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Iowa's first electro dialysis reversal water treatment plant

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Abstract

In 1979 the City of Washington was notified by the Iowa Department of Natural Resources (IDNR) that the City was in violation of the radium standard for drinking water. The City of Washington authorized an engineering study to determine the most cost-effective and practical way to remove radium and, at the same time, improve overall water quality. Several possible treatment alternatives were evaluated. It was finally decided to utilize electro dialysis reversal (EDR). Washington obtains its water from three deep wells ranging in capacity from 600–780 gpm. The untreated water withdrawn from the wells first passes through the EDR units. There are three EDR units, each able to produce 285 gpm of finished water. In the future, another EDR unit can be easily added to the other three units, since the new plant was built and plumbed for an additional EDR unit if water demand increased. The Jordan aquifer supply is adequate for current and future needs. The average daily water usage in 1993 was 818,000 gal/d. In order to meet peak flows, it is possible to bypass the EDR units with part of the untreated water and then blend treated and untreated water. The treated water meets IDNR standards of 5.0 pC/L. After the EDR units, the water flows through an aerator where odor-causing gases and carbon dioxide are removed. Aeration reduces the amount of caustic soda and chlorine used in the finished water. The hydrogen sulfide gas leaves the water as it passes through the aerator, and this loss of gas creates less chlorine demand. Total and free chlorine residuals are now detected in every water main of the town, whereas before, the residuals would not be detected in certain area of Washington. Phosphates have been cut back from 7 pounds per day to one pound per day. Better water quality is now being achieved with fewer chemicals added to the finished water. Washington's water treatment plant is the first municipal EDR plant in the State of Iowa and one of the largest municipal installations in the United States.

Keywords: Water treatment plant; Electro dialysis reversal; Costs

1. Background data

The City of Washington, located in southeast Iowa, is the county seat and largest city in Washington County. The immediate area around Washington is composed mainly of rural com-

munities of less than 1,000 population, making Washington a trade center for that area. The area around Washington is primarily flat prairie agricultural land. The closest major stream is the Skunk River, about 10 miles southwest of the city.

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2. Population and economic data

Washington's population was 7,074 in the 1990 census and has grown 5.2% (average)/decade since 1920. Several industries are located in Washington, including a seed corn and agronomy industry, an industrial equipment manufacturer, and a printing factory. These industries provide a good economic base and job availability which should ensure Washington's continued growth.

3. Historical background about the water supply

Washington has three municipal wells with an average yield of 300,482,500 gal/y (Table 1). Prior to 1993, these wells were used alternately, except for periods of high water use. Phosphate was added at each well site to control iron in the water mains. Water from the wells converged at the plant and was injected with chlorine and caustic soda before going into a million-gallon ground reservoir. There was no other treatment prior to 1993. From the ground storage reservoir, water was pumped into the distribution system by four pumps. The capacities ranged from 700–1200 gpm (gal/min). Besides the million-gallon ground reservoir, Washington has two elevated storage tanks: a 150 ft high 500,000 gal tank and a 125 ft high 200,000 gal tank.

4. Water quality and treatment

In 1979 the City of Washington was notified by the Iowa Department of Natural Resources (IDNR) that the City was in violation of the radium standard for drinking water. Radium, a naturally occurring constituent in deep well water, is a suspected carcinogen.

The City of Washington authorized an engineering study to determine the most cost-effective and practical way to remove radium and, at the same time, improve overall water quality.

Table 1
Water supply — Washington, Iowa

Well No.	Date drilled	Depth, ft	Capacity, gpm	Aquifer
5	1946	1900	700	Jordan
6	1956	1900	600	Jordan
7	1969	1825	780	Jordan

Several possible treatment alternatives were evaluated. It was finally decided to utilize electro dialysis reversal (EDR).

EDR is a high-tech process where minerals and other constituents in water are separated by an electrical charge. The resulting ions are transferred through membranes from a less concentrated to a more concentrated solution. By varying the amount of the electrical charge input to the system, it is possible to remove the dissolved solids in water to the extent desired. EDR is a process which can also be used in desalinating sea water. The dissolved solids removed are concentrated in a "brine" or salt solution. About 15% of water pumped from wells ends up as brine waste.

Howard R. Green Company was retained to design the new water treatment plant in September 1991. The design was completed and a letting was held in April 1992. The plant began treating water in January 1993, and final construction was completed in April 1993.

Washington obtains its water from three deep wells ranging in capacity from 600–780 gpm. Water can be withdrawn from any of the wells separately or in a combination of any two at one time. The untreated water first passes through the EDR units. There are three EDR units, each able to produce 261 gpm of finished water. Total EDR treatment capacity is 783 gpm (1.1 million gal/d). The treatment plant normally operates between the hours of 8:00 p.m. through 11:00 a.m. to take advantage of lower off-peak electrical rates. The average daily water usage in

1993 was 818,000 gal/d. In order to meet peak flows, it is possible to bypass the EDR units with part of the untreated water and then blend treated and untreated water.

After the EDR units, the water flows through an aerator where odor-causing gases and carbon dioxide are removed. The removal of carbon dioxide raises the finished water pH and causes the water to be stable or slightly alkaline, resulting in some deposition of scale in the water mains. Aeration reduces the amount of caustic soda and chlorine used in the finished water. Thirty pounds of chlorine and 10 gal of caustic soda were injected per day into the finished water; now, no caustic soda and 20 pounds of chlorine are used per day as a result of aeration. The hydrogen sulfide gas leaves the water as it passes through the aerator, and this loss of gas creates less chlorine demand. Total and free chlorine residuals are now detected in every water main of the town, whereas before, the residuals would not be detected in certain areas of Washington. The pH level of the water increases as it passes through the aerator by removed CO_2 ; whereas before, caustic soda was added to raise the pH. Before aeration the pH is 7.1; after treatment it is 7.7. This gives a stable water quality, which is important because some water mains are 100 years old and have deposits in them. Phosphates have been cut back from seven pounds per day to one pound per day. Better water quality is now being achieved with fewer chemicals added to the finished water.

From the aerator the water falls into an underground concrete basin where chlorine (disinfectant) and polyphosphate (control for scaling) are added. Caustic soda (pH adjustment) and fluoride (dental protectant) may also be added, if needed. The water is pumped by either of two transfer pumps to the ground storage reservoir from where it is pumped again into the distribution system by three high-service pumps. The capacities of the pumps are 750, 1000, and 1200 gpm. The plant has the ability to remove

varying percentages of dissolved solids depending upon the final water quality goal for plant flow. At the present time the EDR units remove about 50% of the total dissolved solids. Radium levels in Washington's finished water are now far below the maximum allowable drinking water standard.

The EDR equipment is housed in a 52' × 64' precast concrete building with a metal standing-seam roof over precast concrete beams. The building is low maintenance and is very energy efficient. For example, since the plant went on-line in January 1993, space heaters in the main operating room have seldom operated, due to the naturally warm temperature and the heat given off by the equipment. Also, to further reduce costs, the plant is designed to run during off-peak electrical demand periods. Total cost of the facility, including improvements to the existing plant and ground storage reservoir was about \$1,800,000. Operational costs have been less than anticipated (Table 2).

Washington's water treatment plant is the first municipal EDR plant in the State of Iowa and one of the largest in the United States. Washington's new water treatment plant exemplifies the city's commitment to supplying safe and aesthetically pleasing water to the citizens of Washington.

5. Costs of water to the consumer

Present water rates are according to the following rate schedule:

- a) for the first 1,400 ft³: $\$1.45/100 \text{ ft}^3 = \$1.93/1000 \text{ gal}$
- b) for 1,400–15,000 ft³: $\$1.30/100 \text{ ft}^3 = \$1.73/1000 \text{ gal}$
- c) for 15,000–100,000 ft³: $\$1.10/100 \text{ ft}^3 = \$1.47/1000 \text{ gal}$
- d) for >100,000 ft³: $\$0.85/100 \text{ ft}^3 = \$1.13/1000 \text{ gal}$.

Table 2
Costs of water production

	\$	\$/1000 gal
Operation and maintenance		
Deep well pumping		0.05
Waste disposal		0.00
Plant power		0.12
High service pumping		0.04
Membrane costs		0.25
Labor		0.04
Anti-scalant		0.01
Acid, chlorine, phosphate		0.01
Cartridge filters		0.04
Maintenance		0.03
O&M cost/1000 gal		0.59
Capital costs		
Process equipment	1,212,600	
Building	280,000	
Related work	315,000	
Total capital	1,807,600	
Annual payment*	152,900	
Annual total capital costs	1,960,500	
Capital cost/1000 gal		0.52
Total cost of production/ 1000 gal		1.11

Total estimated cost/1000 gal to produce water = \$1.11 or approximately one tenth of a cent/gal.

*Assumed: 6% for 20 years. (Received \$676,000.00 Block Grant.)

The charge for bulk water purchased from the water plant is \$0.25/100 gal. In addition to the above rates, a monthly water service charge of \$6.00/m is billed. There are no plans to increase current rates.

In the future, another EDR unit can be easily added to the other three units, since the new plant was built and plumbed for an additional EDR unit if water demand increased. The Jordan aquifer supply is adequate for current and future needs.

6. Number of consumers

There were 2,737 service connections and 7,074 people being served in 1993. The largest

Table 3
Analysis of raw and finished water, Washington, Iowa

	Jordan wells	EDR treated
Radium, pCi/L	7	3.3
pH	7.3	8.05
Total dissolved solids, mg/L	1,200	628
Silica, mg/L	9.5	10
Potassium, mg/L	22	9.2
Sodium, mg/L	200	140
Calcium, mg/L	110	42
Iron, mg/L	0.8	0.6
Manganese, mg/L	0.04	<0.02
Magnesium, mg/L	47	19
Nitrate, mg/L	<0.1	<0.1
Fluoride, mg/L	1.3	1.2
Chloride, mg/L	60	46
Sulfate, mg/L	600	230
Bicarbonate, mg/L	290	221
Carbonate, mg/L	—	—
Hardness as CaCO ₃ , mg/L	480	183
Temperature, °F	72	72

user was Northrup-King, which uses water for irrigation. A ten-year meter change-out program has been ongoing since 1989. This means that every ten years all meters are due to be changed or tested for accuracy. Six hundred and seventy meters have been changed out or tested since 1989. The purpose is to increase the accounted-for water, which was about 80% in 1993, an increase over the pre-1989 level of about 70%.

7. Water quality

Currently there are no water quality problems. All current and proposed Primary Drinking Water regulations are being met, including the proposed Primary Standard for sulfate. An analysis of raw and finished water is shown in Table 3.

The City of Washington was also interested in lowering sodium, total dissolved solids (TDS), and sulfates in anticipation of new standards.

The new treatment plan does remove these chemicals, in part.