a result of proposal submission, EPA granted UTEP and NMSU $498,906 for the pilot study to examine the feasibility and sustainability of POU water treatment technologies in selected *colonias* in El Paso County. The current EPA pilot project began in December 2011 and will continue through November 2014, when the EPA wants to demonstrate POU water treatment systems for rapidly mitigating unsanitary drinking water conditions in border communities. The EPA seemingly recognized the conflict of interest associated with direct collaborations between themselves and VF, but have persisted through an interesting loop hole where a range of POU devices are now being considered for implementation. A university scientist on the project commented on the situation,

> I agree that there is a fundamental problem with the federal government endorsing a particular product, but furthermore, in my mind, an inferior technology. There are other technologies that are more robust and our research has approached it from the perspective of 'let's look at this class of technologies and think about…which technologies seem more robust from a technological standpoint.' So I think our approach is a little different than the way the other conversation was happening.

The events described in the above section reveal the ways that knowledge and expertise was circulated in order for UTEP and NMSU scientists to gain funding to determine the feasibility of POU implementation and promote adoption of the technologies within *colonia* households. Public-private collaborations between VF and the EPA exemplify translational partnerships where social actors define and frame the problem/solution and construct networks (as demonstrated by EPA and VF's presence at the CERM conference). Following this, university collaborations represent operational partnerships where scientists consolidate networks and define the operations necessary to produce desired outcomes (acquire funding and further, implement technologies).

Making Neoliberal Discourse Coalitions

These translational and operational partnerships provide the social framework necessary for circulation and consolidation of certain discourses that contribute and bolster the intervention. Further, social actors in this framework coalesce around specific discourses which ideologically enabled actors to operate and materially apply these technologies. The following section analyzes the specific hegemonic discourse, adopting a theoretical approach advocated for by Maarten Hajer (1995). Hajer examines the constitutive role of discourse in environmental politics by allocating a central role to the discoursing subjects. He suggests that "social action originates in human agency of clever, creative human beings but in a context of social structures of various sorts that both enable and constrain their agency" (Hajer 1995, pg. 58). Coalitions between actors across various institutions develop and sustain a particular discourse, as actors attempt to secure support for their definition of reality as a basis of action. I draw on Hajer's insights to analyze findings from the qualitative interviews in terms of the way that discourse coalitions among key actors and informants develop and sustain a particular way of talking and thinking about POU technologies and their intervention. Further, in the discussion that follows I seek to link the discourse coalition to the broader, increasingly neoliberal political-economic forces in which it is embedded (e.g. Lave 2012c).

The following subsections discuss the results of this analysis, identifying the neoliberal philosophies embedded in the discourse coalition that yields overwhelming support and legitimizes the technological intervention. I discuss three major framings around which key actors coalesce: 1) scientific expertise and injustice; 2) rendering the solution technical; and 3) privatization as an ideal outcome of the study. Having distinctive affinities with neoliberal ideas, this coalition ultimately constitutes the application of POU technologies in the *colonias* through the EPA-funded project (Appendix A-6).

Expertise and Injustice

> The more I started looking into [the project], the more I realized that it's not only good for people, but it also provides a wide range of understanding on the filtration devices and on water treatment. So, it's an amazing project. (University Scientist, 2013)

Key actors involved in the project tend to describe their motivation for involvement as a natural extension of their ability to provide expertise to help those in the US that are not connected to a public water system. Most saw the institutionalization of the devices as a step forward in the process to provide an equitable privilege to access clean water. For example, one university scientist involved in the project describes,

> These people are in a bad situation, and the reality is that they probably won't be getting water anytime soon…I think it's just a natural fit that if I want to help people and I know how to use water – if you will – that the topic I understand the most is water – it's only natural that I want to help them through what I know the most, which is engineering-technology expertise.

With this framing, engineers, policy makers, and university professors frame water insecurity as a natural situation of the *colonias* that can be fixed with the application of technical expertise. Understanding water scarcity as a narrow physical problem of water quality diverts attention from the political and economic circumstances that produce water insecurity and frames the solution in predominantly technical terms that ‘naturally’ must be solved by experts (Linton 2010). For example, sentences often begin with, “Because of the technical expertise that we have…” One expert expressed, “There are still political issues, there are still economic issues, and maybe I can collaborate to help on those, but at least it should not be a technical challenge. We can solve the technical problems.”

Motivations to improve the lives of *colonias* residents are predicated by the understanding of the *colonias* as a third-world development space, where water access is an environmental injustice. The principal investigator explained that he had just returned from a trip to Ecuador “where people really appreciated the value [of the filters] and saw obvious, major health benefits associated with clean water, so I was really inspired to think that we could help people rapidly, locally.” This injustice is understood by actors as one that can be substantially mitigated with the use of POU technologies in the home. One scientist states, “I think that [our project] could substantially mitigate that environmental injustice.” In fact, the proposal title is, “Point of use water treatment systems for improving sustainability and *environmental justice* in Colonias of the Paso del Norte region” (emphasis added).

Most express their perception that the environmental injustice is due to the fact that numerous *colonias* residents were cheated into their deed agreements where they were promised basic services by developers, but that those services were never delivered. One subject states, “so the injustice there is that, yes, they were cheated badly." Another key actor mentioned that the project is already serving its purpose to combat environmental injustice as it helps to assure potable drinking water to US citizens that are in third world conditions. Another informant of the project states, "we see or acknowledge this obligation to help people in those communities…so, I think the EPA saw value in funding research on helping people who are in the US not connected to a public water system." In fact, with adoption of this technology, "they still are bearing an unfair burden, but at least they're bearing a burden and getting clean water – which they don't currently have."

This framing carries a highly individual notion of injustice, where the injustice is understood as an individualized problem with a solution oriented to the individual – a distinctly neoliberal ideology. Further, the ideologies expressed by actors in the above section inherently situate residents as 'victims' to individual injustices whose lives must and *can* be improved with appropriate technical expertise. One scientist expressed, "If only we could help the residents know what they need…" From this perspective, scientists legitimize their intervention and disqualify the feelings and experiences of the 'victim', creating a normative that he or she then must be educated by the expert.

Rendering Technical

> I think that not only in emergency situations, but in everyday life, the filter could really be a benefit in those contexts [*colonias*]. (Federal Agency Staff 2013)

Informants and key actors overwhelmingly agree that the project and the technologies have great potential for positive impacts on the lives of *colonia* residents. Characteristics that were often discussed in the interviews include water quality, capital costs and money savings, maintenance and labor requirements, and the health benefits and risks associated with use of the filter in the home.

The device's ability to improve drinking water quality in the household is a common discourse reproduced among experts. One actor suggests that the devices would presumably even produce better quality water than the water vending machines of which most *colonias* residents obtain their drinking water. Another notes, "…we know definitely, because of all of the already trials and lab analysis that when this water runs through the kits the water quality is of a condition that is definitely much better than the water that is usually used for drinking within these communities."

Another similar aspect of POU technologies that is reproduced and emphasized by experts is that they are 'cost-effective' due to low initial costs and high potential for monthly savings. Although a prevalent discourse, understandings of the exact initial cost and monthly savings vary greatly among interview participants and expose the disjuncture in the discursive framings and reality. Key actors believe the devices will cost residents as little as $10, when in reality, the cheapest device for consideration in the study is $60 on the current market. One actor states, "…this filter will cost no more than $30." One actor posits that with adoption of a POU device residents would, "…just spend $10 per month" and the devices could save one family "$140 to $150 per month." An engineer noted the devices could save a family, "…I want to believe in the hundreds of dollars." Based on my survey results residents would save between 35$ and 42$ (on average) per month with adoption of a POU/POE device.

Additionally, the technologies are referred to as 'low-tech' and labor costs are often minimized, erased, and uncalculated by key actors. For example, "The only maintenance you'll be providing on the system that we're designing is just replacing the cartridge filtration." In fact, the preparation time and labor required to prepare a water storage tank for installation of a filtration device was never mentioned by scientists engaged on the project.

When university scientists were asked of the technology's limitations, the only characteristic noted was the filter membrane's susceptibility to fouling, acknowledging the possibility that bacteria, viruses, and protozoa could form on the filter membrane, clog the filter, and re-contaminate the filtered water. For this reason, civil engineers have quickly devised a 'fix' by engineering multiple filtration process into the POE system to reduce the possibility of membrane fouling.

A key aspect of the technology's consideration owes to the standardized, easily transferable nature of POU devices capable of producing benefits rapidly. This discourse is heavily reproduced as actors often emphasize these characteristics as such. One mentions, "At least I want to help people have a rapidly deployable solution in the short term." Another states, "For the communities that don't have clean water right now, it's a rapidly deployable solution- so we could get these people-at least-clean drinking water in a manner of minutes." A federal agency staff member also offers, "[our priority] is more into a hands-on and immediate application within the communities."

In some cases, the inherent trust in the technology's ability to provide rapid benefits in the *colonias* owed to the actors anecdotal experience of device implementation abroad, producing positive effects in those communities. An agency staff member pointed out in our discussion, "In Africa this was already proven to improve water quality and health parameters." Another key informant mentioned, "Although it's very low-tech, it has been a big savior for a lot of those communities where there have been GI problems and additional infections and so forth that they [residents] haven't been able to deal with or treat in the past."

Actors draw on these positive anecdotes, which frame the technologies as 'blueprints' capable for application in new geographic spaces. As discourses of a cost-effective, standardized, low-tech, and rapidly deployable technological fix permeate across institutional networks, the technological intervention is effectively constructed as *legitimate* and even *ethical*. With *colonias* residents as 'victims' in need of technical assistance, a cheap and mobile quick-fix can be framed as characteristically logical as an intervention. Where solutions are effective and efficient elsewhere, experts employ what Jasanoff (2003) terms 'technologies of hubris' that ignore the possibility of unforeseen consequences in the intervention and diminish the necessity of direct, contextual experience to inform decisions.

Privatization

Acceptance is the output that we want. (Federal Agency Staff, 2013)

Actors are also united in discourse around privatization as an appropriate mechanism for residents to obtain filtration devices for water provision in the household. Scholars identify two main objectives of the study: 1) to identify which particular filter technology (or technologies) is the most useful for providing clean water to *colonias* residents; and 2) understand the perceptions of residents towards the filters in order for acceptance and dissemination to occur. The principal investigator on the project articulates,

> I think we have a good role to play in terms of just helping sort through what technologies are available and help inform the homeowners to be able to make a good decision on what they [the residents] need.

An integral component of the study outcome includes the dissemination of knowledge and uptake throughout the *colonias* as a result of the study. One actor provides, "…and the last part is, 'would you recommend this to a friend or family member in this type of situation?' Those types of acceptability questions, I think are important for the social sustainability aspect of this project." Further, he documents,

> I would hope that the pilot studies that we do with individual families would be examples in those communities of treatment systems that can work and the people in those communities by word of mouth and relationships would figure out ways to leverage resources to replicate those in other peoples households so that there would be a diffusion – not just of this technology – but of this concept, this awareness of their ability to *take care of themselves with water*.

If acceptance and diffusion of knowledge throughout *colonia* communities is achieved through this intervention, residents would be required to purchase a filter unit for their home from a local hardware store. One scientist articulates, “Ideally, we would be able to provide people with water in a privatized industry.”

Because there is no funding mechanism in place to provide for the capital costs of the devices, and local water utilities are unwilling to accept responsibility for the installation and maintenance of the filter under the SDWA, the EPA’s investment in this pilot project remains to be the extent of the state’s efforts to provide water to families that are not connected to a community water service. This makes the outcomes of adoption and dissemination within the communities substantially more important for shifts in who is responsible for the provision of acceptable drinking water in the *colonias*.

Key actors and informants of the project discuss their perception on this in the interviews, illuminating neoliberal notions of individual responsibility. With adoption of POU devices, residents would be required to play major roles in providing water for their households by purchasing, installing, operating, and maintaining their filtration devices in the home (a responsibility that no household bears when connected to a community water system). Federal agency staff notes that the initial capital cost for the device is important because it creates a sense of ownership and invokes responsible maintenance by the homeowner:

> So at the moment EPA cannot fund devices: The strategy from the beginning is that that should not be the path because as soon as this

> particular type of straw from the company – they say that so many millions of gallons, etc… so by the time that this ends they expect so many months or gallons 'come and replace it'- that's not a part of it! It is important that there is a cost, and I put it this way – it is very important that [they] embrace the project as something that is saving them money, not that is costing them money. It's not costing them 18 or 25 dollars; it is an initiative that is saving them money. And EPA is not going to come to save them money; the EPA is coming here so that YOU save money. And I think that should be the approach because otherwise they expect that after this, so many hours or days or gallons, then EPA must replace it and that's not going to help.

Even further, he states that by engaging residents from the beginning of the process, i.e. focus groups, residents will not only be recipients of a device and told what to do, but also will be made to feel that they have been a part of the research process, "you know – top down, but *actually* bottom-up."

In light of this, experts produce discourse around the importance of the educational component of the intervention, "Once they know [about the technologies benefits], I imagine that they can leverage relationships and resources that they have available to purchase those and maintain them and replace them...if they just know what they need." Further, "I want to at least help people take care of themselves, even as an interim solution." In this framework POU adoption is predicated by highly individualistic neoliberal ideologies of privatization, demanding that residents assume responsibility for providing the household with acceptable drinking water. Further, scientists understand that residents are resourceful and therefore *capable* and *willing* to do assume such responsibilities. This is then compounded by the willful ignorance of the difficulties of poverty that *colonias* residents face.

Participants also discuss, however, the possibility of these devices becoming a permanent solution where the devices are instituted for regulatory compliance and managed by a utility, “So, really we are a feasibility study. And in a way, if we can prove that it is possible, the EPA or even EPWU could even potentially be providing people with this water in a way that is actually manageable and cost-effective for the utility company.” Yet, one university scientist actively engaged on the project describes his understanding for why a water utility may be uninterested in using POU devices for regulatory compliance: “The initial ones [POU devices] provide a great level of satisfaction, but then you realize that you have to keep on paying, keep repairing, keep maintaining them and that’s when you start to say, ‘well, can we pull the plug on this?’” Ironically, there is a widely held perception that these monetary and labor costs are feasible for *colonia* residents to incur- an assumption that is widely off the mark with reality.

Conclusion

In this chapter I discussed the results of qualitative interviews in order to determine the process by which POU/POE technologies have been decontextualized from their role in disaster relief and repurposed as a technological “fix” to poor water services in the *colonias*. Taking a critical stance on the efforts of experts, I investigated the discourses of key actors and informants in order to expose the limits of expert knowledge by highlighting the gap between neoliberal discourses and *colonias* realities.

A series of translational and operational partnerships between private industry, federal agency staff, and university scientists have enabled POU/POE technologies to be considered, through the EPA-funded project, as the de facto alternative to community water supply infrastructure in El Paso. Beginning with EPAs relationship with the CEO of VF, this partnership translated their interest to rapidly mitigate unsanitary drinking water conditions in the *colonias* using POU technologies to university scientists at a university research conference. As a result of this conference, partnerships between the EPA and university scientists operationalized this desired outcome.

Actors within translational and operational partnerships secure overwhelming support for the application of POU technologies in the *colonias* through the formation of discourse coalitions constructed around their scientific expertise, benefits of the technologies, and privatization a mechanism for water provision. United in the ideology of the *colonias* as a third-world development space populated with victims to the environmental injustice of water insecurity, actors fill a 'naturalized' role as experts with a rapidly deployable, decentralized technical solution. Within this framework, expert's understanding of water insecurity ceases to be a matter of lived experience, but is a matter of providing specific qualities of water to the individual by technical means. In rendering the problem technical, actors effectively sideline the politics of connecting *colonias* residents to a community water system.

I return to the initial question raised at the beginning of the chapter: Why is the state investigating technological means as a solution to the socio-economic problem of water insecurity in the United States? I argue that the reason is the material and discursive contradictions of social actors legitimizing the application of low-cost, quick fix water filtration technologies. Analysis of this case allows me to substantiate the conditions and processes that permit authority to be constructed and legitimize technological means, particularly soft-path technologies, as a solution to the socio-economic problem of water insecurity in the United States.

CHAPTER VII

CONCLUSION

Using theoretical insights from science and technology studies and political ecology this research builds a case study that explores the intricate politics at the intersection of technology, water privatization, water governance, and the role of water technologies in reshaping the lives of its users. Results of the analysis identify the role of soft-path water technologies on socio-technical change in low-income rural settlements of El Paso, Texas, where individual users are purposefully enrolled in the management of water provision through shifts in governance from community efforts to the individual household. This research empirically substantiates theoretical scholarship that recognizes the processes through which these configurations become produced in the way POU water technologies are defined, managed, and for whose benefit.

I first reviewed the development of POU devices in order to contextualize how the technologies fit within a neoliberal political-economy. Second, I conducted a household water security assessment as a means to analyze how POU/POE technologies may improve water security in individual households. Finally, I investigated the discourses of key actors and informants in order to highlight the gap between neoliberal discursive framings and *colonias* realities.

As I have described in the preceding chapters, the neoliberal political-economic context of POU technologies plays a key role in their institutionalization process domestically, as it influences the range of technologies available for application, mechanisms of capitalization, and their social construction. The household water security assessment allowed me to assess the impacts of soft technologies on the everyday lives of *colonias* residents along the US-Mexico border, if taken at full face value. Results of the assessment reveal a weakness of the technology as a solution to poor water service with marginal improvement to household water security as well as the poor likelihood of adoption by household residents. Findings suggest that household adoption of POU/POE technologies will likely add more financial and labor burdens on already vulnerable populations. Analysis of qualitative interviews of key actors engaged on the project identified the partnerships and discourse coalitions which legitimize the application of low-cost, quick-fix water filtration technologies in the *colonias*.

In sum, I argue that the driver of this governance shift is the formation of the neoliberal discourse coalition which mobilizes and constructs soft-technologies as a solution to water insecurity, thus resulting in EPAs support of an epistemic community of technical and behavioral experts determined to disseminate the technologies in the US. As POU technologies are rolled-out in *colonias,* this short-sighted fix re-enrolls residents in mediating water-society relations and provides a technical mechanism for the state to evade responsibility for lack of basic services. This process generates socio-hydrological conditions that are inequitable, where individual households are forced to bear the burden of water service provision and management. What remains to be seen are the consequences of this shift for water governance in low-income settings in the US and the lives of the residents who are subject to it.

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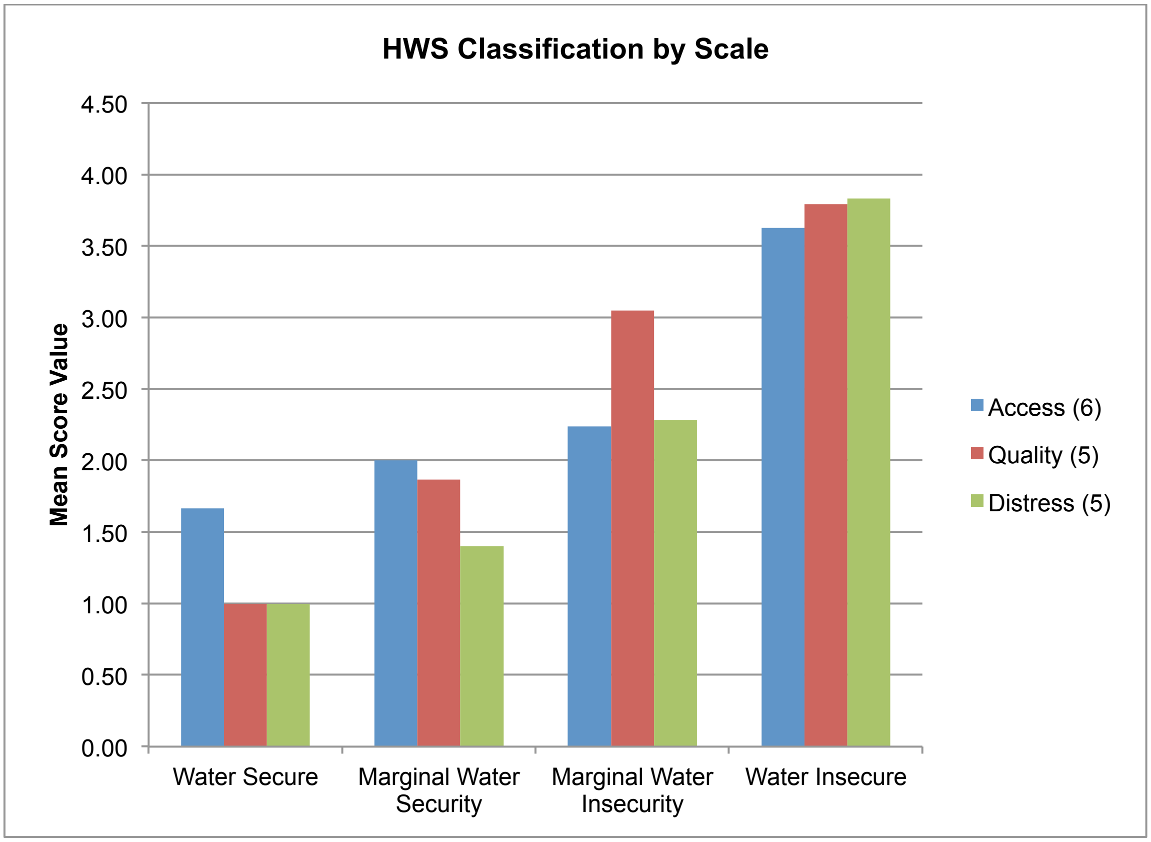
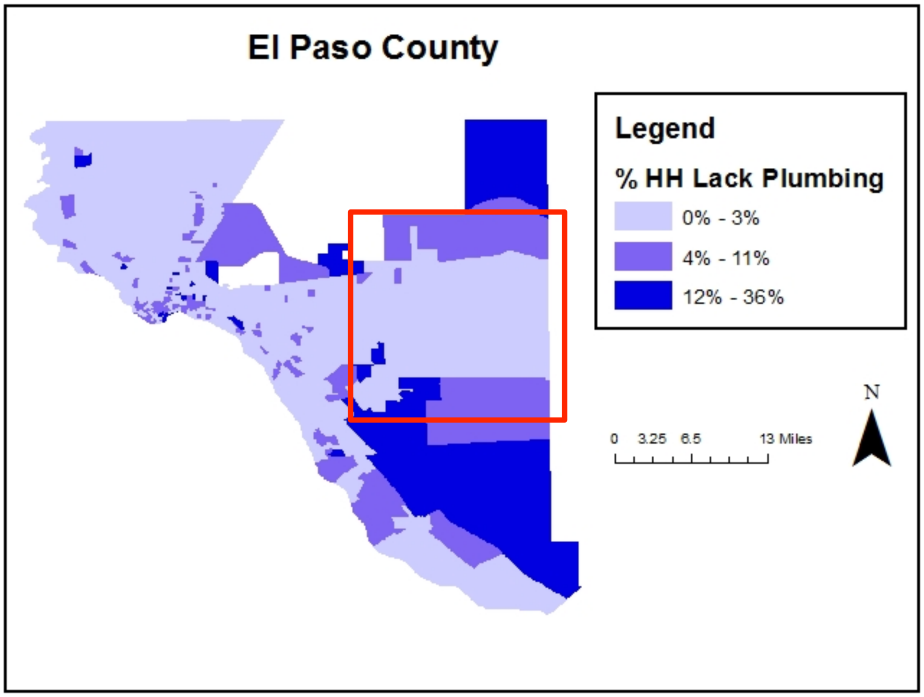
APPENDIX A

FIGURES

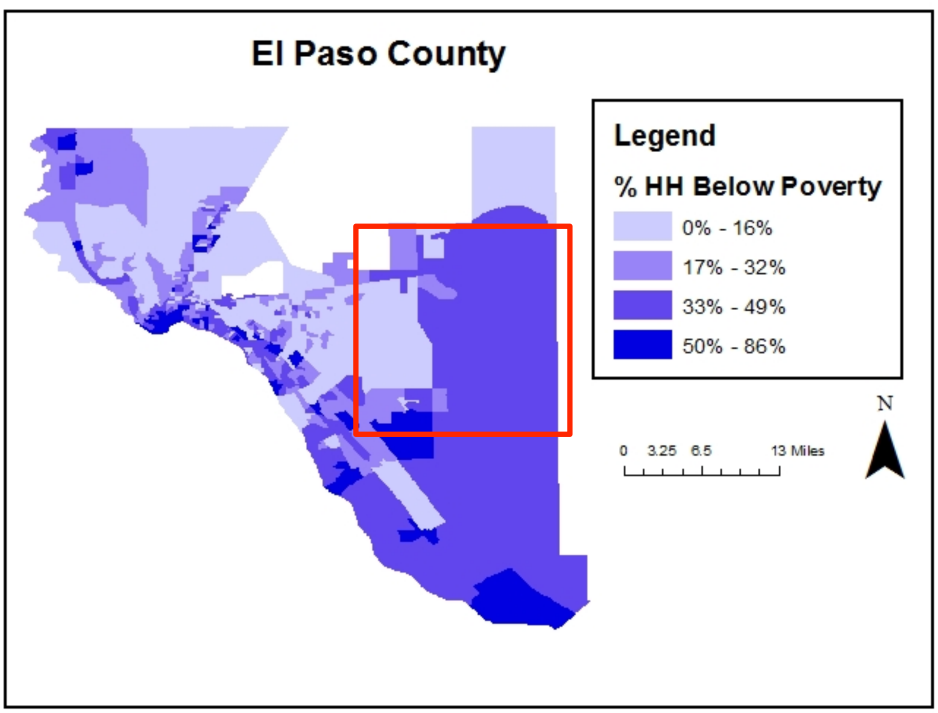
A-1: Mean Score Value by HWS Classification



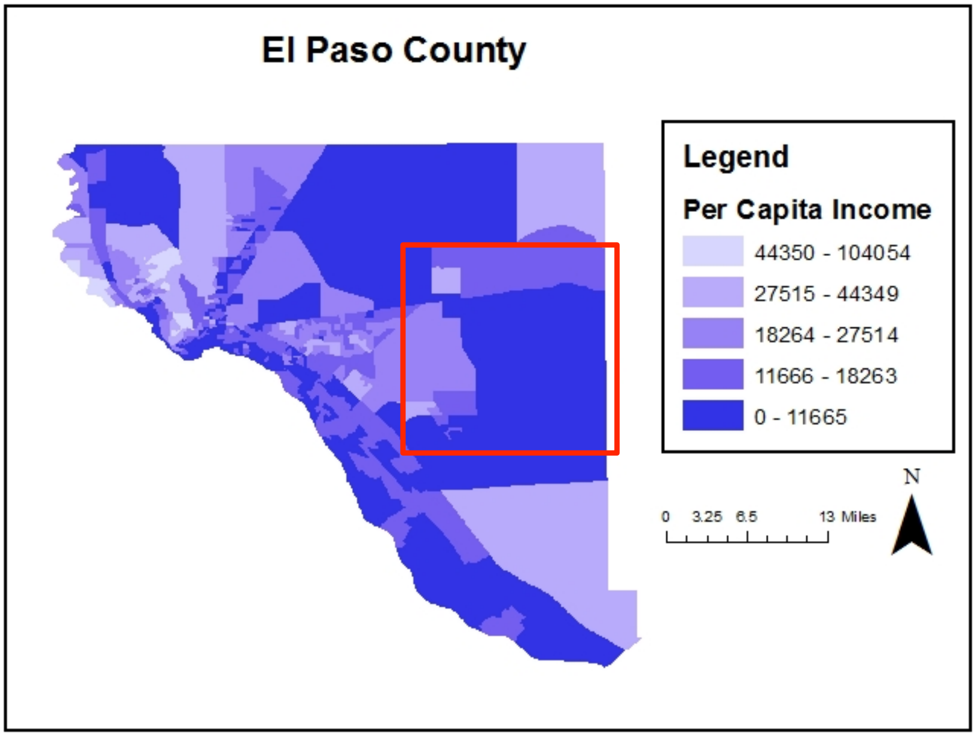
A-2: Plumbing Facilities: %HH Lacking Complete Plumbing Facilities



A-3: Poverty Status: %HH Income in Past 12 Months below Poverty Level



A-4: Per Capita Income in Past 12 Months (Dollars)



A-5: POU Images

Biosand Filter (Physical Treatment)  http://upload.wikimedia.org/wikipedia/commons/thumb/b/b9/Biosand_Filters_in_Guatemala.JPG/220px-Biosand_Filters_in_Guatemala.JPG	**Ceramic Filter (Pressure-Driven Microfiltration)**  http://www.practica.org/wp-content/uploads/filtron.jpg
Chlorination Tablets (Chemical Treatment)  http://armyissue.com/catalog/images/IMG_5618.JPG	**FilterPen & LifeStraw Personal (Microfiltration)**  http://www.filtrix.com/Resources/Images/725.jpg http://www.ippinka.com/wp-content/uploads/2012/09/lifestraw-7.jpeg
Watercone (Light-based Treatment)  http://www.watercone.com/1600/work1600.jpg	**LifeStraw Family (Ultrafiltration)**  http://media.treehugger.com/assets/images/2011/10/lifestraw-family-system-water-filter-photo.jpg
Hydration Bag (Forward Osmosis)  http://www.storeitfoods.com/files/1730690/uploaded.jpg	

A-6: Process of Circulation and Application

APPENDIX B

TABLES

B-1: Colonia Classifications by Color

Degree of health risk	**Color Classification**	**Criteria**
High health risk	Red (North Fabens, Hillcrest, Panorama Village, Huego Mountain, Camel Back, Buena Suerte, Dairyland)	At least one of the following factors applies: 1) Either all or some of the lots have inadequate wastewater disposal 2) All lots do not have a potable water supply 3) Not platted
Medium health risk	Yellow (Agua Dulce, Montana Vista, Sparks Addition, Paso View)	Platted colonias with a potable water supply and adequate wastewater disposal, and at least one of the following factors: 1) Either all or some of the lots lack solid waste disposal, i.e. trash disposal 2) Not all roads are paved 3) Not all roads are passable in all weather conditions 4) It floods during a precipitation event
Low health risk	Green (East Wind, Desert Meadows, Mission Trail)	All of the following factors apply to all of the lots: 1) Platted 2) Have a potable water supply 3) Have adequate wastewater disposal 4) Have solid waste disposal 5) All roads are paved 6) All roads are passable in all weather conditions 7) Lot does not flood during precipitation event

(2005 State of Texas Senate Bill 827)

B-2: Interview Subject Affiliations

University Scientists	University of Texas at El Paso Texas A&M University Colonias Program
Federal Agency Staff	Environmental Protection Agency Texas Secretary of State
Public Health Agency Staff	Pan American Health Organization

B-3: Idealized Water Scales

Idealized Water Scales			
Idealized Guttman Scale for Water Access	**%HH**	**Definition**	**Score**
shares water meter with others or given water	27%	1 - Adequate Water Access	0
problems with transportation to buy water or pay bill (no gas money; no car)	30%	2 - Marginal Water Access	1 to 3
physical burden to buy water at vending point/haul water	33%	3 - Low Water Access	4 to 5
lacked money to pay for water/missed bill	35%	4 - Very Low Water Access	6 to 7
physical burden to clean garrafones/tank	56%		
conserves water to reduce bill or reallocation of resources to pay for water	74%		
not affordable (more than 2.5% cash income)	91%		
Idealized Guttman Scale for Water Quality Acceptability	**%HH**	**Definition**	**Score**
garrafones older than 6 months/inadequate	24%	1 - Acceptable Water Quality	0
do not disinfect garrafones/tank after each use	36%	2 - Marginal Water Quality Acceptability	1
tap/tank water is visually unclean (dirty; cloudy; floaters)	42%	3 - Low Water Quality Acceptability	2 to 3
tap or trucked water has unpalatable (chlorine; soil; metallic; salty) taste or smell	71%	4 - Very Low Water Quality Acceptability	4 to 5
more than 50% drinking water from bottles or water vending machines	76%		
Idealized Guttman Scale for Water Distress	**%HH**	**Definition**	**Score**
asustarse/miedo (frighten or scared)	42%	1 - Low Water Distress	0
discutir; hacer commentario (argued about water; made negative comments)	45%	2 - Marginal Water Distress	1 to 2
mortificar/feo (disgusted)	47%	3 - High Water Distress	3 to 5
preocuparse (worried)	47%	4 - Very High Water Distress	6
inquietar (troubled or uneasy)	53%		
disatisfecho (dissatisfied)	58%		

B-4: Reliability Measures

Measurements of Reliability			
	Water Access	Water Quality Acceptability	Water Distress
Coefficient of Reproducibility	0.94	0.95	0.91
Minimum Marginal Reproducibility	0.50	0.50	0.49
Coefficient of Scalability	0.87	0.90	0.83

B-5: Non-Membrane-Based Technologies

Summary of key characteristics of non-membrane-based POU water technologies

	Type	Filtration method	Production rate	Cost (US$)	Performance	Diarrheal disease reduction estimate (95% CI)
Physical Treatment	Biosand filtration (BSF)	Crushed granite, gravel or sand	0.25-1 L/min	25-100$/ Unit	0.3-4 LRV bacteria; 3.8-5 LRV protozoa; 0-1.3 LRV viruses; 96% turbidity removal	47% (21%-64%)
	Stuctured Matrix					
Chemical Treatment	Chlorination (tablets)	dispense tablet to water, mix briefly	1 tablet/20 L	$0.01-0.001/ L	1-2.8 LRV bacteria; 3 LRV protozoa; 3LRV viruses	29% (25%-48%)
	Chlorination (liquid)	dispense liquid to water, mix briefly	5-10mL/20 L	1$/1000 L	1-2.8 LRV bacteria; 3 LRV protozoa; 3LRV viruses	29% (25%-48%)
	Combined coagulant-disinfectant powder	dispense sachet to water, sir, sit for 30 mins	1 sachet/ 10 L	$0.003->0.01/ L	4-8 LRV bacteria; >2.5 LRV protozoa; 1-4 LRV viruses	29% (18%-42%)
Thermal/Light-based Treatment	Thermal pasteurization	Chulli & aluminum coil; lorena-stove	0.5-2 L/min	6$/ Unit	4- > 5 LRV bacteria	n/a
	SODIS	PET bottles	varies	none if available locally	3-5.5 LRV bacteria; 1-3 LRV protozoa; 2-4 LRV viruses	31% (26%-37%)
	Solar distillation	poly(vinyl chloride) pyramidal or prism still	0.5-0.9 L/d	$0.046-0.063/L	> 3 LRV bacteria; distillate <3NTU; removes non-volatile contaminatns and radionuclides	n/a

(Islam and Johnston 2006; Sobsey, Stauber et al. 2008; Wassouf, Peska et al. 2011; Loo, Fane et al. 2012).

B-6: Membrane-Based Technologies

Summary of key characteristics of membrane-based POU water technologies

	Type	Filtration method	Production rate	Cost (US$)	Performance	Diarrheal disease reduction estimate (95% CI)
Pressure-Driven	Ceramic filter	microfiltration through pores	0.04-0.3 L/min	8-10/unit; 4-5/unit of filter replaced	2 - >4 LRV bacteria; 2-6 LRV protozoa; 1-2.3 LRV viruses	46% (29%-59%)
Pressure-Driven	Katadyn Mini Ceramic	0.2µm ceramic Ag-impregnated	0.5 L/min	250-600/unit	1.7-4.9 LRV of bacteria	n/a
Pressure-Driven	FilterPen	0.15µm micromembrane	0.1 L/min	21/unit	6 LRV of bacteria	n/a
Pressure-Driven	LifeStraw Personal	0.2µm	0.1 L/min	20/unit	> 6 LRV bacteria; 2-4 LRV viruses	little to none
Pressure-Driven	Reverse Osmosis	RO spiral-wound membrane module	~ 4 L/min	200-700/unit	permeate < 100 mg/L TDS	n/a
Pressure-Driven	SawyerSaves	UF membrane technology .02µm	2.6-5.3 gal/hr	0.04/35 L	6 LRV bacteria; 3 LRV protozoan; 4 LRV viruses	n/a
Pressure-Driven	LifeStraw Family	UF hollow fiber membrane of 20nm	8.6-12 L/h	0.001/L	6-7 LRV bacteria; 3.6 LRV protozoa; 2-4.7 LRV viruses	15%
Osmotically-Driven	hydration bags	FO membrane; draw solute: mixture minerals and sugar	1.6 L/d	~4/L; 64/ unit	6 LRV bacteria; 3 LRV protozoan; 4 LRV viruses	n/a

(WHO 2005; LifeStraw 2008; Sobsey, Stauber et al. 2008; Peter-Varbanets, Zurbrugg et al. 2009; HTI 2010; Katadyn 2012; Loo, Fane et al. 2012; Pentair 2012; Sawyer 2012)

B-7: Major Corporations

Summary of key characteristics of major corporations

Technology	Technology Name	Company Name	Location of HQ	Year Established	Patented (Y/N)
	Biosand Filter	Pure Filtered Water Ltd.	Calgary, Canada	1999	Yes
Biosand Filter	Hydraid	Triple Quest, LLC: Cascade Engineering and The Windquest Group	Grand Rapids, Michigan	2006	Yes
Chlorination (tablets)	Aquatabs	Medentech Ltd.	Wexford, Ireland	1984	Yes
	Jet Chemicals Ltd.	WaterGuard	Nyanza, Kenya	2003	Yes
Chlorination (liquid)	Gadyen Dlo	Dlo Social Enterprises (DSI)	Leogane, Haiti	2002	No
	PuR	Procter and Gamble	Cincinnati, OH	2004	Yes
Combined Coagulant-disinfectant powder	WaterMaker	Control Chemicals Ltd.	Alexandria, VA	1996	Yes
	Chulli Purifier	Wagtech International Ltd	Tyne and Wear, UK	2004	Yes
Thermal pasteurization	WADIS	Aprovecho (NGO)	Cottage Grove, OR	1976	Yes
SODIS	SODIS	The SODIS Foundation (NGO)	Cochabamba Bolivia	1990	No
Solar distillation stills	Watercone	MAGE Water Management	Odelzhausen, Germany	2008	Yes
	"Rabbit" Flower Pot	Potters for Peace (NGO)	Bisbee, Arizona	1998	No
	Candle Filter	Oxfam GB (NGO)	Oxford, UK	1942	No
Ceramic Filter	Tulip	Basic Water Needs India Pvt Ltd.	Tamil Nadu, India	2008	Yes
	Katadyn Mini Ceramic	Katadyn Products Inc.	Kemptthal-Zurich, Switzerland	1930s	Yes
Microfiltration	FilterPen	Pentair Ltd	Minneapolis, MN	1966	Yes
	LifeStraw Personal Lifestraw Family	Vestergaard Frandsen	Lausanne, Switzerland	1990s	Yes
Ultrafiltration	Sawyer PointONE Sawyer Point Zero Two	Sawyer Products	Safety Harbor, FL	1984	Yes
Forward Osmosis	Hydration Bag	Hydration Technology Innovations	Albany, OR	1986	Yes

(LifeStraw 2008; Watercone 2008; HTI 2010; Tulip 2010; CDC 2012; CDC 2012; CDC 2012; CDC 2012; Sawyer 2012)

B-8: Water Expenses

	Total Spring Expenses	% Spring Income	Total Fall Expenses	% Fall Income	% HH Unaffordable	>50% DW Purified	Purified Exp. Spring	Purified Exp. Fall
CWS (N=48)								
Average	$78	13	$65	11	88%	66%	$27	$23
Min	$15	1	$15	1			$0	$0
Max	$248	56	$182	47			$135	$135
No Service (N=18)								
	Total Spring Expenses	% Spring Income	Total Fall Expenses	% Fall Income	% HH Unaffordable	>50% DW Purified	Purified Expenses Spring	Purified Expenses Fall
Average	$144	18	$127	16	100%	100%	$42	$35
Min	$46	3	$46	3			$8	$8
Max	$324	77	$284	72			$132	$92

B-9: Mean Scale Score Values

	Access (6)	Quality (5)	Distress (5)
Water Secure	1.67	1.00	1.00
Marginal Water Security	2.00	1.87	1.40
Marginal Water Insecurity	2.24	3.05	2.29
Water Insecure	3.63	3.79	3.83

B-10: Socio-Economic Info by HWS Classification

Household water security class	HH Demographics				Income				Federal Poverty Level		
	Total HH	%HH	Avg. #/HH	Total pop.	Avg. HH cash inc./mo. ($)	Fall Water cost (% cash inc.)	Spring Water cost (% cash inc.)	Per capita inc. ($)	Above	100% and 50%	49% and below
Water Secure	6	9	4.16	25	1806	3.64	4.24	594	1	4	1
Marginally Water Secure	15	23	3.23	47	1141	13.01	15.11	642	2	5	6
Marginally Water Insecure	21	32	3.57	75	1078	11	12.82	362	1	11	8
Water Insecure	24	36	3.46	83	1145	14.85	17.26	455	6	7	10
TOTAL	66			230					10	27	25

B-11: Water Security Impacts (assuming full acceptance and correct usage)

	CWS	No Service
Water Access	minimal improvement	decrease
Water Quality Acceptability	marginal improvement	marginal improvement
Water Distress	marginal improvement	no change
Overall HWS	marginal improvement	no change

B-12: Resident Responses

Filter Adoption	N=48		N=18			N=66		
	#HH CWS	**%HH CWS**	**#HH No Service**	**%HH No Service**	**% HH All Surveys**	**Above FPL**	**100% and 50%**	**Below 50%**
Has prior experience with filter	12	25%	7	39%	29%			
Willing to pay > $100	6	13%	6	33%	18%	3	9	2
Willing to pay $10 - $100	12	25%	3	17%	23%	1	4	10
Willing to pay $0	30	63%	9	50%	59%	6	14	13
Could replace current practices to obtain drinking water	19	40%	10	56%	44%			

APPENDIX C

ACTOR INTERVIEWS

C-1: Interview Question List

Can you describe your role in the implementation of the POU water filtration project?

Can you describe the motivation for your involvement in the project or how you were engaged as an actor?

Based on your knowledge of POU and POE technologies, what do you believe are the strengths and weaknesses of POU devices? Can you compare with that of POE?

What is your view on Point-of-Use water filtration technology's ability to provide potable drinking water in these communities? On its ability to reduce time/cost/work if it were to replace current drinking water practices in the household?

Can you explain your thoughts on the project's contribution to serving an environmental injustice? What IS the injustice you perceive? And how does this particular technology speak to the need?

Do you feel that this solution is temporary or permanent for these *colonia* residents? Why? Is there tension regarding the WAY you talk about the project's intentions?

What do you regard as the *cause* for the lack of infrastructure in the colonias?

Given that the EPA/ TCEQ are hesitant to endorse and regulate POU technologies for permanent use in the home, what do you feel is EPA's motivation for funding the UTEP pilot study?

How do you feel that this project fits into the broader context of public-private partnerships in the provision of drinking water in the household for low-income areas?

What is your view of an ideal outcome of the study?

Were you in attendance of the CERM meeting conducted in August 2011? If so, what was your perception and understanding of the meetings intentions?

What do you feel are the day to day implications for families adopting the use of this technology?

What was your interaction with government officials, if any, regarding this project?

What do you hope to gain from the results of the project?

Are you confident that these technologies can provide positive health impacts for residents engaging them?

APPENDIX D

HOUSEHOLD SURVEYS

D-1: Survey Information Sheet (English) for Institutional Review Board Compliance

INFORMATION SHEET
Household water security in El Paso Texas colonias

Introduction
The purpose of this form is to provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research. You have been asked to participate in a research study that aims to examine household water security, which is defined as adequate, reliable, and affordable water and sanitation for a healthy life, and its variability among low-income Mexican-American communities in El Paso and Dona Ana County, Texas. This research will describe the meaning and experience of household water insecurity and understand the dynamics of variability among low-income populations through household case studies. You were selected to be a possible participant because you live in a colonia selected for this study. Approximately 60 people will be taking part in this study. The survey may take 50 to 60 minutes of your time.

What will I be asked to do? This is a survey focusing on the meaning and experience of household water use in the colonias as well as the perceptions of water security technologies. If you agree to participate in this study, you will be asked background demographic and socio-economic information and a series of questions about water use in the household. The questions will be about water access (quality and quantity) and behaviors and attitudes about drinking water and water technologies for household activities.

What are the risks involved in this study? The risks associated with this study are minimal, and are not greater than risks ordinarily encountered in daily life.

What are the possible benefits of this study? You will receive no direct benefit from participating in this study; however, the expected research results may advance current knowledge about water access and security and provide scientifically informed policy recommendations to improve the situation of your community.

Do I have to participate? No. Your participation is **voluntary**. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University being affected.

Who will know about my participation in this research study? This study is confidential. The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only research assistants with Texas A&M University will have access to the records.

Whom do I contact with questions about the research? If you have questions regarding this study, you may contact Dr. Wendy Jepson (979-458-2224).

Whom do I contact about my rights as a research participant? This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at (979)458-4067 or irb@tamu.edu.

Participation. Please be sure you have read the above information, asked questions and received answers to your satisfaction.

D-2: Survey Information Sheet (Spanish) for Institutional Review Board Compliance

Informe sobre la investigación
La seguridad domicilar del agua en las colonias de El Paso Texas

Introducción. El propósito de este formulario es dar a Ud. (como un participante posible en esta investigación) la información necesaria que puede afectar su decisión de participar o no en esta investigación. Su participación ha sido solicitada para una investigación que pretende entender la seguridad del agua, que defínese como el agua adequada, fijable e asequible, y saneamiento para una vida saludable, y su variabilidad entre las comunidades mexicanas-americanas en El Paso y Dona Ana County Texas. Esta investigación espera describir el significado y la experiencia de la seguridad del agua, y entender las dinámicas de su variabilidad entre las populaciones de bajos ingresos por medio de estudios de casos de domicilios. Se lo escogió a Ud. como un participante posible por que Ud. vive en una colonia que fue escojida al azar para esta investigación. Participarán aproximadamente 60 personas en las *colonia*s. Su participación durará aproximadamente de 50 a 60 minutos.

Qué voy a hacer? Esta investigación es etnográfica, quiere decir, tiene como enfoque el significado y la experiencia del uso del agua de su domicilio. Se Ud. decide participar en esta investigación, voy a preguntarle sobre información demográfico y sócio-eonomico, y perguntas sobre el agua. Los preguntas se enfoque sobre aceso al agua (la calidad y la cantidad) y comportamientos y actitudes sobre el agua potable y no potable para las actividades de su domicilio así como las ideas de agua tecnologías de seguridad.

Cuáles son los riesgos de participación? Los riesgos asociados con esta investigación son minimas, y no más que los riesgos de su vida normal.

Cuáles son los beneficios posibles de esta investigación? Ud. no receberá benefícios directos de su participación; sin embargo, esperáse que los resultados de la investigación puedan avanzar el conocimiento actual del aceso al agua y de la seguridad del agua, ayudando el desarrollo de las políticas que puedan mejorar la situación de su comunidad.

Es necesario participar? No, su participación es voluntaria. Ud. puede decidir no participar, o salir de la investigación quando quiera sin que sus relaciones, actuales o futuros, con la Texas A&M University sean afectadas.

Quien va a saber sobre mi participación en esta investigación? Esta investigación es completamente confidencial. Los archivos de la investigación se mantienen privados. No se incluye cualquier indentificación personal en informes que serán publicados. Los archivos serán mantidos con seguridad y solamente asistentes de investigación de Texas A&M University tendrán aceso.

A quien puedo contactar si tengo preguntas sobre la investigación? Si Ud. tiene preguntas, puede contactar Dra. Wendy Jepson (979-458-2224).

A quien puedo contactar sobre mis derechos como participante en esta investigación? Esta investigación ha sido aprovado por el programa de Protección de Sujetos Humanos y/o el Consejo Institucional de Texas A&M University. En caso que tengas problemas con la investigación, o sus derechos como participante, Ud. puede contactarles en el telefono (979) 458-4067 o irb@tamu.edu.

Participación. Tenga la seguridad de leer la información arriba, de preguntar y de receber respuestas adequadas. Podemos empezar cuando Ud. queira.