United States
Environmental Protection
Agency

Risk Reduction
Engineering Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-89/050 Mar. 1990

EPA

Project Summary

Point-of-Use Treatment of Drinking Water in San Ysidro, NM

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This study was conducted to determine whether point-of-use (POU) reverse osmosis (RO) units could satisfactorily function in lieu of central treatment to remove arsenic and fluoride from the drinking water supply of San Ysidro, NM. POU treatment was evaluated for removal efficiency, cost, and management effectiveness.

Seventy-eight under-the-sink model RO units were installed in private homes, and 72 were monitored for about 18 mo to evaluate operational and maintenance data for POU treatment.

This Project Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Village of San Ysidro is a small rural community of approximately 200 people located in the north central part of the State of New Mexico approximately 45 mi (72 km) north of Albuquerque. Leedshill-Herkenhoff, Inc. (Engineers and Architects), was initially retained by the Village in June 1982 to evaluate San Ysidro's water supply system. The Village was having problems meeting water demands and was also out of compliance with the National Interim Primary Drinking Water Regulations for arsenic and fluoride. Feasibility studies were to be performed to determine whether economical improvements to the system could be recommended—improvements that would solve both San Ysidro's water quantity and quality inadequacies.

The Village has had a long history of water supply problems including low water pressure, no water at all, and quality problems including taste, color, clarity, and odor in addition to arsenic and fluoride contamination and sporadic coliform violations. The water supply source is an infiltration gallery that produces an average of 27,000 gpd in the winter and 36,000 gpd in the summer from the groundwater. The Village uses an average of 30,000 gpd, which equates to about 150 gpd per person. This consumption rate pushed the production limits of the gallery.

The local groundwater contains leachate from geothermal activity in the area's abundant mineral deposits and is therefore high in mineral content. At the time of the study, the groundwater exceeded the recommended standards and/or maximum contaminant levels (MCL's) for arsenic, fluoride, iron, manganese, chloride, and total dissolved solids. The contaminants of concern in the Village water supply were arsenic V and III and fluoride which exceeded the MCL's by three to four times. Table 1 shows a typical analysis of the water in the infiltration gallery. A University of Houston study indicated that the arsenic present in the San Ysidro water supply averaged 35% as As III.

A variance from the Safe Drinking Water Act (SDWA) for arsenic and fluoride was granted to the Village while U.S. Environmental Protection Agency

(EPA) sponsored research was done (Dr. Dennis Clifford of the University of Houston, Texas) to determine an economical and effective solution to the contaminant problem. The treatment technologies studied were activated alumina and RO. Central and POU treatment were considered.

Table 1. *Analysis of Filtration Gallery Water in San Ysidro*

Analyte	Analytical Results	
As	0.075	mg/L
Cd	<0.008	mg/L
Cr	<0.02	mg/L
Pb	<0.001	mg/L
Hg	<0.01	mg/L
Ca	86.4	mg/L
Alkalinity	447	mg/L
Cl	88	mg/L
Hardness	272	mg/L
Fe	0.06	mg/L
Mg	13.6	mg/L
Mn	0.05	mg/L
pH	7 78	units
SO_4	30	mg/L
NO_3 as N	0.1	mg/L
F	1.6	mg/L
Na	135	mg/L
TDS	914	mg/L

Central treatment of the entire water supply was not considered feasible for many reasons. Firstly, a disposal problem exists with both the arsenic-contaminated wastes from activated alumina regeneration and the reject brine from an RO system. Secondly, the capital costs and the operation and maintenance costs of central treatment were determined to be higher than POU treatment. And, lastly, central treatment was considered too complicated to be efficiently operated by a community the size of San Ysidro. The results of the study indicated the best solution to be POU treatment with RO units.

Procedures

System and Contractor Selection

A notification letter was sent to each water customer, and a public hearing was held on December 18, 1985, in which the cooperative agreement between the Village and the EPA was brought before the villagers to explain the water quality problem and to discuss the procedures needed to have the RO POU devices installed, maintained, and tested during the study period. The Village passed an ordinance requiring the installation of an RO system in each water customer's home if the home had indoor plumbing. The ordinance was deemed necessary because POU treatment could not be considered a viable alternative to central treatment for a public water system unless the utility furnished safe drinking water to each water customer. Each water customer also had to sign a permission form to allow the Village to install the unit in their home and to allow access to the unit for testing and maintenance. The permission form was necessary because an ordinance could not give the Village the authority to enter a person's house (only an individual can grant permission to the Village to enter his home).

A Request for Proposal was prepared in which contractors were asked to prepare competitive bid proposals for furnishing approximately 80 RO units, including installation and 14 mo of unit maintenance, to the Village of San Ysidro.

The RO units were required to be under-the-sink models capable of producing a minimum of 5 gal of drinking water per day with a storage capacity of 3 gal (Figure 1). The system pressure range was given as 40 to 60 psi maximum, with a minimum pressure of 20 psi. The units were required to reduce the contaminants to below the established MCL's as shown in Table 2.

The contractor was required to perform service checks and preventive maintenance on each unit every other month as well as repairs to maintain the units operational during an initial 14-mo period. Maximum time allowed for service calls was 3 working days. The contractor was required to cover the costs of any household damages resulting from malfunction of the RO units during the service period.

Based on the above criteria, each bidder was required to submit prices for a per unit purchase price, a per unit installation price, and a per unit monthly service charge. Each bidder was also required to furnish manufacturer's data covering typical installation instructions, construction details, and operating instructions.

Four bid proposals were received and evaluated by Leedshill-Herkenhoff, the EPA Project Officer, and a representative of the State of New Mexico Environmental Improvement Division. The proposals were evaluated on nine factors (Table 3), and associated weights, as described in the Request for Proposal, were given each factor.

The selected proposal was submitted by Southwest Water Conditioning (a Culligan* representative in Albuque The price per unit for purchase, lation, and monthly service was $2 $35.50, and $8.60, respectively. Th posal also included an RO test m on each unit that consisted of an total dissolved solids (TDS) meter.

Within the first 4 mo of the proje RO units were installed, and 5 more added by the end of the project p Of the 78 units installed, however 72 were actually available for testin regular basis. At three homes, tot meters were also installed on the line to the RO units to measur amount of water used by the systen

Data Collection

The RO units were operatec monitored for an 18-mo period. samples were scheduled to be col every other month for arsenic fluoride analyses. In addition, the were to be sampled every 4 to 6 r chloride, iron, and manganese. Be of various restrictions, only 40 unit analyzed for total coliforms. Each r an average of 31 units were sampl arsenic and fluoride; of these, 15 also sampled for chloride, iron manganese and 10 for total coliform

Results

Water Usage

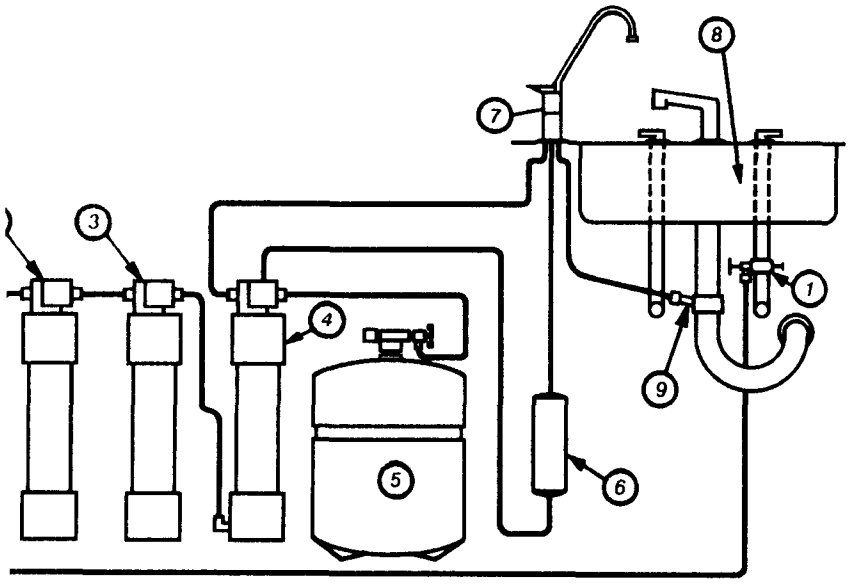
The average water use by th systems recorded at the three h with totalizing meters varied from 17.0 gpd (Table 4). Water use because of the size of the familie their use of the RO-treated water. P water production (recovery) by th system depends on inlet water pr and TDS but ranges from 20% to 3 the total flow into the unit at 50 p less than 1,500 ppm TDS.

Operational Problems

The initial 14-mo maintenance c signed with Southwest Water C tioning was extended to 20 mo contractor could train a Village em to perform routine RO system c and maintenance.

Operational problems were rec during the study. Within the first six RO modules were replaced a installations required service beca

*Mention of trade names or commercial pr does not constitute endorsement or r mendation for use



Legend

1. Tap Connection to Existing Water Line
2. Pre-filter
3. Carbon Filter
4. Reverse Osmosis Unit
5. Storage Tank
6. Carbon Post-filter
7. Faucet with Built-in Air Gap for Drain Line
8. Existing Sink
9. Drain Connection to Existing Sink Drain

gure 1. *Typical under the sink reverse osmosis unit.*

ıble 2. *RO Requirements for Contaminant Reduction*

Contaminant	Contaminant-mg/L From	To
ron	2.0	0.3
Manganese	0.2	0.05
Chloride	325.0	250.0
Fluoride	5.2	1.8
Arsenic V & III	0.2	0.05
Total Dissolved Solids	1000.0	500.0

leaks, TDS monitor problems, or water flow problems. A summary of service calls performed during the 20-mo service period is shown in Table 5.

Because a few RO-treated water samples tested positive for coliform and the central water system did not test positive during the sampling period, an extensive investigation was conducted to determine the cause. During the investigation, all RO units were found to have been installed with the RO drain connected directly to the kitchen sink drain (without an air gap). Because every home in San Ysidro has a septic tank, the cross-connection between the RO drain line and disposal line was strongly suspected to be causing the positive coliform tests. The installer modified all systems to eliminate the cross-connection by providing an air gap between the discharge line and drain line. After the air-gap problem was corrected, no more positive coliform tests were obtained. Only a few months of samples were taken after the change, however, and therefore the air-gap problem could not be positively identified as the source of the problem.

Chemical Contaminant Removal

The RO units effectively removed arsenic and fluoride from the water. The RO units also effectively removed chloride, iron, manganese, and TDS, but did not quite meet the removal rates stated in the manufacturer's cause of the number and concentration of literature. This was probably because of the contaminants in the water supply. Table 6 shows average removal percentage for each of the contaminants during the project period.

Because of the high costs of arsenic and fluoride analyses, conductivity measurements were evaluated as a substitute for arsenic and fluoride tests. An analysis of the arsenic, fluoride and conductivity data showed a rule of thumb could be established whereby a conductivity measurement of less than 600 micromohs/cm would maintain less than 0.03 mg/L of arsenic and less than 1.0 mg/L of fluoride.

Bacteria Samples

Over a 13-mo period, 131 water samples were collected from 40 RO unit special taps for coliform analysis by membrane filter technique. Nine of these tests were positive for coliforms. In addition, 10 tests showed non-coliform counts from 11 to too-numerous-to-count (TNTC). Of the microbiological tests, 15

Table 3. *Factors and Weights for Proposal Evaluation*

Factor	Weight
1. Construction of Unit	5%
2. History of Similar Installations	5%
3. Proposal Completeness	5%
4. Removal Efficiencies (including amount of water wasted by treatment)	15%
5. Maintenance Record	10%
6. Ease of Maintenance	5%
7. Maintenance Service Contract	15%
8. Price of Units and Installation Cost	20%
9. Maintenance Service Contract Costs	20%
Total	100%

Table 4. *Water Usage by RO Units*

Family	Family Size	Average Flow (gpd)	Maximum Flow (gpd)
1*	6	8.5	13.3
2+	2	14.2	20.0
3#	5	17.0	30.0

* Water used for cooking only.
\+ Water used for cooking and drinking.
\# Water used for all purposes.

Table 5. *Service Calls by Types for 20-Month Period*

Type	Number	Comments
Leak	38	8% of leaks were not from the RO unit.
TDS Monitor	11	All calls regarding red light of monitor. 3 calls required a part replacement, others required adjustments only.
Flow Problem	9	2 of reported flow problems were due to low system pressure (25 psi).
Routine Check	217	25% of routine checks resulted in repair or adjustment of unit not identified by customer.
Other	150	Other customer complaints included taste or odor problems, broken faucet handles, noisy air gaps, and reinstallations.
Routine Check—No One home	122	This is 36% of the total routine checks attempted. The actual percentage is probably higher since some "not at home" calls were unrecorded.
Total	412*	

*Average number of calls per month = 412/20 = 20.6.
Number of calls required by contract = 33 to 35.
Contract required checks on each installed unit every other month.
Number installed varied over contract period.

Table 6. *Contaminant Removal by RO Systems*

Contaminant	Average Influent (mg/L)	Average Effluent (mg/L)	% Removal	% Remov (Manufactu Data)
Arsenic	0.059	0.008	86	68/96*
Fluoride	2.7	0.339	87	82
Chloride	91	14.59	84	94
Iron	0.58	0.019	97	—
Manganese	0.09	0.012	87	97
TDS +	780	93	88	94

* 68% removal of Arsenic III, 96% removal of Arsenic V.
\+ As tested by contractor's service technicians on routine checks

of the 131 samples from the RO u showed some evidence of bacte contamination.

Five water samples were collected fr sink taps, and three of these tested h high noncoliform counts. None of th samples tested positive for coliforms did any of the community's chlorina water supply samples test positive coliform during the study. The cart prefilter in the RO unit removes chlorine protect the polyamide RO membrane.

An extensive investigation was m into the coliform problem. A gene description of the investigation and action taken to correct the problem given in the previous section on *Ope tional Problems.*

Regulations and Compliance

When the project started, the Villa passed an ordinance requiring each wa customer to have an RO unit, if the ho had indoor plumbing. Also, each wa customer had to sign a permission form allow the Village personnel access to th home to install, test, and maintain the unit. At the end of the project, ordinance was modified to deal w several problems and situations t developed during the project. The n ordinance required "commercial users" provide water treatment to meet drinking water standards and allowed Village to sample their water. The Villa therefore, maintained complete con over the residential systems and tra ferred all responsibility for providing s drinking water to the commercial us The ordinance also provided some latitu to the commercial user in selecting most economical treatment method.

The new ordinance required that residential RO units continue to be own maintained, and monitored by the Villa but made certain requirements of

individual water customer. The ordinance prohibits tampering with the RO unit in any way and requires a weekly check for leaks and operation of the TDS test switch. Also, the user is required to protect the unit from freezing and standing dry.

The new ordinance also addressed two liability issues. The Village assumed liability for damages to the users home caused by the RO unit, with limitations. The user is held liable for damages if the user did not perform the maintenance check, tampered with the unit, or allowed the membrane to be destroyed because of temperature (freezing) or drying out.

Cost

Cost data and information were collected on the replacement parts, maintenance, bookkeeping, analytical tests, and insurance. These data indicated that a monthly service charge of $7 would be necessary to cover the costs. If the cost of the unit was included in the monthly charge, the surcharge would be $12 to $15, which is about half of the $30 to $40 estimated cost of central treatment for the Village. The actual cost of treated water based on an average RO production of 7 gpd is, however, $0.06 per gal as compared to less than $0.01 per gal for central treatment.

Public Acceptance

A survey of the users (80 forms) was conducted at the end of the project. Twenty-five responses representing 73 residents were returned. Approximately 85% of the responses indicated they were pleased with the RO units, which was about the same as results from a house-to-house survey.

The majority of the negative comments dealt with the quantity of water produced and the water pressure from the unit's faucet. Thirty-eight percent were not pleased with the quantity, and all of these comments were from families of four or more persons. Of the responses, 64% indicated a willingness to pay $5 to $10 per mo for continued use of the RO units, 20% were willing to pay more than $10 per mo, and 16% were unwilling to pay anything at all.

Conclusions and Recommendations

The following conclusions were drawn as a result of the San Ysidro study:

POU treatment of drinking water is an effective, economical, reliable, and viable alternative to central treatment in a small community like San Ysidro to remove arsenic as well as other contaminants.

Adopting a POU treatment system in a small community requires more care than does a central treatment system relative to time-keeping to monitor the individual systems.

POU systems require special regulations regarding customer responsibilities, water utility responsibilities, and the requirement of installation of the devices in each home obtaining water from the utility.

POU systems require special considerations from regulatory agencies to determine appropriate methods for record keeping, monitoring, and testing frequencies that may differ from existing regulations.

The RO units with polyamide membranes installed in San Ysidro resulted in the following removal percentages, bringing all of the contaminant levels well below the MCL's: arsenic (total) - 86%; fluoride - 87%; TDS - 88%; chloride - 84%; iron - 97%; and manganese - 87%.

The cost to the customer of POU treatment per month ($7) in San Ysidro is less than half of the estimated cost of central treatment ($30 to $40 per mo). The cost per gal of treated water, however, is over three times that of central treatment, since central treatment treats the entire water supply and the POU device treats a small fraction of the supply.

Total usage of water through the RO units, including consumption, averaged from 8.5 to 17.0 gpd. The units were designed to produce 5 to 8 gal of treated water.

The full report was submitted in fulfillment of Cooperative Agreement CR-812499 by Leedshill-Herkenhoff, Inc., under the sponsorship of the U.S. Environmental Protection Agency.

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***Kim R. Fox** is the EPA Project Officer (see below).*
The complete report, entitled "Point-of-Use Treatment of Drinking Water in San Ysidro, NM," (Order No. PB 90-108 838/AS; Cost: $17.00, subject to change) will be available only from:
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