DRINKING WATER QUALITY ISSUES FOR DELTA SOURCE WATERS

ISSUE PAPER

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IMPACTS OF DELTA WATER QUALITY ON THE
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Summary

Meeting the existing drinking water regulations at Metropolitan using water from the Delta has been achievable through moderate modifications in treatment and costs. It has required Metropolitan to "optimize" filtration (defined as achieving an effluent turbidity of 0.1 NTU), and convert from free chlorine to chloramines. Metropolitan's costs for these process changes are estimated at $5-6 million for capital and $300,000-$500,000 for annual O&M costs.

Meeting the new or pending regulations when treating SPW subject to contamination in the Delta, however, will have significant impacts to Metropolitan. Likely requirements for enhanced coagulation may cost Metropolitan's customers in Southern California $120 million in capital facilities and approximately $100 million/year in O&M costs. Enhanced coagulation, or even reverse osmosis, may also be required for Metropolitan to meet a revised arsenic MCL. Enhanced coagulation may cause operational problems at Metropolitan by shifting the point in treatment where disinfection requirements are met. Although ozonation may be required for adequate disinfection, excessive bromate levels are produced in SPW unless a reliable bromate removal technology is developed. Finally, if bromate production cannot be controlled, Metropolitan could be forced into using GAC, which has environmental impacts as well as an estimated capital cost to Metropolitan's customers of $2-3 billion.

Collectively, this information suggests that the simple, economic, and technological improvements in water treatment previously used to meet drinking water regulations when treating Delta water may no longer be an option. It is essential that source water protection issues in the Delta be given a much greater emphasis, and the new regulations are the driving force for this approach. Otherwise, the impact of financing new treatment facilities may be a severe restriction on the Southern Californian economy or a potential loss of supply if treatment is not feasible.

IMPACTS OF DELTA ON METROPOLITAN'S ABILITY TO MEET EXISTING DRINKING WATER REGULATIONS

Trihalomethane Precursors

As water passes through the Delta the levels of total organic carbon (TOC) and bromide increase primarily from agricultural drainage and saltwater intrusion, respectively. Both TOC and bromide are precursors of disinfection by-products

(DBPs). The current DBP regulation specifies a total THM standard of 0.10 mg/L, which applies only to utilities serving a population of ≥10,000. This regulation was promulgated in 1979. In anticipation of the regulation, Metropolitan began a survey of its Colorado River and State Water Project source waters in 1979 to determine the quantity and distribution of THMs with respect to source water (see Attachment 1 for a description of Metropolitan's system). Results of this early work demonstrated that the Delta was a major source of THM precursors and that chlorination of SPW from the Delta consistently produced THMs in excess of 0.1 mg/L.

Impact of THM Standard on Metropolitan

Initial efforts to reduce THM levels at Metropolitan consisted of adjustments in the dosage and location of chlorine application, and optimization of the coagulation process. Although this work demonstrated that THM levels could be reduced to below the standard in Metropolitan's system, some of it's member agencies would still violate the standard because of extended detention time in the system or rechlorination practices. This concern provided the impetus for Metropolitan to convert from free chlorine to chloramines for disinfection in 1984. It was well recognized that chloramines form fewer THMs than does chlorination. Initially, chloramines were applied via preammoniation (i.e. ammonia ahead of chlorine), to minimize the presence of any free chlorine which could lead to elevated THMs. However, this application technique was abandoned for a prechlorination procedure (free chlorine at the plant influent and post-filtration ammoniation to generate a chloramine residual in the distribution system) because of the inability of preammoniation to remove certain tastes and odors. Although prechlorination produced significantly higher THM levels than preammoniation, both Metropolitan and its member agencies were able to comply with the 1979 total THM standard and certain T&O problems were controlled.

One negative impact on water quality resulting from the changeover to chloramines has been the occasional occurrence of nitrification. In this biologically-mediated process, the ammonia used to form chloramines is oxidized sequentially to nitrite and nitrate by nitrifying bacteria. This can result in a complete loss of ammonia and chloramine residuals. The absence of a disinfectant in the distribution system may cause a utility to be out of compliance with one of the provisions of the Surface Water Treatment Rule (SWTR). To minimize nitrification, Metropolitan developed strategies for controlling the growth of nitrifying bacteria.

Also, because of the toxicity of the chloramine molecule should it enter the bloodstream, extensive notification had to be made to those using kidney dialysis facilities and to aquarium owners. Granular activated carbon (GAC) had to be installed at all kidney dialysis facilities to ensure chloramine removal.

It is significant to note that Metropolitan would not have had to switch to chloramines were it not for the elevated levels of THM precursors produced in the Delta. In addition, the SWTR, which goes into effect in June, 1993, precludes the use of chloramines as a primary disinfectant at Metropolitan's plant, so predisinfection with chlorine or ozone is required.

Cost Impact of Chloramines

The estimated capital cost for Metropolitan to switch to chloramines in 1984 was $5.8 million and the estimated operation and maintenance costs were approximately $325,000 per year (in 1984 dollars).

Selenium and Pesticides

Although both selenium and pesticides are released in the Delta, extensive monitoring at Metropolitan has demonstrated that these constituent do not impact Metropolitan's water quality. In spite of the potential for selenium to enter the Delta via the San Joaquin River, Metropolitan has only detected selenium in one sample (at a level of 1 ug/L, which is substantially below the current and proposed standards of 10 and 50 ug/L, respectively) of its SPW source water reservoirs since monitoring for selenium began in 1985. Similarly, Metropolitan has detected only a few pesticides (Atrazine, Simazine, and Dibromochloropropane) in its SPW source water reservoirs, and all **were well below the MCLs and even the minimum reporting limits. These compounds are decomposed by the time they reach Metropolitan's source water reservoirs through natural mechanisms.**

Asbestos

In 1981, Metropolitan optimized its treatment process to achieve an effluent turbidity goal of 0.1 NTU. Although the primary purpose of optimizing treatment was an interim measure to reduce pathogens and THM precursors, it also enhanced asbestos removal. Asbestos concentrations were higher in Metropolitan's SPW supplies than in CRW, owing to some contribution from the Delta watershed. However, asbestos levels in SPW were well below the MCL.

Tastes and Odors

Occasionally, Metropolitan experiences taste and odor (T&O) problems in SPW. High levels of the earthy/musty odorants 2-methylisoborneol and geosmin have been detected in Castaic Lake, Lake Perris and Lake Skinner. More recently, high concentrations of MIB have been detected in the East Branch Aqueduct. Although the algae responsible for producing these malodorants have been identified, it is unclear if passage of SPW through the Delta is a factor in T&O production.

IMPACTS OF DELTA ON METROPOLITAN'S ABILITY TO MEET NEW OR PENDING DRINKING WATER REGULATIONS

DBP Precursors

The U. S. Environmental Protection Agency (EPA) is currently conducting a regulatory negotiation (reg-neg) in order to develop a consensus-based regulation for disinfectants and disinfection by-products (D/DBP). Metropolitan is a participant in this process. Recently, a tentative agreement has been reached on certain elements of the rule, which will likely consist of MCLs for total THMs (80 ug/L), total haloacetic acids (total HAAS--60 ug/L), and bromate (likely set at 5 ug/L). The rule will also include limits on disinfectant residual in the distribution system.

In addition, surface water utilities operating conventional treatment plants, with treated-water TOC levels exceeding 2.0 mg/L, would be required to implement enhanced coagulation to maximize DBP precursor removal. EPA's rationale is that by reducing TOC levels, unknown or potential health risks are also decreased. Enhanced coagulation would be defined based on achieving specific TOC removal, depending upon source water TOC levels and alkalinity. Application of a chlorine-based primary disinfectant would be delayed until after sedimentation. Specified TOC removals would be accomplished through the use of increased coagulant dosages and decreased pH levels.

The D/DBP rule is scheduled for proposal in 1993 with promulgation in 1995 and compliance required in 1997. A second reg-neg scheduled for 1988 may reduce the MCLs for total THMs and THAAs, introduce standards for other DBPs, and may even require installation of expensive best available technologies (e.g., GAC). Compliance with this later DBP regulation would be required by 2005.

The reg-neg approach represents a significant shift in EPA's approach for developing a D/DBP rule from earlier proposals since it considers the need for a balanced approach for microbial and chemical risks. For example, in the D/DBP rule proposed in 1989, EPA indicated their intent to lower the THM standard to 25 or 50 ug/L, and to set MCLs for individual THMs, haloacetic acids, and several other disinfectants or DBPs. EPA recognized that reducing disinfection to limit the formation of by-products may increase the risk of waterborne disease.

In anticipation of EPA's intent to lower the total THM MCL, Metropolitan implemented a monthly monitoring program in 1990 to survey its source waters to determine the levels of DBP precursors and THM levels expected in the distribution system following disinfection. Importantly, this program included samples of SPW above and below the Delta to ascertain the impacts of seawater intrusion and agricultural drainage on THM formation. Samples were collected at Greene's landing (above the Delta on the Sacramento River), H. O Banks (immediately below the Delta), checkpoint 13 (California Aqueduct), Foothill Pressure Control Structure (West Branch terminus), Devil Canyon Afterbay (East Branch terminus), and Lake Mathews (Colorado River Aqueduct terminus). Data collected from November, 1990 through September, 1992 clearly demonstrate that Metropolitan's current treatment processes would produce total THM levels in excess of the proposed standard when treating Delta water (Attachment 2). For example, the total THM level predicted in Metropolitan's system (based on a 3 hour exposure to chlorine with a 1-1.5 mg/L residual, at 25°C) using water from above the Delta was 28 ug/L, whereas a sample from below the Delta (H.O. Banks) generated a mean THM level of 100 ug/L, with a range of 59 to 201 ug/L. Chlorination of CRW produced an average THM level of 33 ug/L. The mean simulated THM levels in East and West Branch terminus waters were 76 and 95 ug/L, respectively.

Impact of D/DBP Rule on Metropolitan

Metropolitan should be able to comply with proposed MCLs for total THMs (80 ug/L) and total HAAs (60 ug/L) under current operating conditions, except when 100 percent SPW is treated. However, some of Metropolitan's member agencies will not meet these standards if they are primarily using Mills or Jensen plant water in their distribution systems. Importantly, since Metropolitan's treated water TOC levels exceed 2.0 mg/L, Metropolitan would be expected to implement enhanced coagulation at all of its plants. The total THM and total HAA MCLs should be achievable in SPW when enhanced coagulation is utilized. The target TOC removal required for SPW is greater that that for CRW because it has lower alkalinity. Achieving the target removal for SPW will require an alum dosage of 40 mg/L and lowering the pH of the water to 6.3. Implementing enhanced coagulation has implications for complying with the disinfection requirements of the SWTR, since disinfection would have to be delayed until after the sedimentation process. In addition, this process will significantly impact sludge production and increase corrosion concerns within the sedimentation basins. Furthermore, special handling of sulfuric acid will be required. Metropolitan is currently studying enhanced coagulation at its 5.5 MGD demonstration-scale facility.

Cost Impact of Enhanced Coagulation

The total capital cost for implementing enhanced coagulation at Metropolitan is estimated at $120 million. This amount includes the capital costs for alum, caustic soda, and sulfuric acid, chemical storage and feed facilities and containment. The annual O&M costs to our customers for implementing enhanced coagulation at Metropolitan is estimated at $48 acre-ft (approximately $100 million annually for both State Project and Colorado River supplies).

Disinfection Requirements Under the Surface and Enhanced Surface Water Treatment Rule

EPA's SWTR takes effect in June, 1993. This regulation requires specific requirements for the removal and inactivation of Giardia (minimum of 99.9%) and enteric viruses (minimum of 99.99%). Since Metropolitan has conventional or direct filtration at all of its facilities, only a portion of the pathogen removal requirements must be met by disinfection. Metropolitan will be able to comply with the SWTR requirements in its current mode of disinfection (i.e. prechlorination, postammoniation, but not preammoniation). However, Metropolitan may have difficulty if enhanced coagulation is implemented since it would require delaying the disinfection process until after sedimentation or filtration. Disinfection requirements for Giardia and virus would have to be achieved either across the filters or in the clearwell. However, using the clearwells for primary disinfection (free chlorine at the influent and ammonia at the effluent) would no longer provide operational flexibility should an equipment or operational problem develop, and will result in increased DBP formation. The disinfection constraints could be alleviated by disinfecting solely with free chlorine, were it not for the elevated levels of DBP precursors in SPW from the Delta.

Another benefit of ozone is that it is a strong disinfectant and could readily achieve the necessary disinfection requirements in the SWTR. However, the excessive bromate levels formed with ozonating SPW may limit its usefulness at Metropolitan, unless potential bromate control strategies are successful and cost effective.

EPA has indicated its intent to develop an Enhanced SWTR. This regulation would require additional percent removals of Giardia and viruses, based on source water pathogen levels. This regulation may also include removal requirements for Cryptosporidium, another protozoan parasite. Because of the extensive agricultural runoff and municipal wastewater discharges into the Delta, it is likely that significant quantities of pathogens are entering the SPW aqueduct. Results of a comprehensive one year pathogen monitoring program in Metropolitan's source water reservoirs has shown low but persistent levels of Giardia, Cryptosporidium and viruses. It is likely that the pathogen levels are greatly reduced due to settling and natural purification in the reservoirs, owing to the extended detention times in water transported from the Delta. Metropolitan is presently analyzing samples collected immediately above and below the Delta to determine pathogen loading from municipal and agricultural runoff. Depending upon the levels found, utilities that withdraw water closer to the Delta may be required to achieve higher pathogen removal requirements, which would substantially increase costs.

Bromate Issue and Ozonation

As an alternative to chlorination, utilities may be able to apply ozone to the raw water for primary disinfection. However, it must be followed by biological filtration to reduce assimilable organic carbon and aldehyde levels. The secondary disinfectant would be applied to the filtered water. Unfortunately, ozonation of waters containing bromide produces a myriad of brominated DBPs, the most significant of which is bromate. Although a bromate MCL has not yet been established, EPA is likely to regulate it at the 10^{-4} risk level, which is 5 ug/L. Extensive research at Metropolitan has shown that ozonation of SPW (with bromide concentrations ranging from 0.3-0.5 mg/L) consistently produces bromate at concentrations above the expected MCL range. By comparison, ozonation of CRW does not form detectable levels of bromate. Bromate formation is highly dependent upon ozone residual and concentration of bromide in the source water. Metropolitan also participated in a survey to determine bromate formation in ozonated waters from ten utilities across the US. The results of these findings confirmed

Metropolitan's results concerning the importance of bromide levels and ozone residuals on bromate production. It was observed that bromate was not detected (detection limit of 5-10 ug/L) when the bromide concentration was approximately 0.1 mg/L, when the ozone demand of the water was met. This bromide concentration is lower than recently observed in SPW. Based on the ratio of chlorine-to-bromide in seawater (the major source of bromide in SPW) chloride levels below 30 mg/L would ensure minimal bromide levels for bromate detection. As higher ozone levels are needed for additional disinfection or for T&O control, more bromate will be formed. Lowering the pH can minimize bromate production, however, it has not consistently reduced bromate levels below the possible MCLs in the demonstration-scale facility. Hence, GAC may have to be implemented in lieu of ozone. The current estimated capital cost for GAC at Metropolitan is $2-3 billion and annual O&M costs are approximately $100 million. These costs would be borne by Metropolitan's 15 million customers, placing severe economic burdens on the Southern California economy.

These findings strongly suggest that ozonation of SPW will not be acceptable unless bromate control strategies are employed or salt water intrusion in the Delta is eliminated. Preliminary work at Metropolitan indicates that reducing the pH of SPW to 6.0-6.3 prior to ozonation will minimize bromate formation. Lowering the pH, however, will impact the ability of ozone and may impact PEROXONE (a combination of ozone and hydrogen peroxide) to control T&O compounds.

Arsenic

EPA intends to propose a new MCL for arsenic by September 1994, which is likely to be dramatically lower than the current MCL of 50 ug/L. New scientific health effects studies have recently been completed which indicate that very low levels of arsenic in drinking water are carcinogenic. The 10^{-4} lifetime risk level for excess cancers corresponds to an arsenic level of 0.25 ug/L. Arsenic concentrations in Metropolitan's source waters range between 2 and 5 ug/L and the current detection limit is 0.5 ug/L. Based on a recently completed nationwide survey by Metropolitan, it appears that that arsenic is primarily a California problem.

Impact of Arsenic Revised Arsenic Regulation on Metropolitan

A new arsenic MCL of 5 ug/L or less could require additional treatment with enhanced coagulation using high dosages of alum or ferric chloride. Enhanced coagulation may also be required as part of the new D/DBP regulations as described above. More significantly, reverse osmosis (RO) could be required if the new standard is 0.5 ug/L or less. If required, RO would cost Metropolitan approximately $15 billion. At present, it is not clear what is the source of the arsenic in SPW is coming from the Delta. Metropolitan is currently studying the effect of varying coagulant dosages and reduced pH on arsenic removal at its demonstration-scale facility.

ATTACHMENT 1

DESCRIPTION OF METROPOLITAN'S SYSTEM

The Metropolitan Water District of Southern California (Metropolitan) is a public and municipal corporation of the State of California, which provides supplemental water as a wholesaler through 27 member agencies (cities and water districts) to over 15 million people in a 5,200 mi^2 service area on the coastal plain of Southern California. Approximately one-third of this supplemental water (700,000 acre-ft) is imported through 242 miles of aqueduct from the Colorado River. Initial deliveries of Colorado River water (CRW) began in 1941. The Colorado River Aqueduct terminates in Lake Mathews (186,000 acre-ft), which receives exclusively CRW.

In addition, Metropolitan has contracted to receive more than (2 million acre-ft) annually of Northern California water through the 444-mile-long State Water Project. First deliveries of SPW began in 1972. The aqueduct extends south from the Sacramento-San Joaquin Delta (Delta) along the western edge of the San Joaquin Valley to the base of the Tehachapi Mountains. The water is pumped to the crest of the Tehachapi Mountains, and is then diverted into the East and West Branch Aqueducts. Five reservoirs in Southern California provide storage of SPW for Metropolitan's facilities. Water flows from Pyramid Lake (171,200 acre-ft), the uppermost reservoir in the West Branch to Castaic Lake (323,700 acre-ft). East Branch water flows into Lake Silverwood (74,970 acre-ft) and can be conveyed to Lake Perris (131,450 acre-ft) and Lake Skinner (52,000 acre-ft). Lake Skinner can also receive CRW via the Colorado River Aqueduct.

Metropolitan currently has five conventional filtration plants (one of which incorporates a direct filtration module) with a combined treatment capacity of 2.1 billion gallons per day. The Joseph Jensen and Henry J. Mills Filtration Plant receive West and East Branch water, respectively, (on a few occasions the Jensen plant has received water from the Los Angeles Aqueduct, which transports water from Mono Lake in Owens Valley). The Frank E. Weymouth and Robert B. Diemer Filtration Plants treat a blend (ranging from 0 to 100%) of East Branch water from Lake Silverwood and CRW from Lake Mathews. The Robert A. Skinner Plant receives a blend of East Branch SPW from either Lake Silverwood or Lake Perris, and CRW from a turnout on the Colorado River Aqueduct before it enters lake Mathews.

ATTACHMENT 2

IMPACT OF DELTA WATER QUALITY ON
TOTAL ORGANIC CARBON (TOC), BROMIDE, AND TOTAL TRIHALOMETHANES*

SITES	TOC (mg/L)			BROMIDE (mg/L)			Total THMS** (μgL)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Greene's Landing (above Delta)	1.97	1.26	4.31	0.02	0.01	0.03	28	20	49
H.O. Banks (below Delta)	4.02	2.32	8.56	0.34	0.09	0.57	100	59	201
Check Point 13 (below Delta)	3.98	2.42	5.84	0.36	0.12	0.51	103	58	168
Foothill PCS (West Branch terminus)	2.85	2.38	3.61	0.32	0.28	0.35	76	54	95
Devil Canyon (East Branch terminus)	3.34	2.54	4.12	0.35	0.24	0.46	95	68	143
Lake Mathews (CRW terminus)	2.86	2.57	3.21	0.08	0.08	0.09	33	28	36

*Based on monthly analyses from 11/90-9/92.
**Simulated distribution system THMS, 3 hour exposure to free chlorine, 1-1.5 mg/L residual, 25°C, jar treatment.