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Assessment Of Point Of Use (POU) Systems For Reducing Health Risks Associated With Drinking Water Along The U.S.-Mexico Colonias In The Paso Del Norte Region

Varinia Viridiana Felix Parra
University of Texas at El Paso

ASSESSMENT OF POINT OF USE (POU) SYSTEMS FOR REDUCING HEALTH RISKS ASSOCIATED WITH DRINKING WATER ALONG THE U.S.-MEXICO COLONIAS IN THE PASO DEL NORTE REGION

VARINIA VIRIDIANA FELIX PARRA

Master's Program in Environmental Engineering

APPROVED:

Ivonne Santiago, Ph.D., Chair

Shane Walker, Ph.D.

Kristina Mena, Ph.D.

Stephen L. Crites, Jr., Ph.D.
Dean of the Graduate School

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VARINIA VIRIDIANA FELIX PARRA B.ARCH.

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Table of Contents

Acknowledgments ... iv

Table of Contents ... v

List of Tables ... viii

List of Figures ... ix

Chapter 1: Introduction ... 1

1.1 Background ... 1

1.2 Problem statement ... 2

1.3 Research goals ... 4

Chapter 2: Literature review ... 6

2.1 Colonias in El Paso ... 6

2.2 Colonias in Juárez ... 7

2.3 Drinking water contaminants ... 8

Safe drinking water standards ... 8

Inorganic contaminants ... 10

Chlorine ... 10

Hardness ... 11

Heavy metals ... 11

Microbiologic contaminants ... 12

Chlorophyll A and B ... 13

2.4 Point of use systems for drinking water ... 13

Overview ... 13

POU systems and technology ... 15

Chapter 3: Methodology ... 18

3.1 Surveys ... 18

3.2 Focus groups ... 20

3.3 Water sample collection and analyses ... 21

Inorganic contaminants ... 24

pH and Conductivity ... 24

Total Dissolved Solids ... 24

Chlorine....24
Ions 24
Heavy Metals 24
Microbiologic contaminants 26
Total coliforms, E. coli, and Enterococcus 26
Cryptosporidium and Giardia Lamblia 27
Chlorophyll A and B 27
3.3 Microbial health risk assessment 27
3.4 POUs selection 28
Chapter 4: Results and discussion....30
4.1 Pre-intervention....30
Surveys....30
Colonias in Juárez 30
Colonias in El Paso 32
Comparison of Juárez and El Paso colonias pre-survey results. 33
Focus Group....37
Water quality analyses 41
pH 41
Total Dissolved Solids (TDS) 42
Hardness....43
Total and free Chlorine 44
Heavy metals....45
Microbiological contaminants 45
Microbial health risk assessment 46
Point of Use system selection 48
Selected POU systems characteristics and comparisons 53
POU systems installations....58
POU Investment cost return....62
4.2 Post-intervention results....63
Surveys....63
Colonias in Juárez 64
Colonias in El Paso 65

Comparison of post-survey results for Juárez and El Paso 66
Focus groups 68
Water quality analyses 68
pH 68
Total Dissolved Solids 69
Hardness 70
Total and free Chlorine 70
Heavy Metals 70
Microbial contamination 71
Microbial health risk assessment 72
Chapter 5: Conclusions 75
Recommendations 76
References 77
Appendix A 84
Pre-survey copy 84
Focus group protocol for moderator 96
Post-survey copy 98
Appendix B 102
Pre-survey results for colonias in Juárez 102
Pre-survey results for colonias in El Paso 105
Post-Intervention perceptions and practices results 108
Appendix C 110
Water quality results 110
Vita 126

List of Tables

Table 2.1: Basic infrastructure classification of select counties in Texas, 2010 7

Table 2.3.1: Drinking water contaminant limits by agency.. 9

Table 2.3.2: Health effects and sources of inorganic contaminants (EPA, 2017) 11

Table 2.3.3: Health effects and sources of microbiological contaminants (EPA, 2017) 13

Table 3.3.1: Sample collection and contaminants tested 23

Table 3.3.2: Wavelengths and detection limits for elements analyzed by ICP-OES................... 25

Table 3.4.1: Summary of ranking criteria for POU drinking water treatment systems. Copied from Campos, 2015 29

Table 4.1.1: Comparison of discrepancies between practices and perceptions of hauled water by colonia residents.. 35

Table 4.1.2: Samples with microbiological contamination by location....................................... 46

Table 4.1.3: Top ranking systems by evaluation score, modified from Campos, 2015................ 49

Table 4.1.4. Selected systems comparison.. 55

Table 4.2.1: Post-survey POU general perceptions and practices. 64

Table 4.2.2: Post-survey POU general perceptions and practices. 65

Table 4.2.3 Percent samples and MPN values for samples with microbiological contamination by location.. 71

List of Figures

Figure 1.1. Location of targeted research areas 3

Figure 1.2: Water supply storage in colonias..... 4

Figure 2.1: PDUS welfare levels in Juárez 2010. 8

Figure 3.1: Research approach..... 18

Figure 3.2: POUs presented during pre-intervention focus group. 21

Figure 3.3: Example calibration curves for Ca, K, Ba, and Mg. 26

Figure 4.1: Hauled water perception and practice comparison by colonia..... 34

Figure 4.2: Oil film observed in stored water from colonia in Juárez 37

Figure 4.3: Larvae found on water samples collected during summer 2018 focus group 38

Figure 4.4: Specimens collected from hauled water storage tanks at colonias in Juárez 38

Figure 4.5: Algae present in samples collected from colonias in Juárez. 40

Figure 4.6: Low capacity Rotoplasma tank at colonias in Juárez..... 40

Figure 4.7: Clear and uncovered tanks at colonias in Juárez..... 40

Figure 4.8: Statistical pH values for pre-intervention sampled water 42

Figure 4.9: TDS concentrations of households Pre-Intervention sampled water 43

Figure 4.10: Water sample with high Chlorine concentration collected in El Paso 44

Figure 4.11: Highest MPN count of samples with microbiological contamination 45

Figure 4.12: Annual health risk for *E. coli* on pre-intervention samples..... 47

Figure 4.13: Sawyer Point One Filter Bucket setup and components (Sawyer International Products, 2019) 53

Figure 4.14: Under the sink RO typical installation. (Whirlpool Water Solutions, 2019) 54

Figure 4.15: Colonias POU system implementation process..... 58

Figure 4.16: Sawyer PointONE 5 gallon bucket system installation. 60

Figure 4.17: Whirlpool WHER25 under the sink RO system installation. 62

Figure 4.18: Pre- and post-survey perceptions and practices by colonia residents 67

Figure 4.19: Statistical pH values for Post-Intervention sampled water 69

Figure 4.20 Statistical representation of results for TDS post POU intervention. 70

Figure 4.21: Percentage of samples with presence of microbiological contaminants comparison according to location and type of sample 72

Figure 4.22: Annual health risk for *E. coli* for post-intervention unfiltered filtered samples 74

Figure 4.23: Annual health risk for *E. coli* for post-intervention POU filtered samples 74

Chapter 1: Introduction

Access to clean drinking water and sanitation is essential to the realization of all human rights. While in present day drinking water reaches users by piping systems throughout most the U.S. and Mexico, there are still communities that have yet to reach adequate standards of infrastructure and water systems. Along the U.S.-Mexico border, we find a loose network of over 2,500 settlements ranging in size from villages to cities (Donelson and Esparza, 2005) known as colonias, where this narrative is an everyday reality. The Spanish word “colonia” refers to informal, unincorporated impoverished settlements outside the auspices of local government that lack all or some essential public services and infrastructure (Rivera, 2014)

Residents living in colonias typically live in poverty and lack adequate healthcare, potable water, and sanitation systems, which can create substantial health risks for them and their surrounding communities. There is a need to explore reliable, alternate, immediate, low cost, and sustainable treatment systems that can assure and preserve safe drinking water for colonias. Worldwide, Point of Use water units (POU) are emerging as a means to improve the quality of drinking water for households in the developing world (Sobsey et al., 2008) or with unreliable access to safe drinking water, like many colonias in the Paso Del Norte Region.

1.1 Background

Land developers that used loopholes that allowed lot splits for low-cost subdivisions without any attendant infrastructure improvements resulted in a lack of improved roads and utilities. Some of this low-cost land offered by these deceptive land developers was purchased, and small colonia communities formed.

In Ciudad Juárez (Juárez) reports show between 4,800 (Martínez Cabrera, 2012) and 7,119 families (IMIP, 2010) that depend on water delivery trucks (“pipas”) for domestic needs.

These pipas deliver water that residents store in open containers or “tombas.” In El Paso County, there may be over 5,000 people in colonias that lack potable water infrastructure. Water storage practices by colonia residents pose an enormous risk for waterborne disease outbreaks and heavy metal contamination because the water quality can decrease rapidly due to volatilization of residual Chlorine, intrusion of rainfall, and air-laden dust.

Currently, residents who can afford it, rely on bottled water and jug refill stations for drinking water that can be as far as 30 miles away from their residences (Davidhizar and Bechtel, 1999). This creates an overall inconvenience as bottled water can only be practical for some of the domestic needs of a household.

Even though legislation to improve the current situation of the colonias exists, connection to centralized water treatment systems is uncertain, in some cases unfeasible, or at best still many years away. The consequences for the lack of essential services are a reality for colonia residents and often result in health problems (Davidhizar and Bechtel, 1999), additional time and monetary expenses due to the necessity to purchase additional water for drinking.

1.2 PROBLEM STATEMENT

Colonias often suffer from environmental injustice, such as the lack of safe drinking water and sewage collection infrastructure. The colonias along the U.S.-Mexico border are at best years away to get allocation with necessary conventional water infrastructure due to various reasons such as policy, geographic location, and economic constraints. Furthermore, the cost that consumers in these the low-income sectors is not sufficient to cover the capital, maintenance, and operational costs required to connect them to public drinking water delivery infrastructure systems (Goldblatt,1999 and Merrett 2002). Additionally, many of these communities lack the capability to access or develop the technical or managerial resources for the water treatment

infrastructure needed to comply with the increasing environmental regulations and customer expectations.

The project locations included Juárez colonias in Kilómetros 27-32 of Mexico 2 highway to Casas Grandes and El Paso's Far East Montana and Hueco Tanks colonias (See Figure 1.1).

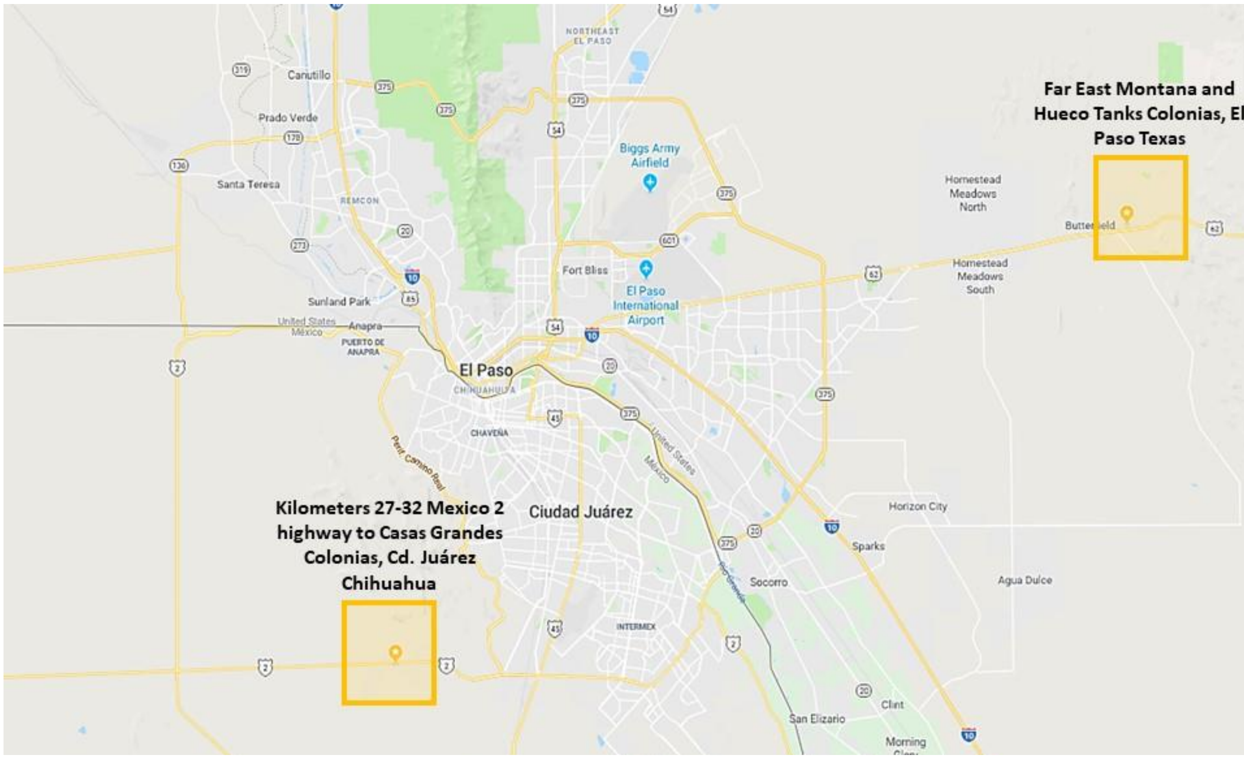


Figure 1.1. Location of targeted research areas
Colonias in Paso Del Norte U.S.-Mexico region (a) Kilómetros in Juárez, Chihuahua (b) Hueco Tanks in El Paso, Texas.

Colonias in Juárez, Chihuahua and El Paso, Texas not only share the same water source (Hueco Bolson aquifer and Rio Grande) but rely on well bulk transport (hauling) of water for domestic purposes. On both sides of the border, there are public and private water haulers that need to comply with parameters established by the Texas Commission on Environmental Quality (TCEQ, 2013) and Mexico's Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT NOM 127, 2000). While at the time of delivery, water may comply with drinking water standards, this water can be stored for days or even weeks in the residents' tanks, and

disinfectant residual diminishes within hours, which allows microbiological growth at dangerous levels. Furthermore, cracked storage tanks, improperly sealed access covers, or infrequent cleaning may exacerbate the problem. Contamination can range from microbiological pathogenic (e.g., virus, bacteria, and parasites) to heavy metals and algae growth inside storage tanks (Campos et al., 2013).

While all colonias selected for this project rely on treated hauled water there are some differences between them, in El Paso colonia residents use large (over 2000 gallon capacity), dark, closed tanks that directly connect to the residences thanks to electricity and indoor plumbing; in contrast, Juárez colonia residents use several small (under 300 gallons), clear or light color uncovered tanks to store their water and lack access to legal electricity or indoor plumbing. Figure 1.2 shows water supply storage difference by location.

Figure 1.2: Water supply storage in colonias.
From left to right Kilómetros in Cd. Juárez, Chihuahua, Hueco Tanks in El Paso, Texas.

1.3 Research goals

The overarching goal of this research is to improve colonia residents understanding of safe drinking water practices and improve their health by improving their drinking water quality by using POUs

The objectives of this study are:

1. To evaluate the use of POUs as a low-cost, sustainable, and effective means to provide safe drinking water to colonias in Cd. Juárez and El Paso
2. To assess and evaluate the use and sustainability of using POUs in reducing health risks associated with drinking water quality in the colonias in Cd. Juárez and in El Paso

The objectives were accomplished by:

1. Performing Water and POU Perception and Use Inventory surveys of colonia residents
2. Providing an outreach education campaign in the form of workshops, forums, or focus groups to colonia residents on both sides of the border on how to minimize pollution of their drinking water storage tanks;
3. Measuring and quantifying the microbial and heavy metal contamination found in the drinking water in the colonias
4. Performing a quantitative microbial risk assessment (QMRA) of the drinking water in the colonias
5. Selecting and providing POU systems for specific water contaminants of these colonias.

Chapter 2: Literature review

2.1 Colonias in El Paso

In Texas, some colonia residents depend on the bulk transport (hauling) of water for domestic needs, and many of those residents purchase of additional quantities of bottled water for drinking and cooking. The potential for contamination during transport and storage poses an enormous challenge to providing safe drinking water for these impoverished communities. The water quality in these hauled water storage containers can decline rapidly due to intrusion of rainfall and air-laden dust, which concomitantly with the volatilization of the residual Chlorine present at the time of delivery, greatly increase the levels of microbial contamination and place the population, especially children, at risk for waterborne disease outbreaks.

The Colonia Initiatives Program Office of Texas (2010) developed a three-tiered color classification scheme to identify colonias posing the greatest public health risk as follows:

- Green: Colonias with access to potable water, adequate wastewater disposal, adequate paved road, drainage, and solid waste disposal.
- Yellow: Colonias with access to potable water via functional water well or connection to a public water system, functional septic tank or connection to a public wastewater collection system but lacks adequate road paving, drainage or solid waste disposal.
- Red: Colonias lack access to potable water, adequate wastewater disposal, or platting.

The infrastructure service classification system has been applied to the six counties with the largest colonia populations in Texas (as shown in Table 2.1): Cameron, El Paso, Hidalgo, Maverick, Starr, and Webb Counties, with a combined estimated population of 369,007. While

almost 50% of the colonias in these six counties are classified as “Green,” an estimated 44,526 residents are living in 353 colonias that lack basic infrastructure such as potable water (Red). In El Paso County alone, over five thousand people in colonias lack potable water infrastructure, and the development of conventional water supply systems may be financially infeasible.

Table 2.1: Basic infrastructure classification of select counties in Texas, 2010

Basic Infrastructure Classification	Number of Colonias in Six Texas Counties	Population of Colonias in Six Texas Counties	Number of Colonias in El Paso County	Population of Colonias in El Paso County
Green	891	194,085	193	59,684
Yellow	519	126,334	49	19,631
Red	353	44,526	56	5,529
Unknown	62	4,062	23	1,628
Total	**1,825**	**369,007**	**321**	**86,472**

2.2 COLONIAS IN JUÁREZ

According to the Plan de Desarollo Urbano Sostenible (PDUS, 2016) and Junta Municipal de Agua y Saneamiento (JMAS), by the end of 2011, there was a potable water coverage of 96% of the city. However, due to the accelerated growth of the city in the last decades, the government has not been able to connect all the population to centralized water supply systems. It is estimated that at least 25 colonias with approximately 5,500 families in the southwest of the city rely on hauled water and lack sewage and draining systems.

PDUS uses a color classification scheme gradient from green (very high) to red (very low) to identify social welfare levels throughout the city based on indicators like financial situation, percentage of illiterate population, access to schools and education, level of education, number of people per home, access to basic services and type of home. Colonias in the southwest of the city that rely on hauled water have some of the lowest levels of quality of life in Juárez (As shown in Figure 2.1).

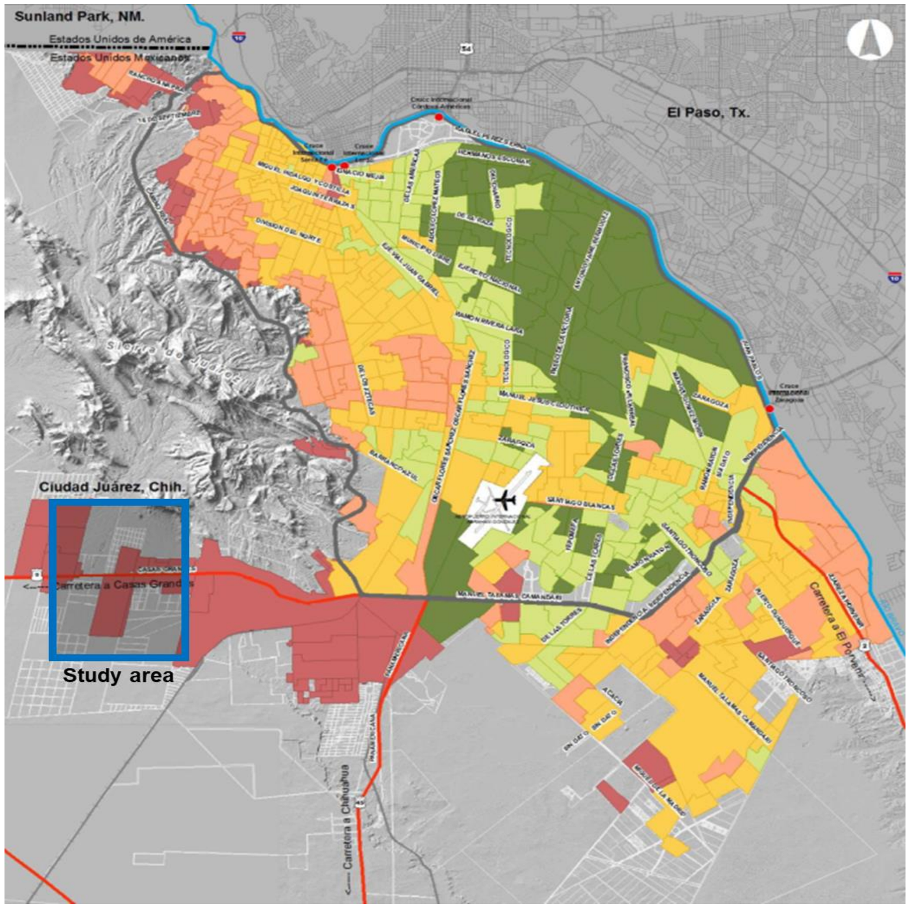


Figure 2.1: PDUS welfare levels in Juárez 2010.

Colonias that lack potable water service and rely on hauled water are Kilómetro 27, Kilómetro 28, Kilómetro 29, Campesina, Bello Horizonte, Granjas de Santa Elena, Granjas Polo Gamboa, Valle Dorado I, Valle Dorado II, Granjas Unidas, Palo Chino, Siglo XXI, Ladrilleros de Juárez y Gobernadores

Providing water infrastructure services to these colonias would represent a very high investment cost ($140,000 Mexican pesos or $7,277.00 US dollars for each house).

2.3 Drinking water contaminants

Safe drinking water standards

Contaminant regulations are established to protect the public against the consumption of drinking water contaminants that present a risk to human health (EPA 2019). Some of the

standards are enforceable (primary), and others are non-mandatory considerations such as taste and odor. Table 2.3.1 shows safe drinking water standards by national agencies, in U.S. Environmental Protection Agency (EPA), in Mexico's SEMARNAT, and local Texas Commission on Environmental Quality (TECQ)

Table 2.3.1: Drinking water contaminant limits by agency

Contaminant		**Safe drinking water standards**			
Name	**Type**	**EPA Primary regulations MCL**[1]	**EPA Secondary regulations MCL**	**TCEQ**	**SEMARNAT**[2]
Arsenic	Inorganic chemical	0.010 mg/L	NA[3]	0.01 mg/L	0.05 mg/L
Barium	Inorganic chemical	2 mg/L	NA	2 mg/L	0.7 mg/L
Cadmium	Inorganic chemical	0.005 mg/L	NA	0.005 mg/L	0.005 mg/L
Chromium	Inorganic chemical	0.1 mg/L	NA	0.1 mg/L	0.05 mg/L
Copper	Inorganic chemical	TT[5]; Action level=1.3	NA	1 mg/L	2 mg/L
Cryptosporidium	Microorganism	Zero	NA	Zero	Zero
Fecal coliform and E. coli	Microorganism	Zero	NA	Zero	Zero
Giardia Lamblia	Microorganism	Zero	NA	Zero	Zero
Iron	Inorganic chemical	NA	0.3 mg/L	0.3 mg/L	0.3 mg/L
Lead	Inorganic chemical	TT[4]; Action level=0.015	NA	0.015 mg/L	0.01 mg/L
Manganese	Inorganic chemical	NA	0.05 mg/L	0.05 mg/L	0.15 mg/L
Mercury	Inorganic chemical	0.002 mg/L	NA	0.002 mg/L	0.001 mg/L
pH	Chemical property	6.5 - 8.5	NA	>7.0	6.5 - 8.5
Chlorine	Inorganic chemical	4 mg/L MRDLG[5] as Cl_2	NA	0.2 mg/L Free Cl	0.2 - 1.5 mg/L Free Cl
Selenium	Inorganic chemical	0.05 mg/L	NA	0.002 mg/L	NA
Sulfate	Inorganic chemical	NA	250 mg/L	300 mg/L	400 mg/L

Contaminant		Safe drinking water standards			
Name	**Type**	**EPA Primary regulations MCL**[1]	**EPA Secondary regulations MCL**	**TCEQ**	**SEMARNAT**[2]
Total Dissolved Solids	Inorganic salts and organic matter	NA	500 mg/L	1000 mg/L	1000 mg/L
Total Coliforms	Microorganism	5.0 percent per month	NA	Zero	Zero
Uranium	Inorganic chemical	30 µg/L	NA	30 µg/L	NA
Zinc	Inorganic chemical	NA	5 mg/L	5 mg/L	5 mg/L
Hardness	Physical property	NA	500 mg/L	NA	500 mg/L

[1] The highest level of a contaminant that is allowed in drinking water. MCLs are enforceable standards.

[2] NOM-127-SSA1-1994 Not Applicable

[3] Not Applicable

[4] A required process intended to reduce the level of a contaminant in drinking water. Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

[5] Maximum Residual Disinfectant Level Goal (MRDLG) The level of a drinking water disinfectant below which there is no known or expected risk to health.

Inorganic contaminants

Chlorine

One of the most critical factors, when preserving water quality and preventing diseases transmitted through water, is the addition of disinfectant (Bowden et al. 2006) The most widely used disinfectant is Chlorine (Milot, Rodriguez, and Serodes 2002). Leaving drinking water disinfection to non-professionals could lead to inconsistent and inaccurate disinfectant dosing. (Corella-Barud et al. 2009). Excess chlorination can lead to disinfection byproducts (DPBs) (40 CFR §141.65 2007), which are known to be carcinogenic (Boorman et al. 1999) and other health concerns such as itchy skin and rashes.

Hardness

Dissolved minerals contribute to the taste of drinking-water to varying degrees. Depending upon interactions with other factors, such as pH and alkalinity, hard water and sulfates can cause increased soap consumption and scale deposition (World Health Organization 2011, 2004a), when excessively hard, water can have corrosion tendencies from leachates, associated with health risks and reduced lifespan of appliances

Drinking hard water with magnesium and sulfate at high concentrations (above approximately 250 mg/l each) can have a laxative effect, exposure to hard water has been suggested to be a risk factor that could exacerbate eczema (McNally 1998).

Heavy metals

Heavy metals refer to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations (e.g., mercury, cadmium, arsenic,) high concentration in drinking water poses a threat to human health; some heavy metals can bioaccumulate in the human body causing poisoning. In addition, some heavy metals may induce cancer. Table 2.3.2 shows potential health effect and sources for heavy metals and other inorganic contaminants

Table 2.3.2: Health effects and sources of inorganic contaminants (EPA, 2017)

Contaminant	**Potential health effects from exposure above the MCL**	**Sources of contaminant in drinking water**
Arsenic	Skin damage or problems with circulatory systems, and may have increased risk of cancer	Erosion of natural deposits; runoff from orchards, runoff from glass and electronics production wastes
Barium	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Cadmium	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits

Contaminant	Potential health effects from exposure above the MCL	Sources of contaminant in drinking water
Copper	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Lead	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities. Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Selenium	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Uranium	Increased risk of cancer, kidney toxicity	Erosion of natural deposits
Chlorine	Eye/nose irritation; stomach discomfort	Water additive used to control microbes

Microbiologic contaminants

Some of the most common contaminants tested to assess water quality are *Cryptosporidium*, *Giardia Lamblia*, and coliforms. *Cryptosporidium* is a single-celled protozoan parasite commonly found in lakes and rivers, especially when the water is contaminated with sewage and animal waste. *Giardia Lamblia* is a single-celled protozoan parasite that lives in the intestine of infected humans or animals, it is found on surfaces or in soil, food, or water that has been contaminated with the feces from infected humans or animals. Coliforms are bacteria naturally present in the environment and used as an indicator that other, potentially harmful, bacteria may be present; coliforms can be a warning of potential problems. Fecal coliforms, *E. coli,* and *Enterococcus* are bacteria whose presence indicates that water may be contaminated by fecal contamination.

Microbes in these wastes can cause short-term health effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a particular health risk for infants, young children, some of the elderly, and people with severely compromised immune systems. (EPA, 2017) Table 2.3.3 shows a summary of the contaminants mentioned, their source and exposure health effects.

Table 2.3.3: Health effects and sources of microbiological contaminants (EPA, 2017)

Pathogen	Potential health effects from long-term exposure above the MCL	Sources of contaminant in drinking water
Cryptosporidium	Gastrointestinal illness (such as diarrhea, vomiting, and cramps)	Human and animal fecal waste
Giardia Lamblia	Gastrointestinal illness (such as diarrhea, vomiting, and cramps)	Human and animal fecal waste
Fecal coliform and *E. coli*	Gastrointestinal illness (such as diarrhea, vomiting, and cramps), headaches	Fecal coliforms and E. coli only come from human and animal fecal waste.
Total Coliforms (Including fecal coliform and *E. Coli*)	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and E. coli only come from human and animal fecal waste.

Chlorophyll A and B

Green algae are eukaryotic organisms that contain chlorophyll a, much like plants, (Maier, Pepper, and Gerba 2009). Some algae can harm humans either by facilitating the conditions for other pathogenic microorganisms to thrive or by directly poisoning humans (Paerl 1988).

2.4 Point of use systems for drinking water

Overview

Point-of-use (POU), water treatment systems, have been proposed in recent years as low-cost, scalable, and effective solutions to the significant challenge of providing potable drinking water in lower income settings. Despite their usefulness, levels of adoption and continued use

remain low (Harris, 2005). Nevertheless, they are becoming more popular in developing countries (Sobsey et al, 2005), however, there is a lack of focus for POUs in developed countries such as the U.S. where POUs water treatment devices have been cited by the U.S. EPA Water Security Research and Technical Support Action Plan as a topic requiring further research (Silverstein, 2005).

As of 2015, 283 million people in the U.S. used water provided by public water suppliers including hauled water (USGS, 2015), by 2010 in México only 74 million people used water provided by suppliers of which at least seven percent represent alternative supply methods (INEGI, 2015). POU technologies not only can provide additional security against contamination, but can be used as a "compliance technology" [EPA 1412(b)(4)(E)(ii)] (US EPA, 2011) for communities relying on alternative water supply such as the colonias in Paso Del Norte, where exposure and poor storage techniques can result in environmental contamination of the water supply. Success in using POU technologies as a compliance tool depends as much on the effectiveness of the technology as the willingness of the population to use it, which in turn depends on its social and economic sustainability.

Recent studies have emphasized the importance of ensuring water quality at the point of use, and have demonstrated the health impact of water interventions targeting household treatment and safe storage (Clasen and Cairncross, 2004). The concept and validation of POU household drinking water treatment as an appropriate, effective, affordable, and sustainable technology for the developing world is relatively new, and attempts to promote and distribute these technologies on a large scale have only recently begun (Sobsey *et al.*, 2005). Conventional approaches involving large scale, high capital cost projects are not sufficient to provide

thousands of people in economically disadvantaged small communities with safe water in a timely manner.

Most colonias do not have the option of replacing their water source and storage with better ones; the use of POU technology may allow communities to rapidly and cost-effectively achieve greater protection against water-borne diseases. In these cases, the POU treatment systems should be designed and tested to remove the contaminant or groups of contaminants of concern.

POU systems and technology

Depending on the type of contaminants that need to be removed, POU treatment methods may include one or a combination of technologies such as ultrafiltration, nanofiltration, ceramic filtration, UV, distillation, or specialized membrane filters (e.g., to remove arsenic). POU systems are found in different geometries such as faucet mount, counter-top manual fill, counter-top connected to sink faucet, or plumbed in.

POU systems typically treat water in batches and deliver water to a single tap, such as a kitchen sink faucet or an auxiliary faucet mounted next to the kitchen sink, or a designated container. The following information contains a brief explanation of different POU systems and points to consider when determining which style of a system will best suit the needs. The list below is ordered from simple installation/operation too difficult or complex:

- Personal Water Bottle: This type of product consists of a bottle and a filter. The filter may be integrated with the push/pull cap of the filter bottle or a straw.
- Pour Through: In pour-through products (typically lower capacity), gravity causes water to drip through a pitcher.

- Faucet Mount: This type of filter is mounted on an existing kitchen sink faucet, and may employ a diverter to direct water through the filter when treated drinking water is desired.
- Counter-Top Manual Fill: This system is usually placed on a counter and filled by manually pouring water into the system and activating it for a batch of water.
- Counter-Top Connected to Sink Faucet: This product is usually placed on a counter and connected by tubing to an existing kitchen sink faucet.
- Plumbed-In: This system is usually installed under the sink and requires a permanent connection to existing water pipe. Filtered water is dispensed through the existing faucet.
- Plumbed-In to Separate Tap: This product installs in the same manner as plumbed-in systems (above), but filtered water is dispensed through an auxiliary faucet.

POU systems utilized in this research are commercially available. Potential POU technologies with descriptions, contaminant removal and operation, and maintenance (O&M) commentary are summarized in Table 2.4, not any one of the potential POU technologies alone is expected to provide optimal treatment.

Table 2.4: Contaminant and O&M issues with some POU technologies

POU Technology	Brief Description	Contaminants that can be removed	Contaminants that cannot be removed	Comments
Granular or Solid-Block Activated Carbon Filter	GAC packed in a column or fused into a solid block with pore size that can be 0.5 micrometers	Many organic compounds, select Synthetic Organic Contaminants, Natural Organic Matter, and solid block can remove Asbestos fibers,	Heavy metals, viruses, fluoride, chloride, arsenic, nitrate, hardness or most metal ions. Not recommended for radon, Volatile	Needs periodic backwashing. Variance to comply with Safe Drinking Water Act can when this technology is used. Solid block is

POU Technology	Brief Description	Contaminants that can be removed	Contaminants that cannot be removed	Comments
		protozoan cysts and some bacterial, some insecticides, pesticides	Organic Compounds (VOCs), Solid Block Activated Carbon.	National Sanitation Foundation International approved for several contaminants.
Specialty media	Similar configuration to Granular Activated Carbon	Activated alumina would remove arsenic and fluoride	Anything other than arsenic and fluoride or similar inorganic contaminants	Require periodic replacement and cleaning
Microfiltration	Membrane filtration with pore sizes from 0.1 to 0.2 micrometers	Bacteria and Cysts	Dissolved particles less than 0.1 micrometers	Can be used as pre-filters for reverse osmosis units
Ultrafiltration	Membrane with pore sizes from 0.01 to 0.04 micrometers	Prevents passage of particles greater than 100,000 Daltons, proteins, suspended solids, viruses, bacteria, and cysts.	Mono- and disaccharides, salts, amino acids, low-weight organic compounds, inorganic acids, sodium hydroxide	Requires periodic replacement of cartridge
Nanofiltration or Reverse Osmosis	Membrane filtration under pressure. Membrane pore size between 0.00025 and 0.001 micrometers.	High molecular weight organic compounds, low molecular weight anionic species, and metals such as chlorides, fluoride, and sulfates.	Molecules less than 200 Daltons in size, trichloroethylene, trihalomethanes, and some pesticides.	Waste is 30-50% of the influent water. Due to required pressure, it is energy intensive. Membrane life depends on pH, is not Chlorine-resistant, and is prone to fouling.

Chapter 3: Methodology

The investigation included surveys of individuals and focus groups, water quality analyses of source, and treated water. Research approach steps are summarized Figure 3.1

Figure 3.1: Research approach

Experimental activities were classified as pre- and post-intervention, pre-intervention.

Pre-intervention activities refer to all activities performed before outreach and educational workshops, post-intervention refer to activities performed after distribution of educational material, workshops, and POUs installation.

3.1 Surveys

The primary goal of the survey campaigns was to assess water practices and perceptions of colonia residents with regards to their hauled water quality and their change if any following educational campaigns and POUs installation.

Methodology for surveys follows the approach used by a UTEP and New Mexico State University NMSU research group on a previous study of POUs performed in the Far East El Paso and Southern NM colonias in 2012-2016. (Campos et al., 2013a, b, c, 2014; Palacios et al., 2014).

Surveys were conducted under approved Institutional review boards (IRB) for protection of human subjects in research of the University of Texas at El Paso (UTEP) and the University of Texas at Houston (School of Public Health).

To be successful, the implementation of programs that are achievable and culturally appropriate use a community partner approach (Davidhizar and Bechtel, 1999). Therefore,

selection for recruited participants was made possible with assistance from the Non-government Organizations (NGO) in Juárez, Juárez Limpio, and Familias Triunfadoras in El Paso.

Both pre- and post-intervention surveys used close-ended and open-ended questions with variables related to water consumption, perceptions, and practices. Copies of surveys can be found in Appendix A.

Specific variables assessed via questionnaire included:

- Primary water source (e.g., private well, hauled water, other?).
- Current source for cooking (i.e., same as primary source or bottled?).
- Current source for drinking (i.e., same as primary source or bottled?).
- Average water consumption per day (ounces/glasses/liters/gallons) for the household.
- Trust in water quality of primary source.
- Perceptions of water quality from primary source on multiple dimensions (taste, smell, color, clarity, safety).
- Level of concern about the overall safety of the water from the primary source and level of concern from contaminants: In general, from bacteria/fecal contamination, pesticides, chemical, and metals.
- Current use of water treatment devices (e.g., pitcher filter such as Brita, tap filter, inline filter, boiling, Chlorine, reverse osmosis, UV, iron removal device, softener).
- Need for education and information.
- Health problems potentially related to contaminated water source.

Resulting data from both pre- and post-surveys were entered on an excel sheet and exported into ATLAS.TI 8 and SPSS for qualitative and quantitative analyses and comparison by location, respectively.

3.2 Focus groups

The purpose of the focus groups had the purpose was to reveal additional concerns, attitudes, and acceptability (i.e., willingness to use, concerns about use) of POU technologies for selection and follow-up after installation. Similarly to surveys, focus groups followed the previously mentioned approach and IRB.

Focus groups were conducted in Juárez but not in El Paso. A previous project funded by EPA (Campos et al., 2013a,b,c, 2014; Palacios et al., 2014) provided the necessary information to proceed with the other components of the research.

Pre- and post-intervention focus group sessions in Juárez took place at "Centro Familiar Pedro Zaragoza," a colonia community center. The community center provided time and facilities for workshops and residents with accessibility, leadership, and community involvement willing to participate in the project.

Size for the focus groups ranged from 10-20 participants who were regular attendees to the community center on Tuesdays. This was done to ensure follow-up participation; in total, three focus groups were conducted at the community center, on September 4^{th,} 2018, February 5th, and March 6th, 2019.

Focus group presentations were conducted following the Moderator's guide (see appendix A) developed by Dr. Rebeca Palacios from New Mexico State University and conducted by Dr. Ivonne Santiago and Varinia Felix.

Various POUs were shown to the participants to reveal user preferences and willingness to adopt different setups as shown in Figure 3.2 a) pitcher units, b) gravity driven microfiltration systems, c) 1-gallon jug with integrated filter and individual straw like filters and d) under the sink in-line cartridge systems.

Figure 3.2: POUs presented during pre-intervention focus group.

Description of how each of the POU technologies works and what maintenance is required were demonstrated. For each of the devices described, participants were asked to:

- Discuss specific or general questions they have about the POU device.
- Discuss how easy the device would be to use.
- Discuss what they like about the specific device.
- Discuss what they dislike about the device.
- Discuss any additional concerns they might have about the device (e.g., ease of use, replacement filter cost),
- Discuss how likely they would be to use this kind of device.

Lastly, participants were informed about the implementation phase of the project and asked if they would like to be considered for participation.

3.3 WATER SAMPLE COLLECTION AND ANALYSES

The principal objectives for the water quality analyses were: 1) to identify and quantify the presence of microbiological and inorganic contaminants in stored water that residents of colonias use for drinking in order to select the appropriate POUs; 2) to evaluate the effectiveness

of the POUs in removing those contaminants and; 3) to obtain microbial contaminant data to perform the quantitative microbial risk assessment.

Sample collections were classified as pre-intervention and post-intervention campaigns. The pre-intervention sampling campaign consisted of collection and analyses of samples from the unfiltered drinking water the residents used. This took place immediately after surveys and focus group but before selection and delivery, if applicable, of the POU. The post-intervention campaign consisted of collection and analyses of samples from the unfiltered and POU filtered water after outreach campaign and/or delivery. There were three sampling campaigns, June 2018, January 2019, and April 2019. For both campaigns, water samples were collected according to Standard Method (SM) 9060 A (AWWA 2017) and EPA's Methods Approved to Analyze Drinking Water Samples. All sample bottles were labeled with the date, time, and location of the sample, as well as the name of the individual who collected the sample.

For the pre-intervention sampling campaign, two samples were collected, samples included at least one duplicate, and one blank per set incursion was taken. In El Paso, samples were collected directly from the kitchen faucet. In colonias in Juárez samples were taken directly from the storage tanks used for drinking located outside of the residences since colonias studied in our research project lacked plumbing installations.

- Samples intended for microbiological analysis (Total coliforms, *E. coli*, and *Enterococcus*) were collected using a sterile bottle with (sodium thiosulfate). For *Giardia* and *Cryptosporidium*, 10-liter samples were collected using sterile cubitainer and placed in a cooler with ice to be transported back to the laboratory. All microbiological samples were analyzed within 8 hours after collection.

- Samples collected for inorganic chemical analysis were collected using sterile low-density polyethylene (LDPE) 500 ml bottles; samples were transported using a cooler with no added ice to avoid precipitation of sparingly soluble inorganic constituents.

During the post-intervention campaign, four samples for each site were collected following procedures mentioned before, the additional two samples collected from colonias in El Paso were taken directly from the POUs faucet, in colonias of Juárez, the additional two samples were collected directly from the POUs selected, and same material and transportation procedures were followed. If required any additional tests not performed by UTEP or a collaborator, samples were delivered to a suitable EPA certified laboratory.

Table 3.3.1 shows a summary of samples collected and tests performed by location and campaign.

Table 3.3.1: Sample collection and contaminants tested

	Campaign	**Location**	**Type**	**Samples collected**	**Contaminant tested**	
					Chemical	**Microbiological**
Pre-intervention	Summer 2018 (June)	Cd. Juárez	Unfiltered	20	20	20
		El Paso	Unfiltered	5	5	5
Post-intervention	Winter 2019 (January)	Cd. Juárez	Unfiltered	11	11	11
			Filtered by POU	8	8	8
	Spring 2019 (April)	Cd. Juárez	Unfiltered	8	8	8
			Filtered by POU	14	14	7
		El Paso	Unfiltered	10	10	10
			Filtered by POU	8	8	8
Total samples				**84**	**84**	**77**

Inorganic contaminants

pH and Conductivity

pH and conductivity were measured using a Thermo Orion Star A325 pH and conductivity meter fitted with an Oakton 35805-10 pH probe and an Orion 013010MD Conductivity Cell previously calibrated with standard solutions for pH (4, 7, 10) and conductivity according to Standard Methods 4500-H+B and 2510 B respectively, probe was rinsed with Deionized water (DI) water and dried using Kimtech Kimwipes after every sample measuring.

Total Dissolved Solids

TDS were measured gravimetrically according to Standard Methods 2540 C

Chlorine

Total and free Chlorine were analyzed immediately after sample collection using the DR/890 Colorimeter following EPA accepted colorimeter handbook method 8021 for free Chlorine analysis and method 8167 for total Chlorine analysis, both DPD Method Procedures are equivalent to US EPA method 4500-Cl G for drinking water.

Ions

Anions such as chloride, sulfate were analyzed according to EPA 300.1 with a DIONEX 2100 IC with an AS-18 column and a KOH eluent generator.

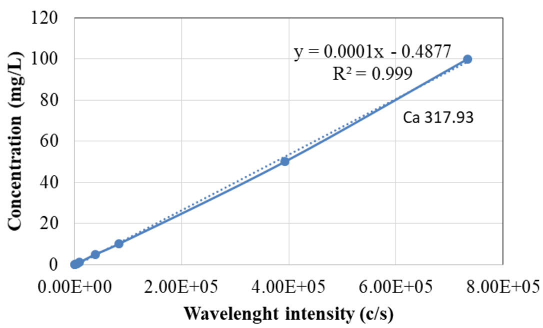
Heavy Metals

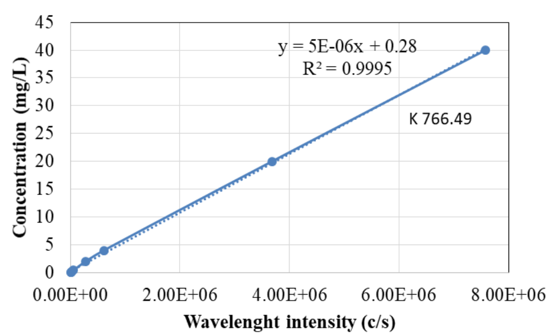
Metals and semi-metals including but not limited to arsenic, sodium, potassium, magnesium, calcium, strontium, barium, or silica were analyzed according to EPA 200.5 Rev 4.2 and EPA 200.7 with a Perkin-Elmer OPTIMA 7300DV ICP-OES, the preparation for each of the tested samples consisted of 10 ml acidified by adding 200 micro L (20%) of 15.8 N Nitric Acid,

wavelengths and detection limits analyzed in the ICP-OES for each cation are presented in Table 3.3.2, Example calibration curves are shown in Figure 3.3

Table 3.3.2: Wavelengths and detection limits for elements analyzed by ICP-OES

Element		Wavelengths (nm)	Minimum Detection Limit (mg/L)	Maximum Detection Limit(mg/L)
Ca	Calcium	317.93	0.5	100
K	Potassium	766.49	0.2	40
Mg	Magnesium	285.21	0.125	25
Na	Sodium	330.24	12.5	250
P	Phosphorus	213.62	0.01	1
As	Arsenic	188.98	0.05	1
Ba	Barium	233.53	0.01	1
Cd	Cadmium	228.80	0.001	1
Cr	Chromium	267.72	0.005	1
Cu	Copper	327.39	0.001	1
Fe	Iron	238.20	0.05	1
Hg	Mercury	253.65	0.005	1
Li	Lithium	670.78	0.05	1
Mn	Manganese	257.61	0.01	1
Ni	Nickel	231.60	0.01	1
Pb	Lead	220.35	0.01	1
Se	Selenium	196.03	0.05	1
Sn	Tin	189.93	0.01	1
Sr	Strontium	407.77	0.01	1
U	Uranium	385.96	0.01	1
V	Vanadium	290.88	0.05	1
W	Tungsten	207.91	0.01	1
Zn	Zinc	206.20	0.01	1
Si	Silicon	252.85	0.05	1





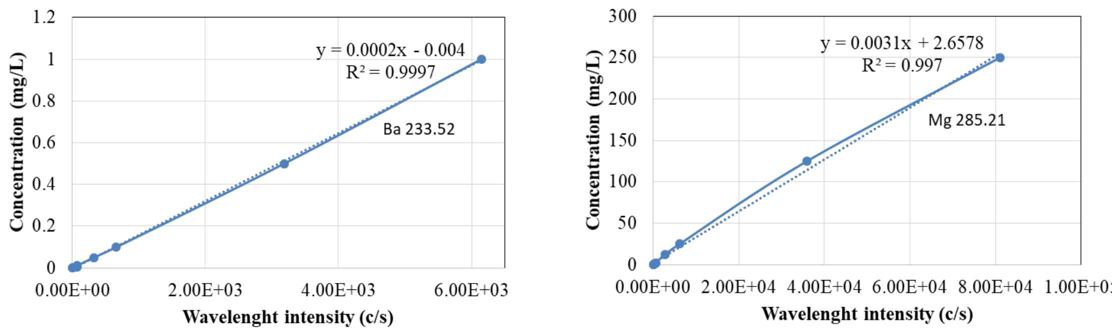


Figure 3.3: Example calibration curves for Ca, K, Ba, and Mg.

Microbiologic contaminants

***Total coliforms,* E. coli, *and* Enterococcus**

Microbiological analyses took place with the assistance of the University of Texas - Houston School of Public Health laboratory at the University of Texas at El Paso; tests were performed according to standard methods approved by the EPA as follows: Coliform by 9223-B 2004 Colilert standard method; *Enterococcus* by Enterolert Quanti-Tray™ according to method 9230D-B.

In these procedures, powder reagents for each bacterium contain reagents that provide a nutrient-indicator. Thus when bacteria metabolize specified nutrients, it activates either a colored or fluorescent indicator. Fluorescent indicators are specified only for *E. coli* and *Enterococcus* and can only be seen with a 6-watt UV ray of 365 nm. A hundred milliliters were taken from all of the samples and tested for both *E. coli* and Total coliforms and *Enterococcus*. Samples were then placed in a Quanti-tray 2000; the trays are based on the same statistical model as the traditional fifteen-tube serial dilution meaning no dilutions are necessary. Quanti-trays are then sealed and incubated at thirty-four degrees Celsius for 17 hours. Finally, samples are taken out and accounted for by either UV light or color change due to selective nutrients being metabolized.

Cryptosporidium *and* Giardia Lamblia

Cryptosporidium and *Giardia* were tested following a modification of EPA method 1623 that uses tangential flow hollow-fiber ultrafiltration, and heat dissociation steps to detect waterborne *Cryptosporidium* and *Giardia*. First samples of 10 L are filtered, thus trapping organisms and microscopic debris. Next, separation from the filter and foregoing centrifuge is applied to have a concentrated sample. Then utilizing immunomagnetic separation the concentrated water is infused with immunomagnetic beads that bind to *Cryptosporidium* and *Giardia* thus, allowing selective removal of the parasites from any micro concentrated debris; magnetic beads are then separated from parasites by an acid dissociation procedure. Lastly, immunofluorescence staining and cysts counts are applied to slides, where they are stained, and tallied through microscopy.

Chlorophyll A and B

Chlorophyll A and B were analyzed using Turners Designs AquaFluor custom handheld fluorimeter/turbidimeter 8000-010.

3.3 MICROBIAL HEALTH RISK ASSESSMENT

Quantitative Microbial Risk Assessment (QMRA) was used to identify health risk levels related to microbial contamination. Exposure assessment was used to address the probability of hazard occurring to an individual who is exposed to any potential pathogen, using fitted beta-Poisson models (Haas, Rose, and Gerba, 1999)

$$\textit{(Eq.1)} \quad d = c * \frac{1}{R} * 1 * 10^{-DR} * V$$

d is the number of *E. coli* ingested per day from water, C is the concentration of *E. coli* determined by the MPN per Liter, R is the recovery efficiency of the detection, DR is the decimal reduction, and V is the volume of water an average person ingests per day (2 L/per day).

The MPN given by IDEXX determined the concentration. The decimal reduction may vary from zero to three, but for *E. coli* detection limit used respecting a conservative approach, zero was applied for all studies. The recovery efficiency of one out of a range of one to zero was used, based off of similar seeded studies in which were conducted in the lab prior to testing samples.

A beta Poisson model is used to provide an annual risk of infection per year. The output followed the statistical variable of one to zero to determine the percentage of risk of ailment a person may face if exposed to contaminated water. QMRA Beta Poisson model for *E. coli* risk assessment (Dupont et al., 1971) used is presented in Equation 2.

$$(Eq.\ 2) \quad P(response) = 1 - \left[1 + dose\,\frac{\left(2^{\frac{1}{\alpha}} - 1\right)}{N_{50}}\right]^{-\alpha}$$

P will equal the yearly response ranging from one to zero. Alpha of 0.155 and N50 of 2110000 are used by the given strain of *E. coli* and its ailments.

3.4 POUS SELECTION

A ranking system developed by Campos 2015, was used as the method for POUs selection. Criteria for the ranking system is found in Table 3.4.1; where the score values were assigned. The POU ranking system considers the following aspects: (1) the technical performance of the unit with respect to removing contaminants and providing adequate drinking water quality; (2) the verification of reliable performance; (3) user preferences for unit operation; (4) the economic costs of the unit; (5) and the environmental impacts (pollution) of the unit. Summation without weights is employed in this method to compute the total score for each water treatment unit, shown in Equation 3.

(Eq. 3) Overall Score = Performance + Verification + Preference + Affordability + Environmental

Table 3.4.1: Summary of ranking criteria for POU drinking water treatment systems. Copied from Campos, 2015

	Score		
Category	**1**	**2**	**3**
Technical/treatment Performance	Removes aesthetic contaminants	Removes pathogens	Removes dissolved solids
Verification and Certification	Internal testing	Independently tested	NSF certified
User preference	Small batch (<5 L)	Large batch (≥5 L)	In-line (on demand)
Economic affordability	Cost ≥ $200	$20 < Cost < $200	Cost ≤ $20
Environmental Sustainability	Produces regular solid waste	Produces liquid waste stream (r < 90%)	Produces minimal liquid waste

Chapter 4: Results and discussion

Qualitative and quantitative data was divided into pre- and post-intervention results. As stated earlier, pre-intervention will refer to any data gathered prior to the selection and implementation of POUs as well as educational campaigns and other outreach activities. It is necessary to perform a comparison of pre- and post-intervention results in order to evaluate the success, efficacy, and overall acceptance of the systems proposed as well as assess the health risk reductions from the outreach campaign and the use of POUs for both Juárez and El Paso colonias.

4.1 Pre-intervention

Surveys

Subjective perceptions of water quality are essential to understand quality of life issues amongst residents of colonias (Garcia, 2016). Measuring the level of confidence and trust of residents in their water providers is needed in order to analyze the progress or change of perception after the intervention, as well as the willingness of the residents to adopt proposed POU technologies.

Pre-survey were divided into sections: Water Source/Treatment/Water Use, water quality, additional drinking water, water storage/tanks, and demographics. Complete survey results values by percent are presented on Appendix B. Surveys were offered in English or Spanish according to the participant preference.

Colonias in Juárez

Pre-intervention surveys were conducted to 44 colonia residents that rely on hauled water stored in small above ground tanks as their primary water source; all participants provided demographic information, seven decided not to provide general information and 12 decide not to

report ethnicity, three participants decided not to report income, and another three were unsure of their income. For any variables with results containing no answers, adjustments were made to calculate accurate percentages of summarized results by modifying n=44 to the adequate n variable, in cases were response was on a 1-5 scale to agree or disagree with a particular sentence, no answers were accounted for as a no strong feelings number 3 variable.

Of the respondents, 78% female with a mean age of 44 years, and 80% identified as Hispanic. Out of the participants that reported income, it was observed that 73% was classified as living under the poverty level.

For household income, conversion of currency was applied in order to have the same units for El Paso and Cd. Juárez, Mid Exchange Rate of 1 USD= 19.01 Mexican pesos for the year 2018 was used. Results were re-coded into binary variables of ¨at or below poverty level¨ and ¨above poverty level¨ from 2019 federal poverty guidelines using a family of four poverty rates measured by Mexico's National Council for the Evaluation of Social Development Policy (CONEVAL 2015) defined as living on less than $11,291.00 pesos or $593.65 U.S. dollars a month.

For perceptions of drinking water the following values were obtained, out of all participants, 56% reported their water unsafe to drink, 36% considered it safe for drinking, and 8% were indifferent to the situation; regarding taste and smell 59%, and 32% respectively reported them as not acceptable. Out of all participants and to the best of their knowledge, 81% have never had their water quality tested, and over 72% expressed that they did not know ways to maintain or improve water quality. A majority of 83% of participants expressed concern on getting ill by drinking their stored hauled water, and 33% reported experiencing an illness that they attribute to drinking the main source of water.

The following values represent practices from colonia residents:

- 29% reported hauled water to be their main source for drinking water,
- 51% to brush their teeth
- 31% uses hauled water to cook
- 35% to prepare hot drinks such as coffee or tea
- 18% to prepare cold drinks

During the data analysis, a trend of inconsistencies was noticed between user perceptions on water and their actual practices. For example 55% of participants expressed concern on the safety of their water for drinking purposes, however 76% of participants reported purchasing additional of bottled or jugged water for drinking, resulting on a 21% percent of people reporting confidence in hauled water for drinking but yet purchasing additional water for the same purpose, same can be compared to smell and taste, only 28% of participants reported the taste of the water to be acceptable, and 48% percent was happy with the smell of the hauled water.

Only 27% of participants reporting giving treatment prior to using it for drinking, at the same time 96% of participants expressed desire to learn about ways to treat water, and a 100% of participants expressed interest in learning about water filtration systems.

Colonias in El Paso

Surveys were conducted to five colonia El Paso colonia residents relying on hauled water stored in large above ground tanks as their primary water source. As previously stated for any variables with results containing unanswered variables, adjustments were made to calculate accurate percentages using the actual number of responses.

All respondents were female and identified themselves as Hispanics with an average with age of 51 years, 40% of participants reported an income that places them under poverty lines for a family of four by U.S. Department of Health & Human Services 2019.

Out of all participants, 60% reported their water unsafe to drink with unacceptable taste, 40% were indifferent to the quality of their water; 40% reported perceiving a bad smell from their water tanks. To their best knowledge, only 20% having their water tested in the previous five years.

Participants showed concerns regarding proper ways to maintain the quality of their water, 80% reported to worry about chemical and microbiological contamination and 100% worry that consuming hauled water could pose a risk to their health, only 20% reported to have experienced an illness attributed to drinking hauled water.

Pertaining water practices, 80% use hauled water to brush their teeth, 40% uses hauled water to cook. However, none of the participants reported giving further treatment to their water.

Finally, all participants expressed desire to learn about water treatment and water filtration systems.

Inconsistencies were found during survey analyses, while participants reported hauled water to be their main drinking water source, 60 % considered it unsafe to drink and the taste to be unacceptable, at the same time 100% reported purchasing additional drinking water.

Comparison of Juárez and El Paso colonias pre-survey results.

In order to accurately compare water perceptions and practices from colonia residents of Juárez and El Paso, a more significant number of surveys would be required. However, it was observed that the residents in Juárez were more open to sharing information about their water

supply. The use of the community center may have provided a familiar atmosphere on which participants felt comfortable to answer survey questions.

Water storage setups differ by location. In El Paso, we observed large capacity tanks (>1000 gallons) that were dark and covered; people had indoor plumbing installations allowing access to water by a faucet. In Juárez several small capacity tanks (<300 gallons) are used, often left uncovered, none of the residents had indoor plumbing. In both of the colonias, residents expressed concerns about the safety of their water supply that result in purchasing of additional water for drinking.

Results showed that residents in colonias in El Paso were more distrustful of their water quality than in Juárez. However, practices show inconsistencies between practices and perceptions for both of the colonias, as shown in Figure 4.1. These results are consistent with results reported by Garcia et al., 2016 for colonias in El Paso.

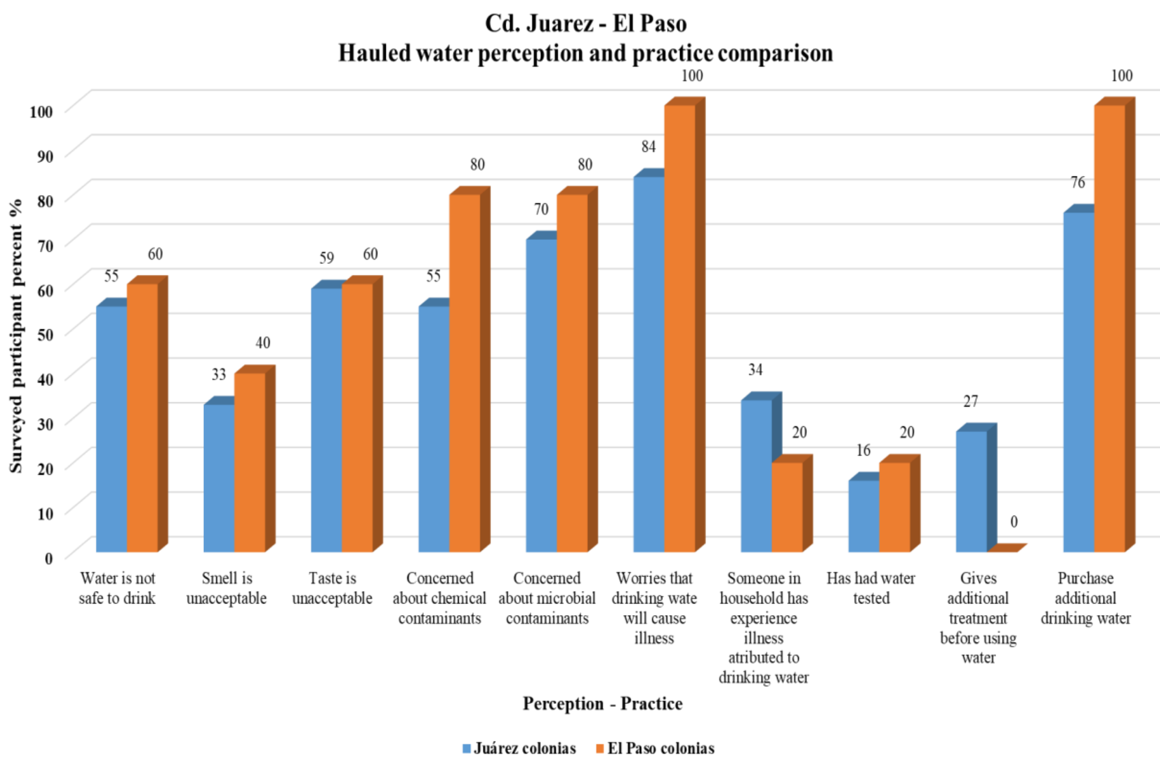


Figure 4.1: Hauled water perception and practice comparison by colonia

Despite most Juárez and El Paso colonia perceptions that their water is not safe, they continue using it for drinking. Table 4.1.1 presents a comparison of the summarized data on practices and perception inconsistencies by colonia.

Table 4.1.1: Comparison of discrepancies between practices and perceptions of hauled water by colonia residents.

Discrepancy	Cd. Juárez	El Paso
	n=44 (100%)	n=5 (100%)
Water is not safe to drink VS	**55% (24/44)**	**60% (3/5)**
Used water for cooking	37.5% (9/24)	33.33% (1/3)
Used water to brush teeth	50% (12/24)	66.6% (2/3)
Used water to make drinks hot/cold	37.5% (9/24)	0% (0/3)
Smell is unacceptable VS	**33% (15/44)**	**40% (2/5)**
Used water for cooking	6.6% (1/15)	50% (2/4)
Used water to brush teeth	60% (9/15)	100% (4/4)
Used water to make drinks hot/cold	26.6% (4/15)	0% (0/4)
Taste is unacceptable VS	**59% (26/44)**	**60 % (3/5)**
Used water for cooking	15.3% (4/26)	33.3% (1/3)
Used water to brush teeth	50% (13/26)	66.6% (2/3)
Used water to make drinks hot/cold	30.7% (8/26)	0% (0/3)
Concerned about chemical contaminants VS	**55% (24/44)**	**80% (4/5)**
Used water for cooking	16% (4/24)	25% (1/4)
Used water to brush teeth	54.1% (13/24)	75% (3/4)
Used water to make drinks hot/cold	41.6% (10/24)	0% (0/4)
Concerned about microbial contaminants VS	**70% (31/44)**	**80% (4/5)**
Used water for cooking	26% (8/31)	25% (1/4)
Used water to brush teeth	81% (17/21)	75% (3/4)
Used water to make drinks hot/cold	51.6% (16/31)	0% (0/4)
Worries that drinking water will cause illness VS	**84% (37/44)**	**100% (5/5)**
Used water for cooking	29.72% (11/37)	40% (2/5)
Used water to brush teeth	59.45% (22/37)	80% (4/5)
Used water to make drinks hot/cold	62.1% (23/37)	0% (0/5)
Someone in household has experience illness attributed to drinking water VS	**34% (15/44)**	**20% (1/5)**
Used water for cooking	26.6% (4/15)	0% (0/1)
Used water to brush teeth	40% (6/15)	0% (0/1)
Used water to make drinks hot/cold	60% (9/15)	0% (0/1)

Results showed that colonia residents perceive hauled water stored in tanks as an unacceptable source for drinking water. Negative perceptions of water safety and quality compared to contradictions in water practices showed a lack of alternatives to drinking water.

The majority of the participants lacked confidence in the quality of the water and how they store it.

One of significant difference is that 33% of residents in Juárez who claim to have presented illness attributed to the use of their hauled water for drinking versus 20% in El Paso, also of the respondents in Juárez 83% worry about contracting illness versus 100% of the residents in El Paso.

A large percent of the residents in both of the colonias live under poverty conditions and expressed the need to purchase additional drinking water. This additional expense is one example of how the lack of infrastructure and lack of connection to centralized systems, leads to a lower quality of life level.

By examining the numerical values of percentages of participants contradicting their practices to perceptions of water quality indicate unsafe practices:

- Only 27% of the participants in Juárez give additional treatment to water before using it
- 60% of El Paso participant report to never have cleaned their tanks
- Inconsistency in quality testing (Only 16% of the residents in Juárez and 20% in El Paso recall having their water previously tested)

For all residents in both El Paso and Juárez the lack of information about safe practices for treating and conserving the water quality add to health risks.

Focus Group

As stated earlier, focus group participants were asked questions regarding their water source, perception of water quality, and concerns from using hauled water for domestic purposes. Recurrent comments expressed a lack of trust in the hygiene of hauling trucks and debris presence from the source at delivery time such as tree branches and leaves.

Colonia residents reported feeling like the price they pay is too high for que quality of their water service. It was revealed that JMAS provides potable water free of charge for up to two five gallon jugs per family daily. However, residents are required to drive or walk their homes to these water stations, a practice that can be cumbersome for those who lack a means of transportation. Some of the residents had the perception that water quality differs by colonia and were willing to travel long distance in order to get what they perceive to be "better" quality, as a consequence, some of the water stations that are perceived as "better" quality run out of water before some of the residents in the area can get their share, forcing them to purchase additional water from private sources.

During the September focus group session, several of the residents complained about an oil film in the surface of their tanks (Figure 4.2) and "worms" (Figure 4.3), and expressed a lack of knowledge regarding their origin, they perceived that these contaminants are coming from unclean hauling trucks, but were concerned that speaking up may result in conflict.

Figure 4.2: Oil film observed in stored water from colonia in Juárez

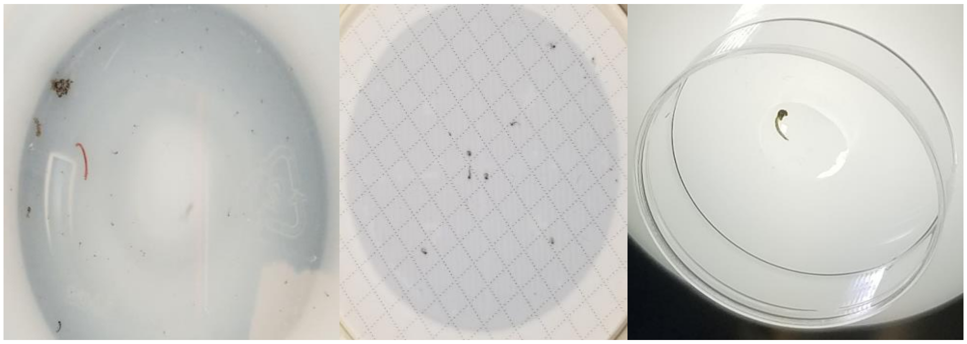


Figure 4.3: Larvae found on water samples collected during summer 2018 focus group

Samples of the so-called "worms" were collected for analysis by Dr. Doug Watts Co-Director of Infectious Disease and Immunology Border Biomedical Research Center. Dr. Watts identified them as Ochlerotatus epactius, and Chironomus midge larvae may be vectors for Nile virus and Dengue fever. Figure 4.4 shows photos of the specimens taken with a high-resolution microscope.

Figure 4.4: Specimens collected from hauled water storage tanks at colonias in Juárez

The discussion revealed that residents lack knowledge on how to properly clean their storage tanks. The majority of them expressed that often storage tanks are refilled before they get an opportunity to clean them, as hauling trucks for colonias in Juárez run on fixed schedules they either take the supply or face running out of water. This could also represent contamination of the new supply by mixing it with residual water that has been stored for over a week.

In addition, residents reported concern about skin conditions that they attributed to showering with hauled water, such as dry skin, dandruff, and rashes, participants had no knowledge of proper methods for chlorination of their supply and admitted to adding up to a cup

of Chlorine to storage tanks with capacity under 300 gallons, while others mentioned they had never added any disinfectant.

A typical overall perception of poor water quality was evident, as was the interest of the participants to improve their current condition.

For the second part of the focus group different POUs were presented the group, participants were asked what they like or dislike about them, what challenges they foresee and their willingness to use it considering the ease of use, preference of set up, cost, maintenance, and any additional comments. Limitations on the systems that could be provided had to do with current installations at the colonias, as the vast majority of the residents lack access electricity or indoor plumbing. Preferences showed participants want a gravity system that is low cost, easy to use, that would assure removal of debris, insects, and worms, as well as improve the smell and taste of the water.

For the final section of the groups, participants were asked to provide additional comments and concerns regarding the quality and use of the water, in this section the overall concern was algae growth (Shown in Figure 4.5). Most participants would like to change the type of tanks that are provided to them for a design that would hermetically closing lids, such as the Rotoplasma brand tanks (Figure 4.6) as they have observed that there is an increase of air laden dust contamination on high wind days due to tanks not being appropriately covered (Figure 4.7). As stated in the pre-survey result section, a large percentage of colonia residents live in impoverished conditions, with little or no means to purchase appropriate storage tanks. Therefore, residents end up purchasing any tank they can afford.

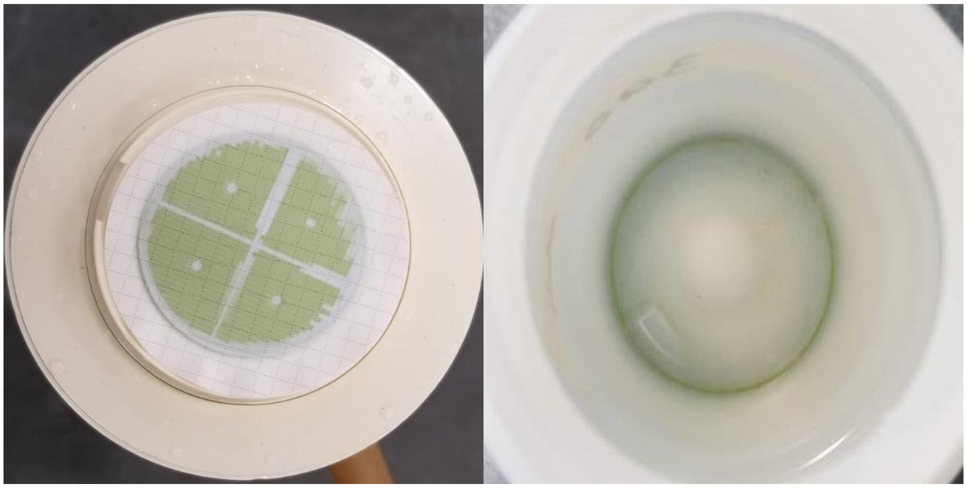


Figure 4.5: Algae present in samples collected from colonias in Juárez.

Figure 4.6: Low capacity Rotoplasma tank at colonias in Juárez

Figure 4.7: Clear and uncovered tanks at colonias in Juárez

One of the most important findings of the focus groups is the willingness of the residents of colonias to participate in this study and their desire to improve the quality of their water and learn about proper storage practices and further techniques. Participants preferences were driven by ease of use of the devices proposed, followed by contamination removal.

As mentioned earlier, previously performed focus groups in colonias in El Paso as part of an EPA project (Campos et al., 2013a, b, c, 2014; Palacios et al., 2014) provided information necessary for analysis. In the previous study, participants appeared to be influenced by the convenience of using an under the sink POU and the contaminants they could remove, followed by their cost and environmental impact.

The qualitative data gathered and analyzed support the need for intervention in colonias to identify possible contaminants present in their water, their treatment options, in combination with educational campaigns, workshops, and dissemination material.

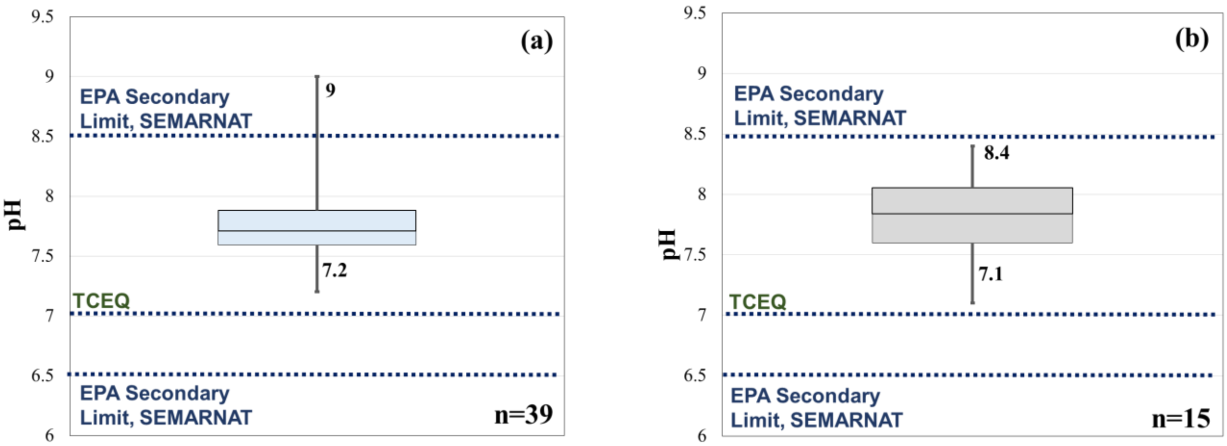
All these combined activities help improve the public health of residents in colonias. Not having control over the water quality used in unprivileged communities such as the colonias can result in waterborne disease. Efforts to implement effective, sustainable, and low-cost treatment, as well as periodic testing, are imperative.

Water quality analyses

pH

Results were compared to EPA 6.5-8.5 secondary limits and TCEQ >7 (30 TAC §290.105(b)). For colonias in El Paso, all samples complied with EPA secondary limits; however, 100% of the samples were over TCEQ secondary limits, with a pH recorded ranging from 7.1 to 8.4. pH values per sample are shown in Appendix C

Samples taken from colonias in Juárez have a pH range from 7.20–9.00, out of the samples 5.12% were out of compliance by EPA´s secondary limit and SEMARNAT's Norma Oficial Mexicana NOM-127-SSA1-1994, exceeding pH of 8.5, a 100% of the samples from colonias in Juárez were out of compliance for pH recordings under TCEQ secondary limit. Summarized statistical results are shown in Figure 4.8 using a box and whiskers plot.[1]



Cd. Juárez Kilómetros Colonias Pre-Intervention Samples **El Paso Hueco Tanks Colonias Pre-Intervention Samples**

Figure 4.8: Statistical pH values for pre-intervention sampled water

Total Dissolved Solids (TDS)

Results for Total Dissolved Solids TDS concentrations can be found in Appendix C; Graphical representation of summarized results using box and whiskers plots[1] are shown in Figure 4.9. For analysis consideration, EPA's secondary limit of 500 mg/L TDS (40 CFR §143.3) and Texas Commission on Environmental Quality and Norma Oficial Mexicana NOM-127-SSA1-1994 secondary limit of 1,000 mg/L TDS (30 TAC §290.105b) were used as parameters. Pre-intervention samples show that over 84% of samples collected from colonias in Juárez exceed EPA's limit, and over 7% exceed TCEQ secondary limits. The concentration of TDS ranges from 448 – 1510 mg/L.

[1]Every box represents a quartile and whiskers represent minimum and maximum values recorded, the line between the two boxes represents the 50th percentile median value.

In samples collected from colonias in El Paso, we found that 100% exceed EPA's secondary limit and 33% of the samples exceed TCEQ secondary limit for TDS, concentration ranges from 561 mg/L to 1280 mg/L.

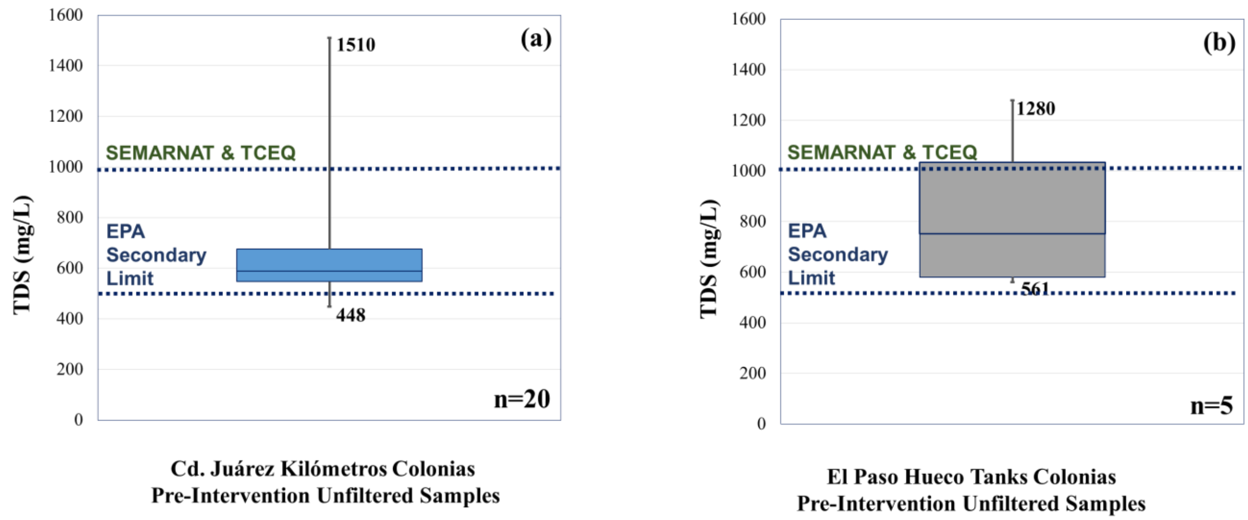


Figure 4.9: TDS concentrations of households Pre-Intervention sampled water

Hardness

When analyzing results for water hardness as $CaCO_3$ water containing concentrations below 60 mg/l was considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard (McGowan, 2000).

Unfiltered samples from the colonias at Juárez show hardness values as $CaCO_3$ of 15.9 to 142 mg/L, of this six percent are considered as soft water, 83 % moderately hard, and 11 % hard.

Results for unfiltered samples show a hardness range from hard (67 %) to moderately hard (11%) and very hard (22%) water with values of 94.6 to 203 mg/L as $CaCO_3$ for samples collected from colonias in El Paso. Unfiltered samples show hauled water from colonias in Juárez to be slightly less hard than those from El Paso.

Total and free Chlorine

Total and free Chlorine concentrations were measured for each of the samples; during collection, it was learned that disinfectant is not usually added as a control measure by residents of the colonias. The small percentage of residents who reported doing so admitted to not knowing the proper dosage for their tank capacity.

Figure 4.10 shows a sample collected from a colonia in El Paso, a Chlorine concentration of 5.5 mg/L can be observed in the left vial as sample turns a bright pink color when in contact with reagent. Total and free Chlorine concentrations found on pre-intervention samples are presented in Appendix C. Results show that 20% of samples from colonias in El Paso to be over established limits for total Chlorine.

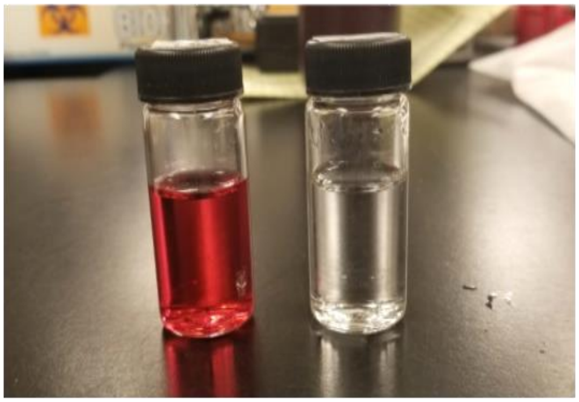


Figure 4.10: Water sample with high Chlorine concentration collected in El Paso

Due to the use of clear uncovered tanks, chlorination for colonias in Juárez presents an additional challenge, it is known that exposure to light significantly decreases the decay rate of Chlorine (Cooper et al., 2007) which can lead to algae growth (values for chlorophyll A and B found in water samples are shown in Appendix C) observed in several samples, for this and various reasons residents often opt to add large amounts of Chlorine which can translate into additional health risks.

Heavy metals

ICP-OES tested concentrations for inorganic chemicals mentioned earlier, any duplicate samples showing inconsistency in concentrations were re-tested, if concentrations showed a significant difference that would place them above permissible limits, they were preserved by adding two percent Nitric Acid according to sample volume, in order to get tested by a certified laboratory. Final results found in Appendix C show that none of the samples tested for both Juárez and El Paso colonias exceeded standards and therefore were not accounted for health risk assessment.

Microbiological contaminants

Pre-intervention sample analyses show microbial contamination (Total coliforms, *E. coli,* and *Enterococcus*) in both of the colonias. Results were quantified using the most probable number (MPN); these values are necessary to simulate health risk factor into a beta model.

After analyzing the data collected from the complete summer campaign, it was evident that colonia households in Juárez had a substantially higher number of bacteria present than households in El Paso (As shown in Figure 4.11)

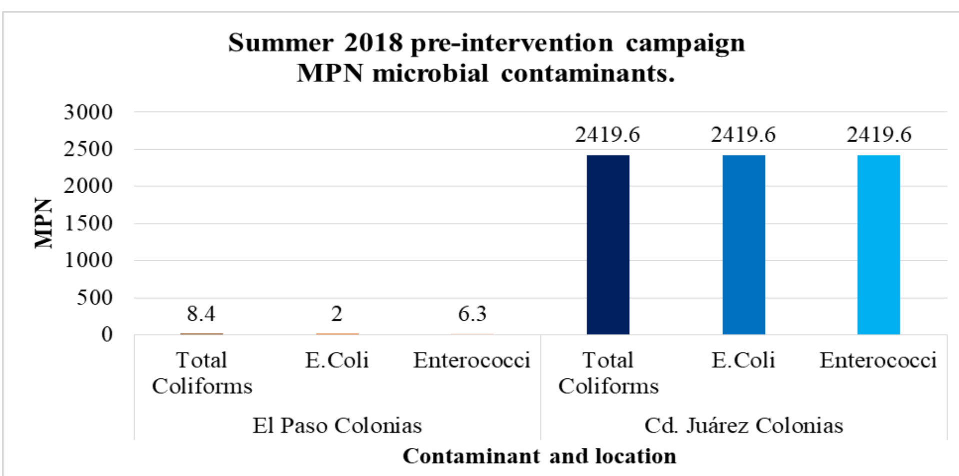


Figure 4.11: Highest MPN count of samples with microbiological contamination

Results not only indicated that contaminant presence differs by multitudes from Juárez to El Paso but also showed that colonias in Juárez were by far more likely to have health issues due to microbial contamination. Table 4.1.2 shows the percent of samples with contaminant present as well as high and lowest MPN values by location.

Table 4.1.2: Samples with microbiological contamination by location.

Microbial contaminant presence		
Summer 2018 pre-intervention campaign		**% Samples contaminated**
El Paso Colonias	Total Coliforms	40%
	E. Coli	20%
	Enterococcus	100%
Juárez Colonias	Total Coliforms	75%
	E. Coli	40%
	Enterococcus	85%

These results are of extreme importance to develop educational material, disseminated via workshops, and to select adequate POUs.

Microbial health risk assessment

Quantitative microbial health risk assessment was performed for *E. coli*, specifically dose-response modeling and exposure data to estimate the likelihood of infection, disease, or death when exposed to hazards. This method also helps to evaluate the efficacy and effectiveness of water treatment technologies by comparing results to health risk-based criteria.

Pre-intervention results show calculations for annual risk probability in ranges of 0.00% to 99% for colonias in Juárez, a great contrast to risk values obtained for colonias in El Paso with estimated risks probability ranges from 0.00% to 0.47%.

Out of the samples analyzed from colonias in Juárez, calculations show that at least 25% fall under the moderate risk classification, while risk values for colonias in El Paso are considered very low risk. Average results showed that colonia residents in Juárez have a 17% risk of infection for colonia residents in Juárez, compared to 0.09% for residents of colonias in El

Paso. Therefore the risk of adverse health due to the consumption of hauled water is about 190 times greater than residents of colonias in Juárez. Figure 4.12 shows a) graphical representation of annual risk values by colonia, b) box and whiskers plot, if shown every box represents a quartile and whiskers represent minimum and maximum values recorded, the line between the two boxes represents the 50th percentile median value, in Juarez case M= 0.23 meaning that while some of the sites present a high risk calculation this does not necessarily mean that colonia residents are at an immediate threat of an adverse effect happening due to microbial contamination and consumption of their hauled water the, for El Paso shown to the right, health risk values are close to zero. Therefore only error bars are shown in the plot.

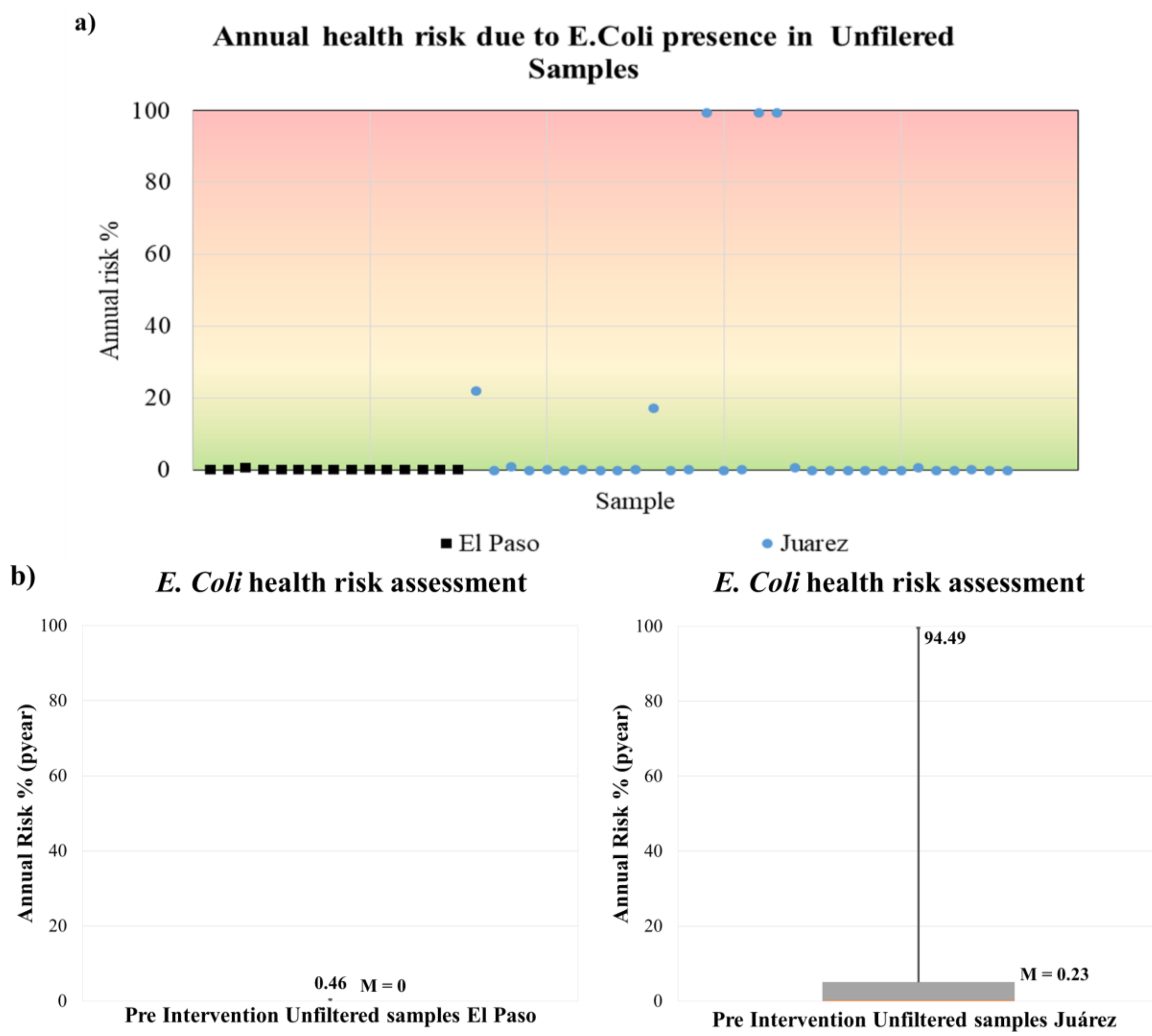


Figure 4.12: Annual health risk for *E. coli* on pre-intervention samples

Point of Use system selection

The goal is to select a POU system that complies with the contaminant removal needs shown during water quality analysis and criteria mentioned previously (social acceptance, possibility of implementation, sustainability). The systems selected would need to remove microbial contaminants in accordance with the suitability designed by EPA as a Small System Compliance Technology (SSCT) (Federal Register, volume 63, No 152, August 6, 1998) and NSF /ANSI list.

For the POUs to be accepted by colonia residents, the systems needed to be able to provide safe water at a similar or lower cost than the families are currently spending.

Due to differences of setup by location, as well as contaminant presence, it was not expected that the same POU could provide optimal treatment for both of the colonias. Observations showed that residents from colonias in Juárez required a portable, low energy consuming system, while residents in El Paso would benefit from in-line systems. Table 4.1.3 shows POU score analysis modified from the previously developed top-list table by Campos, 2015.

Table 4.1.3: Top ranking systems by evaluation score, modified from Campos, 2015

Rank	Company and Model #	Configuration	Type of Treatment	Technical Perform.	Verif. and Certif.	User Pref.	Economic Sustain.	Env. Sustain.	Total
1	GE-GXRM10RBL	POU In-Line Filtration	Reverse Osmosis (RO)	3	3	3	2	2	13
1	Pentair-RO-2550	POU In-Line-Filtration	RO	3	3	3	2	2	13
1	Whirlpool-WHER25	POU In-Line-Filtration	RO	3	3	3	2	2	13
1	Whirlpool-WHAPSRO	POU In-Line Filtration	Reverse Osmosis (RO)	3	3	3	2	2	13
2	GE-PXRQ15RBL	POU In-Line Filtration	Reverse Osmosis (RO)	3	3	3	1	2	12
2	Multipure-MP750PlusRO	POU In-Line Filtration	RO	3	3	3	1	2	12
2	Sawyer- PointONE Filter with Bucket Adapter Kit	POU Batch	MF	2	2	2	3	3	12
2	Whirlpool-WHAROS5	POU In-Line Filtration	Reverse Osmosis (RO)	3	3	3	1	2	12
3	AMI-M-U2540PES	POE In-Line Filtration	UF	3	1	3	1	3	11
3	Filtrete-4US-MAXL-S01	POU	Cartridge/Carbon	2	3	3	2	1	11

		In-Line Filtration							
3	Clorox-4460030799	POU Batch Disinfection	Sodium Hypochlorite	2	1	2	3	3	11
3	Basic Water Needs-Tulip-Siphon	POU Batch Filtration	Ceramic Filter	2	2	2	2	3	11
3	Sawyer-SP293	POU Batch Filtration	UF	2	2	2	2	3	11
4	Philips-UV-2GPM-220-CE*	POU In-Line Disinfection	UV	2	1	3	2	3	10
4	Pure-Ozone Faucet Tap Water System	POU In-Line Disinfection	Ozone	2	1	3	2	3	10
4	Viqua-SC1	POU In-Line Disinfection	UV	2	1	3	2	3	10
4	OEM-QY- HFUF 10	POU In-Line Filtration	UF	2	1	3	3	1	10
4	Everpure-ViruPure	POU In-Line Filtration	UF'	2	3	3	1	1	10
4	Filtrete-3US-PS01	POU In-Line	Cartridge/Carbon†	1	3	3	2	1	10

		Filtration							
4	GE-GXSV65R	POU In-Line Filtration	Carbon Block	1	3	3	2	1	10
5	Multipure-MP880SC	POU In-Line Filtration	Cartridge/Carbon†	1	3	3	1	1	9
5	Seychelle-1-10300-FC-K	POU Batch Filtration	Ionic Adsorption Micron Filtration System	2	2	2	2	1	9
5	Seychelle-1-40101-W	POU Batch Filtration	Cartridge/Carbon†	3	2	1	2	1	9
5	Cascade Designs-Platypus Filter	POU Batch Filtration	MF	2	1	1	2	3	9
5	Steripen-SteriPEN Classic 3	POU Batch Disinfection	UV	2	2	1	2	3	9
5	Steripen-SteriPEN Sidewinder	POU Batch Disinfection	UV	2	2	1	2	3	9
6	Fairey-HIP-Supercarb	POU In-Line Filtration	MF	1	3	2	1	1	8
6	Fairey-HIP- Ultracarb	POU In-Line	MF	1	3	2	1	1	8

		Filtration							
6	Camelback- 90783	POU Batch Disinfection	UV	2	1	1	2	3	8
6	Pure Hydration-Aquapure Traveller	POU Batch Filtration	2-micron Electrostatic Filter with PAC	2	2	1	2	1	8
7	Lifesafer-LIFESAVER jerrycan 10000UF	POU Batch Filtration	UF	1	2	2	1	1	7
8	PUR Water Pitcher	POU-Batch	Cartridge/Carbon	1	1	1	2	1	6

Several units with similar score values, depending on the possibility of implementation two systems were selected, Sawyer Point ONE gravity driven filter with a 5-gallon bucket for colonias in Juárez and an in-line Reverse Osmosis (RO) under the sink setup for colonias in El Paso.

Many of the RO filters evaluated and most all of the gravity filtration systems are not NSF certified to remove pathogens as point of use devices may not be employed to meet microbiological MCLs on a macro scale (40 CFR §141.100). However, removal of TDS in reverse osmosis (RO) systems and pore size of 0.1 microns "U" hollow fiber microtubes for the selected gravity filtration units suggest removal of bacteria and other pathogens.

Selected POU systems characteristics and comparisons

The Sawyer Point One Filter Bucket SP180 shown in Figure 4.1.13 was selected as the best option for colonias in Juárez, consisting of a high number of 0.1 microns "U" shape hollow-fiber microtubes, this system has the capacity to remove any microbiological contaminants found in the water. The setup for this POU allows the user to choose the amount of water to filter at a time, making it accessible for residents who find difficulty in carrying five-gallon jugs or boxes of bottled water.

Figure 4.13: Sawyer Point One Filter Bucket setup and components (Sawyer International Products, 2019)

The Sawyer system if considered of easy use as it requires almost no effort with gravity doing most of the work, while it exceeds EPA's requirements for removal of bacteria (99.9999% or 6 log) protozoa (99.9% or 3 log) viruses (99.99% or 4 log) it has not yet been NSF certified.

The manufacturer states that at sea level with a standard length hose, a Sawyer filter installed on a bucket can filter 170 gallons per day with a life expectancy of over 50 years if properly maintained by using backwash syringe included on the kit. A successful backwash can restore up to 98.5% of the filter's flow rate. In case of future development of the area, the Sawyer filter can be adapted onto faucets in case infrastructure reaches the colonias.

The limitation found in this system is heavy metal and hardness removal. However, since metal contamination was not found the Sawyer bucker filter is the best option that provides the most significant benefit to the water quality and the highest life expectancy in comparison to other manual filters.

At colonias in El Paso, infrastructure allows for installation of In-Line systems; the selected system was an under the sink reverse osmosis filtration unit by Whirlpool with model WHER25 (Figure 4.14 shows the typical system installation setup).

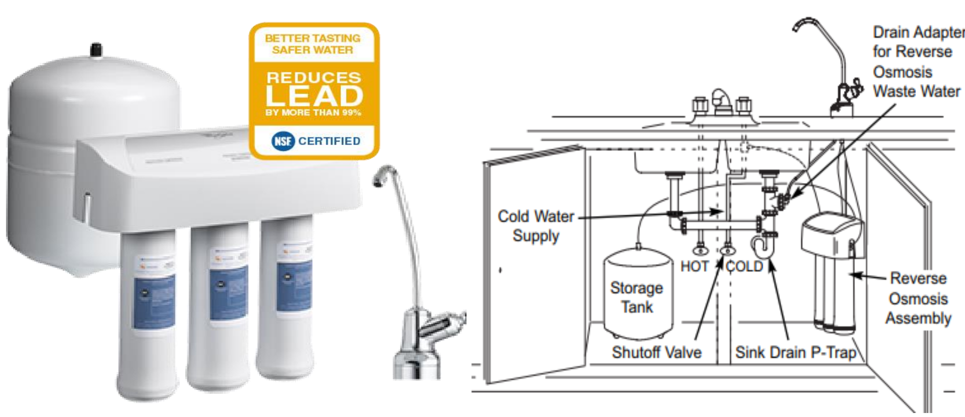


Figure 4.14: Under the sink RO typical installation. (Whirlpool Water Solutions, 2019)

This system includes three stages of filtration, a storage tank, and a product water faucet. The first stage of filtration is a carbon filter to prepare the water for the reverse osmosis filter.

The importance of this stage is the removal of sediments and the lowering of the Chlorine concentration to protect the reverse osmosis filter. The second stage of filtration is the reverse osmosis filter, removal of TDS suggests a high removal of bacteria, viral pathogens, and other possibly harmful contaminants. From the second stage, the product water is sent to the storage tank until the product water faucet is turned on. The concentrate from the second stage is sent to the drain. When the product faucet is turned on, the water travels through the third stage of filtration, which is a second carbon filter that helps with taste and odor. Overall, the system is relatively easy to install and operate when standard measurement plumbing is present. Another benefit of the system is easily replaceable filter cartridges for when the filters are at the end of their life cycles.

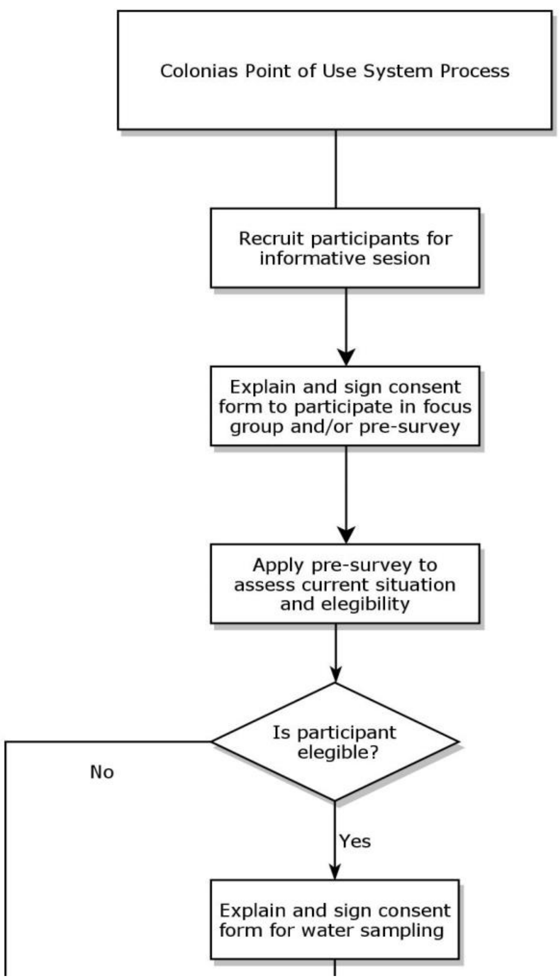
Table 4.1.4 presents a summary of the characteristics of filters selected for both communities.

Table 4.1.4. Selected systems comparison

	Colonias in El Paso	**Colonias in Juárez**
Analysis	**Whirlpool Reverse Osmosis Under the Sink System**	**Sawyer Point One Bucket System Filter**
Cost	$150.00 -$170.00 U.S. dollars	$25.00 - $60.00 U.S. dollars
Capacity cost by flow rate	$8.00-$9.20 U.S. dollars/gal	$0.15-$ 0.35 U.S. dollars/ gal
Maintenance Cost	$60.00 Dollars every 6 Months	Maintenance consists of backwashing the filter with kit supplies.
Life cycle	10-15 Years	50 + years
Microbiological Contaminant removal	Yes	Yes
Heavy Metal Removal	Yes	No
Needs Electricity and Connection to Water Line	Yes	No
Daily Capacity (6 hour use)	4.6 Gal	42.5 Gal
Meets EPA requirements	Yes	Yes

	Colonias in El Paso	Colonias in Juárez
Analysis	**Whirlpool Reverse Osmosis Under the Sink System**	**Sawyer Point One Bucket System Filter**
NSF	Certified for Standard 42 (reduction of Chlorine, taste, and odor), Standard 58 (reduction of arsenic, barium, cadmium, chromium (hexavalent), chromium (trivalent), copper, cysts, lead, nitrate, radium 226/228, selenium, turbidity, and TDS)	Exceeds NSF Recommendations for Viruses, Bacteria, and Protozoa. Not certified

General POU implementation model from participant recruiting to system installation is shown in Figure 4.15



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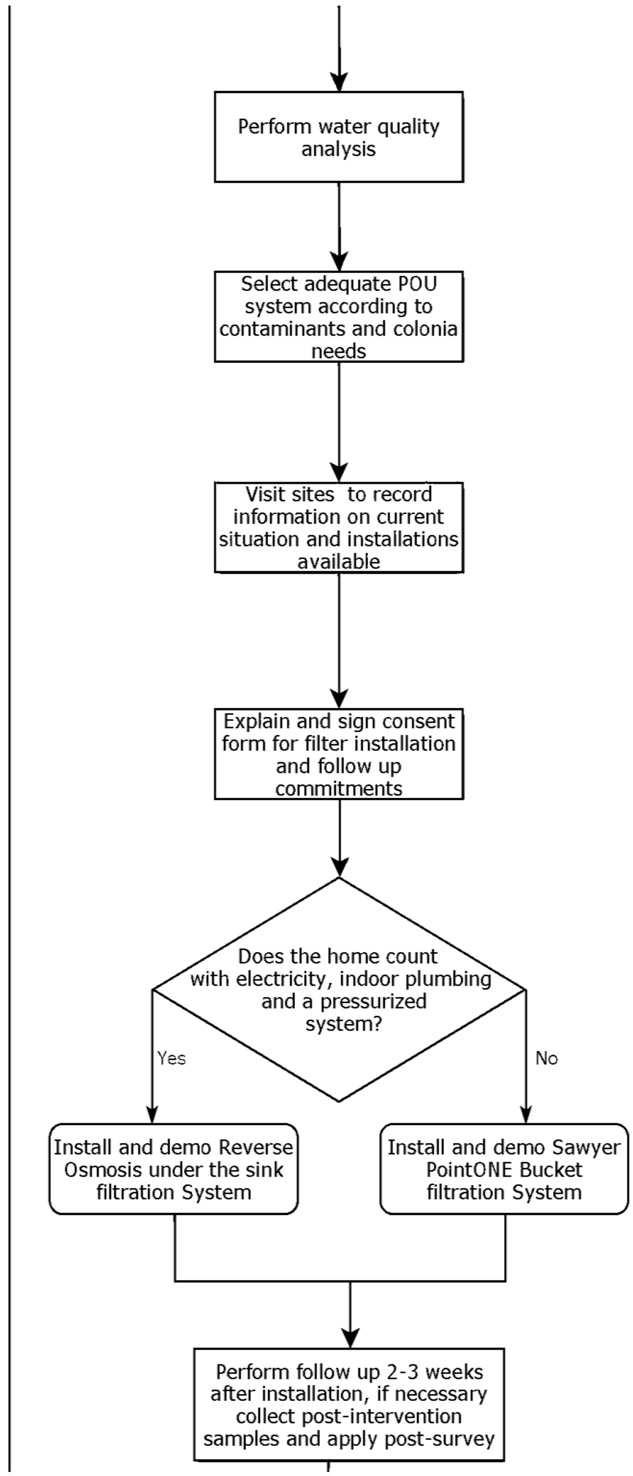
Perform water quality analysis
Select adequate POU system according to contaminants and colonia needs
Visit sites to record information on current situation and installations available
Explain and sign consent form for filter installation and follow up commitments
Does the home count with electricity, indoor plumbing and a pressurized system?
Yes
No
Install and demo Reverse Osmosis under the sink filtration System
Install and demo Sawyer PointONE Bucket filtration System
Perform follow up 2-3 weeks after installation, if necessary collect post-intervention samples and apply post-survey

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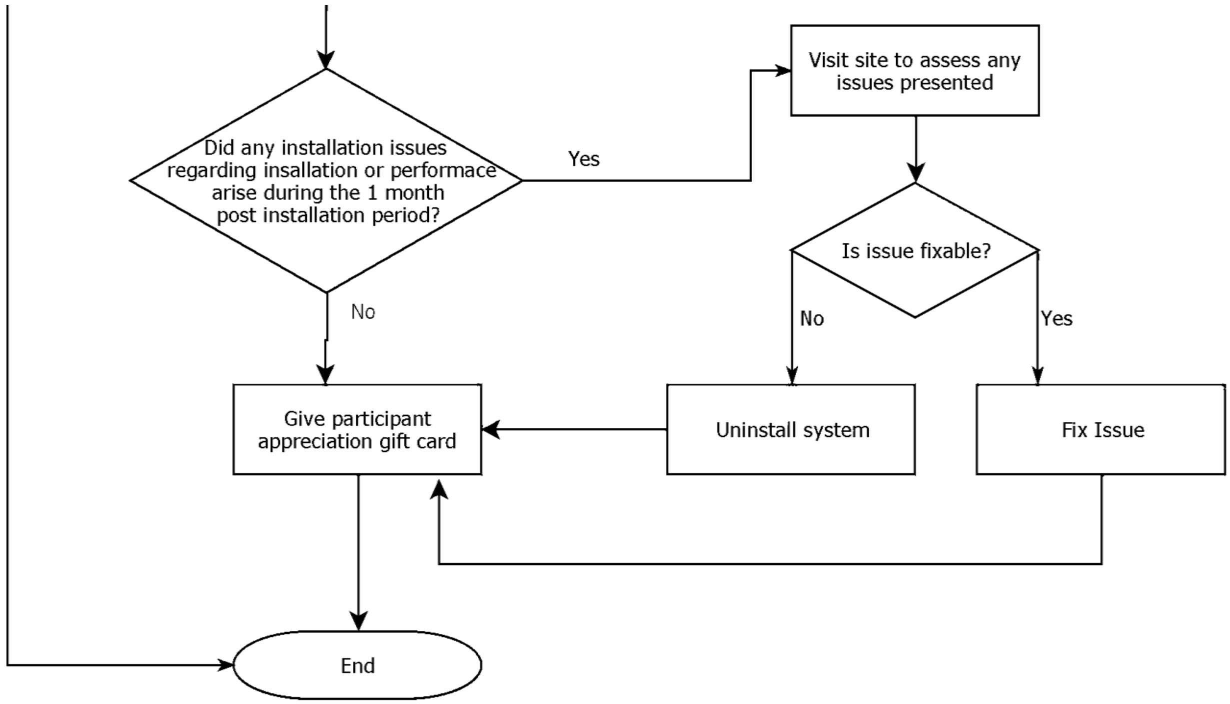
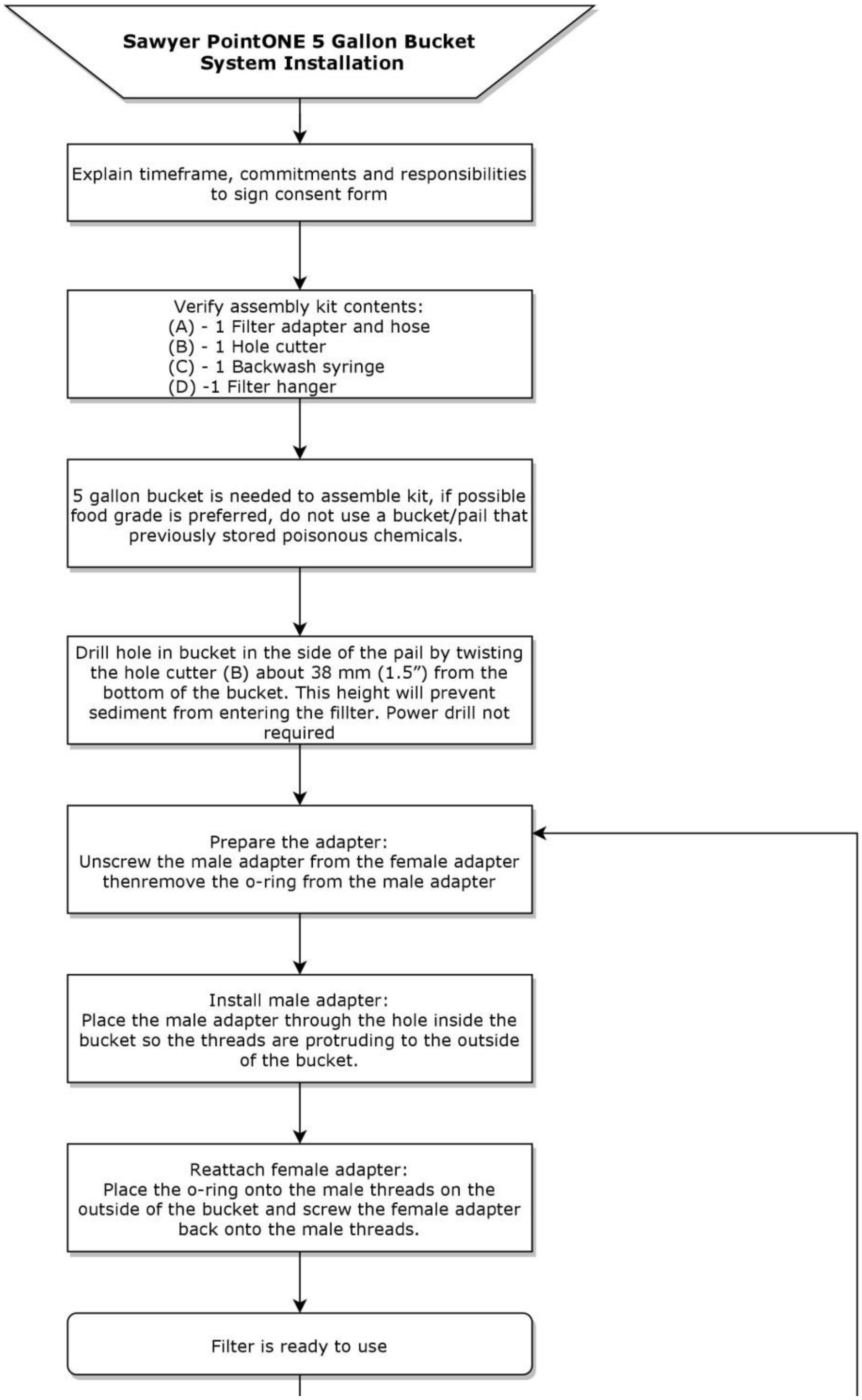


Figure 4.15: Colonias POU system implementation process

POU systems installations

Project staff consisting of volunteers from American Society of Civil Engineers (ASCE), Texas Society of Professional Engineers (TSPE) and Engineers for a Sustainable World (ESW), arranged visits to each of the participating homes to install the selected POUs. The study staff instructed participants on the use and maintenance of the device during this project, a total of 60 sawyer point one filtration units and 15 reverse osmosis filters were installed. Recipients of filtration units were required to attend an educational presentation before the filter installation. The number of filters installed in El Paso is significantly lower, due to the type of system provided, average time for under the sink systems installation is from two to three hours with more than one person performing the installation. In comparison, Sawyer bucket systems that take 15-30 minutes for installation and demonstration can be installed by easily installed by one person. Installation procedures adapted from manufactures and field experience for both systems

are shown in Figure 4.16 and 4.17, respectively, in them, we can observe the difference in complexity by system.



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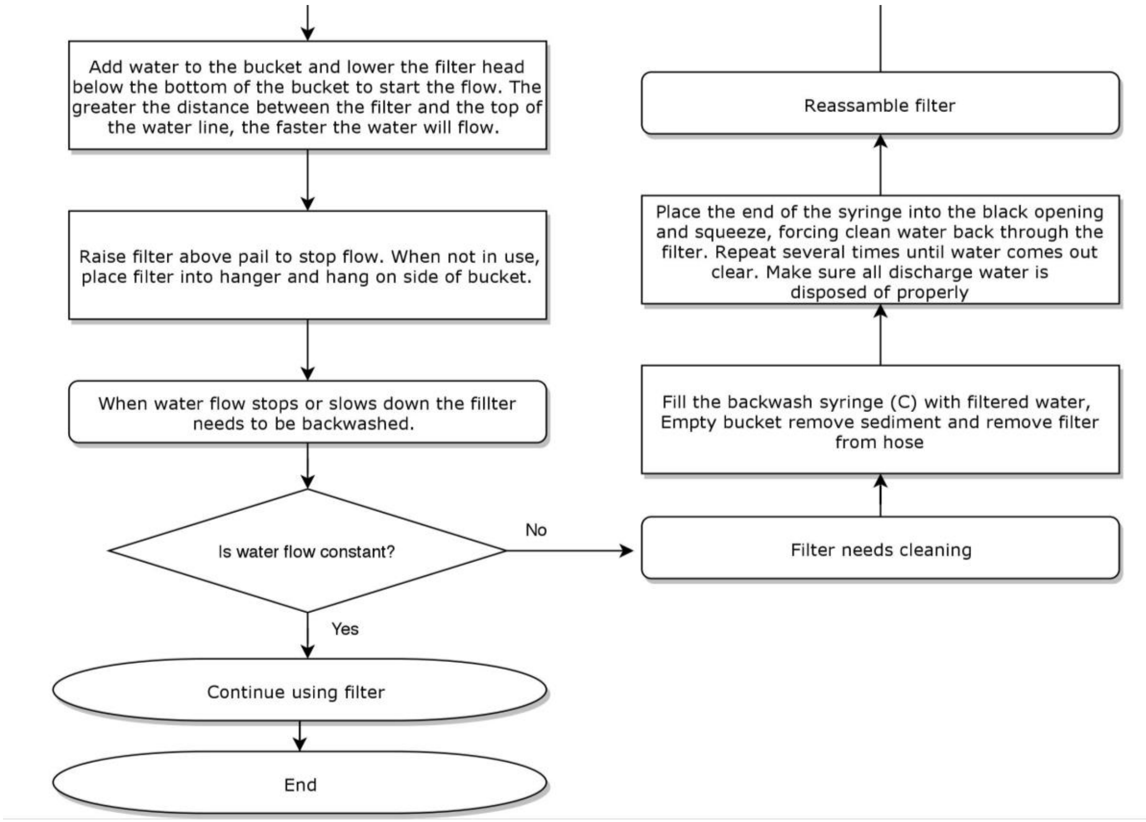
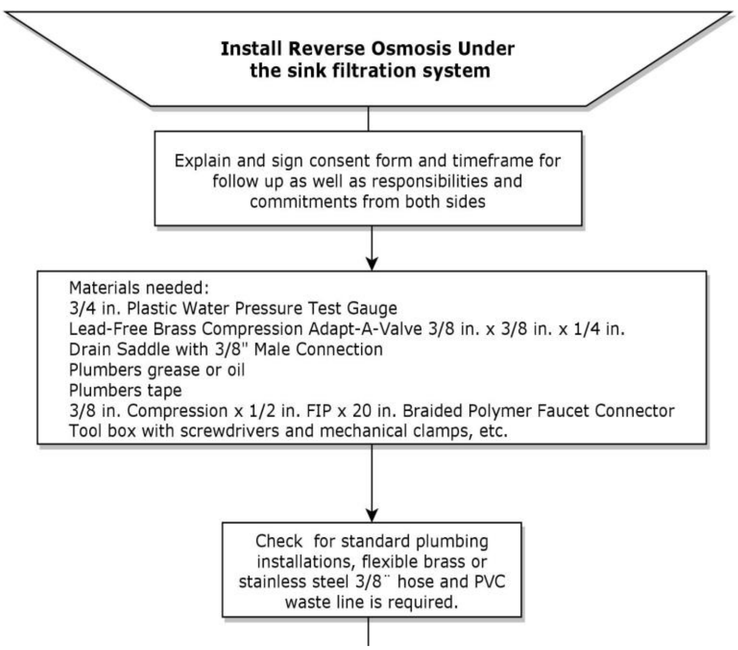


Figure 4.16: Sawyer PointONE 5 gallon bucket system installation.



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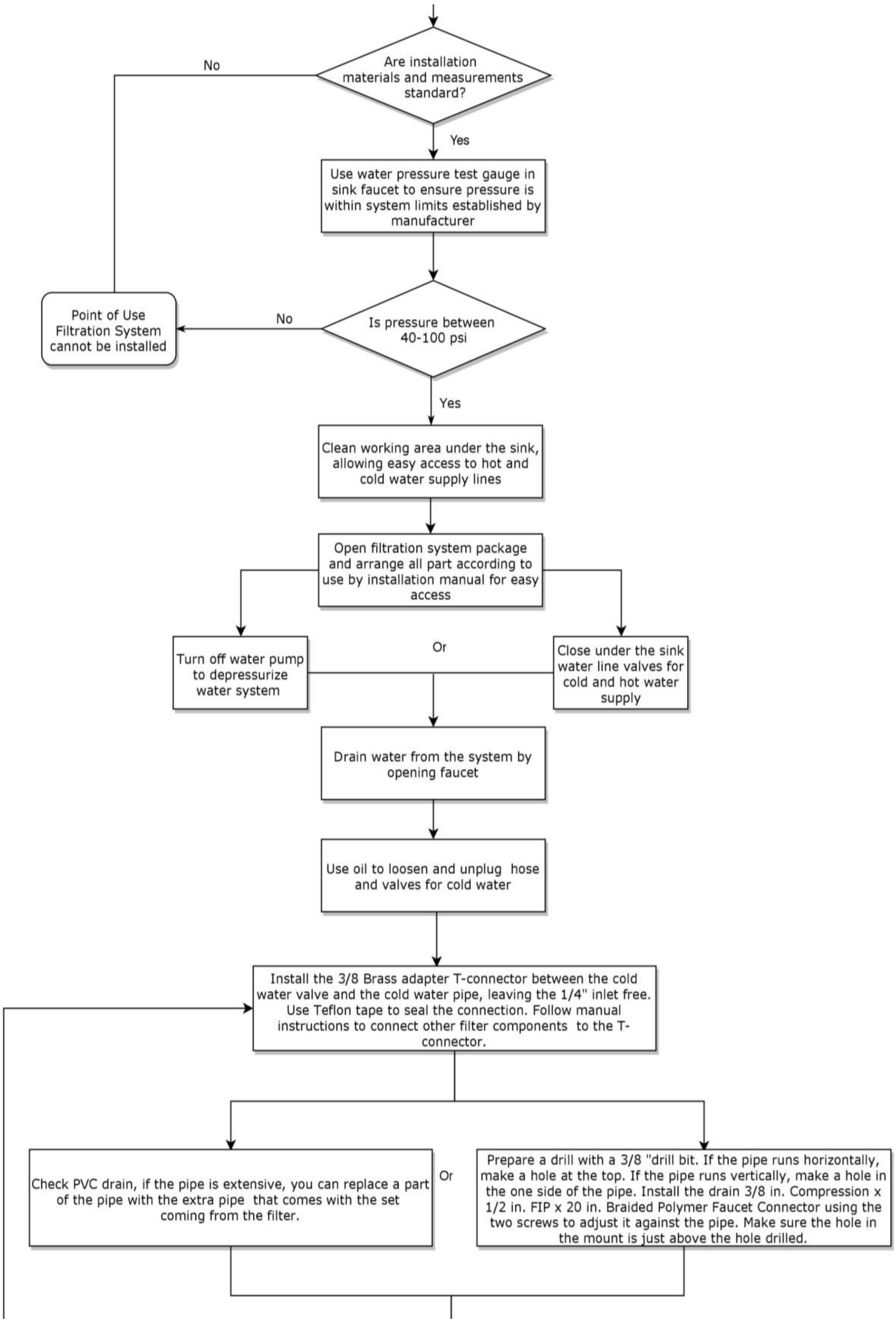

Are installation materials and measurements standard?
No
Yes
Use water pressure test gauge in sink faucet to ensure pressure is within system limits established by manufacturer
Is pressure between 40-100 psi
No
Point of Use Filtration System cannot be installed
Yes
Clean working area under the sink, allowing easy access to hot and cold water supply lines
Open filtration system package and arrange all part according to use by installation manual for easy access
Turn off water pump to depressurize water system
Or
Close under the sink water line valves for cold and hot water supply
Drain water from the system by opening faucet
Use oil to loosen and unplug hose and valves for cold water
Install the 3/8 Brass adapter T-connector between the cold water valve and the cold water pipe, leaving the 1/4" inlet free. Use Teflon tape to seal the connection. Follow manual instructions to connect other filter components to the T-connector.
Check PVC drain, if the pipe is extensive, you can replace a part of the pipe with the extra pipe that comes with the set coming from the filter.
Or
Prepare a drill with a 3/8 "drill bit. If the pipe runs horizontally, make a hole at the top. If the pipe runs vertically, make a hole in the one side of the pipe. Install the drain 3/8 in. Compression x 1/2 in. FIP x 20 in. Braided Polymer Faucet Connector using the two screws to adjust it against the pipe. Make sure the hole in the mount is just above the hole drilled.

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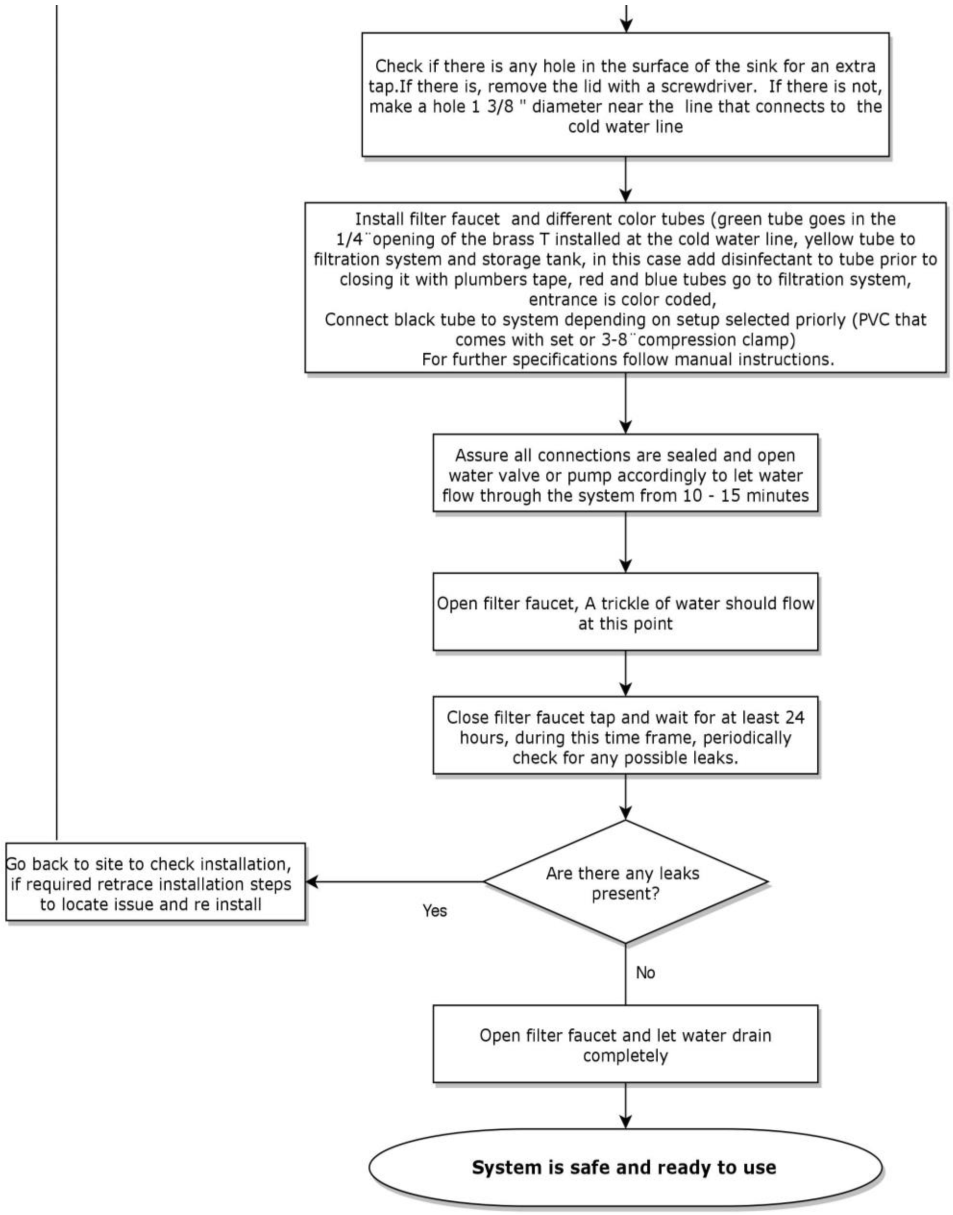


Figure 4.17: Whirlpool WHER25 under the sink RO system installation.

POU Investment cost return

By exploring the initial investment that would be needed to acquire the different POUs and the current expenditures that colonia residents attribute to purchasing additional water for drinking purposed we were able to perform a simple investment return analysis. The cost value used for Juárez Sawyer system was $60.00 USD, for El Paso, $170.00 USD was used as the price for the reverse osmosis Whirlpool system.

Residents in Juárez reported spending an average of $23.00 USD monthly for purchasing of additional water for drinking, while in El Paso the number was $28.40 USD.

With this values we can calculate that in a six month period residents from El Paso would be able to recover the initial investment, an additional three month period would be required for residents from El Paso colonias to allocate sufficient funds for yearly maintenance in the form of cartridge replacement. In total this nine month period could translate into colonia residents taking control of their drinking water scenario.

For residents in Juárez, investment return would happen after three month period. Taking into account that maintenance of the Sawyer POU system consists in backwashing with supplies found in the filtration kit, no maintenance costs were considered.

4.2 Post-intervention results

To assess the effectiveness of the systems implemented as well as the impact of educational workshops and campaigns, surveys focus groups and water quality were analyzed. Comparison of pre- and post-intervention results were evaluated.

Surveys

In order to compare and record changes in practices and perceptions after the selected POUs were given and used by families and started to be used regularly in the colonias, a post-intervention survey approved by IRB was applied. The survey consisted of similar questions regarding the practices and perceptions sections for the pre-intervention survey plus questions about the use of their POU. A copy of the post-survey applied can be found in Appendix A, summarized numerical results for post-survey can be found in Appendix B. A total of 26 surveys were analyzed, out of this 10 of the participants received an under the rink in line reverse

osmosis Whirlpool system and 16 a gravity-driven Sawyer Point One 5 Gallon Bucket filtration system.

The differences between and practices and perceptions were less than before, with few inconsistencies.

Colonias in Juárez

Table 4.2.1 shows that 63% of the participants surveyed reported using the system regularly, of those, 94% expressed trusting the water produced by such, only 31% of participants surveyed continue to purchase additional water for drinking, 88% said to be satisfied with their water filtration system and described it as easy to use.

Table 4.2.1: Post-survey POU general perceptions and practices.

Post Intervention Survey Cd Juárez (n=16)	
Sawyer Point One Bucket System	100%
Currently using system	63%
How much do you trust the quality of your water now?	
Completely trust	69%
Somewhat trust	25%
Distrust	6%
Do you still purchase additional water?	31%
How much?	20 Gallons
How satisfied are you with the water treatment system?	
Extremely satisfied	38%
Satisfied	50%
Neutral	19%
Extremely dissatisfied	0%
Please tell us how easy it is to use your water treatment system?	
Very easy	63%
Somewhat easy	25%
Not easy or hard	6%
Very hard	6%
How likely are you to continue using and maintaining your water treatment system when this study ends?	
Very likely	47%
Somewhat likely	13%

Post Intervention Survey Cd Juárez (n=16)	
Neutral	31%
Very unlikely	0%

Perceptions of water quality improved among colonia residents in Juárez; this translated to fewer inconsistencies between perception and practices. Post-survey results for practices and perceptions can be found in Appendix B.

Colonias in El Paso

All of the colonia participants surveyed in El Paso reported using their POU system regularly, 80% expressed trusting the water produced and were satisfied by the system provided they find it easy to use. However, 40% continue to purchase additional water for drinking. Table 4.2.2 shows post-intervention survey results for questions regarding the POU system.

Table 4.2.2: Post-survey POU general perceptions and practices.

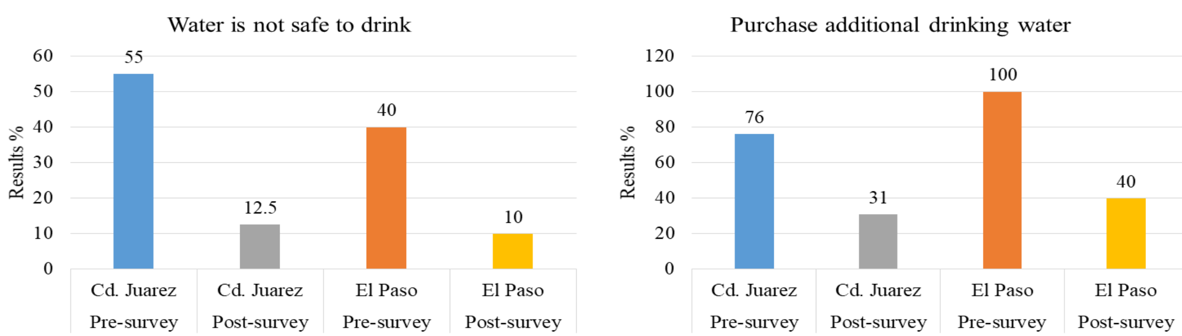
Post Intervention Survey El Paso (n=10)	
Under the Sink RO System	100%
Currently using system	100%
How much do you trust the quality of your water now?	
Completely trust	70%
Somewhat trust	10%
Distrust	20%
Purchase additional water	40%
How much?	62 Gallons
How satisfied are you with the water treatment system?	
Extremely satisfied	40%
Satisfied	40%
Neutral	0%
Extremely dissatisfied	20%
Please tell us how easy it is to use your water treatment system?	
Very easy	70%
Somewhat easy	20%
Not easy or hard	0%
Very hard	10%
How likely are you to continue using and maintaining your water treatment system when this study ends?	

Very likely	60%
Somewhat likely	20%
Neutral	0%
Very unlikely	20%

Comparison of post-survey results for Juárez and El Paso

In general, results show a change in perception for the hauled water supply did not change. However, residents were more confident in the quality of filtered water than the hauled water. In both of the colonias, residents purchased less water for drinking after they obtained their POU system. Results show that participants in El Paso are 20% more likely to continue using the POU systems after the project finishes. Comments from residents in Juárez indicated that sometimes they do not have the time to filter water.

Comparison between pre- and post-survey perceptions and practices are shown in Figure 4.18 In all cases, negative perceptions of water quality were reduced by using POUs. In Juárez negative perceptions of the hauled water quality may have been reduced due to their new understanding that hauled water they receive was treated by JMAS and were now using it for drinking after filtration with POU.



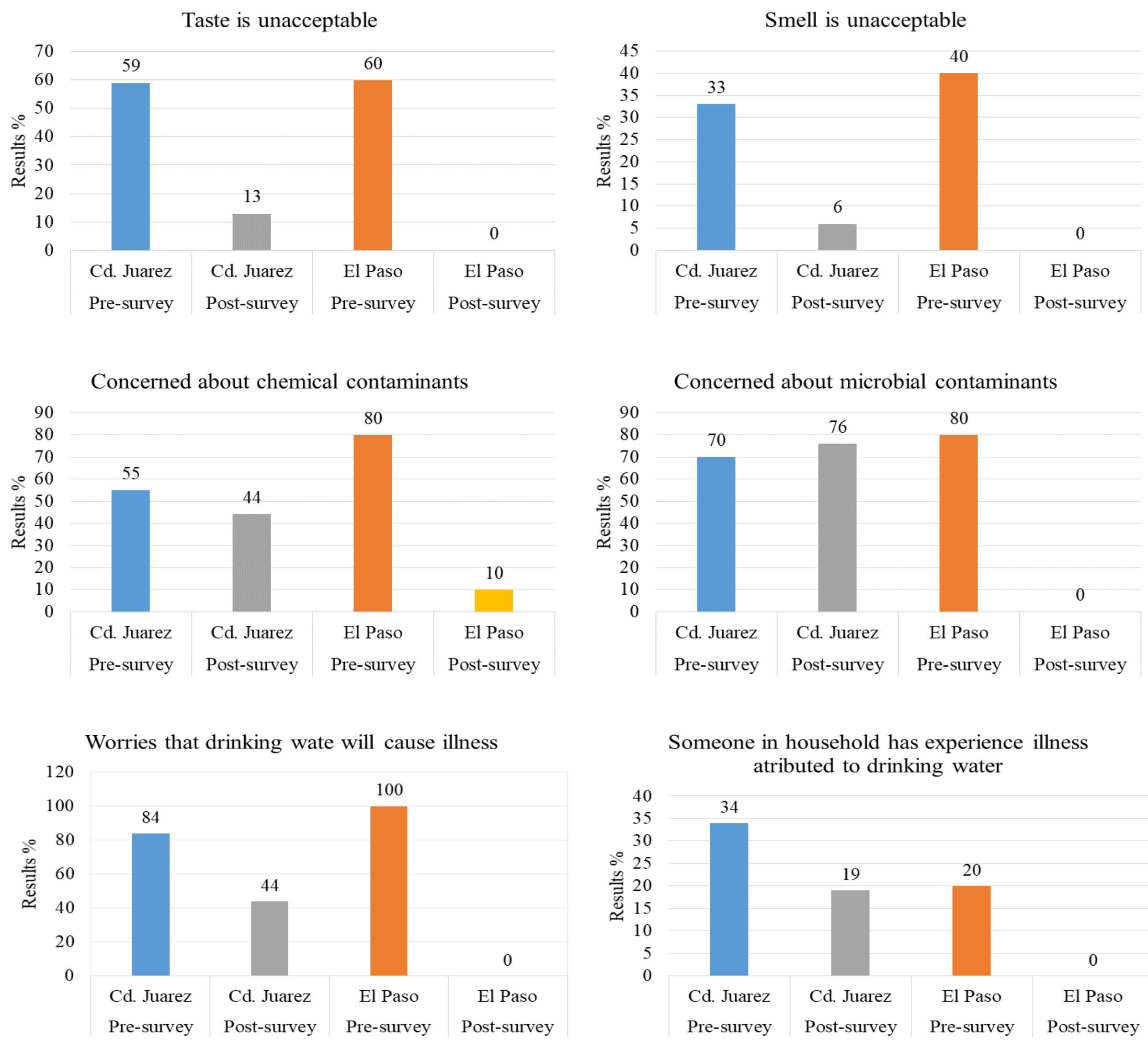


Figure 4.18: Pre- and post-survey perceptions and practices by colonia residents

Coherence between perceptions and practices shown in post-survey results translate into safer water practices and an ease of mental and financial burden for families in the colonias, as they take charge of the safety or their water a path to healthier lives with decrease of daily stressed induced by uncertainties resulting from using poor quality water opens allowing for quality of life improvement.

Even though a more significant number of samples is needed in future analysis, current information provides evidence that intervention to promote public health and alternative water treatment systems is needed and effective.

Focus groups

During the first post-intervention focus group session immediately following the delivery of filters for residents of colonias in Juárez, it was found that some of the residents were not using the provided POUs regularly, due to forgetting instructions of maintenance and daily use, for this cases, additional educational campaigns and instructional sessions were programmed.

During a second post-intervention focus group session a majority of the participants reported to use their systems daily and attributed a great part of the success to educational campaigns and information given about proper storage practices, cleaning of their tanks, and further disinfection for their supply.

Water quality analyses

Post-intervention water quality testing was imperative to measure the effectiveness of outreach campaigns and POUs. Two sampling campaigns took place, as state earlier, the first right after the first set of educational workshops during the winter 2019 and another one during spring 2019. In these campaigns samples, unfiltered samples from storage tanks and filtered samples were taken directly from POUs were collected for pre- and post-intervention comparison. Detailed data results on water quality post-intervention are found in Appendix C.

pH

Filtered water samples taken from POUs given to residents of colonias in Juárez had a pH range from 7.18 – 7.82, making 100% of the sites out of compliance for TCEQ secondary limit of pH > 7. For EPA and Mexico's Norma Oficial Mexicana NOM-127-SSA1-1994 all sites were within limits.

Post Intervention samples taken directly from the POUs installed at El Paso Colonias have a pH that ranges from 6.5 to 7.13, meaning that all the samples are in compliance with EPA´s secondary limit and only 25% of the samples are out of compliance by TCEQ limits.

Summarized statistical analysis by colonia is presented as a box and whiskers plot in Figure 4.19

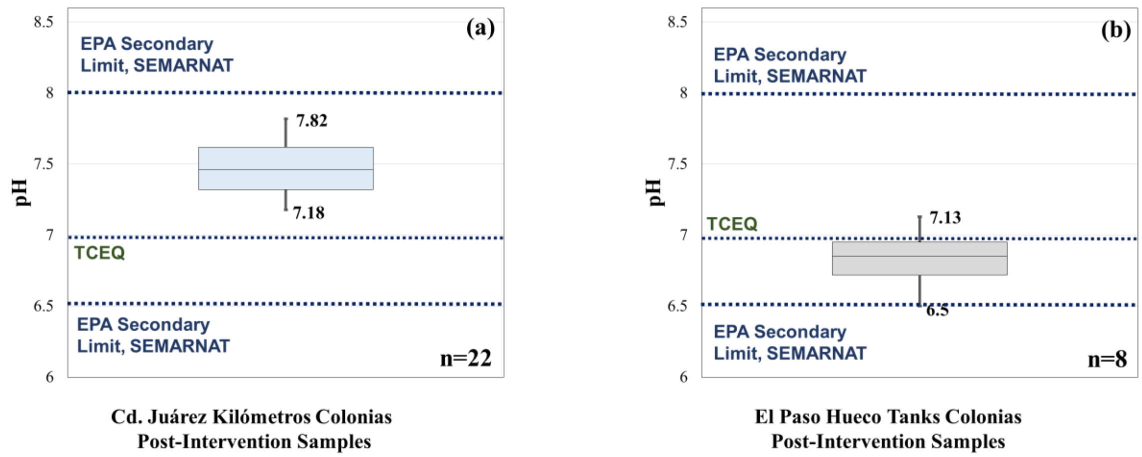


Figure 4.19: Statistical pH values for Post-Intervention sampled water

Total Dissolved Solids

Post-Intervention results for TDS show 45% of colonias in Juárez to be out of compliance with EPA secondary limit of 500 mg/L, sample range from 260-585 mg/l concentration, in contrast, all samples comply with TCEQ secondary limit. Although there is a significant decrease from 84% pre-intervention to 45% post-intervention of the sites out of compliance by EPA standards, the percentage of residencies out of compliance by TDS limits is still high.

For colonias in El Paso, samples taken after the intervention and directly from POUs from all sites comply with EPA, Mexico´s and TCEQ limits. Sample TDS range from 49-235 mg/L. A statistical representation of TDS results are found in Figure 4.20.

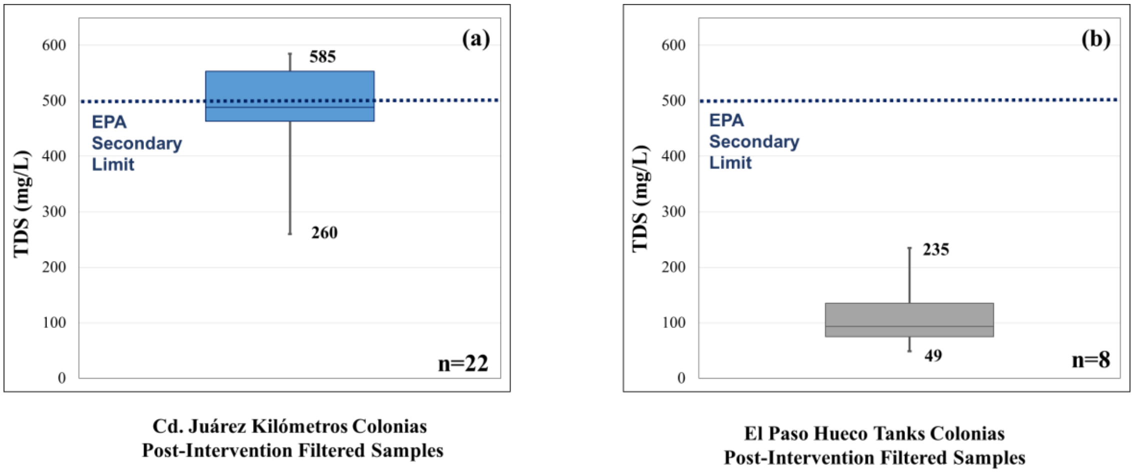


Figure 4.20 Statistical representation of results for TDS post POU intervention.

Hardness

The POU system used for colonias in Juárez is not particularly targeted to remove TDS. Therefore, the values obtained from filtered samples during the post-intervention campaign are consistent with results from unfiltered samples. Values range from 8.15 to 136 mg/L as $CaCO_3$ with 32% of the samples considered as hard water, 54% moderately hard, and 14% as soft water.

After POU implementation, harness values show a significant decrease in samples gathered from colonia*s* in El Paso, as the POU used consists on an RO system, removal of TDS result in 100% of the samples analyzed falling onto the soft water category with a range of 6.3 to 10.6 mg/L as $CaCO_3$.

Total and free Chlorine

None of the samples tested, post-intervention exceeded total, and free Chlorine limits mentioned previously.

Heavy Metals

None of the unfiltered and filtered post-intervention samples collected and tested heavy metal testing exceeded standards.

Microbial contamination

Winter and spring 2019 water quality sampling campaigns of unfiltered water showed a significant decrease in the presence of contaminants, as well as lower MPN counts, resulting in an overall improvement in water quality from summer 2018 campaigns. Table 4.2.3 shows percent values for the presence of contaminants and highest MPN value by colonia.

Table 4.2.3 Percent samples and MPN values for samples with microbiological contamination by location.

Microbial contaminant presence					
Winter and Spring 2019 post-intervention campaign		**Unfiltered Post-Intervention**		**Post Intervention Filtered Samples**	
		% of Samples contaminated	**Highest MPN**	**% of Samples contaminated**	**Highest MPN**
El Paso Colonias	Total Coliforms	0%	0	0%	0
	E. Coli	0%	0	0%	0
	Enterococcus	0%	0	0%	0
Juárez Colonias	Total Coliforms	63%	2419.6	0%	0
	E. Coli	36%	81.56	0%	0
	Enterococcus	52%	52	0%	0

The values shown for colonias in Juárez are significantly lower than those obtained from unfiltered samples on pre-intervention campaigns. However, the first sampling campaign was in the summer, and the second sampling campaign was in the winter and spring. Outreach intervention may have resulted in improved water storage practices or the results we compounded could show difference due to the lower temperatures in the winter and thus, less microbial activity.

Post-intervention unfiltered samples from colonias in El Paso showed no microbial contamination, meaning what can be assumed as a total decrease of contaminants prior to the POU installation.

Post-intervention filtered samples data shows that for samples collected from POUs in both of the colonias, there is almost total elimination (over 90% reduction) of microbial presence.

Figure 4.21 shows a comparison of samples with microbial contamination presence from pre- and post-intervention campaigns as well as a separation between unfiltered samples and those obtained directly from the POU installed.

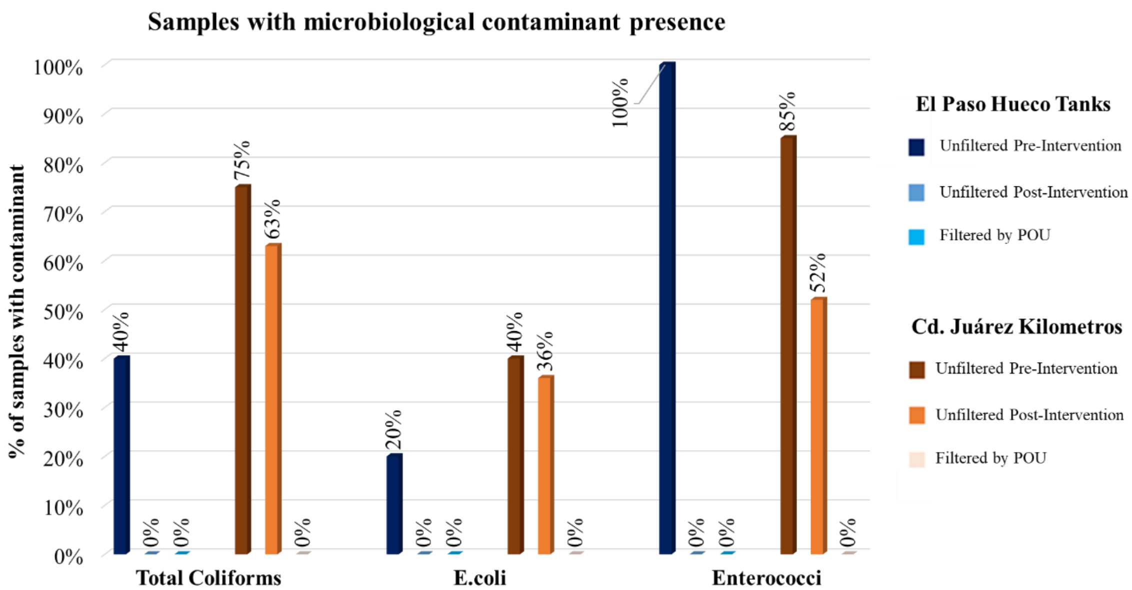


Figure 4.21: Percentage of samples with presence of microbiological contaminants comparison according to location and type of sample

Microbial health risk assessment

Heath risk assessment helps to evaluate the efficacy and effectiveness of water treatment technologies by comparing results to health risk-based criteria.

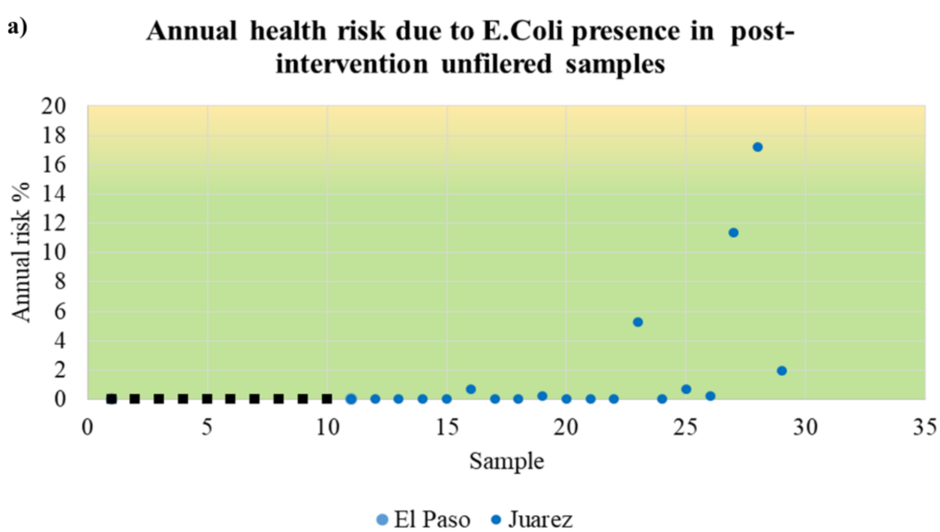
Results from colonias in Juárez show a significant decrease in annual risk calculations for microbial contamination in unfiltered samples obtained pre- and post-educational intervention and POU implementation. Therefore activities resulted in a positive response and willingness to learn about additional techniques to ensure and maintain water quality. Unfiltered samples collected after performing educational workshops showed lower count levels for microbial

contaminants as well, lowering risk levels. Therefore results obtained in this campaign translated into a risk factor close to 0% in colonias of El Paso, meaning that no presence of *E. coli* was found on unfiltered samples posterior to educational campaigns and installation of POUs.

Risk values for residents in Juárez decreased significantly, annual percent risk for post-intervention unfiltered samples range from 0.00% to 17% in comparison to pre-intervention unfiltered summer campaigns, where some samples presented a 99% risk value calculation.

In comparison to results from summer 2018 pre-intervention unfiltered campaign, there has been a reduction of 82% for the highest risk calculated for post-intervention, all unfiltered samples classified at a low-risk percent. Median values for annual risk calculations values in Juarez colonias from pre-intervention to post-intervention campaigns changed from 0.23 to 0.47.

Figure 4.22 shows a) plot representation of annual risk values for post-intervention unfiltered samples collected from El Paso and Juárez colonias and b) box and whiskers plot for unfiltered samples collected from Juárez, every box represents a quartile and whiskers represent minimum and maximum values recorded, the line between the two boxes represents the 50th percentile median value no box and whiskers plot was developed for El Paso samples due to risk percentage being too low to show in plot.



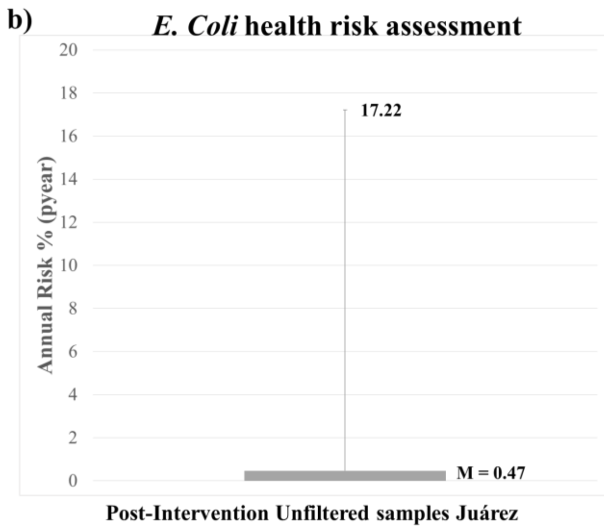


Figure 4.22: Annual health risk for *E. coli* for post-intervention unfiltered filtered samples

Post-intervention samples from the POUs installed in both of the colonias show significant reduction of health risk in unfiltered samples in Juárez and no presence of *E. coli* El Paso.

For both El Paso and Juárez post-intervention results for POU filtered samples show that risk was practically eliminated for microbial contamination due to *E. coli* (over 90% decrease of samples with the risk presented by calculations). Figure 4.23 shows a plot representation of annual risk values for samples filtered by POU systems

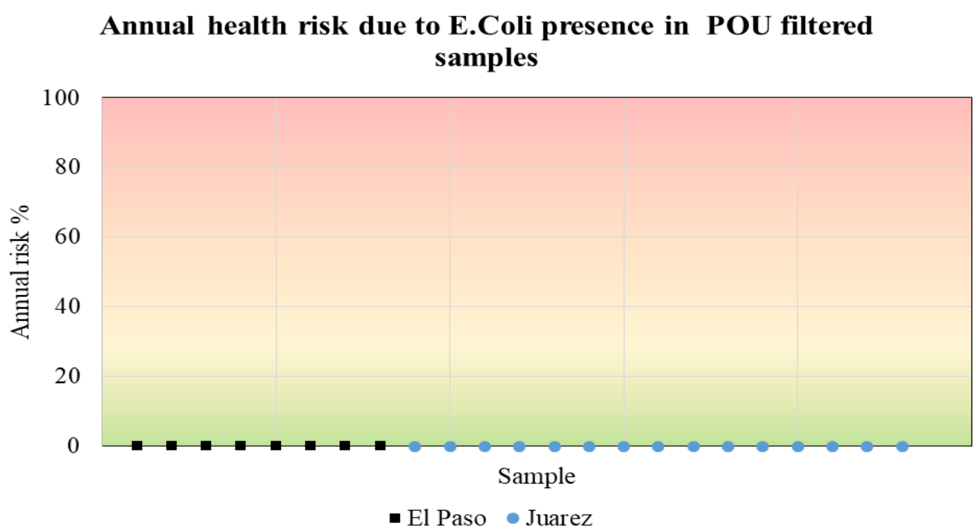


Figure 4.23: Annual health risk for *E. coli* for post-intervention POU filtered samples

Chapter 5: Conclusions

In this project, we were able to provide immediate solutions that solve drinking water issues and challenges in the U.S. Mexico Paso Del Norte border colonias. This goal was achieved through phases established earlier in the project. Social acceptance represented a crucial factor for the study to be successful; the willingness of colonia residents to participate implement and allow follow up visits was vital for the success of the project.

Analyses of surveys focus groups, and water quality was a crucial factor in understanding the challenges colonias face due to the lack of safe drinking water. While in both Juárez and El Paso colonias discrepancies were found between water perceptions and practices, pre-intervention concerns about hauled water consumption were present in both colonias. By conducting focus groups, we were able to understand and assess preferences, perceptions, practices, and concerns from colonia residents of Juárez and El Paso.

By performing water quality analysis, it became evident that residents from Juárez colonias face higher health risks due to microbial contamination than those from El Paso. Following outreach educational campaigns, a significant decrease in annual health risk for colonia residents in Juárez was observed.

Selection of POU systems for drinking water at household level units was performed by using a previously established ranking system that took into consideration economic, social and environmental factors as well as colonia needs revealed during experimental phases of the study. Over 15 RO in-line systems were installed for residents of colonias in El Paso, and 60 Sawyer PointONE gravity microfiltration units were delivered to residents of colonias in Juárez. Post-intervention testing proved the POU efficiency by significantly reducing risks associated with microbial presence in drinking water. Therefore Point of Use systems are an effective,

sustainable, and low-cost option to reduce health risks associated with unsafe water consumption for communities in need and general improvement of water quality.

After successful evaluation of the systems installed, a model for POU implementation process was developed that can be replicated in similar colonias.

Additionally, the analysis demonstrated a change in the perception of water safety from 45% to 87.5 % in Juárez colonias and 60% to 90% in El Paso, willingness of consumers to implement additional and alternative treatment options was demonstrated by reduction of additional purchases of water from 76% to 31 % in Juárez and 100% to 40% in El Paso.

By engaging colonia residents in practical, technical opportunities for improving the quality of water they drink and increasing their knowledge of water quality issues, we empower them to invest in the development of their communities.

Recommendations

Additional sampling campaigns are recommended to assess how seasonal changes such as temperature affect contaminant presence and algae growth in stored water. A larger number of samples are to compare to previous campaigns is needed to characterize additional findings such as algae and larvae identification to evaluate possible threats to public health.

References

[30 TAC §290.105. Texas Administrative Code. Title 30- Environment Quality. Part 1-Texas Commission on Environmental Quality. Chapter 290-Public Drinking Water. Subchapter F: Drinking Water Standards Governing Drinking Water Quality and Reporting Requirements for Public Waste.]

[40 CFR §141.100. Code of Federal Regulations.]

[40 CFR §141.2. 1996. Code of Federal Regulations. Title 40 - Protection to the Environment. Chapter I Environmental Protection Agency (continued). Subchapter D]

[AWWA. 2017. Standard Methods for the Examination of Water and Wastewater. 23rd. Standard Methods for the Examination of Water and Wastewater.]

[B Garcia, Lydia & Sobin, Christina & Tomaka, Joseph & Santiago, Ivonne & Palacios, Rebecca & Walker, Shane. (2016). A Comparison of Water-Related Perceptions and Practices Among West Texas and South New Mexico Colonia Residents Using Hauled-Stored and Private Well Water. Journal of environmental health. 79. 14-20.]

[Boorman, Gary A, Vicki Dellarco, June K Dunnick, Robert E Chapin, Sid Hunter, Fred Hauchman, Hank Gardner, Mike Cox, and Robert C Sills. 1999. "Drinking Water Disinfection Byproducts: Review and Approach to Toxicity Evaluation." Environmental Health Perspectives 107 (Supplement 1: Reviews in Environmental Health, 1999): 207–17. http://www.jstor.org/stable/3434484]

[Bowden, Gavin J., John B. Nixon, Graeme C. Dandy, Holger R. Maier, and Mike Holmes. 2006. "Forecasting Chlorine Residuals in a Water Distribution System Using a General Regression Neural Network." Mathematical and Computer Modelling 44 (5-6): 469–84. doi:10.1016/j.mcm.2006.01.006.]

[Campos, I., Walker, S., Santiago, I., & Walton, J. (2013a). Comparison methodology for selecting point of use drinking water filtration systems for colonias in the Paso del Norte region. Paper presented at the Texas Water, 2013, Galveston, TX]

[Campos, I., Walker, S., Walton, J., Santiago, I., Tomaka, J., & Palacios, R. (2013b). Point-of-use and point-of-entry water treatment units for colonias in the Paso del Norte region. Paper presented at the3rd International Congress on Sustainability Science & Engineering, 2013]

[Campos, I., Walker, S., Walton, J., Santiago, I., Tomaka, J., & Palacios, R. (2013c). Selection and evaluation of point of use drinking water filtration for colonias in the Paso del Norte region. Paper presented at Membrane Technology Conference Proceedings; American Water Works Association, 2013]

[Campos, I., Walker, S., Walton, J., Santiago, I., Tomaka, J., & Palacios, R. (2014). Developing A sustainable POE/POU water treatment system for households without basic infrastructure in the United States. Paper presented at the American Water Works Association Annual Conference and Exposition, 2014, Boston, MA]

[Campos Flores, Isaac, "Evaluation of point of use drinking water treatment systems for colonias in the Southwest United States" (2015). ETD Collection for University of Texas, El Paso. AAI3724910. https://digitalcommons.utep.edu/dissertations/AAI3724910]

[Chowdhury, Shakhawat & Jafar Mazumder, M.A. & Al-Attas, Omar & Husain, Tahir. (2016). Heavy metals in drinking water: Occurrences, implications, and future needs in developing countries. The Science of the total environment. 569-570. 476-488. 10.1016/j.scitotenv.2016.06.166.]

[Clasen TF and Cairncross S (2004). Household water management: refining the dominant paradigm. Tropical Medicine and International Health. Vol 9 No 2 pp 187-191.]

[Colonias Development Council (2009). “About Us.” Available at: http://www.colonias.org/about_us.html]

[CONEVAL. 2015. Indices de pobreza en la Republica Mexicana a nivel nacional y entidad https://www.coneval.org.mx/Medicion/Paginas/PobrezaInicio.aspx]

[Cooper, William J, Adam C Jones, Robert F Whitehead, and Rod G Zika. 2007. “SunlightInduced Photochemical Decay of Oxidants in Natural Waters: Implications in Ballast Water Treatment.” ENVIRONMENTAL SCIENCE & TECHNOLOGY 41 (10). 1155 16TH ST, NW, WASHINGTON, DC 20036 USA: AMER CHEMICAL SOC: 3728–33. doi:10.1021/es062975a]

[Corella-Barud, Verónica, Kristina D Mena, Shawn G Gibbs, Patrick L Gurian, and Alberto Barud. 2009. “Evaluation of Neighborhood Treatment Systems for Potable Water Supply.” International Journal of Environmental Health Research 19 (1): 49–58. doi:10.1080/09603120802392850.]

[Davidhizar, Ruth, and Gregory A Bechtel. 1999. “Health and Quality of Life Within Colonias Settlements Along the United States and Mexico Border.” Public Health Nursing, 16 (4). Blackwell Science Inc: 300–305. doi:10.1046/j.1525-1446.1999.00301.x.]

[Donelson, Angela. 2004. “The Role of NGOs and NGO Networks in Meeting the Needs of US Colonias.” Community Development Journal 39 (4): 332–44. doi:10.1093/cdj/bsh030.]

[Dupont et al., 1971. “Pathogenesis of Escherichia coli diarrhea” New England journal of medicine, v. 285 no. 1, pp. 1]

[EPA. 2019. “National Primary Drinking Water Regulations¨ https://www.epa.gov/ground water-and-drinking-water/national-primary-drinking-water-regulations#Disinfectants]

[EPA. 2019. “Secondary Drinking Water Standards: Guidance for Nuisance Chemicals https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance]

[EPA.2019. ¨ Methods Approved to Analyze Drinking Water Samples to Ensure Compliance with Regulations. https://www.epa.gov/dwanalyticalmethods/approved-drinking-water-analytical-methods]

[Fewtrell, Lorna, Rachel B Kaufmann, David Kay, Wayne Enanoria, Laurence Haller, and John M Colford. 2005. “Water, Sanitation, and Hygiene Interventions to Reduce Diarrhoea in Less Developed Countries: A Systematic Review and Meta-Analysis.” The Lancet. Infectious Diseases 5 (1): 42–52. doi:10.1016/S1473-3099(04)01253-8.]

[Goldblatt M (1999). Assessing the effective demand for improved water supplies in informal settlements: a willingness to pay survey in Vlakfontein and Finetown, Johannesburg. Geoforum. Vol 30, pp27-41.]

[Haas, Rose, And Gerba, 2014 “Quantitative Microbial Risk Assessment: Second Edition” Wiley Blackwell 9781118145296]

[Harris, John (2005). Challenges to the Commercial Viability of Point-of-Use (POU) Water Treatment Systems in Low-Income Settings. Dissertation MSc in Water Science Policy and Management, School of Geography and the Environment, Oxford University, September 2, 2005]

[Instituto Municipal de Investigación y Planeación. (2010). Plan de desarrollo urbano Cd. Juárez 2010Ayuntamiento de Cd. Juárez.]

[Maier, Raina M, Ian L Pepper, and Charles P Gerba. 2009. Environmental Microbiology. Edited by 2nd. Academic Press.]

[Martínez Cabrera, Alejandro. (5/27/2012), Implementa Cd. Juárez medidas para conservar el agua. Somos Frontera]

[McGowan W (2000) Water processing: residential, commercial, light-industrial, 3rd ed. Lisle, IL, Water Quality Association.]

[McNally NJ et al. (1998) Atopic eczema and domestic water hardness. Lancet, 352(9127):527–531]

[Merrett S (2002). Willingness to pay—A review: Deconstructing households' willingness-to-pay for water in low-income countries. Water Policy. Vol 4 pp 157- 172.]

[Norma Oficial Mexicana NOM-127-SSA1-1994 modification, Salud ambiental. Agua para uso y consumo humano. http://www.salud.gob.mx/unidades/cdi/nom/m127ssa14.html]

[Milot, J, M J Rodriguez, and J B Serodes. 2002. "Contribution of Neural Networks for Modeling Trihalomethanes Occurrence in Drinking Water." JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT-ASCE 128 (5). 1801 ALEXANDER BELL DR, RESTON, VA 20191-4400 USA: ASCE-AMER SOC CIVIL ENGINEERS: 370–76. doi:10.1061/(ASCE)0733-9496(2002)128:5(370).]

[NSF International. 2019. "NSF International."]

[Paerl, Hans W., 1988. "Nuisance Phytoplankton Blooms in Coastal, Estuarine, and Inland Waters." Limnology and Oceanography 33 (4, Part 2: Comparative Ecology of Freshwater and Marine Ecosystems): 823–47. http://www.jstor.org/stable/2837225]

[Palacios, R., Tomaka, J., Torres, A., Garcia, L., Campos-Flores, I., Santiago, I., Walker, W.S., and Walton, J. Colonia Residents' Perceptions of Water Quality in Dona Ana, NM and El

Paso, TX. Accepted for presentation at 35th Annual Meeting & Scientific Session of the Society of Behavioral Medicine, Philadelphia, PA, April 25, 2014, C-131.]

[Rivera, Danielle Zoe, "The Forgotten Americans: A Visual Exploration of Lower Rio Grande Valley Colonias" (2014).]

[Sawyer. (2011) "Water Filtration and Purification. Available at: http://www.sawyerpointonefilters.com/]

[Silverstein, I (2005). Investigation of the Capability of Point-Of-Use/Point-Of- Entry Treatment Devices as a Means of Providing Water Security. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/012 (NTIS PB2006-107461).]

[Sobsey, Mark D. 2005. Managing Water in the Home: Accelerated Health Gains from Improved Water Supply. http://apps.who.int/iris/bitstream/10665/67319/1/WHO_SDE_WSH_02.07.pdf?ua=1.]

[Sobsey, Mark D, Christine E Stauber, Lisa M Casanova, Joseph M Brown, and Mark A Elliott.2008. "Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World." Environmental Science & Technology 42 (12): 4261–67. doi:10.1021/es702746n.]

[Texas Commission on Environmental Quality. Standards and Reporting Requirements for Public Water Systems 2015. Water Supply Division, RG-346]

The Colonia Initiatives Program, Office of the Texas Secretary of State (2010). Tracking the Progress of State Funded Projects that benefit Colonias. Senate Bill 99, 82nd Texas Legislature Regular Session, December 1, 2010. Available at: http://www.sos.state.tx.us/border/forms/reports-11/sb-99-progress.pdf

[World Health Organization. 2004a. Sulfates in Drinking Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality.]

[World Health Organization, 2011. Hardness in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality. https://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf]

Appendix A

Pre-survey copy

Subject ID: _

SECTION I: Water Source / Treatment / Water Use

Q1. What is the main water source for your house?
- ☐ Municipal water from a water district or local public water company
- ☐ Hauled water (stored in a large water tank)
- ☐ Well water
- ☐ Other: _ (specify)

Q2. Does this water come into your home through a faucet?
- ☐ Yes
- ☐ No

Q3. Is this your household's main source of **drinking** water?
- ☐ Yes
- ☐ No

Q3A. If no, what is your main source of drinking water? _

Q4. Including yourself, how many people (adults and children) live in your household? _

Q4-A. On a typical day, how much water from your household faucets does your family use for drinking?

gallons for drinking

- ☐ My family does not use water from household faucets for drinking

Q4-B. On a typical day, how much water from your household faucets does your family use for cooking?

gallons for cooking

- ☐ My family does not use water from household faucets for cooking

Q5. Is the water that comes to your faucet treated in any way before you drink it?
- ☐ My family does not drink water from the faucet
- ☐ Yes, always
- ☐ Yes, usually
- ☐ Yes, sometimes
- ☐ No, never

Q5-A. If yes, how do you treat the water **for drinking**? ***(Check all that apply)***
- ☐ I do not treat my water
- ☐ Boil the water
- ☐ Chlorine tablets or drops
- ☐ Iodine tablets or drops
- ☐ Pitcher filter, such as Brita
- ☐ Filter at kitchen tap/faucet
- ☐ Sun (containers in the sun)
- ☐ Other _ (Specify)

Q5-B. If you treat your water, which household members use it **for drinking**? ***(Check all that apply)***

- ☐ I do not treat my water
- ☐ All members
- ☐ None of the members
- ☐ Children under 5 years of age
- ☐ Members over 65 years of age
- ☐ Pregnant women
- ☐ Family members who are sick

Q6. Is the water that comes to your faucet treated in any way before you **cook with it**?

- ☐ My family does not cook with water from the faucet
- ☐ Yes, always
- ☐ Yes, usually
- ☐ Yes, sometimes
- ☐ No, never

Q6-A. If yes, how do you treat the water for **cooking**? ***(Check all that apply)***

- ☐ I do not treat my water
- ☐ Boil the water
- ☐ Chlorine tablets or drops
- ☐ Iodine tablets or drops
- ☐ Pitcher filter, such as Brita
- ☐ Filter at kitchen tap/faucet
- ☐ Sun (containers in the sun)
- ☐ Other: _
  (Specify)

Q7. Is the water that comes to your faucet treated in any way before you clean with it (e.g., washing dishes, cleaning kitchen surfaces)?

- ☐ My family does not clean with water from the faucet
- ☐ Yes, always
- ☐ Yes, usually
- ☐ Yes, sometimes
- ☐ No, never

Q7-A. If yes, how do you treat the water for cleaning? *(Check all that apply)*

- ☐ I do not treat my water
- ☐ Boil the water
- ☐ Chlorine tablets or drops
- ☐ Iodine tablets or drops
- ☐ Pitcher filter, such as Brita
- ☐ Filter at kitchen tap/faucet
- ☐ Sun (containers in the sun)
- ☐ Other: _
  (Specify)

Q8. Which of the following things have you done in the past month? (Answer all boxes)

	Tap water	Filtered water	Bottled water
Mixed infant formula with	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No
Cooked with	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No
Mixed powdered drink (e.g. Kool-Aid)	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No
Washed dishes with	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No
Brushed your teeth with	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No
Made coffee or tea with	☐ Yes ☐No	☐ Yes ☐No	☐ Yes ☐No

Q9. Would you like to learn about various ways to treat your water that can make it safer to drink?

☐ Yes
☐ No

Q9-A. Would you like to learn about water filtration systems that can make your water safer to drink**?**

☐ Yes
☐ No

SECTION II: Water Quality

Please tell me whether you "**Agree**", "**Disagree**", or "Have **no strong feelings** either way" concerning the following statements.

	Strongly Disagree	Disagree	No Strong Feelings	Agree	Strongly Agree
Q10. My well/tank water is safe to drink	1	2	3	4	5
Q11. I worry about chemicals in my well/tank water	1	2	3	4	5
Q12. I am happy with the quality of my well/tank water	1	2	3	4	5
Q13. The taste of my well/tank water is acceptable	1	2	3	4	5
Q14. The smell of my well/tank water is acceptable	1	2	3	4	5
Q15. I have been told what is the quality of my well/tank water	1	2	3	4	5
Q16. I know ways to improve my well/tank water	1	2	3	4	5
Q17. I worry about microbes in my well/tank water	1	2	3	4	5
Q18. The quality of my well/tank water is good	1	2	3	4	5
Q19. I worry about the quality of the tank/well water I use for cleaning	1	2	3	4	5
Q20. I worry that drinking the water from my well/tank will make me or my family sick	1	2	3	4	5

The following questions ask about water that comes into your home either from a large water storage tank or a well. Please answer these questions as they apply to your home's water source.

Q21. Has your well/tank water at home ever been tested for chemicals, microbes, or other contaminants?

☐ Yes_
☐ No

Q21-A. If yes, about how long has it been since it was tested?

☐ Never tested
☐ Within the last 3 years
☐ 4 to 5 years ago
☐ 6 to 10 years ago
☐ Over 10 years

Q22. Has anyone in your home had any of these conditions from drinking well/tank water in the past six-months? (Check all that apply)

☐ Diarrhea
☐ Vomiting
☐ Nausea
☐ Stomach pain
☐ Other water-borne illness: _ (specify)
☐ None

Q23. In the last year, have you or any member of your family done something to improve your well/tank water?

☐ Yes_ (specify)
☐ No

Q24. Do you have any comments about the quality of your well/tank water?

____

____

SECTION III: Additional Drinking Water

The following questions are about additional water purchases you make (not including well water or water deposited in a large water storage tank):

Q25. Do you purchase drinking water from a source such as a grocery store or water mill? (DO NOT include water purchased from the local public water company or water hauled for an outdoor tank.)

☐ Yes, always
☐ Yes, usually
☐ Yes, sometimes
☐ No, never

Q25-A. If yes, where do you purchase the drinking water for your household? ***(Check all that apply)***

- ☐ I do not purchase additional drinking water.
- ☐ From a supermarket or wholesale store (Wal-Mart, Sam's club, etc.)
- ☐ From machines, such as watermills
- ☐ Other: _
  (Specify)

Q25-B. What is the main reason you get water from this place?

- ☐ I do not purchase additional drinking water.
- ☐ Proximity (it is close to my home)
- ☐ Cost (it is inexpensive)
- ☐ There is no other source
- ☐ High Quality
- ☐ Other: _
  (Specify)

Q26. Which of these household members drink water that has been purchased from water mills or from a store? ***(Check all that apply)***

- ☐ I do not purchase additional drinking water
- ☐ All members
- ☐ Children under 5 years of age
- ☐ Members over 65 years of age
- ☐ Pregnant women
- ☐ Only if family member is sick

Q27. On a typical day, how much purchased water does your family use for drinking:

gallons for **drinking**

☐ My family does not use purchased water for drinking

Q27-A. On a typical day, how much purchased water does your family use for cooking:

gallons for **cooking**

☐ My family does not use purchased water for cooking

Q27-B. On a typical day, how much purchased water does your family use for cleaning:

gallons for **cleaning**

☐ My family does not use purchased water for cleaning

Q28. How far do you travel to purchase drinking water from a store and/or water mill?

miles

☐ I do not travel to purchase additional water

Q28-A. How much water do you buy from a store and/or water mill each month?

- Gallons

Or

- Cases of 24 bottles

☐ I do not purchase additional drinking water.

Subject ID: _

Q28-B. In total, how much money do you pay per month to buy water from a store or water mill?

- ☐ I do not purchase additional drinking water.
- $ per month

Q29. How much would you be willing to pay (initial cost, not monthly) for a drinking water treatment system? Select one.

- ☐ 0-$50
- ☐ $50-$100
- ☐ $100-$150
- ☐ $150-$200
- ☐ $200-$250
- ☐ More than $250

Q30. How much money would you be willing to pay per month to maintain a water treatment system (e.g., buying replacement filters)?

- ☐ 0-$10
- ☐ $10-$20
- ☐ $30-$40
- ☐ $40-$50
- ☐ More than $50

Q31-A. Would you be willing to purchase a water treatment device or replacement filters online?

☐ Yes ☐ No

Q31-B. If no, why is that?

- ☐ I do not have internet access
- ☐ I do not know how to use the computer/internet
- ☐ My house is not in the range of parcel services (e.g. UPS, Fedex)
- ☐ I do not like purchasing items online
- ☐ I do not have a credit/debit card
- ☐ Other: _

Subject ID: [redacted]

Please tell me whether you are "**Not all Likely**", "**Likely**", or "**Extremely Likely**" concerning the following statements.

	Not at All Likely	Somewhat Likely	Likely	Very Likely	Extremely Likely
Q32. If you could purchase a water treatment system at a hardware store and online at the same price, how likely are you to purchase that filter at the hardware store?	1	2	3	4	5
Q33. If the only way you could purchase a water treatment system was to order it online, how likely are you to purchase it?	1	2	3	4	5
Q34. If there was water treatment system that costs around $20 every 6 months and requires 15 min of your time to replace it every six months, how likely are you to use it?	1	2	3	4	5
Q35. If there was a water treatment system that required 5 min of your time every day, but wouldn't cost you anything to maintain, how likely are you to use it?	1	2	3	4	5

Q36. How important are the following concerns when purchasing a drinking water treatment system?	Not Important	Important	Very Important
Cost	1	2	3
Labor to replace filter	1	2	3
Pollution to the environment	1	2	3

SECTION IV: Water Storage/Tanks

The following questions are for those who use/have a large <u>water storage container outside of their home.</u>

Q37. Do you have a large water storage tank **outside** of your home?

☐ Yes
☐ No

Subject ID: _

Q38. What is your large water storage tank made of?
- ☐ I do not have a large water storage tank
- ☐ Metal
- ☐ Glass
- ☐ Plastic
- ☐ Fiberglass

Q39. If you have a large water storage tank, what color is it?
- ☐ I do not have a large water storage tank
- ☐ White
- ☐ Black
- ☐ Other light color
- ☐ Other dark color

Q40. Is your large water storage tank covered or sealed?
- ☐ I do not have a large water storage tank.
- ☐ Yes
- ☐ No

Q41. Do you have a filter attached to your large water tank or anywhere in the line between the tank and your faucets?
- ☐ I do not have a large water storage tank.
- ☐ Yes
- ☐ No

Q42. What do you use to clean your large water storage tank?
- ☐ I do not have a large water storage tank.
- ☐ I do not clean my tank
- ☐ Liquid bleach
- ☐ Chlorine tablets
- ☐ Detergent/soap
- ☐ Other_ (Specify product)

Q43-A. How often do you clean your large water storage tank?
- ☐ I do not have a large water storage tank.
- ☐ Never
- ☐ One time per year
- ☐ Two times per year
- ☐ Three times per year
- ☐ Four times per year
- ☐ Once every two months
- ☐ Once a month
- ☐ More than once a month

Q43-B. If you do not clean your large water storage tank, what are the reasons?
(Check all that apply)
- ☐ I do not have a large water storage tank
- ☐ It is hard for me to clean it and I do not have the help to do it
- ☐ I do not know how to properly clean my tank
- ☐ I think it is dangerous
- ☐ Other_ (Specify)

Subject ID: _

Q44. How many times do you fill your large water storage tank in a year?

☐ I do not have a large water storage tank

Times per year: _

Q45-A. How much water do you purchase every time you fill up your large water storage tank?

☐ I do not have a large water storage tank

Gallons: _

Q45-B. How much do you pay every time you fill your large water storage tank?

☐ I do not have a large water storage tank

Cost: $_

Q45-C. How far in advance do you need to schedule water delivery for your large storage tank?

_ days

Q45-D. What kind of problems have you had in scheduling water delivery?

Please tell us whether you **"Agree"**, **"Disagree"**, or **"Have no strong feelings either way"** concerning the following statements.

	Strongly Disagree	Disagree	No strong feelings	Agree	Strongly Agree
Q46. I can trust my water supplier to provide me with safe water to drink	1	2	3	4	5
Q47. I worry about the quality of water from my supplier	1	2	3	4	5

Subject ID:

SECTION V: Water Wells

The following questions are for those individuals who use <u>water from a well:</u>

Q48. How far is your water well from your septic system?
- ☐ I do not have a water well.
- ☐ 0-15 feet
- ☐ 16-30 feet
- ☐ 31-45 feet
- ☐ 46-60 feet
- ☐ More than 60 feet
- ☐ Other, please list:
- ☐ I don't know

Q49. How deep is your water well?
- ☐ I do not have a water well.
- ☐ 0-50 feet deep
- ☐ 51-100 feet deep
- ☐ 101- 150 feet deep
- ☐ Deeper than 150 feet
- ☐ I don't know

Q50. How old is your water well?
- ☐ I do not have a water well.
- ☐ 0-5 years old
- ☐ 6-10 years old
- ☐ 11-15 years old
- ☐ 16 -20 years old
- ☐ Older than 20 years old
- ☐ I don't know

Q51. What casing material does your water well have?
- ☐ I do not have a water well.
- ☐ PVC
- ☐ Concrete
- ☐ Steel
- ☐ Other, Specify:
- ☐ I don't know

Q52. Does your water well need repair?
- ☐ I do not have a water well.
- ☐ Yes
- ☐ No
- ☐ I don't know

Q53. Do you have a filter attached to your water well or anywhere in the line between the water well and your faucets?
- ☐ I do not have a water well.
- ☐ Yes
- ☐ No

Subject ID:

SECTION VI: Demographics

Q54. What is your age? Yrs.

Q55. What is your gender?
- ☐ Male
- ☐ Female

Q56. What is your race or ethnicity?
- ☐ Black
- ☐ White/Non-Hispanic
- ☐ White/Hispanic
- ☐ Asian/Pacific Islander
- ☐ Native American Indian
- ☐ Other:

Q57. Do you consider yourself Hispanic or Latino?
- ☐ Yes
- ☐ No

Q58. What is your highest educational degree obtained?
- ☐ Less than HS
- ☐ GED
- ☐ High school
- ☐ Technical school
- ☐ College (Associates, Bachelor's)
- ☐ Graduate School (Master's, PhD)
- ☐ None

Q59. How many years have you lived in your current home? Years

Q60. How many years have you lived in your current community?
Name of Community/Colonia Years

Q61. Which of the following best describes your household income from all sources?
- ☐ Less than 5,000 per year
- ☐ 5,000 to less than 10,000 per year
- ☐ 10,000 to less than 15,000 per year
- ☐ 15,000 to less than 20,000 per year
- ☐ 20,000 to less than 25,000 per year
- ☐ 25,000 to less than 35,000 per year
- ☐ 35,000 to less than 50,000 per year
- ☐ 50,000 to less than 75,000 per year
- ☐ 75,000 to less than 100,000 per year
- ☐ 100,000 or more per year
- ☐ Don't know
- ☐ Refused to answer

# #
#

That is the end of the survey. Thank you for participating in our study.

Focus group protocol for moderator

Upon arrival (30 minutes)

- Distribute nametags to participants (name tags will have first name and ID #)
- Distribute consent forms
- Distribute survey
- Fill in survey, assist as needed
- Invite participants to eat as they complete the survey

I. Introduction by Moderator (10 min)

- Brief introduction to the project & purpose of FG
- Go around table and introduce by first name (ice breaker)

IV. Focus group-water quality/issues (15 min)

Ask participants to discuss the following questions:

1. Tell us about the source/sources of your household water.
   a. How many rely on well water? How many on hauled water stored in a tank?
2. How would you describe the water quality in your household?
3. What are your biggest concerns with using well/hauled water for domestic use, and why?
   a. What are your concerns in using well/hauled water for drinking and cooking purposes?
   b. What are your concerns in using well/hauled water for other household purposes such as bathing and laundry?
4. Does the quality of the water you currently use need to be improved? Why (not)?
   a. Do you believe that water quality needs to be improved in this particular region? Why (not)?
5. What kind of water treatment do you use for your household water prior to consuming or cooking with it?
6. What are all of the major factors that affect water quality in your region?

VII. Perceived observations of POU technologies

- Ask participants to discuss the following questions:

1. Please tell me, what do you like about filter X? Why?
2. Now tell me what you dislike about the filter X? Why?
   - Could you tell me what could be the biggest problem with filter X? Why?
3. Please tell us how easy the device would be to use. (e.g., ease of use, replacement filter, cost), etc.
4. How likely would you be to use this kind of device**?**
5. Do you have any additional questions, comments, or concerns about this POU device?

After all filter systems have been presented:

6. Can you tell me which of the filters did you find more appropriate for your home? Why?

VIII. Closing (5 min)
If you provided your contact information on the consent form, we will be contacting you to invite you to participate in the filter implementation phase of this study. This will occur within XXXX amount of time. We will now distribute the gift cards as a token of our appreciation for your participation in this study.
X. Distribute incentive cards (5 min)

Time: 1.5 hrs

Materials needed:

- Focus group questions guide
- Watch and clock
- Flip chart and markers
- Nametags
- Note pads
- Pens. Markers
- Tape recorders
- Tapes, batteries
- Food
- Incentive cards

Post-survey copy

Subject ID: ______________

Q24. Has anyone in your home had any of the following conditions from drinking well/tank water since the installation of the water treatment system? (Check all that apply)

- ☐ Diarrhea
- ☐ Vomiting
- ☐ Nausea
- ☐ Stomach pain
- ☐ Other water-borne illness: ______________ (specify)
- ☐ None

Q25. How satisfied are you with the water treatment system installed in your home:

- ☐ Extremely satisfied
- ☐ Satisfied
- ☐ Neutral
- ☐ Dissatisfied
- ☐ Extremely dissatisfied

Q26. Please tell us how easy it is to use your water treatment system:

- ☐ Very easy
- ☐ Somewhat easy
- ☐ Not easy or hard
- ☐ Somewhat hard
- ☐ Very hard

Q27. Have you had any problems maintaining your water treatment system?

- ☐ I have not had problems
- ☐ No
- ☐ Yes Specify: ________________

Q28. Have these issues been easy to resolve?

- ☐ No Explain: ________________
- ☐ Yes

Q29. How expensive is it to maintain your water treatment system (e.g. buying new filters)?

- ☐ Extremely expensive
- ☐ Expensive
- ☐ Not expensive/Not inexpensive
- ☐ Inexpensive
- ☐ Extremely inexpensive

Q30. How likely are you to continue using and maintaining your water treatment system when this study ends?

- ☐ Very likely
- ☐ Somewhat likely
- ☐ Neutral
- ☐ Somewhat unlikely
- ☐ Very unlikely

Q31. Are there any other comments that you wish to make?

____

____

Subject ID: _____________

Q14. Which of the following things have you done in the past month? **(Answer all boxes)**

	Filtered water	**Bottled Purchased water**
Mixed infant formula with	☐ Yes ☐No	☐ Yes ☐No
Cooked with	☐ Yes ☐No	☐ Yes ☐No
Mixed powdered drink (e.g. Kool-Aid)	☐ Yes ☐No	☐ Yes ☐No
Washed dishes with	☐ Yes ☐No	☐ Yes ☐No
Brushed your teeth with	☐ Yes ☐No	☐ Yes ☐No
Made coffee or tea with	☐ Yes ☐No	☐ Yes ☐No

Please tell us whether you "**Agree**", "**Disagree**", or "Have **no strong feelings** either way" concerning the following statements.

	Strongly Disagree	**Disagree**	**No strong feelings**	**Agree**	**Strongly Agree**
Q15. My well/tank water is safe to drink now that I use a water treatment system	1	2	3	4	5
Q16. I worry about **chemical** contaminants in my well/tank water even though I have a water treatment system	1	2	3	4	5
Q17. I am happy with the quality of my well/tank water now that I use the water treatment system	1	2	3	4	5
Q18. The taste of my well/tank water is ok now that I use my water treatment system	1	2	3	4	5
Q19. The smell of my well/tank water is ok now that I use my water treatment system	1	2	3	4	5
Q20. I worry about **microbes** in my well/tank water even though I have a water treatment system	1	2	3	4	5
Q21. The quality of my well/tank water is good now that I use a water treatment system	1	2	3	4	5
Q22. I worry about the quality of the tank/well water I use for cleaning purposes even though I have a water treatment system	1	2	3	4	5
Q23. I worry that drinking the water from my well/tank will make me or my family sick even though I have a water treatment system	1	2	3	4	5

Subject ID: ______________

Q8. Do you still purchase drinking water from a source such as a grocery store or water mill? (**DO NOT** include water purchased from the local public water company or water hauled for an outdoor storage tank.)

- ☐ Yes, always
- ☐ Yes, usually
- ☐ Yes, sometimes
- ☐ No, never

Q9. How much water do you **buy** per month when you purchase from a store and/or water mill?

☐ I do not purchase additional drinking water.

________ Gallons

Or

________ Cases of 24 bottles

Q10. How much do you **pay** per month when you buy water from a store or water mill?

☐ I do not purchase additional drinking water.

$___________ per month

Q11. On a typical day, how much purchased water does your family use for drinking?

For **drinking**: #_________ gallons

☐ My family does not use purchased water for drinking

Q12. On a typical day, how much purchased water does your family use for cooking?

For **cooking**: #_________ gallons

☐ My family does not use purchased water for cooking

Q13. On a typical day, how much purchased water does your family use for cleaning?

For **cleaning**: #_________ gallons

☐ My family does not use purchased water for cleaning

Subject ID: ____________

POST Intervention Survey

The following questions are to be answered after having purchased and used a new water treatment system

Q1. Have you purchased a water treatment system?
- ☐ Yes
- ☐ No   If no, why not? ______________

Q2. What kind of water treatment system is it?
- ☐ I have not purchased a water treatment system
- ☐ Pitcher
- ☐ Under the sink
- ☐ Whole-house
- ☐ Other (specify): ________________________.

Q3. Have you installed it?
- ☐ Yes
- ☐ No

Q4. If no, why haven't you installed your water treatment system?
- ☐ I have already installed my water treatment system
- ☐ I have not had time
- ☐ I don't know how to
- ☐ I have not purchased it yet
- ☐ Other   Specify: ______________

Q5. Who installed your water treatment system?
- ☐ I have not installed my water treatment system yet
- ☐ Myself
- ☐ A family member
- ☐ Other   Specify: ____________

Q6 How long have you been using your water treatment system for?
- ☐ About one week
- ☐ About 2 weeks
- ☐ About 3 weeks
- ☐ About 1 month
- ☐ Other   Specify: _____________

Q7. How much do you trust the quality of your water now that your purchased water treatment system is in place?
- ☐ Completely trust
- ☐ Somewhat trust
- ☐ Neither trust nor distrust
- ☐ Somewhat distrust
- ☐ Completely distrust

That is the end of the survey. Thank you for participating in our study.

Appendix B

Pre-survey results for colonias in Juárez

Pre Intervention survey results Juárez			
Section I: Water Source / Treatment / Water Use (n=44)			
Main Water Source	**Public Agency Hauled Water**	**Private Company Hauled water**	
	88%	12%	
Does the water come into your home through a faucet?	**Yes**	**No**	
	10%	90%	
Is this water your main drinking water source?	29%	71%	
How much water from your household faucets does your family use for:	**Average**		
Drinking	3.05 Gallons		
Cooking	5.49 Gallons		
Do you give the water further treatment before drinking it?	**Yes**	**No**	
	27%	73%	
If so What type of treatment?	**Boiling Water**	**Chlorine**	**Other**
	31%	15%	53.85%
Do you give the water further treatment before cooking with it?	**Yes**	**No**	
	82%	18%	
If so What type of treatment?	**Boiling Water**	**Chlorine**	**Other**
	56%	33%	11.1%
Would you like to learn about various ways to treat your water that can make it safer to drink	**Yes**	**No**	
	96%	4%	
Would you like to learn about water filtration systems that can make your water safer to drink	100%	0%	

Pre Intervention survey results Juárez					
Section II: Water Quality (n=44)					
Tank Water	**Strongly Disagree**	**Disagree**	**No Strong Feelings**	**Agree**	**Strongly Agree**
Safe to drink	45%	10%	8%	16%	20%
Worry about	24%	8%	12%	20%	35%

Pre Intervention survey results Juárez					
Section II: Water Quality (n=44)					
Tank Water	**Strongly Disagree**	**Disagree**	**No Strong Feelings**	**Agree**	**Strongly Agree**
chemicals					
Happy with the quality	31%	10%	12%	20%	27%
Taste is acceptable	24%	35%	12%	14%	14%
Smell is acceptable	14%	18%	12%	22%	24%
Has been told what the water quality level is	59%	22%	12%	2%	4%
Knows ways to improve it	43%	29%	6%	10%	8%
Worry about microbial presence	12%	6%	10%	16%	55%
Water quality is good	14%	22%	16%	16%	31%
Worry about quality of water used for cleaning	14%	16%	10%	24%	35%
Drinking the water will make me or my family sick	12%	2%	2%	14%	69%

Pre Intervention survey Juárez results	
Section III: Additional Water (n=44)	
Practice	**Value**
Purchase additional drinking water	76%
Additional purchased water used for drinking	9.56 Gallons
Additional purchased water used for cooking	4.45 Gallons
Additional purchased water used for cleaning	6.42 Gallons
Money spend monthly for additional water	$23.00 USD
Distance traveled to purchase additional water	4.33 Miles
Total Additional water purchased	42.46 Gallons
Discrepancy between water purchased and water used	22 Gallons

Pre Intervention survey Juárez results	
Section III: Additional Water (n=44)	
How important are the following concerns when purchasing a drinking water treatment system?	
Very Important	
Cost	69%
Labor to replace the filter	69%
Pollution to the environment	69%
Important	
Cost	20%
Labor to replace the filter	22%
Pollution to the environment	10%
Not Important	
Cost	10%
Labor to replace the filter	8%
Pollution to the environment	20%
How much would you be willing to pay (initial cost) for a water treatment system? (USD)	
$0-$50	44%
$50-$100	20%
$100-$150	16%
$150-$200	8%
$200-$250	12%
How much would you be willing to pay for maintenance of a water treatment system? (USD)	
$0-$10	27%
$10-$20	16%
$20-$30	16%
$30-$40	27%
$40-$50	14%

Pre Intervention survey Juárez	
Section IV: Water Storage/Tanks	
Has a large storage tank (>1000 Gallons) (n=44)	78%
Tank material (n=38)	
Metal	5%
Plastic	95%
Tank is a dark color	61%
Is the tank covered or sealed?	84%
Cleaning Practices	

Has never cleaned the tank	18%
Cleans tank once a year	11%
Cleans tank twice a year	11%
Cleans tank every two months	11%
Cleans the tank at least once a month	18%
Cleans the tank at more than once a month	32%
Supply Quality Perception	
Trusts providers to supply clean water	41%
Worries about the quality of the water	59%

Pre Intervention survey Juárez results	
Section VI: Demographics (n=44)	
Characteristic	**Mean or % (n=44)**
Age (Years)	**44**
Hispanic or Latino ethnicity	**80%**
Less than or 10 Years in current home	**53%**
Female	**78%**
Income below poverty level*	**73%**
Less than high school education	**78%**
Household size	**4.67**

Pre-survey results for colonias in El Paso

Pre Intervention survey results El Paso		
Section I: Water Source / Treatment / Water Use (n=5)		
Main Water Source	**Public Agency Hauled Water**	**Private Company Hauled water**
	100%	0%
Does the water come into your home through a faucet?	**Yes**	**No**
	100%	0%
Is this water your main drinking water source?	100%	0%
How much water from your household faucets does your family use for:	**Average**	
Drinking	2.83Gallons	
Cooking	2.66 Gallons	
Do you give the water further treatment before drinking it?	**Yes**	**No**
	0%	100%

Pre Intervention survey results El Paso		
Section I: Water Source / Treatment / Water Use (n=5)		
Do you give the water further treatment before cooking with it?	**Yes**	**No**
	0%	100%
Would you like to learn about various ways to treat your water that can make it safer to drink	**Yes**	**No**
	100%	0%
Would you like to learn about water filtration systems that can make your water safer to drink	100%	0%

Pre Intervention survey results El Paso					
Section II: Water Quality (n=5)					
Tank Water	**Strongly Disagree**	**Disagree**	**No Strong Feelings**	**Agree**	**Strongly Agree**
Safe to drink	20%	40%	40%	0%	0%
Worry about chemicals	20%	0%	0%	40%	40%
Happy with the quality	0%	40%	20%	40%	0%
Taste is acceptable	20%	40%	20%	20%	0%
Smell is acceptable	0%	40%	20%	40%	0%
Has been told what the water quality level is	40%	20%	40%	0%	0%
Knows ways to improve it	20%	80%	0%	0%	0%
Worry about microbial presence	0%	20%	0%	40%	40%
Water quality is good	0%	60%	40%	0%	0%
Worry about quality of water used for cleaning	0%	40%	20%	20%	20%
Drinking the water will make me or my family sick	0%	0%	0%	40%	60%

Pre Intervention survey El Paso results	
Section III: Additional Water (n=5)	
Practice	**Value**
Purchase additional drinking water	100%
Additional purchased water used for drinking	4.05 Gallons
Additional purchased water used for cooking	1 Gallons
Additional purchased water used for cleaning	0 Gallons
Money spend monthly for additional water	$28.4 USD
Distance traveled to purchase additional water	11 Miles
Total Additional water purchased	5.05
Discrepancy between water purchased and water used	13.8 Gallons
How important are the following concerns when purchasing a drinking water treatment system?	
Very Important	
Cost	100%
Labor to replace the filter	0%
Pollution to the environment	0%
Important	
Cost	60%
Labor to replace the filter	20%
Pollution to the environment	20%
Not Important	
Cost	100%
Labor to replace the filter	0%
Pollution to the environment	0%
How much would you be willing to pay (initial cost) for a water treatment system? (USD)	
$0-$50	100%
$50-$100	0%
$100-$150	0%
$150-$200	0%
$200-$250	0%
How much would you be willing to pay for maintenance of a water treatment system? (USD)	
$0-$10	60%
$10-$20	20%
$20-$30	20%
$30-$40	0%
$40-$50	0%

Pre Intervention survey El Paso	
Section IV: Water Storage/Tanks	
Has a large storage tank (>1000 Gallons) (n=5)	100%
Tank material (n=38)	
Plastic	100%
Tank is a dark color	100%
Is the tank covered or sealed?	100%
Cleaning Practices	
Has never cleaned the tank	60%
Cleans tank once a year	40%
Supply Quality Perception	
Trusts providers to supply clean water	20%
Worries about the quality of the water	40%

Pre Intervention survey results	
Section VI: Demographics (n=5)	
Characteristic	Mean or % (n=5)
Age (Years)	51
Hispanic or Latino ethnicity	100%
Less than or 10 Years in the current home	40%
Female	100%
Income below poverty level*	40%
Less than high school education	40%
Household size	3.2

Post-Intervention perceptions and practices results

Post-intervention survey results Juárez					
Section II: Water Quality (n=16)					
Tank Water	Strongly Disagree	Disagree	No Strong Feelings	Agree	Strongly Agree
Safe to drink	0%	13%	6%	31%	50%
Worry about chemicals	13%	25%	19%	13%	31%
Happy with the quality	0%	19%	13%	6%	63%
Taste is acceptable	0%	13%	6%	13%	69%
Smell is acceptable	0%	6%	6%	13%	75%
Worry about microbial presence	13%	6%	6%	13%	63%
Water quality is good	0%	6%	19%	6%	69%

Post-intervention survey results Juárez					
Section II: Water Quality (n=16)					
Worry about the quality of water used for cleaning	13%	13%	13%	6%	56%
Drinking the water will make me or my family sick	31%	13%	13%	0%	44%

Post-intervention survey results El Paso					
Section II: Water Quality (n=10)					
Tank Water	**Strongly Disagree**	**Disagree**	**No Strong Feelings**	**Agree**	**Strongly Agree**
Safe to drink	0%	0%	0%	30%	70%
Worry about chemicals	80%	10%	0%	0%	10%
Happy with the quality	0%	0%	0%	0%	100%
Taste is acceptable	0%	0%	10%	0%	90%
Smell is acceptable	0%	0%	0%	0%	100%
Worry about microbial presence	100%	0%	0%	0%	0%
Water quality is good	0%	0%	0%	0%	100%
Worry about quality of water used for cleaning	4%	0%	60%	0%	0%
Drinking the water will make me or my family sick	100%	0%	0%	0%	0%

Appendix C

Water quality results

Pre Intervention Samples General data									
ID	**Location**	**Campaign**	**pH**	**Conductivity µ/cm**	**TDS mg/L**	**Total Chlorine**	**Free Chlorine**	**Chlorophyll A**	**Chlorophyll B**
101801-NF	Hueco Tanks	Summer 2018	8.40	2002	1280	0	0	0.364	0.002
101802-NF	Hueco Tanks	Summer 2018	7.93	1890	1210	5.5	0	9.067	0.366
101803-NF	Hueco Tanks	Summer 2018	8.40	1596	1020	0.1	0	0.007	0
101804-NF	Hueco Tanks	Summer 2018	7.85	1746	1120	0.1	0	0	0
101805-NF	Hueco Tanks	Summer 2018	8.00	1378	882	0	0	0	0
101806-NF	Kilómetros	Summer 2018	8.40	1619	1040	0	0	0.063	0.001
101807-NF	Kilómetros	Summer 2018	9.00	1865	1190	0	0	0	0
101808-NF	Kilómetros	Summer 2018	8.40	1308	837	0	0	0.009	0
101809-NF	Kilómetros	Summer 2018	7.80	942	606	0	0	0	0
101810-NF	Kilómetros	Summer 2018	9.00	1325	848	0	0	0.012	0
101811-NF	Kilómetros	Summer 2018	8.40	858.4	549	0	0	0.034	0.033
101812-NF	Kilómetros	Summer 2018	7.80	958.3	613	0	0	0	0

101813-NF	Kilómetros	Summer 2018	7.20	991.4	634	0.2	0	0.361	0.026
101814-NF	Kilómetros	Summer 2018	7.20	1068	683	1	1	0	0
101815-NF	Kilómetros	Summer 2018	7.80	2366	1510	0	0	0.002	0
101816-NF	Kilómetros	Summer 2018	8.40	1260	806	0	0	0.142	0.007
101817-NF	Kilómetros	Summer 2018	8.40	993.7	636	0	0	0.02	0
101818-NF	Kilómetros	Summer 2018	7.80	1044	668	0	0	0	0
101819-NF	Kilómetros	Summer 2018	7.20	814.7	521	0	0	0.046	0
101820-NF	Kilómetros	Summer 2018	7.57	856.9	548	0.48	0.41	0.632	0.12
101821-NF	Kilómetros	Summer 2018	7.95	872.7	558	0	0	0	0
101822-NF	Kilómetros	Summer 2018	7.88	919.7	588	0	0	0	0
101823-NF	Kilómetros	Summer 2018	7.95	867.5	555	0	0	0	0
101824-NF	Kilómetros	Summer 2018	7.71	873.3	559	0	0	0.135	0.012
101825-NF	Kilómetros	Summer 2018	7.70	770.5	493	0	0	0	0
Post Intervention Unfiltered Samples									
ID	**Location**	**Campaign**	**pH**	**Conductivity µ/cm**	**TDS mg/L**	**Total Chlorine**	**Free Chlorine**	**Chlorophyll A**	**Chlorophyll B**
201901-NF	Kilómetros	Winter 2019	7.62	707.7	448	0	0	0	0
201902-NF	Kilómetros	Winter 2019	7.67	1541	986	0.41	0.4	0	0

201903-NF	Kilómetros	Winter 2019	7.52	1205	771	0	0	0	0
201904-NF	Kilómetros	Winter 2019	7.75	948	607	0.05	0	0	0
201905-NF	Kilómetros	Winter 2019	7.52	856.2	548	0	0	0	0
201906-NF	Kilómetros	Winter 2019	7.64	977.3	625	0.03	0	0	0
201907-NF	Kilómetros	Winter 2019	7.88	952.1	609	0	0	0	0
201908-NF	Kilómetros	Winter 2019	7.79	853.5	546	0	0	0.44	0.032
201909-NF	Kilómetros	Winter 2019	7.68	836.9	535	0.01	0	0	0
201910-NF	Kilómetros	Winter 2019	7.69	925.4	592	0.012	0	0	0
201911-NF	Kilómetros	Winter 2019	7.57	1009.3	703	0.01	0.08	0	0
301901-NF	Hueco Tanks	Spring 2019	7.68	898	575	0.13	0.05	0	0
301902-NF	Hueco Tanks	Spring 2019	7.62	876.1	561	0.84	0.076	279.8	0.59
301903-NF	Hueco Tanks	Spring 2019	7.58	881.9	564	0.21	0.19	58.11	0.1
301904-NF	Hueco Tanks	Spring 2019	7.58	916.3	586	1.7	1.56	0	0
301905-NF	Hueco Tanks	Spring 2019	7.84	1176	752	2.2	2.2	0	0
301906-NF	Hueco Tanks	Spring 2019	7.73	889	569	1.27	1.25	0	0
301907-NF	Hueco Tanks	Spring 2019	8.12	919	588	0.1	0	6.2	0.002

301908-NF	Hueco Tanks	Spring 2019	8.11	918.80	587	0.1	0	5.2	0.002
301909-NF	Hueco Tanks	Spring 2019	7.10	1399	895	0.81	0.7	0.099	0
301910-NF	Hueco Tanks	Spring 2019	7.27	1637	1050	0.25	0.17	0.117	0
301911-NF	Kilómetros	Spring 2019	7.55	867.3	555	0.05	0.01	0	0
301912-NF	Kilómetros	Spring 2019	7.55	712.6	456	0	0	0	0
301913-NF	Kilómetros	Spring 2019	7.70	841.9	539	0	0	1.016	0
301914-NF	Kilómetros	Spring 2019	7.64	713	456	0	0	0.42	0
301915-NF	Kilómetros	Spring 2019	7.82	872	558	0	0	0.119	0
301916-NF	Kilómetros	Spring 2019	7.83	775	496	0.01	0	0.86	0
301917-NF	Kilómetros	Spring 2019	7.46	760	486	0	0	1.466	0
301918-NF	Kilómetros	Spring 2019	7.62	893.1	571	0.03	0.01	4.237	0.002
Post Intervention POU Filtered Samples									
ID	**Location**	**Campaign**	**pH**	**Conductivity µ/cm**	**TDS mg/L**	**Total Chlorine**	**Free Chlorine**	**Chlorophyll A**	**Chlorophyll B**
201902-F	Kilómetros	Winter 2019	7.20	857.8	549	0.03	0.01	0	0
201903-F	Kilómetros	Winter 2019	7.45	722	462	0	0	0	0
201904-F	Kilómetros	Winter 2019	7.27	856	548	0	0	0	0
201905-F	Kilómetros	Winter 2019	7.20	734.4	470	0	0	0	0

201906-F	Kilómetros	Winter 2019	7.32	883.3	565	0	0	0	0
201907-F	Kilómetros	Winter 2019	7.20	845	541	0	0	0	0
201910-F	Kilómetros	Winter 2019	7.35	867.3	555	0	0	0	0
201911-F	Kilómetros	Winter 2019	7.40	873.3	559	0	0	0	0
301901-F	Hueco Tanks	Spring 2019	7.13	204	131	0.03	0.02	0	0
301902-F	Hueco Tanks	Spring 2019	6.78	117	74.9	0.02	0.01	0	0
301903-F	Hueco Tanks	Spring 2019	6.91	76.58	49	0.02	0.01	0	0
301904-F	Hueco Tanks	Spring 2019	6.5	122.5	78.4	0	0	0	0
301905-F	Hueco Tanks	Spring 2019	6.9	169.1	108	0.04	0	0	0
301906-F	Hueco Tanks	Spring 2019	7.08	117.2	75	0	0	0	0
301909-F	Hueco Tanks	Spring 2019	6.54	230.8	148	0	0	0	0
301910-F	Hueco Tanks	Spring 2019	6.8	367.9	235	0	0	0	0
301912-F	Kilómetros	Spring 2019	7.49	711	455	0	0	0	0
301913-F	Kilómetros	Spring 2019	7.70	849	543	0	0	0.269	0
301914-F	Kilómetros	Spring 2019	7.67	705.7	452	0	0	0	0
301915-F	Kilómetros	Spring 2019	7.56	866.7	555	0	0	0	0

301916-F	Kilómetros	Spring 2019	7.80	767	491	0	0	0.06	0
301917-F	Kilómetros	Spring 2019	7.45	760	486	0	0	0.155	0
301918-F	Kilómetros	Spring 2019	7.55	405.9	260	0.05	0.02	0.361	0
301919-F	Kilómetros	Spring 2019	7.82	751.1	481	0.04	0	0.379	0
301920-F	Kilómetros	Spring 2019	7.18	437.5	280	0.02	0	0.231	0
301921-F	Kilómetros	Spring 2019	7.62	892.4	571	0.02	0.01	0	0
301922-F	Kilómetros	Spring 2019	7.50	736.2	471	0	0	0.064	0
301923-F	Kilómetros	Spring 2019	7.68	913.6	585	0	0	0	0
301924-F	Kilómetros	Spring 2019	7.46	730.2	467	0.12	0	0.04	0
301925-F	Kilómetros	Spring 2019	7.11	509.2	326	0.03	0	0.02	0

Pre Intervention Samples – Ions by IC									
ID	Cations by IC (mg/L)				Hardness	Anions by IC (mg/L)			
	Ca^{2+}	K^{+}	Mg^{2+}	Na^{+}	Ca^{2+} + Mg^{2+} as $CaCO_3$	Cl^{-}	F^{-}	$NO3^{-}$	$SO4^{2-}$
101801-NF	59.35	14.95	13.29	175.14	203	107.4	6.52	6.37	146.12
101802-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101803-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101804-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101805-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101806-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101807-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101808-NF	38.91	6.86	5.32	158.66	119	67.75	4.84	N.A.	93.2
101809-NF	21.91	9.16	9.23	230.6	92.6	70.38	4.64	12.4	133.72
101810-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101811-NF	37.17	6.85	5.24	158.47	99.4	66.01	4.77	N.A.	93.21
101812-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101813-NF	24.55	6.69	7.22	180.36	91	66.83	4.87	2.94	104.51
101814-NF	38.74	6.92	5.35	161.53	119	67.29	4.51	N.A.	94.63
101815-NF	36.3	7.77	6.68	185.13	118	70.84	5.3	4.46	109.37
101816-NF	38.93	7.35	6.18	173.74	123	70.6	5.18	2.42	102.72
101817-NF	47.11	7.25	5.93	167.46	142	70.18	5.31	N.A.	117.15
101818-NF	24.69	9.13	8.98	228.29	98.5	71.91	5.37	12.17	132.91
101819-NF	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.	N.T.
101820-NF	22.1	9.24	9.7	236.38	95	70.15	4.94	10.8	130.2
101821-NF	14.09	8.9	10.22	255.34	77.1	77.21	5.52	11.19	144.09
101822-NF	22.19	9.35	9.89	239.71	96	71.61	5.06	10.58	133.32
101823-NF	20.82	10	10.65	255.66	95.7	76.14	5.48	10.42	144.55
101824-NF	22.18	9.44	11.18	242.16	101	70.97	5.18	11.06	134.97
101825-NF	31.98	7.73	6.84	192.12	108	68.62	5.04	5.62	111.78
Post Intervention Unfiltered Samples									
ID	Cations by IC				Hardness	Anions by IC			
	Ca^{2+}	K^{+}	Mg^{2+}	Na^{+}	Ca^{2+} + Mg^{2+} as $CaCO_3$	Cl^{-}	F^{-}	$NO3^{-}$	$SO4^{2-}$
201901-NF	0.6	0.22	12	242.51	50.7	62.18	3.89	1.76	89.42
201902-NF	22.09	9.25	9.65	231.97	94.8	69.88	4.52	12.75	133.24
201903-NF	37.39	6.85	5.25	164.43	115	65.02	4.77	0.26	93.22
201904-NF	22.11	9.28	9.21	231.88	93	70.23	3.43	10.46	132.23

201905-NF	35.54	7.13	5.76	173.93	112	66	4.86	2.6	99.8
201906-NF	23.18	9.59	9.51	242.83	96.9	72.41	5.06	10.51	135.21
201907-NF	22.99	9.38	8.93	230.99	94.1	69.05	4.87	9.28	126.51
201908-NF	21.96	9.3	9.24	235.19	92.8	70.85	4.5	12.97	135.32
201909-NF	23.63	9	9.18	227.2	96.7	69.72	4.99	11.77	130.79
201910-NF	34.03	8.75	7.03	188.91	114	74.22	5	5.51	110.57
201911-NF	24.44	8.94	8.96	225.15	97.8	70.64	4.99	9.18	130.26
301901-NF	n.a.	n.a.	n.a.	5.83	n.a.	3.63	n.a.	1.75	48.73
301902-NF	33.89	11.01	14.81	207.41	145	304.94	2.79	7.24	344.84
301903-NF	34.69	10.93	14.84	207.39	148	309.69	2.75	2.63	361.63
301904-NF	35.5	10.87	15.19	216.16	151	327.3	2.57	7.41	323.3
301905-NF	44.6	13.77	18.82	293.97	189	440.24	3.57	2.38	397.35
301906-NF	34.32	10.75	14.32	210.55	145	312.31	2.56	10.56	336.56
301907-NF	35.47	11.08	15.27	215.5	151	335.65	2.5	6.97	340.7
301908-NF	35.6	10.94	15.2	214.95	151	340.34	2.67	7.31	338.37
301909-NF	24.08	3.34	8.4	173.81	94.6	166.99	n.a.	8.32	1936.14
301910-NF	28.87	3.83	9.46	199	111	57.3	n.a.	13.11	230.94
301911-NF	1.17	0.31	3.16	141.59	15.9	60.18	0.35	1.21	86.5
301912-NF	37.36	4.04	7.27	98.04	123	67.45	0.42	2.48	96.01
301913-NF	22.94	5.62	12.59	139.41	109	71.55	0.4	11.81	131.42
301914-NF	37.41	3.99	7.01	96.7	122	67.15	0.43	2.41	95.06
301915-NF	24.15	5.72	14.08	140.73	118	74.81	0.38	11.82	135.49
301916-NF	31.39	4.69	9.38	111.7	117	69.56	0.42	7.72	111.09
301917-NF	32.88	4.53	8.92	111.43	119	68.7	0.36	4.36	108.16
301918-NF	23.07	5.58	12.6	138.34	109	74.16	0.44	13.09	134.94
Post Intervention POU Filtered Samples									
ID	**Cations by IC**				**Hardness**	**Anions by IC**			
	Ca^{2+}	**K^{+}**	**Mg^{2+}**	**Na^{+}**	**Ca^{2+} + Mg^{2+} as $CaCO_3$**	**Cl^{-}**	**F^{-}**	**$NO3^{-}$**	**$SO4^{2-}$**
201902-F	22.1	9.28	9.22	231.83	93.1	69.86	5.19	12.9	133.66
201903-F	37.68	6.99	5.36	164.77	116	65.33	4.57	0.48	93.56
201904-F	22.71	9.31	9.28	232.66	94.8	71.1	4.94	12.96	136.24
201905-F	35.89	7.27	5.82	174.68	114	67.09	4.99	3.3	101.53
201906-F	23.19	9.6	9.79	239.37	98.1	72.87	5.22	11.39	136.72
201907-F	21.54	9.49	8.79	231.37	89.9	68.91	4.86	8.61	128.1
201910-F	43.18	10.44	6.79	158.42	136	87.28	4.81	n.a.	95.81
201911-F	24.99	8.88	8.99	223.42	99.3	70.71	4.36	10.47	130.41
301901-F	n.a.	n.a.	n.a.	157.64	n.a.	n.a.	n.a.	n.a.	4.78
301902-F	2.39	1.92	1.13	29.77	10.6	36.97	5.45	4.11	6.18

301903-F	1.29	1.38	0.56	20.62	5.52	24.14	1.74	2.1	32.36
301904-F	2.42	2.03	1.11	32.06	10.6	37.07	4.26	4.7	4.73
301905-F	2.62	2.67	1.49	45.63	12.7	52.68	6.08	7.12	6.74
301906-F	1.02	3.88	1.13	33.36	7.18	36.12	3.43	3.58	6.09
301909-F	1.45	0.85	0.66	31.09	6.33	41.27	n.a.	13.63	10.3
301910-F	3.18	1.38	1.42	49.08	111	n.a.	n.a.	n.a.	n.a.
301912-F	37.38	4.03	7.25	97.77	123	67.74	0.43	1.89	96.38
301913-F	23.46	5.59	12.52	137.41	110	72.4	0.41	11.36	132.26
301914-F	37.47	4	7.03	95.38	122	67.46	0.36	2.15	95.47
301915-F	23.88	5.86	12.84	144.48	112	75.3	0.42	11.94	136.5
301916-F	31.67	4.74	9.43	113.15	118	70.79	0.43	7.45	112.79
301917-F	32.88	4.51	9.2	109.66	120	68.77	0.36	4.2	108.19
301918-F	0.67	0.12	1.58	80.4	8.15	35.54	0.19	n.a.	48.28
301919-F	39.44	4.07	7.22	96.95	128	68.68	0.37	2.24	97.1
301920-F	3.64	0.45	2.31	82.28	18.6	37.76	0.27	2.1	53.86
301921-F	22.89	5.6	12.33	137.54	108	72.23	0.36	11.65	132.77
301922-F	37.56	4.01	7.05	95.65	123	67.51	0.37	2.12	95.42
301923-F	23.63	5.8	12.7	140.26	111	74.17	0.45	12.08	136.22
301924-F	37.67	3.88	7	92.89	123	66.77	0.36	n.a.	91.63
301925-F	1.19	0.19	3.56	100.83	17.6	45.38	0.24	1.62	62.68

Pre Intervention Samples Inorganics by ICP-OES																
ID	**Ca**	**K**	**Mg 2**	**Na**	**As**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Pb**	**Se**	**U**	**Zn**
101801-NF	66.920	9.347	13.876	84.025	n.d.	0.067	n.d.	n.d.	0.055	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101802-NF	62.929	8.175	11.702	88.201	n.d.	0.066	n.d.	n.d.	0.012	n.d.	n.d.	n.d.	n.d.	n.d.	0.0207	n.d.
101803-NF	63.267	8.635	12.347	87.962	n.d.	0.066	n.d.	n.d.	0.004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.016
101804-NF	59.145	7.374	11.494	73.589	n.d.	0.061	n.d.	n.d.	0.017	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101805-NF	60.741	7.709	11.829	78.542	n.d.	0.062	n.d.	n.d.	0.002	n.d.	n.d.	n.d.	0.012	n.d.	0.020	n.d.
101806-NF	9.788	10.893	4.861	318.473	n.d.	0.015	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101807-NF	6.650	2.119	1.650	49.332	n.d.	n.d.	n.d.	n.d.	0.006	n.d.	n.d.	n.d.	0.014	n.d.	n.d.	n.d.
101808-NF	40.487	3.688	6.499	72.555	n.d.	0.040	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.015	n.d.	n.d.	n.d.
101809-NF	22.098	6.594	8.522	110.544	n.d.	0.034	n.d.	n.d.	0.002	n.d.	n.d.	n.d.	0.010	n.d.	n.d.	n.d.
101810-NF	34.404	3.081	5.742	70.458	n.d.	0.037	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.029	n.d.
101811-NF	39.264	3.628	6.526	72.423	n.d.	0.041	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101812-NF	20.186	5.441	7.532	103.845	n.d.	0.032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101813-NF	24.862	5.216	6.251	81.922	n.d.	0.032	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101814-NF	40.989	3.734	6.570	73.416	n.d.	0.041	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101815-NF	37.620	4.852	7.398	85.914	n.d.	0.043	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.015	n.d.	n.d.	n.d.
101816-NF	40.024	4.414	6.914	80.093	n.d.	0.042	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101817-NF	49.450	4.285	6.837	77.594	n.d.	0.044	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101818-NF	25.279	6.484	8.497	108.984	n.d.	0.036	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101819-NF	24.470	13.767	7.681	121.133	n.d.	0.032	n.d.	n.d.	0.006	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101820-NF	22.635	6.810	8.670	110.527	n.d.	0.034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101821-NF	14.053	7.088	8.420	122.949	n.d.	0.027	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.
101822-NF	22.994	6.807	8.806	114.308	n.d.	0.034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.
101823-NF	21.307	7.538	9.397	124.278	n.d.	0.035	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
101824-NF	22.267	8.010	8.766	114.610	n.d.	0.034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.013	n.d.	n.d.	n.d.
101825-NF	33.494	4.760	7.203	88.035	n.d.	0.038	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.

Post Intervention Unfiltered Samples Inorganics by ICP-OES																
ID	**Ca**	**K**	**Mg 2**	**Na**	**As**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Pb**	**Se**	**U**	**Zn**
201901-NF	n.d.	8.864	n.d.	112.860	n.d.	n.d.	n.d.	n.d.	0.002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201902-NF	21.838	6.660	8.312	108.535	n.d.	0.033	n.d.	n.d.	0.003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201903-NF	38.189	3.575	6.335	73.583	n.d.	0.039	n.d.	n.d.	0.003	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201904-NF	21.997	6.410	8.454	107.075	n.d.	0.034	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.
201905-NF	36.733	3.908	6.554	75.827	n.d.	0.039	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201906-NF	23.144	6.574	8.638	111.137	n.d.	0.035	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.023
201907-NF	23.487	6.121	8.512	105.404	n.d.	0.036	n.d.	n.d.	0.002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201908-NF	21.876	6.296	8.531	106.116	n.d.	0.033	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201909-NF	23.843	6.230	8.169	102.192	n.d.	0.034	n.d.	n.d.	0.001	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
201910-NF	35.036	4.895	8.162	84.326	n.d.	0.037	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.
201911-NF	24.600	6.298	8.421	104.440	n.d.	0.034	n.d.	n.d.	0.002	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301901-NF	31.340	8.600	8.050	83.240	n.d.	0.100	n.d.	n.d.	0.050	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.140
301902-NF	30.310	8.310	7.880	78.270	n.d.	0.090	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301903-NF	32.120	8.520	8.140	79.740	n.d.	0.090	n.d.	n.d.	0.190	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.010
301904-NF	32.550	8.440	8.280	82.170	n.d.	0.090	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301905-NF	39.530	10.890	10.660	118.870	n.d.	0.120	n.d.	n.d.	0.010	n.d.	n.d.	n.d.	0.010	n.d.	n.d.	n.d.
301906-NF	31.060	8.530	7.860	79.840	n.d.	0.080	n.d.	n.d.	0.030	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301907-NF	32.630	9.130	8.560	82.700	n.d.	0.090	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301908-NF	31.880	8.770	8.290	81.760	n.d.	0.090	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301909-NF	43.860	4.340	9.490	143.960	n.d.	n.d.	n.d.	n.d.	0.020	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301910-NF	55.130	5.570	11.110	173.630	n.d.	n.d.	n.d.	n.d.	0.010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301911-NF	n.d.	0.6500	n.d.	94.420	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301912-NF	36.180	3.190	5.700	64.180	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301913-NF	20.830	5.530	7.860	93.380	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301914-NF	36.650	3.010	5.680	61.630	n.d.	0.040	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.010	n.d.	n.d.	n.d.
301915-NF	22.800	6.630	8.340	98.620	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

301916-NF	31.050	4.150	6.730	73.630	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301917-NF	32.740	3.860	6.400	70.150	n.d.	0.040	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301918-NF	21.770	5.790	8.120	96.680	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Post Intervention POU Filtered Samples Inorganics by ICP-OES																
ID	**Ca**	**K**	**Mg 2**	**Na**	**As**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Mn**	**Pb**	**Se**	**U**	**Zn**
201902-F	22.097	6.366	8.438	108.177	n.d.	0.034	n.d.	n.d.	0.001	n.d.	0.012	n.d.	n.d.	n.d.	n.d.	n.d.
201903-F	38.436	3.721	6.448	74.195	n.d.	0.040	n.d.	n.d.	0.005	n.d.	0.012	n.d.	n.d.	n.d.	n.d.	n.d.
201904-F	22.787	6.561	8.438	107.338	n.d.	0.035	n.d.	n.d.	n.d.	n.d.	0.011	n.d.	n.d.	n.d.	n.d.	n.d.
201905-F	36.954	4.052	6.785	78.072	n.d.	0.039	n.d.	n.d.	0.004	n.d.	0.010	n.d.	0.013	n.d.	n.d.	n.d.
201906-F	23.075	6.759	8.737	110.099	n.d.	0.034	n.d.	n.d.	n.d.	n.d.	0.012	n.d.	n.d.	n.d.	n.d.	0.031
201907-F	21.889	6.027	8.608	106.416	n.d.	0.033	n.d.	n.d.	0.001	n.d.	0.012	n.d.	n.d.	n.d.	n.d.	n.d.
201910-F	46.130	4.417	9.894	72.173	n.d.	0.042	n.d.	n.d.	n.d.	n.d.	0.014	n.d.	n.d.	n.d.	n.d.	n.d.
201911-F	25.139	6.274	8.298	104.871	n.d.	0.034	n.d.	n.d.	0.002	n.d.	0.011	n.d.	n.d.	n.d.	n.d.	n.d.
301901-F	3.760	2.120	0.860	20.030	n.d.	0.010	n.d.	n.d.	0.010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301902-F	1.980	1.190	0.440	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301903-F	0.850	0.850	0.160	n.d.	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301904-F	2.080	1.320	0.450	12.970	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301905-F	2.240	1.730	0.620	17.480	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301906-F	n.d.	2.580	0.290	12.720	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301909-F	2.540	0.740	0.430	23.200	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301910-F	5.730	1.320	1.260	36.070	n.d.	n.d.	0.000	n.d.	0.010	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301912-F	31.440	4.050	6.500	74.410	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301913-F	21.820	5.790	8.040	95.810	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301914-F	36.950	3.030	5.720	62.390	n.d.	0.040	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301915-F	22.620	5.840	8.500	97.990	n.d.	0.030	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301916-F	31.570	4.150	6.840	75.090	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301917-F	35.430	3.190	5.820	62.790	n.d.	0.040	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301918-F	n.d.	0.470	n.d.	50.180	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

301919-F	40.200	3.280	5.990	66.160	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301920-F	2.830	0.910	0.400	53.950	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301921-F	22.360	5.790	8.320	97.440	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301922-F	37.110	3.190	5.970	63.970	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	0.010	n.d.	n.d.	n.d.
301923-F	23.010	6.110	8.670	101.950	n.d.	0.030	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301924-F	38.470	3.070	5.790	63.750	n.d.	0.040	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
301925-F	n.d.	1.4600	n.d.	66.640	n.d.	n.d.	n.d.	n.d.	0.000	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

Pre-intervention Samples Microbial contamination and annual health risk values				
ID	**Total Coliform (MPN/100ml)**	***E. coli* (MPN)**	***Enterococcus* (MPN)**	***E. coli* Annual Risk % (p_{year})**
101801-NF	0	0	2	0.00
101802-NF	3	0	3	0.00
101803-NF	8.4	2	6.2	0.46
101804-NF	0	0	1	0.00
101805-NF	0	0	6.3	0.00
101806-NF	25.4	108.1	960.6	22.14
101807-NF	0	0	1	0.00
101808-NF	7.5	4.1	206.4	0.95
101809-NF	0	0	0	0.00
101810-NF	6.2	1	298.7	0.23
101811-NF	3	0	42.8	0.00
101812-NF	5	1	913.9	0.23
101813-NF	5.1	0	0	0.00
101814-NF	0	0	1011.2	0.00
101815-NF	4	1	52	0.23
101816-NF	72.8	82	456.9	17.30
101817-NF	18.1	0	1011.2	0.00
101818-NF	4.1	1	241.5	0.23
101819-NF	2419.6	2419.6	1011.2	99.53
101820-NF	0	0	2419.6	0.00
101821-NF	488.4	1	2419.6	0.23
101822-NF	2419.6	2419.6	2419.6	99.53
101823-NF	2419.6	2419.6	2419.6	99.53
101824-NF	36.4	3.1	10.8	0.72
101825-NF	0	0	0	0.00
Post Intervention Unfiltered Samples Microbial contamination and annual health risk values				
ID	**Total Coliform (MPN/100ml)**	***E. coli* (MPN)**	***Enterococcus*(MPN)**	***E. coli* Annual Risk % (p_{year})**
201901-NF	0	0	0	0.00
201902-NF	0	0	3	0.00
201903-NF	39.3	0	2	0.00

201904-NF	0	0	0	0.00
201905-NF	9.7	0	23.8	0.00
201906-NF	2419.6	3.1	9.2	0.72
201907-NF	2	0	1	0.00
201908-NF	0	0	0	0.00
201909-NF	3	1	0	0.23
201910-NF	93.2	0	1	0.00
201911-NF	0	0	0	0.00
301901-NF	0	0	0	0.00
301902-NF	0	0	0	0.00
301903-NF	0	0	0	0.00
301904-NF	0	0	0	0.00
301905-NF	0	0	0	0.00
301906-NF	0	0	0	0.00
301907-NF	0	0	0	0.00
301908-NF	0	0	0	0.00
301909-NF	0	0	0	0.00
301910-NF	0	0	0	0.00
301911-NF	0	0	0	0.00
301912-NF	2419.6	23.3	52	5.26
301913-NF	37.9	0	7.2	0.00
301914-NF	2419.6	3.1	0	0.72
301915-NF	6.1	1	0	0.23
301916-NF	0	0	0	0.00
301917-NF	157.6	52	23.3	11.35
301918-NF	195.6	81.6	49.6	17.22
Post Intervention POU Filtered Samples Microbial contamination and annual health risk values				
ID	**Total Coliform (MPN/100ml)**	***E .coli* (MPN)**	***Enterococcus*(MPN)**	***E. coli* Annual Risk % (p_{year})**
201902-F	0	0	0	0.00
201903-F	0	0	0	0.00
201904-F	0	0	0	0.00
201905-F	0	0	0	0.00
201906-F	0	0	0	0.00
201907-F	0	0	0	0.00
201910-F	0	0	0	0.00
201911-F	0	0	0	0.00

301901-F	0	0	0	0.00
301902-F	0	0	0	0.00
301903-F	0	0	0	0.00
301904-F	0	0	0	0.00
301905-F	0	0	0	0.00
301906-F	0	0	0	0.00
301909-F	0	0	0	0.00
301910-F	0	0	0	0.00
301912-F	0	0	0	0.00
301913-F	0	0	0	0.00
301914-F	0	0	0	0.00
301915-F	0	0	0	0.00
301916-F	0	0	0	0.00
301917-F	0	0	0	0.00
301918-F	0	0	0	0.00

Vita

Varinia Felix obtained her Bachelors of Architecture at the Universidad Autónoma de Ciudad Juárez (UACJ) in 2014. In her pursue to expand her knowledge and lead a professional life focused on solving environmental issues, she joined the Master of Science in Environmental Engineering program at The University of Texas at El Paso. While pursuing her Master's degree, she worked as a teaching and research assistant for the Department of Civil Engineering. Her thesis was completed under Dr. Ivonne Santiago's guidance.

Varinia plans to pursue a Doctoral degree in the environmental field with a focus on water treatment technologies.

Permanent address: varinia.felix@hotmail.com

This thesis/dissertation was typed by Varinia Viridiana Felix Parra.