

Treating Farm Water With Reverse Osmosis

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This paper presents the results of the operation of reverse osmosis water treating units on two farms in western North Dakota. The water on both farms is high in dissolved solids and in color. The water is almost impossible to use without treatment. The water is relatively soft which means that a regular water softener does little to improve quality. Operating data, quality tests, and the reactions of the people involved are presented.

Osmosis occurs when two solutions of different concentrations are separated by a semipermeable membrane. The solvent (water) from the less concentrated solution passes through the membrane to the more concentrated solution in an effort to equalize the concentrations of the two solutions.

Simultaneously with the flow of water, a small pressure called osmotic pressure develops on the more concentrated side. If this pressure is opposed by an external pressure greater than the osmotic pressure, then the water flow will be reversed.

A relatively new water treating system based on these phenomena has become technologically, commercially and economically feasible. It is called "reverse osmosis." One of the applications for reverse osmosis is the production of high quality water from poor quality water which may be alkaline, brackish or colored.

In reverse osmosis, the pressure applied to the more concentrated solution is called feed pressure, which normally ranges between 100 and 600 pounds per square inch. The rate of product water flow is proportional to the feed pressure.

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Work on which this project is based was supported by the North Dakota Agricultural Experiment Station Project No. 1424, and by the North Dakota Power Use Council. Acknowledgement is also made for the cooperation received from Howard Hammond, North Dakota State Laboratory, for consultation and the analysis of the water samples for this study.

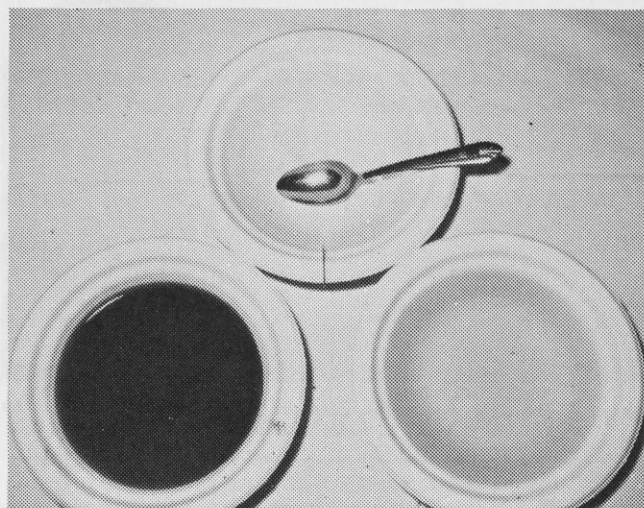


Figure 1. The Color of the Ground Water Ranged from the Dark Sample in Lower Left to the Clear Water in Upper Center.

The membrane used in a reverse osmosis device is a most important consideration. The membrane acts like a filter and rejects dissolved solids as the water flows through. An advantage of reverse osmosis is that it removes such dissolved solids as sodium compounds, while a regular filter would remove only suspended solids. The two commonly used membranes are cellulose acetate and nylon.

An ideal membrane should reject a very high percentage of dissolved solids. It should have good chemical, bacteriological and temperature resistance, and be operable in a wide pH range. Farm water pH usually is between 6 and 9. The membrane should be strong and offer a long life. It is further desirable that the reverse osmosis unit have the large surface area required in a relatively small space.

To treat water on farms, the system must be as simple as possible so the amount of supervision, adjustment, maintenance and required pretreatment be minimal. Precipitates of calcium and other compounds tend to plug the reverse osmosis membrane. This possibility may be avoided by a lower conversion rate, the use of a softener, or acid treatment. Low temperatures reduce flow rates and preheating may be necessary. High pH may need to be reduced by acid treatment or dealkalinizers.

Water in southwestern North Dakota varies considerably in quality. On 11 farms selected for a preliminary study (2, 3), the color varied from 40 to 2,400 platinum cobalt color units (Figure 1), the conductivity from 1,400 to 4,800 micromhos/

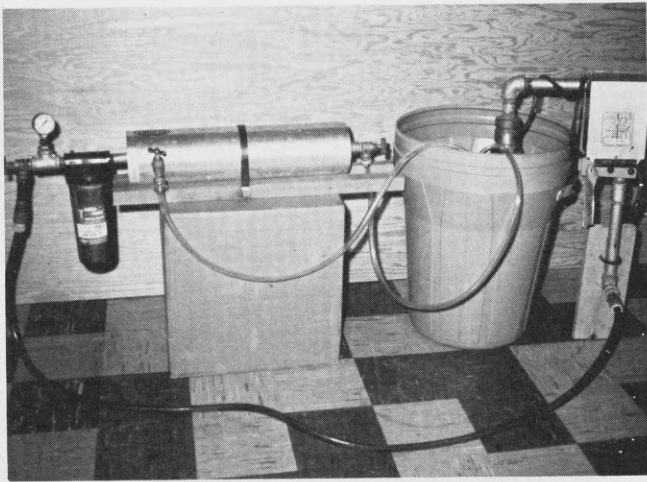


Figure 2. The Test Apparatus Used in the Preliminary Study. The Reverse Osmosis Cylinder is Near the Middle of the Picture.

cm at 25°C, the sulfates from 4 to 2,000 ppm., the hardness from 15 to 375 ppm., the alkalinity from 450 to 900 ppm., and the pH from 7.9 to 8.8. All of the waters did contain a variety of substances, but not consistently high in any one. Total dissolved solids were all high as indicated by the conductivity. The waters would be classified as highly mineralized (1).

The preliminary study (2, 3) indicated that reverse osmosis could successfully treat the water available on farms in this area. Information was needed on operating and maintenance costs. With the cooperation of Lloyd P. Lee, of the Lloyd P. Lee Company, Billings, Montana, and later with the Permutit Company, Paramus, New Jersey, and Don Doud with the Permasep Products Division of E. I. du Pont de Nemours Company, two farm installations were made in October, 1972. The two sites were the James Nelson farm near Dickinson, North Dakota, and the Russell Earsley farm near Reeder, North Dakota.

The reverse osmosis unit selected, called a Permasep permeator, had many hollow fibers (Figure 3) made of nylon. This provided a large surface area. Each fiber is 85 microns outside diameter and 42 microns inside diameter, comparable to the size of human hair. The cylinder, or outer shell, is 5 inches outside diameter and 25 inches long. It contains about one million of these fibers (Figure 2), with a total surface area of more than 800 square feet.

Well water is first treated with a water softener to remove calcium. Water from the softener goes through a 10 micron filter before going to a multi-stage centrifugal pump, increasing the pressure to approximately 200 lbs./square-inch. The water then enters the reverse osmosis unit. The treated water is stored in a 200-gallon non-pressurized storage tank before being pumped into the house system with a small jet water pump. The reject water is discharged into an old well at one farm, and into the sewage system at the other farm.

Systems on both farms were very similar, and the installed costs which included the water softener and some remodeling of the present system, was in the range of \$3,000. This may be reduced when factory assembled systems are available. The toilets were connected directly to the soft water.

The first installation was made at a farm near Dickinson where Jim and Karen Nelson live. The farm is part of the North Dakota State University Branch Agricultural Experiment Station, where Mr. Nelson is the assistant in animal husbandry. The Nelsons have four boys ranging in age from two to seven years. The Nelsons rent their six-room home.

Before installing reverse osmosis, the Nelsons used two wells for their water needs. An old well

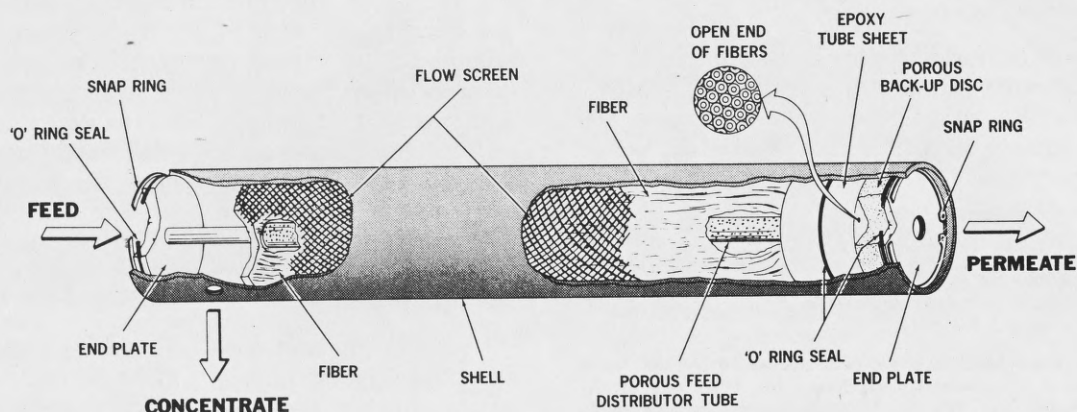


Figure 3. Cutaway Drawing of "Permasep" Reverse Osmosis Unit (courtesy of E. I. du Pont de Nemours and Company).



Figure 4. Mrs. James Nelson with Three of Her Children Performing One of Her Daily Chores.

produced clear water, but it was very hard, with high iron content. In addition, the water supply was limited and the well ran dry on occasion during the summer months. A new well was adequate, but the water was dark in color and high in dissolved solids (see Table 2). Preliminary tests on this water indicated reverse osmosis would effectively remove the color and the dissolved solids. This new well uses a submersible pump throttled to three gallons per minute to control silt. This well supplies the water for the reverse osmosis unit.

Previously, Mrs. Nelson used a wringer type washing machine, but did 75 per cent of her laundry in Dickinson, which is about six miles from their home. This was no simple task with four small children, and was especially inconvenient during the winter months. When the wash was done at home, she used one to one and one-half cups of low-phosphate detergent in each load, and also added a water conditioner to both the wash and rinse cycles and chlorine bleach to the white loads. Other laundry aids used were a fabric softener and a product to sanitize diapers. The results were not satisfying. The laundry was dingy, not soft to the touch and appeared to have a gray film.

For the past year, the Nelsons have had their water treated with a reverse osmosis unit, and pretreated with a softener. They have a new front loading automatic washing machine. There is no further discoloring of the white clothes, the appearance of the diapers is particularly good, and the clothing and sheets feel softer and cleaner.

The Nelsons also have purchased an automatic dryer and a water heater. They have re-

modeled their bathroom, and are in the process of remodeling their kitchen.

The family commented that beverages look and taste better. Previously, cream was not used in the coffee because it curdled. Waxes seem to work better on floors. Karen feels that her hair feels softer after washing. Bathing is more pleasant, and the problem with dry skin has disappeared. All canning has been done with the treated water. Overall, the system is much more convenient for the Nelsons, and Mrs. Nelson enjoys telling others about it.

A second installation, almost identical and made at the same time, was on the farm of Russell and Verena Earsley, north of Reeder, North Dakota. Russell is a farmer and rancher, and a director of the Slope REA Cooperative. They own their home, located on property homesteaded by his father in 1908. It is a seven-room house with a bathroom and a basement. Living on the same farmstead is their son and family, Allan, Virginia, and their daughter, age 2½. They live in a four-room trailer home with a bathroom, but no basement, on the parents' farmstead.

Previously, the Earsleys had several wells which were used for household and livestock needs. The main well near the house produced water which was high in dissolved solids, dark in color, and contained iron. Laundry was difficult because of the staining. The water also contained silt and sand when the well was overpumped.

Water from this main well was supplemented with a rain water system when washing white



Figure 5. Mrs. Russell Earsley, with Granddaughter, Putting Some of the Clothes in the Washing Machine Made Possible with the Reverse Osmosis Unit.

Table 1. Yearly Summary of Water Treatment by Softener and Reverse Osmosis Units.

	Nelson	Earsley
Total water, gal.*	54,638	61,121
Treated water, gal.*	30,941	43,410
Reject water, gal.	23,697	17,711
Conversion	56.6%	71.0%
Kilowatt-hours	1,257	1,472
Gal. of treated water/day	85	119
Gal. of treated water/kwh	24.6	29.5
Gal. of treated water/hour	23.0	35.0
Cost per month @ 2½¢/kwh (\$)	2.61	3.06
Operating time	15.4%	14.2%

*does not include water to toilet

clothes, since the well water caused moderate discoloration of the clothing. All of the laundry was done at home. One-half cup of detergent was used with each load. A chlorine bleach was added to the wash and a fabric softener was added to the rinse. Mrs. Earsley was not satisfied with the appearance of her laundry. The whites turned grayish, and the colors were dull.

Virginia Earsley did all of her laundry at the parents' home, this being a limitation in itself. She used the same laundry aids as her mother-in-law.

Before installing the water treating equipment, the Earsleys dug a new well and installed

a submersible pump in it. The water was similar to that in the old well and the chemical analysis is given in Table 3. Note that it contained an appreciable amount of iron and color.

Both of the Earsley families now have new automatic washing machines. Verena uses an organic laundry cleaner, about ¼-cup per load. Occasionally she adds an oxygen bleach to her whites. A fabric softener is the only other laundry aid used. She commented that her entire laundry, whites and colors, now seems brighter.

Before installation of the reverse osmosis unit, all canning was done with special water acquired for that purpose. Verena was a little suspicious of the new water, and so decided to do half of her canning with the same water used previously, and half with water from their new treating system. The results should be interesting.

The Earsleys have noticed a difference in beverages made with the new water. They no longer add food coloring to cover up the water color when making lemonade. The need for laundry aids has been reduced, and wash day seems more pleasant and easier for both families. Virginia Earsley is most pleased with her own laundry equipment. She uses a detergent for her wash and occasionally adds bleach.

Yearly summary for the two installations is given in Table 1. The lower conversion rate at the Nelson unit was not intentional, but was caused by a discrepancy in reading the flow meters. Calculation of the conversions was based on water meter readings. The difference in conversion rates is reflected in the gallons produced per kilowatt-hour. Electricity measured was used to operate the pressurizing pump for the reverse

Table 2. Water Analyses on Nelson Farm Before and After Treatment.

	Well	November, 1972		October, 1973	
		Product	% Rejection	Product	% Rejection
Conductivity micromhos/cm @ 25°C	2655	53	—	116	—
Total solids ppm	1875	36	98.1	85	95.5
Fixed solids ppm	1780	30	98.3	47	97.4
Hardness ppm	27.7	0	100.0	0	100.0
Sodium ppm	691	15	97.8	30	95.6
Iron ppm	0.76	0.08	89.5	0.09	88.2
Carbonates ppm	28	0	100.0	0	100.0
Bicarbonates ppm	733	24	96.7	44	94.0
Chlorides ppm	6.2	0.5	91.9	3.5	43.5
Sulfates ppm	728	8.0	98.9	8.0	98.9
Nitrates ppm	5	0	100.0	0	100.0
pH	8.45	6	—	7.2	—
Color-platinum-cobalt units	290	0	—	5	—

Table 3. Water Analyses on Earsley Farm Before and After Treatment.

	Well	November, 1972		October, 1973	
		Product	% Rejection	Product	% Rejection
Conductivity micromhos/cm @ 25°C	1630	40	—	394	—
Total solids ppm	1107	33	97.0	215	81.6
Fixed solids ppm	981	22	97.8	214	78.2
Hardness ppm	20.3	0	100.0	0	100.0
Sodium ppm	395	12	97.0	89	77.5
Iron ppm	0.65	0.05	92.3	0.28	57.0
Carbonates ppm	11	0	100.0	0	100.0
Bicarbonates ppm	402	18	95.5	99	75.4
Chlorides ppm	8.4	0	100.0	2.5	70.2
Sulfates ppm	432	8	98.1	88	79.6
Nitrates ppm	0	0	—	0	—
pH	8.3	6.2	—	8.0	—
Color-platinum-cobalt units	620	10	—	—	—

osmosis unit, for the repressurizing pump to put water into the house system, and for the operation of the controls on the water softener.

Well water analysis for the Nelson farm is presented in Table 2 and for the Earsley farm in Table 3. The chemical analysis figures for the well water are the average of four analyses made throughout the year. Results were consistent, even though both wells were practically new. The Nelson water is higher in total dissolved solids, but similar to the Earsley water in pH. The Nelson water has some nitrate. Both have iron above the recommended limit.

The changes in water quality as the result of the softener and the reverse osmosis are also shown in Tables 2 and 3. Results are given from an analysis made of a single sample taken in November 1972 shortly after the equipment was installed. These results are compared with a rather recent analysis made approximately a year later. The softener has had only salt added to the flushing tank. Two intermediate analyses made during the year were, in general, proportional to the operating time.

After one year of operation, the unit on the Earsley farm had increased amounts of solids passing through the membrane. Conductivity increased from 40 to 394 micromhos/cm, and iron had increased to the point where it could cause staining of the laundry. However, at this point the unit was sent back to the manufacturer for cleaning and flushing.

Treatment of the unit was unsuccessful, so it was opened up for inspection. The only problem was the accumulation of fine silt. The water quality deteriorated at a rather high rate. When the report was received regarding the silt problem, the 10 micron filter was replaced with two 5 micron filters in parallel. During about 60 days of

operation the water quality has improved appreciably indicating that the silt is being removed by the filters, and that it also is gradually being removed from the reverse osmosis unit. It appears that the Earsley unit will now give performance equal to that of the Nelson unit.

The Nelson unit, although handling water with higher total solids, is continuing to produce good quality water. Total water handled in one year is 54,638 gallons as compared with 61,121 gallons for the Earsley unit. In addition to a slightly lower rate of water used, the lower conversion rate of 56.6 per cent as compared with 71 per cent may have lengthened the operating time of the reverse osmosis unit before servicing.

Neither unit has had an appreciable reduction in flow rate.

In summary, it has been demonstrated at the Nelson's and Earsley's that reverse osmosis makes it feasible to convert poor quality water into a high quality water thereby allowing a significantly changed and improved way of life on these farms. All of the people on these two farms are benefiting by having an abundance of high quality water available in their homes.

References

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