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Evaluation of Point of Use Reverse Osmosis systems for drinking water in Colonias

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EVALUATION OF POINT OF USE REVERSE OSMOSIS SYSTEMS FOR DRINKING WATER IN COLONIAS

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Master's Program in Environmental Engineering

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EVALUATION OF POINT OF USE REVERSE OSMOSIS SYSTEMS FOR DRINKING WATER IN COLONIAS

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Abstract

Clean drinking water is often considered a right and not a privilege, especially in first world countries. However, thousands of residents of *colonias* (settlements in the U.S. that lack access to basic infrastructure) struggle to obtain clean drinking water, including some in the Paso del Norte Region. Residents of *colonias* located in Doña Ana County, NM, and El Paso County, TX typically rely on domestic wells and hauled water, respectively, but these sources may be of inadequate quality, potentially posing a health risk due to microbiological contamination, presence of arsenic, or elevated concentration of total dissolved solids. This project brings a solution for the current situation in *colonias*, with the implementation of a point-of-use (POU) reverse osmosis (RO) water treatment system. The main goal of this project was to present a practical and economically viable solution to the poor quality water through a treatment system. Two different brands of RO systems were tested in the laboratory to assure a good performance. Community health associations were contacted to work together finding willing participants. Water samples were collected and analyzed for various drinking water quality parameters. Installations took place in five different *colonias,* with 20 families benefiting as of December 1st, 2016. A quality comparison between the tap water and the permeate water from the RO systems was performed, confirming drinking water quality. The filters showed a great performance in both the laboratory and the deployment analysis. Overall, the RO systems proved to be a technically and economically viable solution for the drinking water problem that *colonias* residents have to confront.

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1. Introduction

1.1 Background

Access to clean water is something that people in the United States see as a right, while the reality is that it is a privilege. Throughout the United States, multiple communities exist with lacking or inadequate water infrastructure. *Colonias* (a name commonly given in the Southwest to communities or settlements with minimal infrastructure) are a good example of this. An estimated 500,000 people live in 2,294 *colonias* in Texas. *Colonias* also exist in Arizona, New Mexico and California, but Texas has the largest *colonias* population and the largest number of *colonias* along the U.S.–Mexico border (Barton et al, 2015). Being located in hard-to-get locations is the main reason for the lack of basic infrastructure, due to the high costs and the weak political influence (Olmstead, 2004).

Because of the lack of access to services like clean water, health problems are a common occurrence. Many *colonias* residents have opted for purchasing bottled water for drinking, but they may need to travel long distances to do so. While bottled water offers a solution for their drinking and cooking necessities, it is not practical for hygiene uses like bathing and washing.

Being short on viable options for their main source of water, *colonias* rely on mainly two sources, depending on their location. *Colonias* in Doña Ana County (Northwest of the City of El Paso) mainly get their water from domestic wells, while *colonias* in El Paso County (East of the City of El Paso) typically rely on hauled water. The locations of several *colonias* are shown in Figure 1.1.

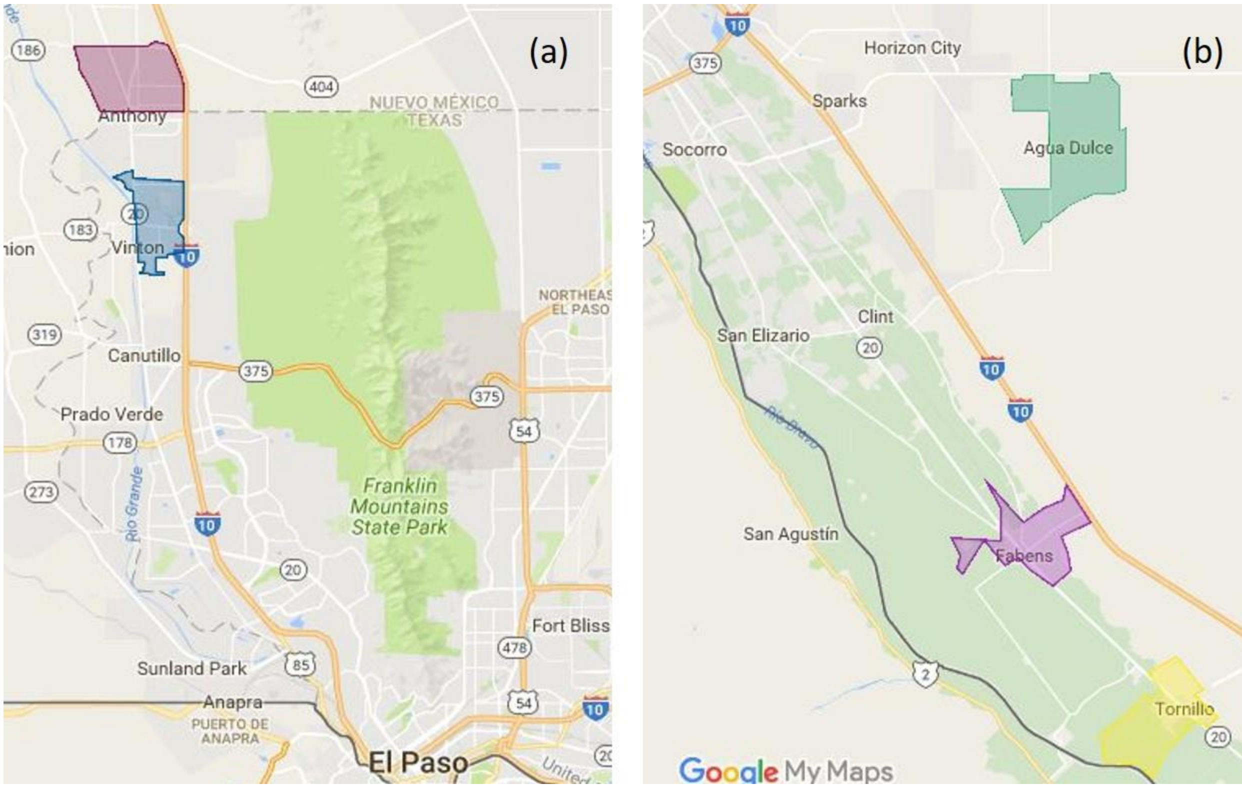

Figure 1.1 Study area – *Colonias* in (a) Doña Ana County, NM and (b) El Paso County, TX

While well water and hauled water cover the water access issue, their quality may not be adequate (Gundry, 2004). Moreover, concerns about the quality at the moment of personal consumption still exist. Some domestic wells located in Doña Ana County have been observed to contain arsenic levels and total dissolved solids (TDS) above the EPA drinking water contaminants levels (Camacho et al, 2011). On the other hand, hauled water is supplied by certified water haulers, whom sources are required to be approved by the Texas Commission on Environmental Quality (TCEQ). While this water may be of a good quality upon delivery, storage in domestic tanks for weeks at a time can lead to recontamination of the water. Common findings in these tanks are algae growth, which may foster other microbiological contamination (Campos et al, 2013).

While there is some legislation aimed at improving *Colonias* infrastructure (Mier et al, 2008) and some programs from different organizations, most *colonias* are still relatively far away from getting clean water supply for their houses. Different options were thought about for an immediate solution, and the one that seemed more viable was by installation of point of use (POU) water treatment systems.

During the early stages of this project, research was performed to find an appropriate and sustainable type of filter that would benefit *colonias* the most, taking into account factors like capital cost, technical, and social requirements. At first, point of entry (POE) systems were proposed, but after some considerations, it was determined that a POU filtration system would be the best option.

1.2 Goals and objectives

The goal of this project is to present a practical and relatively inexpensive solution to the poor quality water through a commercially available point-of-use (POU) water treatment system. In order to accomplish our goal, the objectives of this project are the following:

1. *Perform laboratory comparison of two commercially available POU reverse osmosis (RO) membrane systems.*
2. *Deploy POU systems in colonias in the Paso del Norte Region.*
3. *Monitor water quality of the RO system.*

2. Methodology

2.1 Laboratory comparison of GE and Whirlpool POU RO systems

A test skid was assembled with two different brands of RO membrane water filters in order to compare them. The commercially available models were General Electric (GE) GXRM10 RBL, and the Whirlpool WHER25 (shown in Figure 2.1) from Home Depot and Lowe, respectively. The feed water for the systems was taken from one of the laboratory faucets, with the flow divided between the two. Each system line had pressure gauges installed to compare the relationship between pressure and recovery ratio. Flowrate for the feed, concentrate and permeate lines was measured using a graduated beaker and a timer. Both filters were in operation from April 27 to June 21, 2016 (nine weeks). Flowrates for the feed and the permeate were measured five times per week at four different pressures (20, 25, 30 and 35 psi) to observe the sensitivity of the hydraulic recovery. (That is, an increase in the pressure increased the permeate flowrate and the hydraulic recovery). The assembled test skid is shown in Figure 2.2, and the processes/flow schematics are shown in Figure 2.3.

Figure 2.1 GE and Whirlpool RO water treatment systems

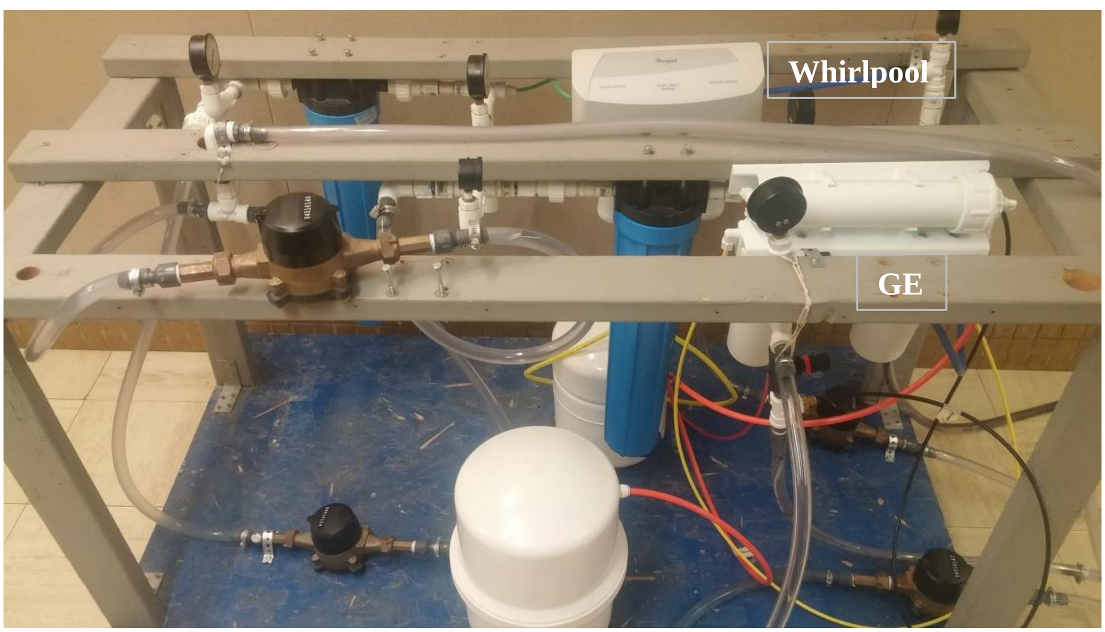

Figure 2.2 Laboratory RO systems skid

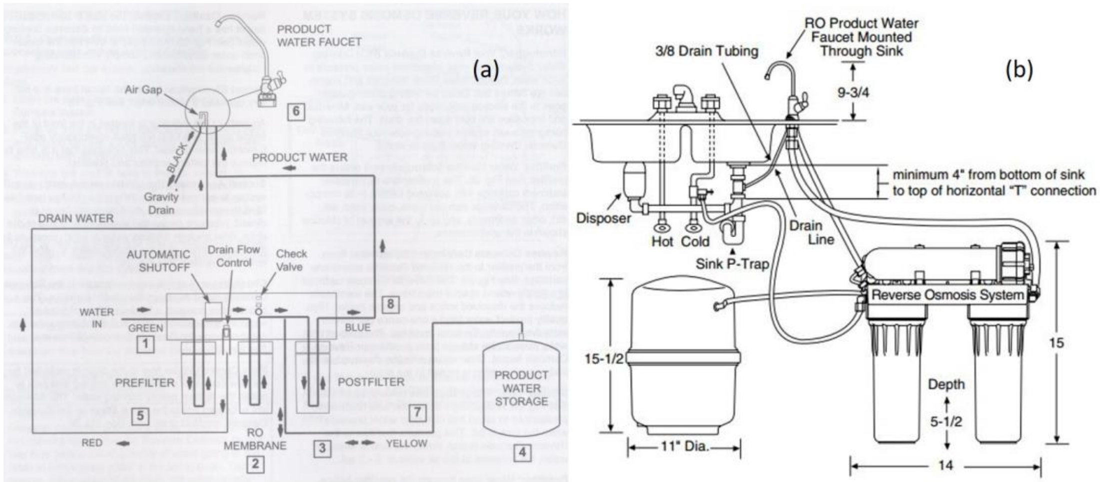

Figure 2.3 Reverse osmosis water flow schematics for (a) Whirlpool & (b) GE

Flowrate readings were taken on a daily basis in order to calculate the recovery of each system. Throughout the nine weeks of operation, different pressures were applied to the systems in order to compare the performance of such systems while working under different pressure.

Once per week, samples were collected from the feed water, the concentrate, and the permeate from each system. Two different samples were taken from each of these sources, following the Standard Method (SM) 9060 A (AWWA 2012). One sample was stored in an IDEXX sterile bottle. These bottles contain sodium thiosulfate and are used for estimating concentrations of total coliforms and *E. coli*. The second sample was collected in a 500 ml polyethylene bottle.

2.2 Installation of POU RO systems in *colonias* households

Families from several *colonias* located in the outskirts of the City of El Paso were contacted in accordance to protocol (IRB Net ID 483287) that was approved by the institutional review boards (IRBs) of the University of Texas at El Paso (UTEP), New Mexico State University (NMSU), and the Environmental Protection Agency (EPA) National Center for Environmental Research (NCER). Focus groups met in a previous stage of the project, providing

researchers with the contact information. The recruiting of participants was through different associations, mainly two of them. *Familias Triunfadoras Inc.,* was founded on December 7, 2006, and is a 501(c)3 women-led nonprofit organization with a mission to empower women, children, and families living in the *colonias* of El Paso County who are affected by domestic violence. Familias Triunfadoras provides programs that address family strengthening, community unity, economic self-sufficiency, asset building and affordable housing development. Familias Triunfadoras has a full-time staff of four employees and a volunteer base of over 25 promotoras(es) (community health workers) who are certified by the Texas Department of State Health Services. Another non-profit bilingual organization, Adult & Youth United Development Association, Inc. (A.Y.U.D.A., Inc.) was founded in 1992 with the aim of obtaining better quality of health services and housing construction, training to improve education and promote leadership in the community of the Lower Valley in the County of El Paso.

Families were contacted, and the research project was explained to them. In order to participate, families had to satisfy EPA's controlled exposure requirements, which excludes: children under the age of eighteen, pregnant women, and nursing women. For the people who qualified and agreed to participate, a consent form was completed. Researchers then administrated a questionnaire divided in six sections regarding: (1) the household's water consumption and approach to their water, (2) perception of water quality, (3) information about water that they acquire for drinking, (4) information regarding hauled water, (5) information regarding domestic wells, and (6) demographics. The results from this questionnaire will not be covered in this thesis. After that, the filters were installed under the main kitchen sink.

Upon visiting the family's houses, two samples were taken from their kitchen faucet. These samples were taken back to the laboratory for analysis. After installation, the filtration

systems require a period of flushing (typically 24 hours) in order to be fully operational. A time frame of about three days was allowed, and then on a second two samples were collected for analysis.

2.3 Water quality analyses

Samples were analyzed for total dissolved solids (TDS) (SM 2540C), ion chromatography (SM 4110B), bacterial count (SM 9221C), inductively coupled plasma (SM 3120B), alkalinity, silica (SM 8185), pH (SM 2510B), and conductivity (SM 4500-H^+B). The alkalinity analysis was performed on a MicroLab® FS-522 automatic titration station using 0.02 N sulfuric acid. Total dissolved solids (TDS) were calculated in accordance with SM 2540C. Conductivity and pH (SM 4500-H^+B and SM 2510B, respectively) were measured using a Thermo Scientific® Orion 5 star meter with Orion 013010MD conductivity cell and pH electrode 9174BN probes. Total coliforms and *E. coli* were analyzed using IDEXX's Colilert®-18 and Quanti-tray 2000® method (SM 9221C). The silica content was measured using a HACH DR 5000 spectrometer and the HACH reagents for the 656 Silica test (SM 8185). Anions (chloride, sulfate and nitrate) and cations (calcium, sodium, magnesium and potassium) were measured using a Dionex simultaneous ion chromatography system with an ICS-2100 unit with an IonPack™ AS18 for anions (SM 4110B) and an ICS-1100 unit with IonPack™ CS16 column for cations (SM 4110B). The ion chromatography system parameters are listed in Table 2.1. Dissolved minerals, such as arsenic, iron, potassium and sodium were analyzed by using inductively coupled plasma optical emission spectroscopy (ICP-OES) on a Perkin Elmer Optima 7300 DV (SM 3120B), for which the samples were acidified with 2% v/v nitric acid. The tested wavelengths and method detection limits (MDL's) are listed in Table 2.2.

Table 2.1 Ion Chromatography (IC) system parameters

Parameter	Cation Dionex ICS-1100	Anion Dionex ICS-2100
Column Model	IonPac CS16	IonPacAS18
Column Temperature	40 °C	35 °C
Sample injection volume	20 µL	20 µL
Eluent concentration	30 mM (MSA)	30 mM (KOH)
Eluent flow rate	1 mL/min	1 mL/min

Table 2.2 Inductively coupled plasma (ICP) detection parameters

Analyte	Wavelength (nm)	Min. Standard (mg/L)	Max. Standard (mg/L)	MDL (mg/L)
Arsenic	188.98	0.0005	1	0.0042
Barium	233.53	0.0005	1	0.005
Cadmium	228.80	0.0005	1	0.01
Calcium	317.93	0.05	100	0.5
Chromium	267.71	0.0005	1	0.01
Copper	327.39	0.0005	1	0.0002
Iron	238.20	0.0005	1	0.05
Lead	220.35	0.0005	1	0.004
Lithium	670.78	0.0005	1	0.005
Magnesium	285.21	0.0125	25	1.25
Manganese	257.61	0.0005	1	0.01
Mercury	253.65	0.0005	1	0.0014
Nickel	231.60	0.0005	1	0.0006
Phosphorous	213.62	0.0005	1	0.0021
Potassium	766.49	0.02	40	0.2
Selenium	196.03	0.0005	1	0.0149
Sodium	330.24	0.125	300	2.5
Strontium	407.77	0.0005	1	0.005
Tin	189.92	0.0005	1	0.008
Tungsten	207.91	0.0005	1	0.05
Uranium	385.96	0.0005	1	0.05
Vanadium	290.88	0.0005	1	0.005
Zinc	206.20	0.0005	1	0.05

3. Results and Discussion

3.1 Laboratory comparison and analysis of hydraulic performance

Flowrates of the permeate and the hydraulic recovery of both systems were compared (Figure 3.1). The Whirlpool RO unit showed higher permeate flowrate and hydraulic recovery than the GE, as shown in Table 3.1.

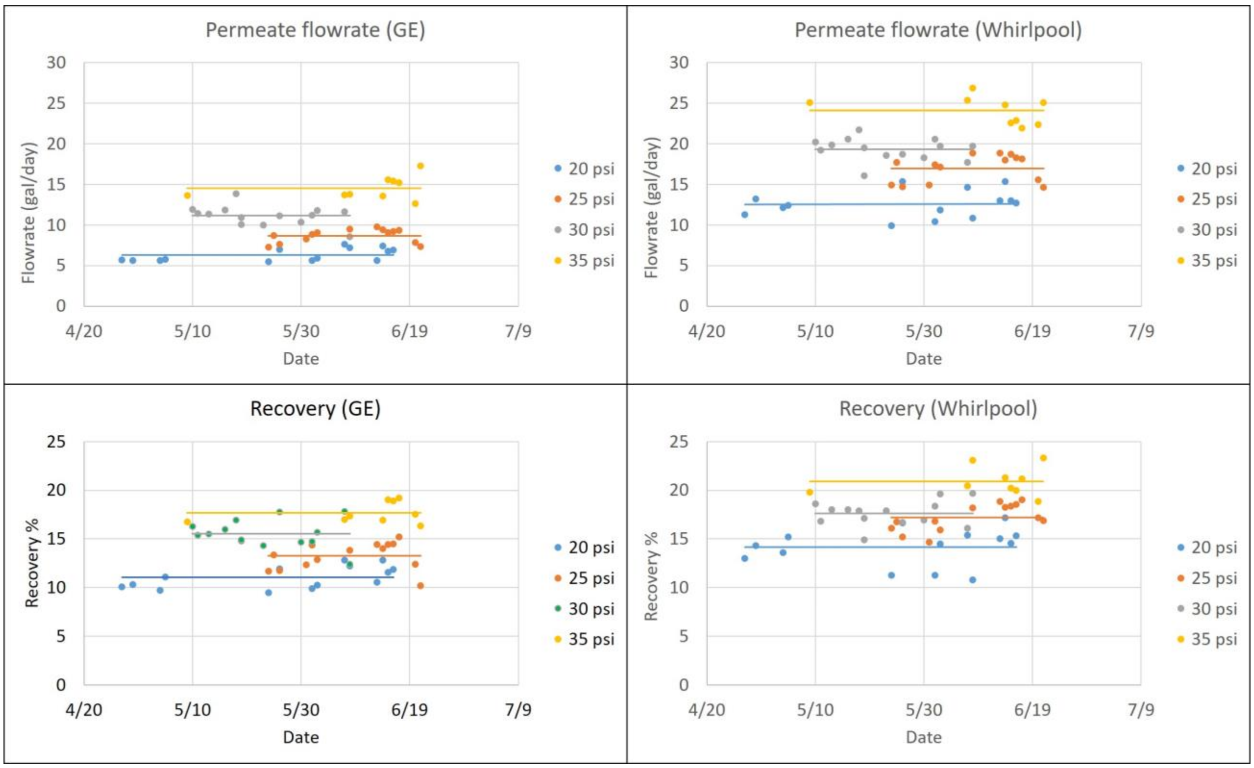

Figure 3.1 Flowrates and recoveries for GE and Whirlpool systems (2016)

Table 3.1 Flowrates and recoveries for GE and Whirlpool systems

Pressure (psi)	Avg. Flowrates (gal/day)		Recovery (%)	
	GE	Whirlpool	GE	Whirlpool
20	6.3	12.6	11.0	14.2
25	8.7	17.0	13.2	17.2
30	11.1	19.3	15.5	17.6
35	14.5	24.1	17.7	20.9

3.2 Laboratory water quality analysis

All of the water quality results are listed in tables in the Appendix, and select water quality results are summarized in Table 3.2. Rejection (shown in Figure 3.2) was calculated for conductivity, alkalinity, silica, ions, cations and anions using the equation:

$$R = 1 - (c_p/c_f)$$

where:

R = Rejection (typically expressed as a percentage)

c_p = product water concentration

c_f = feed concentration

Based on the side-by-side laboratory comparison, the GE and Whirlpool systems performed similarly with respect to product water quality.

Table 3.2 Water quality results for the laboratory performance

Analyte	Min. Tap conc. (mg/L)	Avg. Tap conc. (mg/L)	Max. Tap conc. (mg/L)	Avg. GE Perm. conc. (mg/L)	Avg. Whirl. Perm. conc. (mg/L)	EPA MCL (mg/L)	GE Rej. (%)	Whirlpool Rej. (%)
pH	6.68	6.85	7.01	5.84	5.44	6.5-8.5	N.A.	N.A.
Conductivity (µS/cm)	892	1020	1133	76	77	N.A	92%	92%
Alkalinity (as $CaCO_3$)	110	139	168	28	24.74	N.A	79%	82%
Silica	11	12.44	16	2.78	1.67	N.A	78%	77%
Ca	37.5	59.41	68.74	3.28	2.55	N.A	94%	95%
K	3.97	6.09	7.99	2.64	1.0	N.A	59%	84%
Mg	7.47	11.5	14.6	0.72	0.48	N.A	94%	96%
Na	49.6	92.5	118	6.55	9.7	N.A	92%	89%
Cl	49.1	93.2	124	6.84	13.94	250	92%	84%
NO3	N.D.	1.62	5.85	0.57	1.5	10	39%	53%
SO4	81.1	151	195	1.53	1.23	250	99%	99%
As	N.D.	N.A.	N.D.	N.D.	N.D.	0.01	N.A.	N.A.

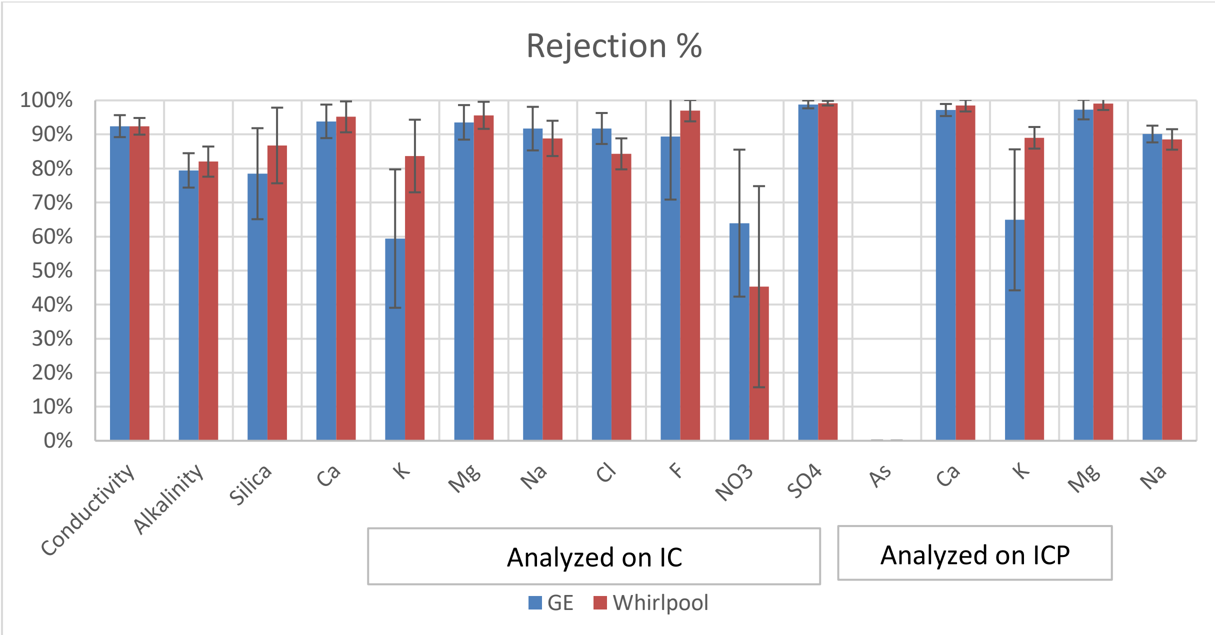

Figure 3.2 RO rejection of water constituents for laboratory samples

The results were compared to the EPA's primary and secondary drinking water regulations. The National Primary Drinking Water Regulations set mandatory water quality standards for drinking water contaminants and are established to protect the public against consumption of drinking water contaminants that present a risk to human health. These primary regulations are enforceable standards called "maximum contaminant levels"or "MCLs". These levels are based on consideration of health risks, technical feasibility of treatment, and cost-benefit analyses. Secondary regulations set non-mandatory water quality standards for 15 contaminants. EPA does not enforce these "secondary maximum contaminant levels" (SMCLs). They are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor.

For the laboratory tap water, 100% of samples were in range of EPA's secondary limit for pH values (6.5-8.5), while 100% samples from both the GE and the Whirlpool systems were under this range, having an average pH value of 5.8 and 5.4 respectively. All tap water, GE and

Whirlpool samples were under Texas Commission on Environmental Quality (TCEQ) and New Mexico Environmental Department (NMED) recommended secondary limit for pH (<7). As for microbiological contamination, neither product water showed any presence of total coliforms nor *E. coli*, with all samples resulting in <1 MPN (detailed in Table 3.3). None of the laboratory tap water or RO permeates showed detectable arsenic levels. With respect to sulfate and chloride, none of the samples exceeded the EPA or state secondary limits.

Figure 3.3 IDEXX Quanti-Tray for total coliforms and *E. coli*, showing no detection

Table 3.3 Total coliform and *E. coli* results for laboratory study

Sample ID	No. of positive cells	Total Coliforms (MPN)	No. of fluorescent cells	E. Coli (MPN)
L-01 TAP	0	<1	0	<1
L-01 GE	0	<1	0	<1
L-01 Whirlpool	0	<1	0	<1
L-02 TAP	0	<1	0	<1
L-02 GE	0	<1	0	<1
L-02 Whirlpool	0	<1	0	<1
L-03 TAP	0	<1	0	<1
L-03 GE	0	<1	0	<1
L-03 Whirlpool	0	<1	0	<1
L-04 TAP	0	<1	0	<1
L-04 GE	0	<1	0	<1
L-04 Whirlpool	0	<1	0	<1
L-05 TAP	0	<1	0	<1
L-05 GE	0	<1	0	<1
L-05 Whirlpool	0	<1	0	<1
L-06 TAP	0	<1	0	<1
L-06 GE	0	<1	0	<1
L-06 Whirlpool	0	<1	0	<1
L-07 TAP	0	<1	0	<1
L-07 GE	0	<1	0	<1
L-07 Whirlpool	0	<1	0	<1
L-08 TAP	0	<1	0	<1
L-08 GE	0	<1	0	<1
L-08 Whirlpool	0	<1	0	<1
L-09 TAP	0	<1	0	<1
L-09 GE	0	<1	0	<1
L-09 Whirlpool	0	<1	0	<1

3.3 Installation of POU RO systems in *colonias* households

As of December 1st 2016, twenty two households agreed to participate in the project. Filters were installed in twenty of them, and the installation was cancelled for two of them because they had children (thus not satisfying EPA's controlled exposure restrictions). These installations took place in five different *colonias*: Anthony and Vinton in Doña Ana County, and Agua Dulce, Fabens, and Tornillo in El Paso County (listed in Table 3.4). The *colonias* located in New Mexico predominantly rely on domestic wells for their water supply. Agua Dulce

residents have their water hauled to them, while Fabens and Tornillo have a public water supply. These two last communities do have a local drinking water distribution system, but public reports indicate high levels of arsenic in drinking water.

Table 3.4 Community distribution of filtration systems

Colonia	Location	Type of water source	No. of systems deployed
Anthony, NM	Doña Ana County	Domestic wells	3
Vinton, TX	Doña Ana County	Domestic wells	2
Agua Dulce, TX	El Paso County	Hauled water	2
Tornillo, TX	El Paso County	Local drinking water system	12
Fabens, TX	El Paso County	Local drinking water system	1

3.4 Household water analysis

By December 1st, 2016, from the twenty systems installed, water quality analyses for both tap and RO water samples were completed for seven households. Sample identification, location, type of source of water and brand of filter installed are listed in Table 3.5, and the water quality results are summarized in Table 3.6. From the seven analyzed water samples, three households received a GE filter, and four received a Whirlpool. The filters were distributed somewhat randomly, subject to the constraint of available space under the sink, as the GE system is larger. RO rejection was calculated for conductivity, alkalinity, total dissolved solids, silica, ions, cations and minerals (shown in Figure 3.5). Comparison of rejection values between brands show an almost identical value on each parameter, with differences in conductivity, TDS, arsenic, magnesium and sulfate rejection of less than 1%.

Table 3.5 Deployment information for the first eight filters

ID	Location	Type of source water	Brand of system installed
D-01	Vinton	Domestic Well	GE
D-02	Anthony	Domestic Well	GE
D-03	Vinton	Domestic Well	GE
D-04	Agua Dulce	Hauled	Whirlpool
D-05	Agua Dulce	Hauled	Whirlpool
D-06	Anthony	Domestic Well	Whirlpool
D-07	Anthony	Domestic Well	Whirlpool

Table 3.6 Water quality results for RO performance in *colonias*

Parameter	Min. Tap conc. (mg/L)	Avg. Tap concentration (mg/L)	Max. Tap conc. (mg/L)	Avg. Permeate concentration (mg/L except where stated)	Rejection (%)
Conductivity (µS/cm)	929	1506	3320	173	89%
Alkalinity (as $CaCO_3$)	122	179	330	34	80%
TDS	495	896	2288	101	89%
Silica	16	27	35	8	71%
Ca	39	87	305	4	99%
K	3.6	7.5	12.5	2.8	66%
Mg	0.26	15	54	0.4	99%
Na	87	172	364	25	87%
Cl	69.92	113	136	23	80%
NO3	3.2	4.6	6.5	1.0	82%
SO4	125	156	191	4.27	97%
As	N.D.	0.009	0.015	N.D.	90%

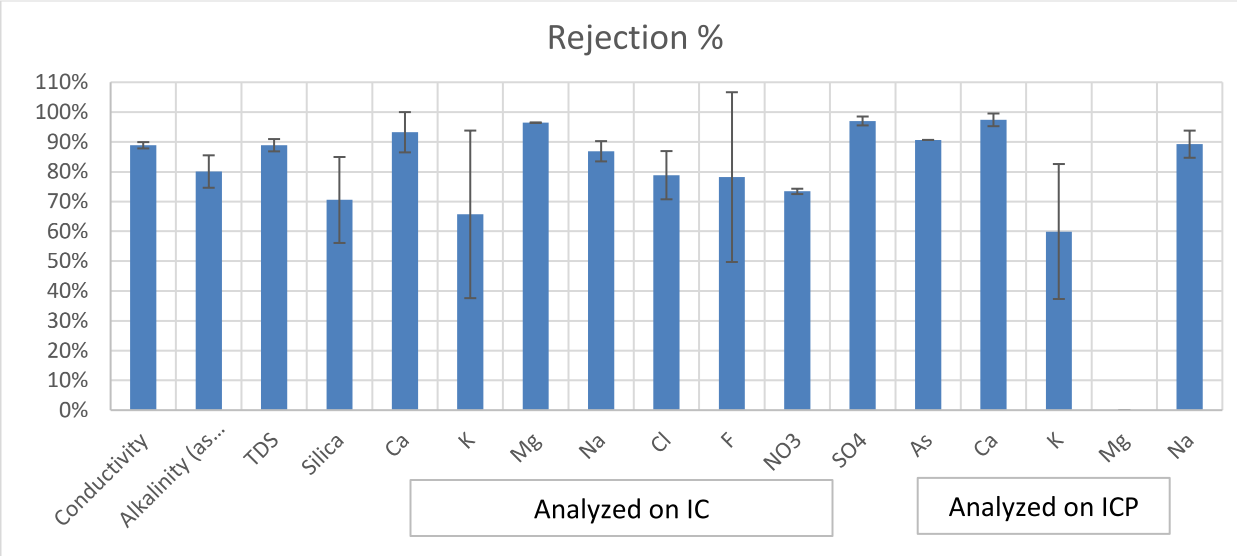

Figure 3.4 RO rejection of water constituents for household samples

For the tap water samples, 100% of samples were in range of EPA, TCEQ, and NMED secondary limits for pH, and most (71%) of the permeate water satisfied EPA's secondary limit. Only 43% of permeate water satisfied the states' secondary limit, with the non-satisfying samples showing an average pH of 6.5. Two of the households with hauled water showed presence of coliforms in their tap water, with values of 165.2 and 23.8 MPN. The analyzed permeate water for those households showed no detection (< 1 MPN). The other tap water and permeate samples show no coliform content. *E. coli* was not detected in any of the samples. Summary for microbiological contamination is shown in Table 3.7. For the tap water, 88% of samples exceeded the EPA secondary limit of 500 mg/L TDS, and 25% exceeded the TCEQ and NMED secondary limit of 1000 mg/L. The two samples exceeding the 1000 mg/L limit were from households relying on a domestic well. All permeate water samples were under all secondary limits for TDS. With respect to arsenic, three out of the seven households tap water exceeded the EPA's secondary limit of 0.01 mg/L, but the permeate for these houses satisfy EPA's limits with an average RO rejection of arsenic of 90%. Magnesium concentrations for the

RO systems analyzed on ICP showed no detect, making the calculation for rejection non applicable. None of the tap or permeate samples exceeded the EPA's nor the states' secondary limits with respect to sulfate and chloride.

Table 3.7 Total coliform and *E. coli* results for *colonia* implementation

Sample ID	No. of positive cells	Total Coliforms (MPN)	No. of fluorescent cells	E. Coli (MPN)
D-01 TAP	0	<1	0	<1
D-01 RO	0	<1	0	<1
D-02 TAP	0	<1	0	<1
D-02 RO	0	<1	0	<1
D-03 TAP	0	<1	0	<1
D-03 RO	0	<1	0	<1
D-04 TAP	49	165.2	0	<1
D-04 RO	0	<1	0	<1
D-05 TAP	19	23.8	0	<1
D-05 RO	0	<1	0	<1
D-06 TAP	0	<1	0	<1
D-06 RO	0	<1	0	<1
D-07 TAP	0	<1	0	<1
D-07 RO	0	<1	0	<1

4. Conclusions

4.1 General observations

The laboratory comparison between GE and Whirlpool systems showed good results and provided confidence on implementing them in the *colonias.* Both systems demonstrated good hydraulic performance and rejection values, showing no objectionable difference between the brands.

Reaching out for people in need of these filters was no easy task, as the EPA's controlled exposure studies safety protocol limited the amount of qualifying families for the project. Thanks to *Familias Triunfadoras* and *A.Y.U.D.A. Inc.,* a great number of families were benefited from this project.

The performance of the systems in deployed households showed great results in terms of water quality. Almost every tap water sample presented a water quality problem (e.g., high TDS concentrations or presence of coliforms), and in all of these cases, the filters were capable of solving the issue. Overall, the RO water filters tested in this research proved to be a great solution for drinking water problems in *colonias.*

Most of the households interviewed spend \$20-\$50 per month on bottled or purified water. With an initial cost of approximately \$140 and maximum annual maintenance costs of approximately \$90, the POU RO systems are expected to have a payback period of six to eight months. In addition to this, having a water filtration system at home mitigates the time and effort that people usually have to invest when buying bottled water.

4.2 Future work

The project is planned to install at least 50 filters in total. As of December 1st, 2016, only 20 installations have been performed. Further deployment is necessary. Contacting more families and organizations is key to achieve this.

Some water quality results for the first 20 installations are still pending. Analyzing all samples is very important to confirm these promising results. Also, a second permeate water sample collection for each household is planned, in order to assure that that after a period of filter usage, the systems keep performing adequately.

Future research will also analyze the results of the pre-installation and post-installation surveys to evaluate user satisfaction.

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Appendix A: Water quality analysis

Table A.1 Laboratory comparison: pH and conductivity

pH and Conductivity					
Week	**Sample ID**		**pH**	**Conductivity (µs/cm)**	**Conductivity Rejection (%)**
1	L-01	Tap	6.77	1050	
	L-01	GE	6.63	77	92.67%
	L-01	Whirlpool	5.72	111.3	89.40%
2	L-02	Tap	7	998	
	L-02	GE	6.08	49	95.09%
	L-02	Whirlpool	5.73	67	93.29%
3	L-03	Tap	6.85	1093	
	L-03	GE	5.47	66.2	93.94%
	L-03	Whirlpool	5.42	77.1	92.95%
4	L-04	Tap	6.93	1133	
	L-04	GE	6.23	94.4	91.67%
	L-04	Whirlpool	5.54	78.3	93.09%
5	L-05	Tap	6.9	1039	
	L-05	GE	5.67	55.3	94.68%
	L-05	Whirlpool	5.54	60.8	94.15%
6	L-06	Tap	7.01	1050	
	L-06	GE	5.67	42.4	95.96%
	L-06	Whirlpool	5.63	58.8	94.40%
7	L-07	Tap	6.87	995	
	L-07	GE	5.55	98.7	90.08%
	L-07	Whirlpool	4.86	54.3	94.54%
8	L-08	Tap	6.68	928	
	L-08	GE	5.72	69.3	92.53%
	L-08	Whirlpool	5.81	117.6	87.33%
9	L-09	Tap	6.68	892	
	L-09	GE	5.58	130.8	85.34%
	L-09	Whirlpool	4.75	68.1	92.37%

Table A.2 Laboratory comparison: alkalinity and silica

Alkalinity and Silica						
Week	Sample ID		Alkalinity as $CaCO_3$ (mg/L)	Alkalinity rejection (%)	Silica (mg/L)	Silica Rejection (%)
1	L-01	Tap	144.39		11	
	L-01	GE	36.45	74.76%	3	72.73%
	L-01	Whirlpool	24.92	82.74%	4	63.64%
2	L-02	Tap	131.66		12	
	L-02	GE	23.16	82.41%	1	91.67%
	L-02	Whirlpool	19.63	85.09%	2	83.33%
3	L-03	Tap	134.43		12	
	L-03	GE	31.11	76.86%	2	83.33%
	L-03	Whirlpool	30.10	77.61%	1	91.67%
4	L-04	Tap	162.65		11	
	L-04	GE	26.24	83.87%	3	72.73%
	L-04	Whirlpool	19.79	87.83%	1	90.91%
5	L-05	Tap	137.59		12	
	L-05	GE	22.65	83.54%	1	91.67%
	L-05	Whirlpool	27.13	80.28%	1	91.67%
6	L-06	Tap	168.32		12	
	L-06	GE	23.82	85.85%	1	91.67%
	L-06	Whirlpool	26.48	84.27%	0	100.00%
7	L-07	Tap	134.47		13	
	L-07	GE	25.49	81.04%	5	61.54%
	L-07	Whirlpool	<20, ND	N.A	1	92.31%
8	L-08	Tap	129.48		13	
	L-08	GE	37.70	70.89%	2	84.62%
	L-08	Whirlpool	34.58	73.30%	1	92.31%
9	L-09	Tap	110.55		16	
	L-09	GE	26.86	75.70%	7	56.25%
	L-09	Whirlpool	<20, ND	N.A.	4	75.00%

Table A.3 Laboratory comparison: cations by IC

Ion Chromatography										
Week	Sample ID		Cation by IC							
			Ca (mgl/L)	Rejection(%)	K (mg/L)	Rejection(%)	Mg (mg/L)	Rejection(%)	Na (mg/L)	Rejection(%)
1	L-01	Tap	68.7360		7.6171		14.2467		110.4481	
	L-01	GE	3.7646	94.52%	6.1800	18.87%	0.7716	94.58%	8.8982	91.94%
	L-01	Whirlpool	3.2695	95.24%	1.6911	77.80%	0.6998	95.09%	17.3183	84.32%
2	L-02	Tap	68.1855		7.4894		13.9415		102.1363	
	L-02	GE	3.3405	95.10%	3.2156	57.06%	0.7038	94.95%	5.4093	94.70%
	L-02	Whirlpool	3.0301	95.56%	1.2397	83.45%	0.6319	95.47%	9.7628	90.44%
3	L-03	Tap	71.3409		7.9880		14.5738		115.3666	
	L-03	GE	4.4165	93.81%	3.3096	58.57%	1.5140	89.61%	7.2609	93.71%
	L-03	Whirlpool	ND	N.A.	1.3626	82.94%	ND	N.A.	11.1474	90.34%
4	L-04	Tap	63.0757		5.4347		10.8020		117.8015	
	L-04	GE	ND	N.A.	2.5552	52.98%	ND	N.A.	5.6993	95.16%
	L-04	Whirlpool	ND	N.A.	ND	N.A.	ND	N.A.	6.0609	94.86%
5	L-05	Tap	59.9960		4.9962		9.9367		98.5997	
	L-05	GE	ND	100.00%	0.4732	90.53%	ND	N.A.	0.8697	99.12%
	L-05	Whirlpool	ND	N.A.	ND	N.A.	ND	N.A.	2.7842	97.18%
6	L-06	Tap	37.9381		3.9704		7.4761		53.3130	
	L-06	GE	3.9039	89.71%	1.0164	74.40%	0.6278	91.60%	5.4106	89.85%
	L-06	Whirlpool	3.6805	90.30%	1.0156	74.42%	0.5981	92.00%	8.5460	83.97%
7	L-07	Tap	37.5091		3.9680		7.4721		49.6093	
	L-07	GE	5.5028	85.33%	1.4862	62.54%	1.1246	84.95%	11.1907	77.44%
	L-07	Whirlpool	3.7599	89.98%	1.0346	73.93%	0.6169	91.74%	7.1737	85.54%
8	L-08	Tap	68.4844		7.2370		13.5926		92.6342	
	L-08	GE	5.2851	92.28%	2.8748	60.28%	0.9903	92.71%	7.6284	91.76%
	L-08	Whirlpool	6.6381	90.31%	1.6790	76.80%	1.2729	90.64%	14.7764	84.05%

Table A.4 Laboratory comparison: anions by IC

	Ion Chromatography									
Week	Sample ID		Anion by IC							
			Cl (mg/L)	R (%)	F (mg/L)	R (%)	NO_3 (mg/L)	R (%)	SO_4 (mg/L)	R(%)
1	L-01	TAP	111.2656		0.5513		0.6530		177.2862	
	L-01	ROGE	6.2146	94.41%	0.3049	44.70%	0.1454	77.74%	0.5604	99.68%
	L-01	ROW	20.6851	81.41%	0.0160	97.10%	0.1735	73.43%	1.3636	99.23%
2	L-02	TAP	102.0762		0.5545		1.2984		167.4189	
	L-02	ROGE	4.3740	95.71%	0.0260	95.31%	0.3788	70.82%	0.6482	99.61%
	L-02	ROW	12.5154	87.74%	0.0121	97.82%	0.2143	83.49%	0.6529	99.61%
3	L-03	TAP	110.9435		0.4885		ND		181.6200	
	L-03	ROGE	6.5272	94.12%	ND	N.A.	ND	N.A.	1.6329	99.10%
	L-03	ROW	13.2700	88.04%	ND	N.A.	ND	N.A.	1.3315	99.27%
4	L-04	TAP	124.2654		0.5907		5.8499		195.3390	
	L-04	ROGE	10.2032	91.79%	0.0022	99.63%	1.1049	81.11%	2.7707	98.58%
	L-04	ROW	14.5100	88.32%	ND	N.A.	2.0714	64.59%	1.0946	99.44%
5	L-05	TAP	105.4496		0.5650		3.0519		174.3736	
	L-05	ROGE	5.8810	94.42%	ND	N.A.	0.7909	74.09%	1.0132	99.42%
	L-05	ROW	11.0848	89.49%	ND	N.A.	1.7914	41.30%	0.6883	99.61%
6	L-06	TAP	51.5721		0.2726		1.3875		84.2780	
	L-06	ROGE	5.0069	90.29%	0.0248	90.89%	0.5443	60.77%	0.4770	99.43%
	L-06	ROW	10.1852	80.25%	0.0227	91.69%	1.1454	17.45%	0.4882	99.42%
7	L-07	TAP	49.1034		0.3136		1.1031		81.0533	
	L-07	ROGE	9.1379	81.39%	0.0348	88.90%	0.9093	17.57%	3.1113	96.16%
	L-07	ROW	9.1203	81.43%	0.0194	93.83%	1.0504	4.78%	0.476427159	99.41%
8	L-08	TAP	90.5177		0.6031		2.1054		149.331846	
	L-08	ROGE	7.3828	91.84%	0.0257	95.74%	0.7275	65.45%	2.01895416	98.65%
	L-08	ROW	20.1667	77.72%	0.0278	95.39%	1.4356	31.81%	3.708057108	97.52%

Table A.5 Laboratory comparison: metals by ICP

Metals by Inductively Coupled Plasma																								
Week	**Sample**	**Ca**	**K**	**Mg**	**Na**	**P**	**As**	**Ba**	**Cd**	**Cr**	**Cu**	**Fe**	**Hg**	**Li**	**Mn**	**Ni**	**Pb**	**Se**	**Sn**	**Sr**	**U**	**V**	**W**	**Zn**
1	Tap	50.2707	5.9664	10.8000	68.0485	0.4238	ND	0.0615	ND	ND	0.4109	ND	0.0550	0.0635	ND	ND	ND	ND	0.134	0.608	ND	ND	ND	ND
	GE	1.0756	3.2737	ND	7.0441	ND	ND	ND	ND	ND	0.0156	ND	0.0531	0.0112	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	0.7418	0.9528	ND	11.2962	0.1134	ND	ND	ND	ND	0.1028	ND	0.0543	0.0133	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	Tap	51.1269	5.5919	10.5083	62.0194	0.1982	ND	0.0598	ND	ND	0.1902	ND	0.0560	0.0588	ND	ND	ND	ND	0.127	0.589	ND	ND	ND	ND
	GE	0.7625	1.5424	ND	5.2625	ND	ND	ND	ND	ND	ND	ND	0.0532	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	0.5011	0.6143	ND	7.1972	ND	ND	ND	ND	ND	ND	ND	0.0533	0.0106	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	Tap	70.3067	8.4962	13.9218	100.5260	0.3099	ND	0.0806	ND	ND	0.3104	ND	ND	0.0860	ND	ND	ND	ND	0.172	0.797	ND	ND	ND	ND
	GE	1.5873	2.5392	ND	7.7920	ND	ND	ND	ND	ND	ND	ND	ND	0.0126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	ND	0.8781	ND	10.4325	ND	ND	ND	ND	ND	ND	ND	ND	0.0132	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4	Tap	69.0524	8.3384	13.5731	103.4180	0.3272	ND	0.0810	ND	ND	0.3146	ND	ND	0.0852	ND	ND	0.012	ND	0.213	0.791	ND	ND	ND	0.076
	GE	2.1491	2.9284	ND	10.0067	ND	ND	ND	ND	ND	ND	ND	ND	0.0140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	ND	0.7900	ND	10.0944	ND	ND	ND	ND	ND	ND	ND	ND	0.0128	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	Tap	66.0579	7.7481	12.6805	86.1079	0.3111	ND	0.0768	ND	ND	0.2927	ND	ND	0.0765	ND	0.013	0.011	ND	0.202	0.75	ND	ND	ND	0.141
	GE	1.2028	1.2746	ND	6.7631	ND	ND	ND	ND	ND	ND	ND	ND	0.0118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	ND	0.6564	ND	7.8732	ND	ND	ND	ND	ND	ND	ND	ND	0.0118	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6	Tap	67.5152	7.7688	12.8524	82.4546	0.3103	ND	0.0764	ND	ND	0.2943	ND	ND	0.0767	ND	ND	ND	ND	0.194	0.726	ND	ND	ND	0.088
	GE	0.5595	0.5980	ND	6.0166	ND	ND	ND	ND	ND	0.0009	ND	ND	0.0114	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	ND	0.6198	ND	7.7923	ND	ND	ND	ND	ND	ND	ND	ND	0.0119	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7	Tap	66.1821	7.4267	12.2922	78.1878	0.2482	ND	0.0766	ND	ND	0.2407	ND	ND	0.0731	ND	ND	ND	ND	0.199	0.711	ND	ND	ND	ND
	GE	2.3361	2.9722	ND	9.6037	ND	ND	ND	ND	ND	ND	ND	ND	0.0137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	ND	0.6088	ND	6.9661	ND	ND	ND	ND	ND	ND	ND	ND	0.0115	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
8	Tap	64.6404	7.0755	11.9825	72.8030	0.3477	ND	0.0739	ND	ND	0.3325	ND	ND	0.0705	ND	ND	0.016	ND	0.187	0.697	ND	ND	ND	ND
	GE	2.1225	1.9103	ND	7.5159	ND	ND	ND	ND	ND	ND	ND	ND	0.0125	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	3.6941	1.1657	ND	12.0204	ND	ND	ND	ND	ND	ND	ND	ND	0.0149	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9	Tap	47.1664	6.1443	9.1325	67.9094	0.3059	ND	0.0565	ND	ND	0.2939	ND	ND	0.0624	ND	ND	0.017	ND	0.165	0.538	ND	ND	ND	0.068
	GE	3.2670	4.7401	ND	10.0929	ND	ND	ND	ND	ND	0.0019	ND	ND	0.0161	0.0110	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Whirlpool	1.2554	0.6770	ND	7.3836	ND	ND	ND	ND	ND	ND	ND	ND	0.0137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table A.6 Household analysis: pH, conductivity and TDS

pH, conductivity and TDS							
Household No.	Sample ID		pH	Conductivity (μs/cm)	Conductivity Rejection (%)	TDS (mg/L)	TDS Rejection (%)
1	D-01	Tap	7.21	929		581.5	
	D-01	RO	6.4	115.9	87.52%	76.4	86.86%
2	D-02	Tap	6.99	3320		2287.5	
	D-02	RO	6.12	341	89.73%	180.6	92.10%
3	D-03	Tap	7.52	2326		1337.5	
	D-03	RO	6.66	250	89.25%	183.2	86.30%
4	D-04	Tap	8.38	1285		700	
	D-04	RO	6.81	123.6	90.38%	74	89.43%
5	D-05	Tap	7.44	1137		605	
	D-05	RO	8.2	139	87.77%	75	87.60%
6	D-06	Tap	7.4	1095		600	
	D-06	RO	7.6	117.6	89.26%	56.4	90.60%
7	D-07	Tap	7.45	1030		565	
	D-07	RO	7.65	122.2	88.14%	60.4	89.31%

Table A.7 Household analysis: alkalinity and silica

Alkalinity and Silica						
Household No.	Sample ID		Alkalinity as $CaCO_3$ (mg/L)	Alkalinity Rejection (%)	Silica (mg/L)	Silica Rejection (%)
1	D-01	Tap	169.2		33	
	D-01	RO	32.4	80.85%	7	78.79%
2	D-02	Tap	270.8		35	
	D-02	RO	34.9	87.11%	5	85.71%
3	D-03	Tap	329.58		32	
	D-03	RO	50.92333333	84.55%	8	75.00%
4	D-04	Tap	175.255		16	
	D-04	RO	28.64	83.66%	3	81.25%
5	D-05	Tap	121.775		17	
	D-05	RO	28.135	76.90%	5	70.59%
6	D-06	Tap	122.02		33	
	D-06	RO	32.49	73.37%	14	57.58%
7	D-07	Tap	123.78		31	
	D-07	RO	32.26	73.94%	17	45.16%

Table A.8 Household analysis: cations by IC

Ion Chromatography									
Sample ID		Cation							
		Ca^{+2}	R (%)	K^{+}	R (%)	Mg^{+2}	R (%)	Na^{+}	R (%)
D-01	TAP	73.46		ND		13.63		94.32	
	RO	ND	-	ND	-	ND	-	13.45	85.74%
D-02	TAP	305.08		12.48		53.56		364.14	
	RO	6.035	98.02%	4.526	63.73%	1.9	96.45%	39.68	89.10%
D-03	TAP	3.574669		6.8764		0.774035		244.1042	
	RO	0.413146	88.44%	1.431978	79.18%	ND	-	45.04519	81.55%
D-04	TAP	74.433		8.5321		14.083		125.9769	
	RO	ND	-	0.6449	92.44%	ND	-	12.2685	90.26%
D-05	TAP	59.291		6.3143		11.244		121.7643	
	RO	ND	-	4.5886	27.33%	ND	-	15.1073	87.59%
D-06	TAP	39.404		3.6387		0.257		165.4174	
	RO	N.A.		N.A.		N.A.		N.A.	
D-07	TAP	N.A.		N.A.		N.A.		N.A.	
	RO	N.A.		N.A.		N.A.		N.A.	

Table A.9 Household analysis: anions by IC

Ion Chromatography									
Sample ID		Anion							
		Cl^{-}	R (%)	F^{-}	R (%)	NO_3^{-}	R (%)	SO_4^{-}	R (%)
D-01	TAP	69.92		NA		NA		150.32	
	RO	12.35	82.34%	NA		NA		6.92	95.40%
D-02	TAP	198.63		0.056896		0.153652		420.68	
	RO	49.27921	75.19%	ND	-	ND	-	18.87177	95.51%
D-03	TAP	118.1197		0.032959		0.111537		191.3961	
	RO	39.71927	66.37%	0.017961	45.51%	ND	-	3.575157	98.13%
D-04	TAP	130.043		0.6413		6.5093		169.819	
	RO	17.655	86.42%	0.0186	97.10%	1.6892	74.05%	4.559	97.32%
D-05	TAP	133.359		0.4926		4.0476		155.103	
	RO	21.62	83.79%	0.0392	92.04%	1.1026	72.76%	2.039	98.69%
D-06	TAP	135.616		0.6138		ND		146.599	
	RO	N.A.		N.A.		N.A.		N.A.	
D-07	TAP	N.A.		N.A.		N.A.		N.A.	
	RO	N.A.		N.A.		N.A.		N.A.	

Table A.10 Household analysis: metals by ICP

Household No.	Sample ID		Ca	K	Mg	Na	P	As	Ba	Cd	Cr	Cu	Fe	Hg
1	D-01	Tap	69.1391	3.00089	13.8816	72.7315	ND	0.00884	0.07629	ND	ND	0.00352	ND	ND
	D-01	RO	4.24658	0.5238	ND	12.7503	ND	ND	ND	ND	ND	0.00264	ND	ND
2	D-02	Tap	N.A.	N.A.	N.A.	N.A.	N.A.	0.005	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	D-02	RO	4.62209	1.18006	1.34535	23.119	ND	ND	ND	0.00057	ND	ND	ND	0.05551
3	D-03	Tap	2.62349	2.9704	0.62448	378.271	ND	0.01149	ND	ND	ND	0.00906	ND	0.05428
	D-03	RO	ND	4.37549	ND	25.8629	ND	ND	ND	ND	ND	0.00065	ND	0.05597
4	D-04	Tap	68.8182	9.88329	13.9667	108.071	ND	ND	0.06716	ND	ND	0.01693	ND	ND
	D-04	RO	2.05	0.68694	ND	7.86777	ND	ND	ND	ND	ND	ND	ND	ND
5	D-05	Tap	52.138	7.36545	11.0872	99.7369	0.02685	0.01517	ND	ND	ND	0.02372	ND	ND
	D-05	RO	0.63545	4.071	ND	14.0709	ND	ND	ND	ND	ND	ND	ND	0.02566
6	D-06	Tap	32.4187	4.70617	1.1135	132.319	ND	ND	ND	ND	ND	0.02127	ND	ND
	D-06	RO	0.60742	0.98181	ND	8.81099	ND	ND	ND	ND	ND	ND	ND	ND
7	D-07	Tap	19.6073	2.76175	0.68568	74.5972	ND	ND	ND	ND	ND	ND	ND	ND
	D-07	RO	0.68282	1.08594	ND	9.05263	ND	ND	ND	ND	ND	ND	ND	ND

Household No.	Sample ID		Li	Mn	Ni	Pb	Se	Sn	Sr	U	V	W	Zn
1	D-01	Tap	ND	0.05125	ND	ND	ND	0.20808	ND	ND	ND	ND	ND
	D-01	RO	0.01665	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	D-02	Tap	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	D-02	RO	0.02328	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	D-03	Tap	0.14537	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	D-03	RO	0.01685	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4	D-04	Tap	0.08786	ND	ND	0.01067	ND	0.23529	0.86068	ND	ND	ND	ND
	D-04	RO	0.01351	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	D-05	Tap	0.07203	ND	ND	ND	ND	0.18315	0.79135	ND	ND	ND	ND
	D-05	RO	0.0166	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
6	D-06	Tap	0.08053	ND	ND	ND	ND	ND	0.363	ND	ND	ND	ND
	D-06	RO	0.0138	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7	D-07	Tap	0.04992	ND	ND	ND	ND	ND	0.22668	ND	ND	ND	ND
	D-07	RO	0.01382	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Appendix B: Systems specifications

Model# GXRM10RBL

- Reverse osmosis filtration - Water is filtered three times
- Chrome faucet with filter replacement indicator - Faucet and full installation kit included
- Premium filtration - Certified to reduce lead, arsenic, pesticides and more than 10 other contaminants
- Six-month filter life - For best filtration results, filters (FX12P) should be replaced every six months and membrane (FX12M) every year

FEATURES	
Faucet Monitor	Electronic Timer
Max. Hardness	10 Grains
Max. TDS (ppm)	2000
Automatic Shut-Off	Yes
Filter	FX12P
Filter Change Indicator	LED
Filter Life	6 Months or 900 gallons
Filter Membrane	FX12M
LED Indicators	Yes
Process Water Used (per gal.)	10.4
TDS Removal	95%
Arsenic Reduction	97%
Barium Reduction	96%
Cadmium Reduction	97%
Chlorine Taste and Odor Reduction	97%
Chromium III Reduction	97%
Chromium VI Reduction	96%
Copper Reduction	98%
Cysts Reduction	99.99%
Fluoride Reduction	87%
Lead Reduction	96%
Nickel Reduction	99%
Radium Reduction	96%
Selenium Reduction	97%
TDS Reduction	95%
Turbidity Reduction	99%
Feed Water pH Limits	4-10
Feed Water Pressure (psi)	40 Min - 125 Max.
Feed Water Temperature	40-100 F
Plumbing Connections	1/4" Inlet - 3/8" Outlet
Water Inlet Valve	Saddle valve
NSF Particulate Reduction	Class I

Figure B.1 GE GXRM10RBL specifications

Performance Claims For WHER25

Substance	NSF Required Influent Challenge Concentration (mg/L)[1]	NSF Max. Permissible Product Water Concentration (mg/L)[1]	Average Influent (mg/L)[1]	Avg./Max Effluent (mg/L)[1]	Avg./Min. Percent Reduction
Arsenic (pentavalent)[2]	0.30 ± 10%	0.010	0.320	0.006 / 0.011	98.2 / 96.6
Barium[2]	10 ± 10%	2.0	10	0.23 / 0.58	97.8 / 94.4
Cadmium[2]	0.03 ± 10%	0.005	0.028	0.0005 / 0.0012	98.1 / 95.7
Chromium (VI)[2]	0.3 ± 10%	0.1	0.310	0.009 /0.017	97.0 / 94.4
Chromium (III)[2]	0.3 ± 10%	0.1	0.310	0.005 / 0.007	98.3 / 97.7
Copper[2]	3.0 ± 10%	1.3	2.9	0.033 / 0.047	98.8 / 98.4
Cysts[2]	≥50,000 #/mL[4]	99.95%[3]	160000 #/mL[4]	9 / 33 #/mL[4]	99.99 / 99.98
Lead[2]	0.15 ± 10%	0.010	0.16	0.001 /0.003	99.1 / 98.1
Nitrate plus Nitrite (as N)[2]	30 ± 10%	10.0	29	7.2 / 8.6	75.4 / 70.8
Nitrate (as N)[2]	27.0 ± 10%	10	26	6.6 / 7.9	74.9 / 70.0
Nitrite (as N)[2]	3.0 ± 10%	1.0	3.2	0.61 / 0.75	80.9 / 76.6
Radium 226/228[2]	25 pCi/L[5] ± 10%	5 pCi/L[5]	25 pCi/L[5]	5 / 5 pCi/L[5]	80 / 80 pCi/L[5]
Selenium[2]	0.10 ± 10%	0.05	0.10	0.002 / 0.003	98.0 / 97.0
Turbidity[2]	11 ± 1 NTU[6]	0.5 NTU[6]	11 NTU[6]	0.1 / 0.2 NTU[6]	99.0 / 98.3
TDS[2]	750 ± 40	187	740	70 / 100	90.6 / 86.5
Chlorine Taste and Odor[2]	2.0 ± 10%	1.0	1.9	0.09 /0.19	95.2 / 90.5
Ammonium[7]	1.2 ± 10%	1.0[8]	2.5	0.24	90
Bicarbonate[7]	300 ± 10%	100[8]	280	10	96
Bromide[7]	1.5 ± 10%	3.3[8]	11	1.3	89
Chloride[7]	800 ± 10%	250[8]	770	60	92
Magnesium[7]	30 ± 10%	10[8]	31	<1.0	97
Sodium[7]	350 ± 10%	117[8]	340	40	88
Sulfate[7]	800 ± 10%	250[8]	780	12	98
Tannin[7]	3.0 ± 10%	1.0[8]	2.9	0.1	97
Zinc[7]	15 ± 10%	5.0[8]	15	0.25	98

Daily Production Rate Model WHER25 – 18.46 gal/day (69.87 liters/day)[2]
Efficiency Rating Model WHER25[9] – 12.22%
Recovery Rating Model WHER25[10] – 22.95 %

Figure B.2 Whirlpool WHER25 specifications

Vita

Oscar Daniel Ramirez Giron obtained his Bachelor of Engineering degree in Civil Engineering at the Autonomous University of Ciudad Juarez, Mexico in December 2012. In order to obtain his bachelors' program, he worked on his thesis entitled "Determination of the hydraulic coefficient of longitudinal dispersion in two sections of Conchos River". Mesmerized by his research for his bachelors' thesis, Oscar pursued a Master's degree in Environmental Engineering at The University of Texas at El Paso. There, he started working on research at the university's water quality laboratory, under the advising and mentoring of Dr. W. Shane Walker. His Master's thesis, entitled "Evaluation of Point of Use Reverse Osmosis Systems for Drinking Water in Colonias", was supervised by Dr. W. Shane Walker.

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