Global Warming—Myth or Reality?

John Crane

Part 4: Has Global Warming Already Begun?

There seems little doubt that a warming trend has been observed during the last century. There has been a global temperature rise of about 0.5-1°F, although there is considerable question as to how much and even as to why. Almost all of mankind's fossil-fuel emissions of carbon dioxide have occurred during the past one hundred years. Coal was predominant for much of that time, but usage has shifted since World War II toward oil and gas in industrialized nations. Non-fossil energy sources—hydroelectric and nuclear power—supply about 15 percent of the global demand for energy.

The greatest per-capita rate of growth of fossil-fuel usage occurred between 1860 and 1900, when fossil-fuel usage grew six times faster than population. Since then the per capita usage has dropped sporadically until today it is less than population growth. However, as the Third World, along with Russia and China, experiences economic growth in coming decades, the per capita production of fossil-fuel emission may increase.

Overall, there has been about a 30 percent increase (from 280 to 360 ppm) in the concentration of carbon dioxide in the atmosphere since the beginning of the Industrial Age about 150 years ago. and it is currently increasing at a rate of about 0.4 percent per year.

While temperature increases in the past century have generally been in line with what models predict should have resulted from man-made emissions of carbon dioxide, it is also small enough to have been caused by natural variability—it is argued by some that a study of only 100 years out of millions of years of the geologic record is ridiculous, that the probability of error is so high as to make the data meaningless—although it is argued on the other hand that natural variability has temporarily masked some of the warming caused by man-made emissions.

In the northern hemisphere, a substantial warming began about 1910 (corresponding more or less to the end of the little ice age) and ended about 1940. Temperatures then fell by about 0.4°F to the mid-1970s, and then increased sharply again. Today, most if not all alpine glaciers in the tropics are shrinking, as are the majority in temperate zones. The trend in the southern hemisphere shows an uneven warming trend beginning around the turn of the century.

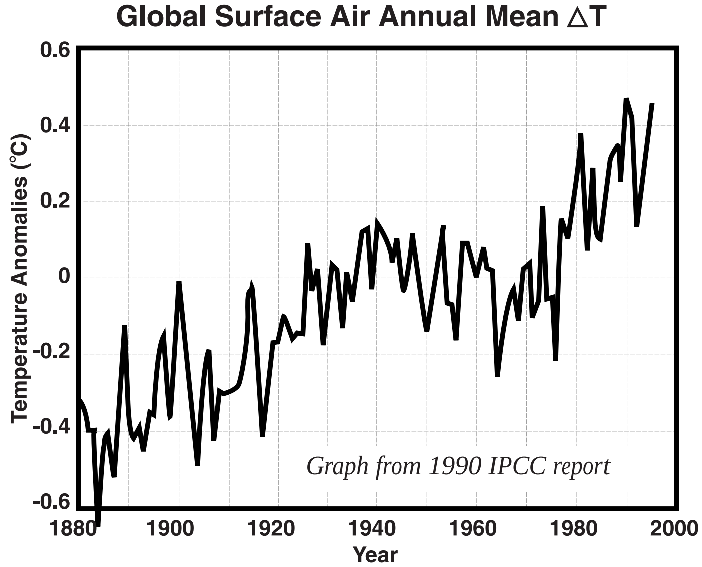
Proponents of the global warming theory are almost embarrassed by the lack of temperature increases for the thirty-five years following 1940, which is ironically during the period of most accurate temperature measurements by satellites.

Most man-made carbon dioxide is produced in the northern hemisphere and does not tend to cross the equator; therefore, carbon dioxide levels in the northern hemisphere should be much higher than the levels in the southern hemisphere. They are, but the difference is much smaller than models suggest it should be. The fact that the northern hemisphere has much more carbon dioxide-absorbing plant life could be a factor, but many scientists doubt that it is enough of a factor to account for the difference.

One criticism of the temperature record of the past century is that the environment of recording stations has changed. It is well-known that urban areas and paved areas, such as airports, collect heat. Many temperature recording stations were located in areas that became increasingly urbanized as well as at expanding airports. Some analysts have attempted to correct for those effects, and the results have been a significant lowering of the measurements of temperature increases.

Other effects that may be even more difficult to correct for include a lack of consistency in taking the readings over the years—for example, were they taken at the same time each day? Also, methods of measurement have changed over the years. One of the major changes has been the use of satellites to measure surface temperatures during the past quarter century or so.

Nevertheless, the warming trend of the past century is probably too large to be dismissed as sampling error, especially considering that many of the sampling errors probably offset one another.



Graph from 1990 IPCC report

Whether the warming trend is a result of man-made emissions or natural variability is another matter. Keigwin (1996) found some evidence that might support the warming trend being natural. In a study of sea surface temperature in the northern Sargasso Sea, he found that it was about 2°F warmer than 400 years ago but about the same amount cooler than 1000 years ago.

There are also some indications that a warming trend began earlier than 1880. Jacoby et al., in a study of tree rings in Siberia, observed that the rings have been getting larger, due, presumably, to warmer weather, since the mid-1800s, or before significant greenhouse gases were accumulated in the atmosphere. The widths peaked in the 1960s and have not gotten wider since.

There have been an increasing number of reports of extreme climate events in recent years, which might seem to confirm global warming theories. Tornado activity in the United States, for instance, has risen steadily over the past forty years. Rising ocean temperatures have been blamed for the increasing frequency in recent years of the El Nino weather pattern, which causes droughts in Australia, heavy rains in Chile and Peru, and hurricanes off the Pacific coast of Mexico. This year El Nino threatens to be worse than the worst season on record,1982-83, which caused $13 billion in economic losses and cost 2,000 lives. (Demonstrating that there is a silver lining in most clouds, El Nino also causes fewer hurricanes in the Atlantic and fewer tornadoes in the United States.)

There is no firm evidence, however, that extreme climate events are indeed becoming more common; there are several other factors at play. Monitoring equipment, especially satellites, have provided incredibly greater sophistication. Increased population and people tending to live in risk-prone areas have led to climatic events being disasters that would hardly have been noticed in previous years. And, not least of all, the communications revolution has made much more information available to many more people, making people more aware of climate events.

Part 5: What Can Be Done to Stop Global Warming?

If steps are needed to curtail global warming, it is obvious they must be undertaken on a planet-wide basis, but the industrialized nations are the most involved since they generate most of the carbon dioxide emissions. Scientists have estimated that a reduction in carbon dioxide generation of as much as 60 percent would be necessary to stabilize the atmosphere at its current level. The cost of doing that could be astronomical.

Fossil fuels—oil, coal, and gas—account for about three quarters of man-made carbon dioxide emissions andfor a significant part of man-made releases of other greenhouse gases. One proposal supported by the United Nations has been a “carbon tax” on fossil fuels to discourage their use. Some industrialized countries, including Finland, the Netherlands, Norway, and Sweden, have already instituted such a tax, and the European Commission has proposed a community-wide carbon tax for member states.

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Catching the Technology Wave on the Internet

Irma M. Reinpoldt

So you'd like to "get wired," "catch the technology wave," or "surf the Net" looking for water information, but you aren't exactly sure what that entails. You've seen an alphabet soup of acronyms like http, www, FTP, and lots of dots and slash marks, but you don't know what they are or what they do. You've heard of home pages and web sites, cross links and e-mail, and you realize these things are important in today's technological computer-driven world, but you have no idea where to start.

Neither did I, until it was suggested that I design a utilities presence on the Internet. Like it or not, the Internet and cyberspace are going to change the way we communicate, and that means utilities should make an effort to become cyber savvy.

A Brief History

The Internet is the result of more than 25 years of linking computer communications at four of the nation's largest university-based research orgarizations and military research contractors. In 1969, the U.S. Department of Defense commissioned a research study to link the computer networks of the four universities doing military funded research, three in California and one in Utah. To build in reliability, the system used dynamic routing to avoid a central hub or pathway that could be destroyed in time of war. Like the transporter on Star Trek that broke travelers into molecules and atoms to be reassembled at a predetermined end destination, the Internet's information is subdivided into little coded sections and sent to various computers throughout the network and then reassembled into a readable whole only when it reached the end user's terminal. Now that's cyberspace!

After the first four colleges and other universities linked computers, increasing numbers of institutional partners joined the network. The World Wide Web (www), a portion of the Internet dedicated to multimedia (such media as pictures, sound, and even movies in addition to text) was developed. In the late 1980's, the first software for using (browsing) the Web was introduced. It was called Mosaic, and it was free.

Mosaic was easy to use and available on the UNIX, PC, and Macintosh platforms. Not long after that, Netscape was introduced, which is today's reigning browser software.

Later, with the appearance of personal and business computers, it was realized that the Internet would be instrumental in spreading messages or other information faster, wider, and cheaper than any other form of communication.

How do you gain access to the Internet? The equipment you will need includes a computer, software, a modem, and a telephone line. Companies that provide connection services are called Internet Service Providers or ISPs. Commercial networks, such as America Online, Prodigy, and CompuServe, also provide connections. Most governmental agencies and libraries are connected to the Internet.

The Internet is called a "hypertext" environment. Hypertext means that certain information that you see on your screen is "linked" to other pieces of information. For instance, in reading text on a web page you will see underlined words or words appearing in a different color. By clicking on them, you go to more information on that topic. So, if you're reading about conservation in a utility or water management district website and see "xeriscape" underlined or in a different color text, by clicking on that word you can bring up a separate document about xeriscaping. The links can go to any type of Internet resource anywhere on the web. Hypertext links are the basic building blocks of the Internet.

On the World Wide Web, links are called Universal Resource Locators (URLs). Every document on the Internet has its own unique URL that allows it to be linked to other documents easily. You can think of URLs as addresses or phone numbers. Each address has three basic elements: The URL type, the domain name or address, and a directory.

The URL type identifies the type of link. For instance "http://" indicates a Web link and is the most common. Other links include FTP and Gopher.

As an example of the domain name or address of an URL, Pinellas County's address is http://www.co.pinellas.fl.us. "http" is the URL link type; "www" is for the World Wide Web; "co" indicates a county; "pinellas" is the name of the county; "fl" indicates it's in Florida; and "us" says it's located in the United States. Notice that all is in lowercase letters and there are no spaces between letters.

If a link is going to a particular document or directory, it would be attached to the end of the URL. Again using the example of Pinellas County's site, the full address is:

http://www.co.pinellas.fl.us.bcc

The term "bcc" at the end indicates that the directory is for the board of county commissioners. By connecting to this URL address the Pinellas County home page will be accessed.

This first screen of the home page will list an internal directory to access a specific county department. By selecting "Utilities," information relevant to conservation or other water, sewer, and solid waste topics can be obtained. Of course, this text is hypertext linked to related information on other sites with a click on the underlined or alternately colored hypertext words.

Hyper Text Markup Language (HTML) is the coding language used to create and format the text files that are transferred across the Internet. Since the Internet process disassembles the text and sends sections of data to various host computers to be reassembled on the receiving computer monitor, the text requires codes to put the text back together again correctly. Various books are available to use as a guide for creating your own web pages using HTML.

Finding Information on the Internet

The Internet is a library in which it is easy to get lost. It has no librarians or Dewey decimal book coding system to lead us to the ideal resource. Fortunately, there are a few ways to explore the Net and the World Wide Web that, with a little practice, will help you find the information you seek.

"Browsing" involves looking into a general area of interest and then focusing more in depth at whatever catches your attention. Internet directories, which are usually arranged by subject, are ideal for browsers. Internet directories include resource specific search services, where it helps to know the specific address, and more general subject directories which can span the various Internet resources.

Internet search engines are for those who need specific information fast. Search engines are powerful devices that can quickly scan the web or the Internet. Among the search engines are Yahoo! (http://www. yahoo.com), Webcrawler (http://www.webcrawler.com), AltaVista (http://www.altavista.digital.com), Excite (http://excite.com), and Infoseek (http://www.infoseek.com). All ask you to follow the same basic approach: type in some key words that suggest what you're looking for. The search engine then matches the key words with its own database. In the context of the Web, the word "search engine" is most often used for searching through databases of HTML documents.

Other Available Services

Electronic mail (email) is a way of typing a memo or letter on your computer and electronically sending it off to another computer user's desk. The primary effect of email is increased human interaction, which can lead to better technical productivity through the exchange of ideas. Email allows people to exchange messages one-to-one, one-to-many (distribution lists or bulletin boards), or many-to-many (news, web pages, or true conferencing).

File Transfer or FTP (File Transfer Protocol) services allow you to browse through directories for information or programs. Anonymous FTP sites allow you to attach as an anonymous user and retrieve publicly accessible files without special permission.

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Comparison Of Membranes, Ozone, and Ion Exchange for a South Florida Groundwater

Francis E. Duran, Glenn W. Dunkelberger, and Chris Helfrich

The city of Sunrise is planning the construction of a new 18-MGD Sawgrass Water Treatment Plant in the western portion of its service area. The new plant must meet drinking water regulations, both existing and future. A treatability study of three different water treatment processes—membrane softening, lime softening/ozonation/filtration, and lime softening/filtration/ion exchange—was performed to determine the ability of each process to meet finished water quality goals. Based on the results of the study, a conceptual treatment process design for each process was developed. Among the major factors used to compare the processes were capital and operating costs, finished water quality, and the ability to meet future regulations.

Raw Water Quality

The source wellfield is a surficial wellfield pumping water from the Biscayne aquifer. The raw water is non-brackish but has high levels of color, total organic carbon, disinfection by-product precursors, calcium hardness, and alkalinity. Table 1 presents the range of values for major raw water quality parameters.

Table 1. Raw Water Quality Characteristics

Alkalinity,Total	250 - 285 mg/L as CaCO3
Calcium Hardness	250 - 275 mg/L as CaCO3
Color	75 - 150 CU
Iron	1.0 - 1.5 mg/L
pH	6.7 - 7.2 pH units
Total Dissolved Solids	350 - 500 mg/L

Membrane Softening Process Description

A schematic for the proposed membrane softening process is shown in Figure 1. Raw water is chemically pretreated and pumped through dual media and cartridge filters before entering the membrane trains. The membranes separate the contaminants from the raw water and produce high quality permeate. As the concentrate with the contaminants is disposed of through underground injection wells, the permeate undergoes post-treatment, including degasification, pH adjustment, and disinfection.

Lime Softening/Ozonation/Filtration Process Description

A schematic for the proposed lime softening/ozonation/filtration process is shown in Figure 2. Raw water is chemically pretreated to enhance color removal in the softeners. Raw water hardness and some color is removed in the lime softening units. Sludge from the softeners is processed in the sludge handing system while the softened water is ozonated to remove more color. The ozonated water is filtered for turbidity removal and then disinfected.

Lime Softening/Filtration/Ion Exchange Process Description

A schematic for the proposed lime softening/filtration/ion exchange process is shown in Figure 3. Raw water is chemically pretreated to enhance color removal in the softeners. The softened water is disinfected and filtered to remove turbidity as the lime sludge is processed in the sludge handing system. The filtered water passes through ion exchange units to remove color. Regenerant waste is neutralized on-site in a waste treatment system and disposed through the sewer system.

Table 2. Qualitative Comparison of Water Treatment Processes

Area of Comparison	Membrane Softening	Lime Softening/ Ozonation/ Filtration	Lime Softening/ Filtration/ Ion Exchange
Capital Cost		X	
Operating Cost		X	
Finished Water Quality	X		
Ability to Meet Future Regulations	X		
Site Issues	X		
Residuals Disposal	X		
Operability	X		

Comparison Of Processes

Table 2 provides a qualitative comparison of the three processes with a mark provided for the treatment process which has an advantage in a specific area. The membrane softening process has the advantage in most of the areas of comparison, especially the important areas of water quality, ability to meet future regulations, and operability. Although the lime softening/ozonation/filtration

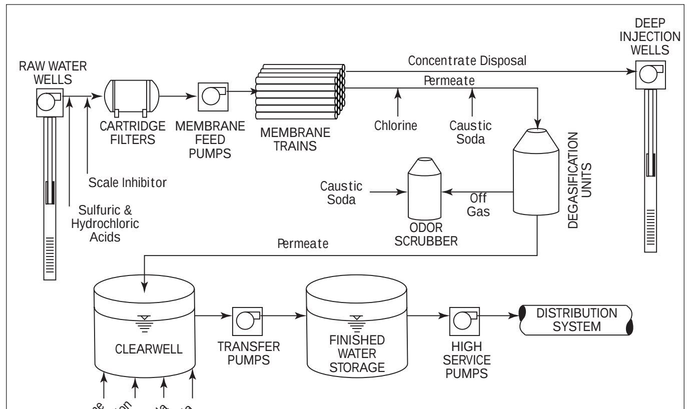

Figure 1. Membrane Softening Process

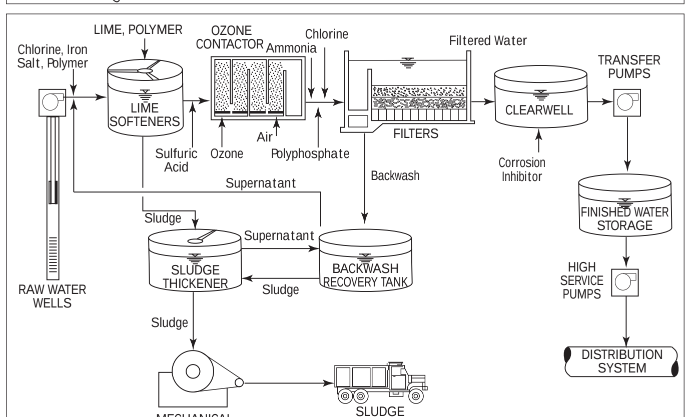

Figure 2. Lime Softening/Filtration Process

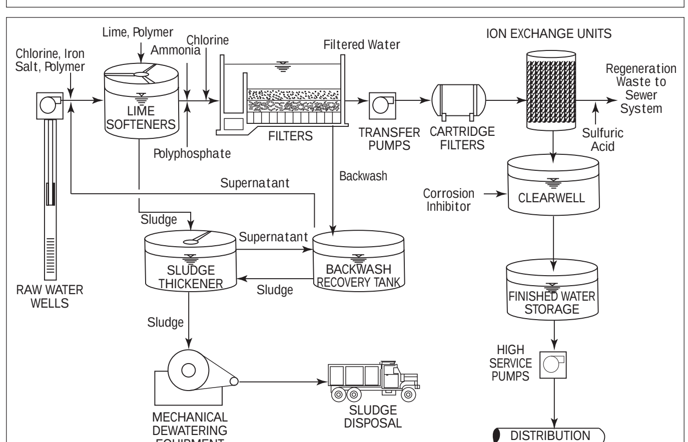

Figure 3. Lime Softening/Filtration/Ion Exchange Process

treatment process was the lowest cost alternative, the membrane softening process provides superior water treatment.

Cost Comparisons: The capital and operating costs presented are based on the conceptual design for each treatment process. The finished water from each design meets all primary and secondary drinking water standards and the established finished water quality goals with one process unit out of service.

In general, the capital cost estimates include the cost of furnishing and installing the process equipment, buildings and containment structures, pipelines, electrical components, and instrumentation. Operational cost estimates include power, chemical, residual disposal, and operations and maintenance labor costs. The operational cost estimates also include the repair and replacement of costly specialty items such as membrane elements and ion exchange resin. For all three treatment processes, the capital and operating cost estimates did not include raw water supply costs. These costs were not included due to the uncertainty of the source(s) of raw water for the proposed facility. Table 3 summarizes the difference in capital cost, operating cost, and total amortized capital and operating cost per 1,000 gallons produced and per year using each of the different treatment processes.

The membrane softening treatment process is the most costly treatment process to construct and operate of the three treatment processes investigated. When comparing amortized capital and operating costs combined, the membrane softening treatment process cost was 25 percent greater than the lime softening/ozonation/filtration process and 15 percent greater than the lime softening/filtration/ion exchange process. The membrane softening treatment process has higher electrical and chemical costs compared to the other two treatment processes. Between the lime softening/ozonation/filtration treatment process and the lime softening/filtration/ion exchange process, the former was less costly mainly due to the lower operational costs.

Table 3. Summary of Cost Comparison Between Treatment Processes

	Membrane Softening	*Lime Softening/ Ozonation/ Filtration*	*Lime Softening/ Filtration/ Ion Exchange*
Capital Cost, $(a)	$36,575,000	$27,430,000	$28,020,000
Capital Cost, $/GPD Capacity	$2.03	$1.52	$1.56
Operating Cost, $/1,000 Gal	$0.93	$0.77	$0.85
Operating plus Amortized Capital, $/1,000 Gal Produced(b)	$1.33	$1.07	$1.16
Operating plus Amortized Capital, $/Year(b)(c)	$6,550,000	$5,270,000	$5,720,000

(a) Capital cost estimates are based on an 18 MGD facility. Accuracy of the capital cost estimate for each of the three treatment processes is plus or minus 30%.
(b) Capital costs are amortized at 6% over a 30 year period.
(c) The operating plus amortized capital costs per year are based on a yearly water production equivalent to 75% of maximum plant capacity.

Finished Water Quality: The three treatment processes met all the major water quality goals. Specifically, each produces a finished water having low hardness, low color, and low turbidity; provides corrosion control of the distribution system; provides a higher level of disinfection than is current practice; and significantly reduces disinfection by-products. Table 4 provides a comparison of how the projected finished water from each treatment process compares to established finished water goals.

The membrane softening treatment process produces the highest quality finished water. The finished water has essentially no color, total organic carbon, turbidity, or disinfection by-product formation potential. The membrane softening process is given credit by EPA as a disinfection barrier that exceeds the viruses inactivation requirements of the Surface Water Treatment Rule (SWTR).

The other two processes, while meeting all the finished water quality goals, have higher levels of total organic carbon, disinfection by-product formation potential, and turbidity. The significant difference between the two lime softening processes is that lime softening/filtration with ozone produced a finished water with a color of 10 color units and higher total organic carbon levels, while the ion exchange process removed all the color and the majority of the total organic carbon.

Ability to Meet Future Regulations: The future Groundwater Disinfection Rule (GDR) and the Disinfectants/Disinfection By-Products (D/DBP) Rule are two major anticipated drinking water regulations which will be impacting the treatment process selection for the Sawgrass WTP. All three conceptual treatment process designs will meet anticipated drinking water regulations associated with these two rules in their current form.

However, other future regulations may negatively impact the treatment processes. The potential future regulations include regulation of more DBPs, classification of the future Sawgrass WTP raw water source as being under the influence of a surface water (UDI), and tighter total organic carbon (TOC) removal requirements or even a TOC MCL. More DBP regulation would likely include aldehydes, which is typically associated with ozone. Classification of the raw water source as UDI would require the Sawgrass WTP to meet Surface Water Treatment Rule (SWTR) standards, including *Giardia* inactivation.

For membrane softening treatment, meeting any of these three potential future regulation scenarios would not be a problem given the proposed design criteria. For lime softening/ozonation/filtration, meeting these future regulations as projected would require treatment modifications from the proposed process design. For example, increasing the ozone dose and lowering the softened water pH to allow for ozone to be used as a disinfectant may be required. Also, converting the dual-media filters to biologically-active filters for TOC and aldehydes removal would be a likely possibility.

For the lime softening/filtration/ion exchange treatment process, meeting the requirements of the SWTR would require additional disinfection contact time for *Giardia* removal through additional water storage. This could be a large volume because primary disinfection must be accomplished with chloramines to prevent DBP formation and chloramines are a poor disinfectant of *Giardia*. Also, consistently meeting a TOC MCL would be very difficult for the lime softening/filtration/ion exchange process, requiring considerably shorter run cycle times based on TOC removal instead of the run cycle times set forth in the proposed process design, which were based on color removal. This would greatly increase the regenerant disposal volume and cost.

Site Issues: The facilities required for all three treatment processes will fit comfortably on the site proposed for the new Sawgrass WTP. Membrane softening process facilities are housed inside structures, so they may be hidden from view of neighboring properties. This limits the visual impact of the new WTP. The lime softening processes, because of the softeners and filter structures, will have a more traditional industrial WTP look. The lime softening processes will require an emergency backwash waste and emergency sludge blowdown ponds on-site, separate from the site drainage pond. The two sludge ponds negatively impact the quality of the site, especially when the sludge ponds are periodically dredged. Also, dried sludge from the sludge handling process can create a dust problem if left on-site for storage. Aesthetically, lime softening process facilities are far less pleasing than membrane softening process facilities.

Residual Disposal: Each treatment process has unique residual disposal issues. For membrane softening treatment, the major disposal issue is the concentrate, a maximum of 4.5 mgd at the ultimate plant capacity of 18.0 mgd. The most cost effective concentrate disposal method is by underground injection. Underground injection requires no pretreatment of the concentrate and saves wastewater treatment costs when compared to disposing of the concentrate via the sewer system and nearby wastewater treatment facility. Other wastes from the membrane softening treatment process include membrane cleaning wastes. The volume of cleaning waste is small enough that it can be easily neutralized on-site and disposed of with the concentrate down an underground injection well.

For the lime softening/ozonation/filtration treatment process, the largest single residual is lime sludge. Currently, the City disposes of its lime sludge from the Springtree WTP by paying to have it hauled away by private contractors. The lime sludge is then land applied. In the future, lime sludge disposal regulations will likely increase sludge disposal costs, especially if landfill disposal of lime sludge is required.

Besides the sludge disposal problems associated with the lime softening process described above, the regenerant waste from the lime softening/filtration/ion exchange treatment process must be disposed of through the sewer system. At a maximum of 30,000 gallons per day at the ultimate plant flow of 18 MGD, the regenerant will be a continual discharge. Because of the nature of the regenerant waste, it will require chemical conditioning, such as pH adjustment, prior to disposal into the sewer system.

Operability: The membrane softening process can be relatively easily automated to minimize manual effort. The operation of the membrane trains is programmed by the membrane system supplier to allow for automatic adjustment of water recovery and permeate flux to keep the membrane system operating properly. Pretreatment and post-treatment chemical addition are easily automated to feed based on plant flow and/or water quality parameters, such as pH and chlorine residual. The most manually intensive function associated with a membrane softening facility is membrane train cleaning. For each train, this is typically done once at least every six months.

Lime softening processes theoretically can be fully automated, but typically require significant manual intervention, considerably more than a membrane softening treatment process. This is especially true for sludge handling associated with the lime softening process. Sludge handling facilities usually require full-time attention of an operator to prevent mishaps and equipment damage. Sludge hauling, even within the site, is also a manually intensive function.

Table 4. Comparison of Processes Finished Water Quality with Finished Water Quality Goals

Parameter	*Finished Water Quality Goals*	*Projected Membrane Softening Finished Water Quality*	*Projected Lime Softening/ Ozonation/ Filtration Finished Water Quality*	*Projected Lime Softening/ Filtration/ Ion Exchange Finished Water Quality*
Alkalinity, Total mg/l as CaCO3	50 - 100	80	50	50
Calcium Hardness mg/l as CaCO3	30-100	30	80	80
Color, CU	<10	*	10	*
Disinfection, log Inactivation of Viruses	4.0	>4.0	4.0	4.0
Haloacetic Acids, µg/l	<30	12	<30	<30
Iron, mg/l	<0.3	*	*	*
Langlier Index	0.3 - 0.5	0.4	0.4	0.4
pH	8.0 - 9.5	9.0	8.8	8.8
TDS, mg/l	<500	150	250	275
TOC Removal, %	30	96.5	30	60-90
Trihalomethanes, µg/l	<40	9	<40	<40
Turbidity, NTU	<0.2**	0.05	0.2	0.2

*Below Detection Limits ** In 95% of Samples

Discussion Of Sawgrass WTP Treatment Process Selection

Based on the comparison between the three treatment processes provided in Table 3, it is recommended that membrane softening be the treatment process for the Sawgrass WTP. It provides a clear advantage over the other two processes for most of the key factors used in the comparison. As a lower cost choice to membrane softening, lime softening/ozonation/filtration can be implemented for the Sawgrass WTP. However, if the lime softening/ozonation/filtration treatment process was selected a lower finished water quality would result. Also, the city would not be as well-positioned to meet future drinking water regulations or worsening raw water quality.

The membrane softening treatment process is the first choice for the Sawgrass WTP despite its higher cost because it provides the highest quality finished water, meets all anticipated future drinking water regulations, and has a proven track record of operation in South Florida. A major negative to the lime softening/ozonation/filtration treatment process is finished water quality. The finished water quality from the lime softening/ozonation/filtration treatment process has a color of 10 color units compared to nondetectable levels with membrane softening. Meeting the finished water color goal of 10 color units requires that the lime softening treatment step remove a significant amount of the color-producing organics. If the raw water supply degrades in water quality, the lime softening/ozonation/filtration process may not be able to consistently meet the finished water goal of 10 color units. The lime softening process and associated lime sludge handling also requires intensive manual labor and negatively impacts site aesthetics due to the storage of dried sludge and emergency sludge ponds.

The third treatment process, lime softening/filtration/ion exchange, has the same negatives associated with lime softening and lime sludge handling as the lime softening/ozonation/filtration process. Furthermore, there is a considerable lack of facility operational experience both nationwide and in South Florida with ion exchange. Long-term or inherent problems associated with the ion exchange resin are unknown. The ability to permit both the ion exchange treatment facility itself and the disposal of regenerant waste via the sewer system are also unknown. Therefore, the lime softening/filtration/ion exchange treatment process was not recommended as a potential treatment process for the Sawgrass WTP.

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Global Warming *from Page 38*

The United Nations admits that because the reaction of energy users and suppliers cannot be reliably predicted, there is no guarantee that a carbon tax would be effective. It has been estimated that the price of crude oil would have to be increased by about two thirds.

Proponents of a carbon tax argue that revenues from the tax would be used to offset other taxes, so that the total tax burden would be unchanged.

The United Nations also proposes that some 10 percent of greenhouse gas emissions can be eliminated by increased energy efficiency. Other actions it favors include the cessation of forest clear cutting, which reduces carbon dioxide absorption, and changes in the diet of cattle and the productivity of individual animals to reduce methane production.

Fossil fuels, the United Nations says, can often be replaced by renewable energy sources, such as solar photovoltaic cells, wind-generated electricity, and biomass-derived fuels, such as ethanol, but admits that such energy sources are currently impractical.

The White House Council of Economic Advisers predicts that measures to stabilize greenhouse gases at their 1990 levels by 2010 would add 26 cents per gallon of gasoline, $1.49 per thousand cubic feet of natural gas, $52.52 per ton of coal, and two cents per kilowatt-hour of electricity. An Energy Department study predicts that energy-price increases could cause significant reductions in output and employment in the chemicals, aluminum, steel, paper and pulp, petroleum refining, and cement industries with job losses possibly totaling 200,000.

Carbon dioxide stays in the atmosphere for about a century on the average, so whatever is done results in a considerable delayed reaction.

The first part of this article appeared in the November 1997 issue. Parts 2 and 3 were in the December 1997 issue. The final part is scheduled for next month.

Raw Water Quality Versus Membrane Fouling Potential

Gabriel Valdes and Ron DiRamio

Deerfield Beach has embarked on a program to consolidate its East and West water treatment plants and provide treatment process improvements to meet anticipated new regulations. Membrane softening was determined as the preferred treatment technology for the expansion of the city's award-winning West lime softening plant through an alternative process analysis study and preliminary design report. This article focuses on membrane pilot testing conducted to evaluate preliminary design concerns and considerations. It presents the results of the first phase of the pilot study with particular emphasis on pretreatment testing and the importance of raw water quality in assessing membrane fouling potential.

The city obtains its drinking water from the Biscayne aquifer in Broward County. The West Wellfield consists of four wells, with a total design capacity of about 16 MGD, and ductile iron piping raw water transmission mains. Wells 17 and 18 are stainless steel screened wells, while Wells 19 and 20 are open hole wells. All four wells have above-ground vertical turbine pumps. Table 1 summarizes the well construction details.

The first phase of the pilot study consisted of various tests at each of the four wells and raw water well composite at the West Water Plant. Testing included BART testing, cartridge filters, well startup tests, and silt density index tests.

Table 1. Well Construction Details

Well	*Year Constructed*	*Total Depth ft*	*Casing & Screen Diameter (in)*	*Cased Interval (ft)*	*Screened* Interval (ft)*
17	1979	180	24	0 - 60	
			14	0 - 60	60 - 90
			14	90 - 155	155 - 180+
18	1979		180	24	0 - 60
			14	0 - 60	60 - 90
			14	90 - 155	155 - 180**
19	1980	101	20	0 - 75	Open Hole
20	1980	103	20	0 - 80	Open Hole

*Screen is 14" Stainless Steel #50 slot well screen.
Depths referenced to feet below land surface (bls)
**Plugged

Bart Testing

The Biological Activity Reaction Test (BART) is a prepackaged test kit that provides a means of detection for specific bacterial groups and algae which may be present in a water source. The groups of bacteria tested were iron-related bacteria, slime-forming bacteria, and sulfate-reducing bacteria. Samples of raw water were collected and placed in bottles containing nutrients and reactants pertaining to each bacterial group. The bottles were observed for two to four weeks to see if there was a reaction in accordance with the table included with the test kit. The results of the BART analyses are tabulated in Table 2.

All three groups of bacteria were detected in all tested wells. The raw water wells and transmission mains will require additional pretreatment or remediation/disinfection and cleaning of the raw water mains prior to a membrane softening process.

Cartridge Filters

Cartridge filters serve as a pretreatment to nanofiltration in most full-scale membrane facilities. Their purpose is to remove larger particulates from raw water to prevent membrane fouling. Cartridge filters tested during the pilot study were wound, polypropylene types with a pore size of 5 micrometers. Another type of filter, the 5-micrometer Betapure filter, was also tested at the West Wellfield Composite location.

The objectives of the cartridge filter tests were to determine the rate of plugging and to observe the nature of the material being collected on the filters.

The material that accumulated on the filters was generally a gray sand. The observed rate of plugging for the filters varied from 8 days to 72 days. Cartridge filters should last for three months or longer. Such longer filter runs cannot be accomplished without changes to the wells or additional pretreatment of the source water prior to the cartridge filters to remove sand.

Well Startup Tests

One or more well startup tests were conducted at each of the wells in the West Wellfield. The primary objectives were to evaluate the amount of sand and suspended solids present during the startup of a well. A 55-gallon tank was used for collection of well water during startup of the well. The collected water was then allowed to settle for a short time, and the contents were visually examined for suspended solids and sand accumulation.

For all of the wells, an initial burst of air was noted prior to the flow of water through the discharge line. Furthermore, startups at Wells 17 and 18 resulted in the introduction of fairly significant

Table 2. Biological Activity Reaction Test (BART) Results

Well	*Date*	*Iron-related Bacteria (IRB)*	*Slime-forming Bacteria (SLYM)*	*Sulfate-reducing Bacteria (SRB)*
17	8/6/96	Clear, yellow-green, no reaction	Dense slime formers	Possible anaerobic bacteria, no SRB active
	10/4/96	No reaction	Dense slime formers	SRB community
18	8/6/96	IRB and mixed aerobes with enteric bacteria	Slime formers, some aerobic flora	Anaerobic bacteria and diverse SRB community
19	8/6/96	IRB and mixed aerobes with some anaerobic activity	Dense slime formers/ mixed bacterial population	Anaerobic bacteria and some SRB
	10/4/96	No reaction	Mixed aerobic flora	Anaerobic bacteria and no SRB activity
	10/10/96	Deep seated aerobic IRB with pseudomonades and anaerobic flora	Dense slime formers (no indication of pseudomonades)	Diverse SRB community (note: heavy whitish-gray thick slime on ball)
20	8/6/96	Deep seated anaerobic flora with pseudomonades, IRB and enteric bacteria	Dense slime formers with some enteric bacteria	Anaerobic bacteria, no SRB active
	10/4/96	IRB with deep seated anaerobic flora with possible pseudomonades and aerobic IRB	Dense slime formers with some enteric bacteria	Diverse SRB community
West Com-posite	7/9/96	Deep seated anaerobic flora with aerobic IRB and pseudomonades	Dense slime formers	Anaerobic bacteria with aerobic bacteria and some SRB
	7/30/96	Total coliform groups mixed with IRB - citrobacter may be dominant	Dense slime formers (mixed aerobic flora)	Diverse SRB community
	10/4/96	Dense slime formers with mixed IRB population	Dense slime formers associated with aerobic bacteria	Diverse SRB community
	10/10/96	Deep seated anaerobic flora with aerobic IRB; possible pseudomonades	Dense slime formers with aerobic bacteria	Diverse SRB community; note: heavy slime around ball and vial

amounts of sand. Well 20 showed little evidence of sand being present, but it was speculated that some of the particulate matter discharging from the well at startup was a type of bacteria.

Based on the results of the startups at these wells, it can be seen that, with the present manner of starting wells, significant quantities of air and sand are being introduced into the raw water transmission lines. This is a cause for concern with respect to a full scale membrane facility because air will precipitate a colloidal iron. Also, colloidal silt will pass through cartridge filters, and too much sand will prematurely clog cartridge filters. All of these can lead to rapid and severe fouling of membrane elements. If the current startup routine continues, the well water will not be suitable for membrane application without the addition of one or more pretreatment steps.

Silt Density Index Tests

The Silt Density Index (SDI) test, sometimes referred to as the fouling index or pluggage test, measures the rate of colloidal and particulate fouling by calculating the percentage of flow resistance over a period of time through a 0.45-micrometer Millipore filter at an applied water pressure of 30 psi. The maximum SDI desired for nanofiltration membrane filters is about 3.0. SDI tests were conducted at Wells 17, 18, 19, 20, and the West composite line. SDIs were taken upstream and downstream of the 5-micrometer cartridge filters. The results are summarized in Table 3.

The SDI testing results indicate that the concentration of colloids in the raw water is typically not excessive (greater than 3.0) in any of the wells. The SDI results at Well 19 indicate that no silt is being produced, even after the startup of the well. For the other three wells, the only SDIs exceeding 3.0 were measured prior to the cartridge filter following the startup of the respective well. This lends credence to the belief that a significant quantity of matter is being introduced to the water plant at the time that a well is turned on. SDIs downstream of the cartridge filters were acceptable for a membrane process for all tests conducted.

Summary

The city's wells were adequately designed for use with a lime softening treatment process. However, the wells as currently constructed and operated do not appear to be suitable for a membrane treatment process. The testing results indicated the following potential areas of concern:

Iron fouling—initial burst of air during well startup precipitating colloidal iron.

Bacteriological—slime forming bacteria buildup in wells and/or transmission piping.

Sand—too much sand for proper operation of cartridge filters.

SDIs—only a concern during certain well startups when levels reach above 3.0.

Conclusions

Some form of pretreatment is required ahead of the proposed membrane softening process to be implemented at the city's West water plant. Pretreatment can be accomplished at the head of the water plant or at the individual wells. The apparent wellfield deficiencies resulting in the above-listed concerns can be categorized as follows:

The four wells and raw water mains are over 15 years old and of unsuitable materials of construction for a membrane treatment process.

Well pumping and valving equipment are creating a surge of air, sand, slime, and other suspended matter during well startup.

Thus, it seems that the water quality itself may not necessarily be the issue. The concerns may lie with the well materials of construction and the mechanical (i.e., pumping, control valving, etc.) equipping of the wells.

A proposed approach to remedy the city's well production concerns consists of a well rehabilitation program. The wells would be redeveloped, chlorinated, and acidified. The well discharge configuration would be modified to incorporate a blow-off valve and control valve to avoid the surges currently occurring during startup. "Pigging" of the raw water transmission mains or replacement with non-metallic piping would also be considered.

An alternative to a well rehabilitation program is to address the concerns at the head of the plant. This could consist of a sand separator, multi-media pressure filters, and/or some other form of pretreatment. However, these forms of pretreatment are typically cost intensive. Based on the proximity of the West Wells to the city's West plant, it may be more cost effective for the city to consider reconstructing the West Wells and associated transmission piping with the proper materials of construction and equipment typically used with a membrane treatment process.

A current construction project for the city evaluated the replacement of Well 20. The replacement well would consist of the proper materials of construction (e.g., PVC casing, stainless steel well screen) desired for the membrane process. Consequently, it may be economically feasible to similarly replace the other three West Wellfield wells and associated transmission piping. With the expansion of the West plant, the West Well Field will require more continuous operation rather than the current practice of alternating wells and frequent start-ups.

Table 3. Silt Density Index (SDI) Results

		Before the Filter		After the Filter	
Well	Date	1st Run	2nd Run	1st Run	2nd Run
17	6/26/96	1.87	1.67	1.21	1.21
	6/28/96	9.29	2.17	1.11	1.45
	7/11/97	0.53	0.77	0.53	0.53
	7/18/96	0.69	0.89	0.92	0.92
	7/19/96	0.71	0.69	0.69	0.71
	7/22/96	0.86		0.69	
	7/26/96	1.33		0.99	
	7/29/96	2.67		1.19	
	7/30/96	2.04		1.03	
	7/30/96	1.07		1.07	
18	7/10/96	0.71	0.95	1.15	1.19
	7/11/96	3.44	0.44	0.43	0.23
	7/15/96	0.95	0.95	0.74	0.74
	7/16/96	0.74	0.74	0.74	0.74
	7/17/96	0.51	0.77	0.51	0.74
	7/18/96	0.92		0.92	
	7/24/96	0.86		0.89	
	7/26/96	1.96		1.19	
	7/29/96	1.15		1.19	
	7/30/96	1.23		1.54	
19	6/13/96	3.81	1.52	1.27	1.59
	6/17/96	0.58	1.33	error	error
	6/18/96	1.87	error	1.59	1.90
	6/26/96	1.33	1.33	1.33	0.35
	7/9/96	0.71	1.08	0.49	0.51
	7/10/96	0.24	0.49	0.74	0.65
	7/16/96	2.16	1.15	0.95	0.74
	7/17/96	0.95		0.99	
	7/22/96	1.11		0.67	
	7/26/96	0.74		0.99	
20	6/17/96	1.45	error	error	0.63
	6/18/96	2.76	1.21	1.59	1.67
	7/12/96	4.31	1.88	0.95	1.19
	7/16/96	0.74	0.74	0.95	0.95
	7/17/96	0.95	0.99	0.74	0.99
	7/24/96	1.08		1.08	
	7/25/96	1.40		1.08	
	7/26/96	1.19		1.19	
	7/29/96	0.95		0.99	
	7/30/96	1.15		1.19	
West Composite	6/18/96	1.33	1.33	1.00	1.00
	6/19/96	1.94	1.59	1.33	1.33
	7/10/96	0.48	0.95	0.77	
	7/11/96	1.72	0.77	1.19	0.77
	7/12/96	1.19	0.95	0.99	1.19
	7/12/96	0.95	0.95	0.74	0.69
	7/16/96	0.77		0.95	
	7/17/96	1.15	0.95	0.99	0.74
	7/24/96	0.67		0.86	
	7/26/96	1.33		0.99	

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Hollywood's Experience with Multi-Source Membrane Treatment Processes

Frederick Bloetscher and Roberto S. Ortiz

South Florida will face challenging water supply issues in the coming years. The area receives an average of 60 inches of rainfall each year, but that is offset by a high evapotranspiration rate, which causes 70 percent of the total rainfall to be returned to the atmosphere. In addition, over 70 percent of the area's precipitation occurs during the wet season, between June and October, the only time of year when rainfall actually exceeds the evapotranspiration rate. The extensive canals in the area drain away twenty-four percent of the total rainfall to the ocean. The excess water that neither evaporates nor is drained to the ocean, replenishes the surficial Biscayne aquifer, which is the principal raw water supply for southeastern Florida. During the remainder of the year, irrigation demands exceed total rainfall, and aquifer levels decline. The result can be saltwater intrusion.

Saltwater intrusion results in affected utilities being faced with restrictions on groundwater withdrawals permitted by SFWMD. Hollywood responded to losses in its allocations by undertaking a long-term water supply plant that evaluated raw water needs. The city pursued an approach of adding to its water supply by purchasing bulk water from Broward County, and supplementing both sources with brackish water supplies from the Floridan aquifer. However, both new water supplies require treatment beyond the lime softening treatment process currently employed by the city. As a result, the city undertook an upgrade of its water treatment process in order to accommodate the new water supplies.

Membrane softening (or nanofiltration) is employed to accommodate the raw water purchased from Broward County and to address concerns with future trihalomethane regulations by improving the treatment quality of a portion of the city's current Biscayne aquifer source. Low-pressure reverse osmosis is employed to treat the brackish Floridan supply. All three waters are to be mixed prior to pumping into the distribution system.

Historical Perspective

The city of Hollywood has operated a water treatment facility that treats local groundwater since the late 1920s. Since then, Hollywood has grown from a population of 2,500 to over 130,000, accompanied by all the associated products of development: paved areas, canals for drainage, drainage piping, and structures that reduce the percolation of rainfall. The result is permanently reduced aquifer levels, which have contributed to the landward migration of saltwater.

In the early 1960s and late 1970s, Hollywood constructed and expanded its water treatment facility with Spiractor treatment units, which involve the discharge of water into the base of the conical shaped Spiractor units, the addition of lime, and the use of a sand catalyst onto which calcium carbonate precipitates and adheres, to remove the hardness found in the water. The technology does a sound job of removing hardness from the raw water supply. Subsequent filtration and chlorination are included in the treatment process. Since the early 1980s, the city has had 37.5 MGD of treatment capacity in the Spiractor units.

The raw water supply from the Biscayne Aquifer, about three miles from the Atlantic Ocean, is generally of good quality, with the exception of organic compounds and the presence of several types of bacteria. Chloride concentrations in the wellfield average 40 to 50 mg/L. Elevated levels of organic and tannic acids exist because of natural seepage of rainwater through the overlying confining layer. Treatment objectives must consider iron and sulfur-reducing bacteria, which are protected by slime-producing bacteria. The bacteria foul membranes and reduce membrane efficiency and increase cleaning and downtime. They are extremely aggressive toward ferrous pipes.

With the passage of the Safe Drinking Water Act, Hollywood became very concerned about its ability to meet trihalomethane limits (100 ppb) because of naturally occurring organics in the raw water. Chlorination of the organics caused the city to be near the trihalomethane limit. Interim measures were taken to add ammoniation to reduce trihalomethane (THM) levels, but proposed THM limits, initially proposed to be 50 ppb, were still a concern.

When the city applied for renewal of its consumptive use (withdrawal) permits to SFWMD in 1989 and 1994, the district reduced allowable groundwater withdrawals because of proximity of the wellfields to a saltwater canal, and because of findings by the district and the USGS of saltwater migration along the coast. The city's allocation was reduced from over 30 MGD to 20.67 MGD for all wellfields. More severe limitations were placed on the city's north wellfield (0.75 MGD), which contains 10 wells with 14 MGD of capacity.

As a result, in 1990 Hollywood contracted for a 20-year assessment of its water treatment needs. The city's consultant recommended that it explore water supply diversification options and construct a membrane process to augment and/or replace the current, aging Spiractor units. Since Broward County was investigating a raw water supply in the vicinity of Hollywood, a contract was secured for up to 8 MGD of raw water from the new county wellfield. Since the new wellfield was in the planning stages, water quality data were not yet available.

In addition, during this period the city drilled a test/production well into the Floridan aquifer. Investigative studies found that the well had artesian pressure at the surface, that plenty of water was available, and that TDS levels of 2200 mg/L could be easily treated by low-pressure reverse osmosis. Heeding the consultant's recommendation to pursue multiple water sources, the city decided to construct the new membrane process with both salt and freshwater components.

Design of Membrane Facility

The consultant, Metcalf & Eddy, designed the new membrane facility. As a part of its charge, the city required that the water quality from all three processes be compatible with one another. This included addressing the potential undersaturation of the reverse osmosis water by mixing with lime softened water, prevention of significant deposition of hardness on pipes, and meeting all SDWA requirements.

The first step in the evaluation of the membrane softening process was to define the operational parameters. A pilot plant study was conducted to evaluate the operation of the proposed membrane design and to verify that the desired quality of treated water was achievable with the existing raw water supply from the Biscayne and Floridan aquifers.

The initial plan was to design a 30-MGD membrane facility consisting of 14-MGD reverse osmosis and 16-MGD membrane softening. A facility of such size was much larger than initially needed, so 14 MGD of membrane softening and 4 MGD of reverse osmosis membranes were installed initially. They would treat the brackish Floridan water and the new county source, which the staff felt would be of poorer quality than the city's Biscayne wells.

The process flow schematics for membrane softening and reverse osmosis treatment are virtually the same, including pretreatment, membrane treatment, and post-treatment. However, there are significant design considerations that must be accounted for in low-pressure reverse osmosis processes. The process recovery rate for membrane softening is 85%, while the reverse osmosis system is estimated to produce a 75% recovery. The reduced recovery by the reverse osmosis process increases the quantity of raw water required to produce the same amount of permeate from one process skid, while producing a larger waste stream of concentrate.

The construction material for the raw water piping was stainless steel. The pipelines were installed above ground to allow for easier maintenance, field observations, and to avoid underground conflicts on the plant site. A scale inhibitor and sulfuric acid are injected into the water to stabilize the water before it flows into the cartridge filters. The design pH for the membrane softening process is 6.0, whereas the reverse osmosis system is designed for a pH value of 6.5.

Cartridge filtration is essential for removal of suspended particulates larger than five microns from the raw water. There are four stainless steel cartridge filters with over 300 40-inch elements in each. The cartridge filters were installed vertically to allow for ease in removing the covers. The maximum flow rate is between 2 and 3 gpm per element.

Once the feedwater is chemically conditioned and suspended solids are removed, it is delivered to the stainless steel feed pumps. A dedicated feed pump supplying each skid increases the feedwater pressure prior to applying the feedwater to the membrane process. The vertical turbine pumps were initially sized for the membrane softening process to deliver 1544 gpm with an operating pressure of 130 psi; 1740 gpm with an operational pressure of 400 psi for the reverse osmosis skids.

The configuration of the membrane skids accommodates two stages of softening membranes and two stages of reverse osmosis membranes. The skids are designed to hold 54 pressure vessels. Each of the membrane softening pressure vessel houses 7 Hydranautics 8040-LSY-PVD1 membrane elements. The reverse osmosis system uses Hydranautics CPA2 membranes with a recovery rate of 75%.

After passage through the membrane skids, the reverse osmosis and membrane softening permeates are combined. The residual pressure allows the water to move the post-treatment processes, which consists of degasification and chemical addition. The permeate flowstreams contain hydrogen sulfide and carbon dioxide gases. While this amount is minimal in the Biscayne water, the Floridan aquifer supply contains about 3.5 mg/L of hydrogen sulfide. The degasifiers remove hydrogen sulfide from the permeate flow streams. The gases are released from the flow stream by forced-draft degasification. The initial design for the permeate flow stream requires two degasifiers. An odor control system is required for the removal of hydrogen sulfide produced by the permeate degasifiers. Two-stage, packed scrubbers with equally sized reaction vessels use sodium hydroxide and sodium hypochlorite for the odor removal process.

The post-treatment chemicals are sodium hydroxide, zinc orthophosphate, sodium, silicofluoride, ammonia, and chlorine. The chemical system equipment (i.e., pipes, valves, feed equipment, chemical storage) is designed to accommodate the feed requirements when the initial 18 MGD is expanded to 30 MGD. After chemical addition, the membrane process waters are combined with the lime softening water and pumped to onsite storage tanks and the distribution system.

The membrane cleaning/flushing system consists of cleaning and flushing solution tanks, 5-micron cartridge filters, and cleaning pumps. The cleaning pumps are constructed to handle high and low pH cleaning chemicals. The cleaning system is designed to accommodate future needs when the system is expanded.

A membrane system shut-down flush is required every time a membrane skid is taken out of operation. The raw water in the membrane elements is replaced with permeate water from the permeate flushing tank. The permeate is pumped through the membrane elements using the feed pump at low pressure. The permeate flushing system is designed to meet future design conditions.

Membrane treatment facilities produce a waste stream commonly referred to as "reject water" or "concentrate." EPA has classified that waste stream as an industrial waste, thereby requiring the city to acquire an industrial wastewater discharge permit from DEP. Because the City's wastewater treatment plant currently disposes of treated effluent via ocean outfall, the city applied for a permit to discharge the concentrate in the same manner, under the premise that it was just concentrated groundwater. The state is in the process of issuing the permit. A back-up disposal via the wastewater treatment plant was also installed.

The treatment plant includes all facilities necessary to produce 18 MGD of finished water, with the provision to install the remaining units at a later date in space that is currently available for the planned expansions. Most of these expansions can be accomplished with minimal impact on continuous plant operation.

The new facility includes a central supervised computer system that allows operations staff to operate and monitor both the lime softening and membrane treatment process from one location. The computer system will also allow the operators to monitor the entire water distribution system, including the wellfields and tanks, and to monitor the wastewater system during storm events.

Construction

Construction began in the fall of 1993. Raw water was introduced in the summer of 1995, with a dedication of the facility on February 5, 1996. During the two years of construction, the most difficult issues to address have been resolving control system integration problems and bacteria in the raw water. The level of bacteria has caused the city to evaluate the continued use of a number of wells, to review modifications to most of the remaining wells, and to initiate a wellfield disinfection program to attenuate the bacterial problems.

The Broward County supply contains even higher levels of bacteria, so to date the source has been unavailable for treatment by the membranes. Upon Broward County being able to reduce the bacteria levels to acceptable levels, the water supply will be delivered to Hollywood's membrane softening system. Until then, no deliveries will be made because the color in this water supply is too high for lime softening process to handle adequately.

The total cost of the facility, including engineering and the concentrate disposal, was $23 million. Future expansion in 2 MGD increments will cost approximately $1.5 million each. The costs of this plant, among the most reasonable for all large membrane facilities in Florida, are similar to what would be expected for more conventional treatment, yet the plant provides significant operator flexibility, improved water quality to customers, and a longer plant operating life.

Annual operating costs are estimated to be about $2.7 million per year. The operating costs of the three processes are $0.45 to $0.55, $0.62, and $0.75 per thousand gallons for the lime softening, membrane softening, and reverse osmosis, respectively. Wells and pumping add about $0.13 to the cost of production.

Conclusions

The new membrane treatment process will help Hollywood meet its potable water demands over the next 20 years. The increase in plant capacity has allowed the city to explore the sale of high quality water to smaller, neighboring utilities, while solving water quality problems in its own system.

The facility can treat both freshwater and brackish water at the same time using divided piping systems integrated into the plant. It is one of the first in the world to install this capacity for both sources in one plant. Expansions can be made economically with minimal disruption to current operations, which benefits all city customers. The costs are comparable to what would be expected for lime softening or similar treatment processes, and therefore do not adversely impact users. Costs will be stable over the long term using this technology.

Membrane treatment is a viable technology and solution for areas with significant amounts of saltwater and variable amounts of freshwater, areas of critical environmental concern and drought-prone areas with saltwater sources. The concept behind the design addresses use of current membrane technology for solving future changes in regulations, changing water sources and quality, and flexibility in operations.

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