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CITY OF SACRAMENTO

DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER AND SEWERS

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January 28, 1985

CITY MANAGER'S OFFICE
RECEIVED
JAN 30 1985

Transportation and Community Development Committee
Sacramento, California

Honorable Members in Session

SUBJECT: Disinfection of the City's Drinking Water

SUMMARY

On August 30, 1983, staff presented to Council a report on the disinfection practices used for the City's drinking water. This report responds to a request for further discussion of this subject.

BACKGROUND

Staff presented the attached report to Council in response to concern about adverse health effects caused by the presence of chlorination by-products in the City's Drinking Water (SEE ATTACHMENT A). When chlorine is added to disinfect the water taken from the American and Sacramento Rivers, compounds collectively known as trihalomethanes are formed. These compounds have been found to cause cancer in animals and thus are suspected human carcinogens. The City is fortunate that the quality of the American and Sacramento Rivers is such that the concentration of trihalomethanes is low compared to other municipalities in California and throughout the Nation. The U.S. Environmental Protection Agency and the California Department of Health Services have established a legal maximum concentration of trihalomethanes to be allowed in drinking water. This standard is 100 parts per billion (ppb). The drinking water supplied the City's residents from the American and Sacramento Rivers contains less than half the legal maximum (approximately 40 ppb).

The legal standard was based on a number of factors. Health risk, reliability of alternatives, practical compliance limitations, and ability of communities to finance alternatives were all considered in arriving at the 100 ppb standard. Federal and State health officials all recognize that the trihalomethane standard is a trade-off of benefit vs. risk.

Trihalomethanes are a group of compounds of which chloroform is the principle member. Chloroform is a ubiquitous compound. It is found everywhere. Contact with the Air Resources Board has disclosed that chloroform is present in California even in the air we breath at concentrations ranging from .05 to .50 ppb. Just as professionals in the water industry would prefer that concentrations in drinking water be zero, professionals in air pollution control would also like to see zero concentrations of chloroform in the air we breath. Mitigation measures in both fields are currently under heavy scrutiny.

In the United States, health experts and municipalities have not taken action to mitigate concentrations of trihalomethanes in drinking water unless they have exceeded the 100 ppb standard. Mitigation measures are expensive and have resulted in problems which were not anticipated. For example, in at least ten public water systems in California the decision was recently made to change the disinfection system from free chlorination to a chlorine-ammonia process which does not result in the formation of trihalomethanes. This solution resulted in severe problems (SEE ATTACHMENT B). Citizens who were on kidney dialysis systems suffered acute anemia including rupturing of red blood cells as a result of the residual chlorine-ammonia compounds in the water supply. This occured in spite of comprehensive attempts to notify dialysis centers that precautionary measures would be necessary.

AVAILABLE ALTERNATIVES

There are two general methods for reducing the levels of trihalomethanes. The first method utilizes the principle of using a disinfectant other than free chlorine thus preventing the formation of these compounds. The second method is the adsorption of trihalomethanes using activated carbon.

I. ALTERNATE DISINFECTION SYSTEM

As indicated in the 1983 report, alternatives to free chlorine as a disinfectant in water treatment include chloramines, chlorine dioxide, ozone, potassium permanganate, hydrogen peroxide, bromine, iodine, ferrate ion, high ph, and ultraviolet radiation. A tremendous amount of research on the national and international level has shown only chloramines, chlorine dioxide, and ozone systems to be feasible for large scale domestic water disinfection.

A. Chloramines

This system consists of adding ammonia to the water prior to introducing chlorine. The chlorine then reacts with the ammonia before reacting with any other organic compounds. If the ammonia concentration is high enough, trihalomenthanes will not be formed. The advantages of chloramine disinfection are: (1) It reduces the levels of trihalomethanes to non detectable; and (2) It is the most cost effective of viable alternatives. The additional cost to the system is solely for equipment to feed ammonia into the process prior to the application of chlorine plus the cost of the ammonia itself. To install such a system in our facilities would require an initial expenditure of approximately $240,000 and ongoing annual expenses of about $35,000. The disadvantage of using chloramines is the aforementioned toxicity of the chlorine-ammonia residual disinfectant to patients on renal dialysis. Even where comprehensive attempts were made to contact these patients to notify them that the water to their machines needed special treatment, many failures occured. In fact the Department of Health Services has placed a moratorium on the use of chloramines to disinfect drinking water until such time as studies indicate it can be used with no health risk.

B. Chlorine Dioxide

Chlorine dioxide has been used traditionally in water treatment to control taste and odors. The City of Sacramento has used this process in the past to combat tastes and odors caused by the presence of phenolic compounds in the Sacramento River. Both the Sacramento River and American River facilities retain the capabilities to add chlorine dioxide to the process water. However, the existing system would result in the presence of both chlorine dioxide and free chlorine in the water with the finished water still containing trihalomethanes. In order to use chlorine dioxide as a disinfectant and eliminate trihalomethanes in the water, a new system would be necessary. The benefits of chlorine dioxide are: (1) It does not react with ammonia or materials which form trihalomethanes thus eliminating chloramines and trihalomethanes from the finished water; and (2) It is an effective process to control certain tastes and odors particularly those caused by phenolic compounds. The risks associated with chlorine dioxide are principally the residual chemicals present in the drinking water. The chlorite ion is known to have adverse health effects, and therefore the process control is to have the residual present solely as chlorate. This is sometimes difficult to achieve.

A consultants estimate in 1978 projected the cost of replacing our present system of chlorination with chlorine dioxide to be an initial capital cost of $674,000 with an annual ongoing cost of $3,117,700. Based on the uncertain health risks of the residual disinfectant it would also be necessary to obtain the approval of the Department of Health Services to install such a system.

C. Ozone

Disinfection with ozone has been used in Europe for many years. There is a slightly different philosophy in treating the drinking water. In European Countries most large treatment plants are preceded by natural sedimentation in pretreatment reservoirs. This allows a period of up to thirty days settling time prior to the treatment with chemicals. A great deal of the organic material in the water is thus removed prior to the disinfection process. This process would be very difficult and expensive to implement where natural storage reservoirs such as large lakes do not exist. The European method consists of using ozone to achieve primary disinfection and finally adding chlorine to give residual disinfection to the distribution pipelines.

The major advantages of ozone are: (1) It has high disinfecting effectiveness; (2) Its potency is unaffected by ammonia or pH of the water; and (3) When the reactions are complete, the residual material is oxygen. The disadvantages include: (1) It has an instantaneous reaction and retains no residual disinfecting powers. This requires the addition of either chlorine or chlorine dioxide after treatment to protect the distribution system. If chlorine is added in low amounts there may be chloramines present in the drinking water. If chlorine is added to a free chlorine residual, there may still be enough organic material to form trihalomethanes. (2) Instability and explosiveness requires the chemical to be generated on site. This is expensive and requires a great deal of electrical energy.

The cost of replacing our existing system with ozone and supplemental chlorination was estimated in 1978 to be $4,277,500. The ongoing annual costs were estimated to be $200,000.

This alternative would also require the permission of the Department of Health Services.

II. REMOVAL OF TRIHALOMETHANES

The second method of eliminating trihalomethanes in drinking water is to remove these compounds after they have been formed. This method is the use of deep bed granular activated carbon filters. The degree and efficiency of removal is proportional to the contact time between the water and the carbon. It would be possible to install such a system at our existing water treatment plants but very expensive. The benefit of this system is the removal of the trihalomethane compounds without forming additional compounds which may be of concern.

The disadvantages of this system are many. The activated carbon filters would require a comprehensive modification of the treatment process. It would be necessary to increase energy consumption to restore the water to the elevation lost because of the depth of the filters. The carbon would be depleted of its effectiveness after a period of use and would have to be regenerated by high temperature methods. For processes as large as the City's, on-site regeneration equipment would be required. Also, in order to retain residual disinfectant protection in the distribution system, it would be necessary to rechlorinate the water after carbon treatment. The resultant drinking water would still contain compounds of residual chlorine.

It is estimated that the initial capital costs necessary to install granular activated carbon systems at the City's treatment plants would be in excess of 12 million dollars. The ongoing annual costs would be approximately 1.5 million dollars per year.

CONCLUSIONS

The most viable alternatives to our present practices are using ozone supplemented by chlorination, or using granular activated carbon followed by rechlorination. Both methods would result in the removal of trihalomethanes from the City's drinking water, but it would still be necessary to maintain residual products of chlorination in the distribution system.

Staff would reiterate that the only places in the state or nation where communities are taking steps to lower concentrations of trihalomethanes are in locations where they cannot meet the 100 ppb standard. Staff sees no current alternative which would result in a significant improvement to our system.

The City is also currently on the brink of making decisions concerning future expansion of our water production system. A decision to implement expensive treatment systems would greatly increase the cost of expansion.

FINANCIAL

There is no financial cost or liability associated with this report.

RECOMMENDATION

Staff recommends the continuation of present policy in the disinfection of the City's drinking water.

Respectfully submitted,

Larry Comarsh
Water & Sewer Division Manager

Recommendation Approved:

Solon Wisham, Jr.
Assistant City Manager

Approved:

Melvin H. Johnson
Director of Public Works

LJH:rg
attachments

14-R-010-00-0

CITY OF SACRAMENTO

ATTACHMENT A

DEPARTMENT OF ENGINEERING

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J.F. VAROZZA
CITY ENGINEER
M.H. JOHNSON
ASSISTANT CITY ENGINEER

August 23, 1983

City Council
Sacramento, California

Honorable Members in Session

SUBJECT: Chlorination Disinfection By-Products - City of Sacramento's Drinking Water

SUMMARY

An overview of the chlorine disinfection process utilized at American and Sacramento River Water Treatment Plants.

BACKGROUND

Prior to 1900, water used for drinking by U.S. Citizens was not disinfected. As a result of this practice, massive outbreaks of water-borne diseases occured in epidemic proportions. The most serious of these were typhoid and cholera. In Sacramento, California there was a massive outbreak of cholera in the 1850's which caused a large number of deaths. People were literally abandoning their families as they fled the City. A mass burial site still exists at the Broadway Cemetary to remind us of the danger of drinking water which is not sanitarily protected.

Since 1900, the practice of disinfecting drinking water by adding liquid chlorine (chlorination) has virtually eliminated typhoid, cholera, and dysentery as diseases of importance in this country. Disinfection is the principal and most common objective of chlorination.

The first chlorination processes used by the City utilized a principle of forming chlorine-ammonia compounds which would kill bacteria and other microorganisms present in the water supply. Although these compounds were effective in protecting the sanitary quality of the water, they also imparted a medicinal taste to the water.

In 1945, the break-point chlorination process was discovered where chlorine is added in sufficient quantity to break down chlorine-ammonia compounds. This results in a free chlorine residual which provides for powerful disinfection without resultant tastes or odors. This process is currently used for disinfecting the City's drinking water (see Exhibit A).

The process has worked well for a number of years. The water is free of organisms and few complaints are received. As with any panacea, it was short-lived. In 1974, new research and improved analytical technology demonstrated that the powerful free chlorine residual reacts with certain natural materials in river water, primarily humic and fulvic acid, to form new compounds. These compounds are collectively called trihalomethanes (THM), and are individually identified as chloroform, bromoform, dibromochloromethane, and dichlorobromomethane. Of these compounds, chloroform is the compound found in the greatest concentration.

HEALTH EFFECTS

Chloroform and other trihalomethanes are now known to be formed without execption during break-point chlorination of drinking water. Because of this, intense international research programs have studied all aspects of the problem.

Research has indicated that these compounds are suspected carcinogens1/. This prompted the Enviromental Protection Agency (EPA) to amend the national interim primary drinking water regulations to include a maximum contaminant level(MCL) of 100 parts per billion(ppb) for total trihalomethanes. Drinking water containing less than this level is considered to be free from chronic or acute effects on human health. This is a legal standard and has been adopted by the State of California, Department of Health Services (DOHS).

The City has been monitoring trihalomethane levels for over two years. Results show that we have never exceeded the standard and can anticipate an average concentration of less than 50 ppb at each of our plants and, throughout our water distribution system. Staff will continue to monitor the drinking water for trihalomethanes on a quarterly basis. Results are routinely reported to the State Department of Health Services.

METHODS TO REDUCE TRIHALOMETHANES

The City is fortunate that levels of trihalomethanes in our drinking water are well below the concentration established as a health hazard. Viable alternatives to remove these compounds are expensive and limited. These alternatives are:

1. Changing The Site of Disinfection

   It has been documented that adding chlorine further into the water treatment process is a viable way to reduce the levels of trihalomethane formation. There are a number of reasons for this. The primary one being the precipitation of precursors2/ in the sedimentation basins. This alternative would certainly be the least expensive to implement requiring only the capital expenditures necessary to reroute chlorine to the desired application point. This alternative does have major disadvantages, however, which prevent staff from recommending implementation. Chief among these is the fact that far less contact time of chlorine with water will be allowed for microorganism kill. The disinfection system will be made less reliable, thus the chance for disease causing organisms to remain in the drinking water will increase.

1/ a substance that tends to produce cancer.
2/ a substance from which trihalomethanes are formed.

2. Oxidation of Precursors Prior to Adding Chlorine

Several oxidants have been evaluated to determine whether they would alter precursors so they would not react with chlorine to form trihalomethanes. The oxidants studied were ozone, chlorine dioxide, potassium permanganate, ultraviolet radiation, and hydrogen peroxide. Each of these chemicals had some effect in lowering the trihalomethane formation by altering the percursors. However, it was found that high dosages of these chemicals were necessary making these processes very expensive. It was also found that other by-products were formed which would require thorough research into health ramifications of these unstudied by-products. This approach is in the experimental stage.

3. Adsorption

Because trihalomethanes are organic compounds, adsorption with activated carbon either in a powdered form dosed as a slurry, or as a granular bed is effective in removing these compounds. The principal drawback is the extreme high cost of these systems. If the City implements either granular or powdered activated carbon treatment, it is estimated that the total cost to treat the water would double.

4. Alternative Disinfectants

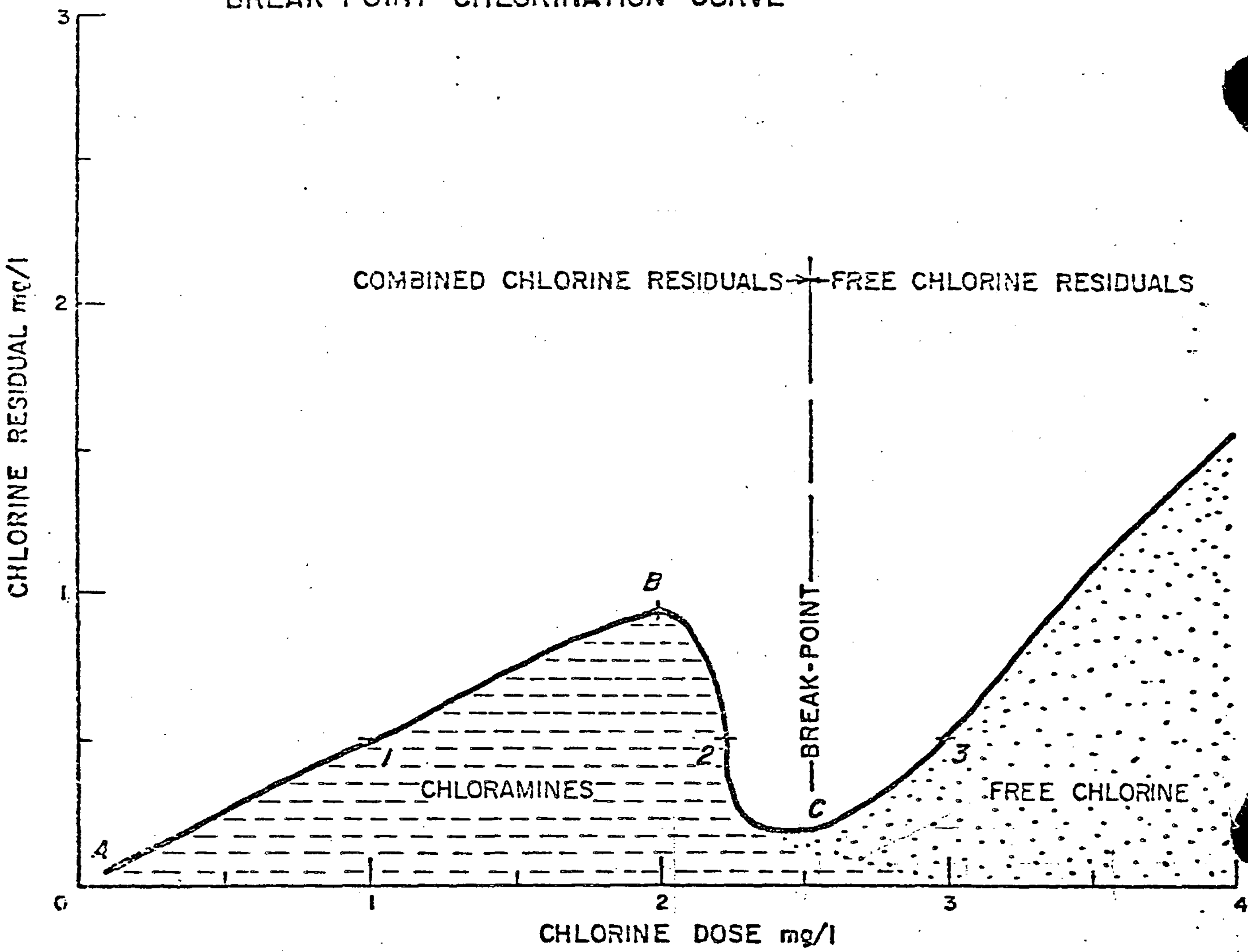
A great deal of research has been done to evaluate alternatives to free chlorine as a water disinfectant. Free chlorine has many advantages. It ensures the destruction of disease organisms during the treatment process and maintains residual disinfecting powers throughout the distribution system. It is easy to test for both at the water treatment plants and in the water distribution system. Finally it is by far the least expensive method to safely disinfect our drinking water.

Alternatives are chloramines (reverting to the chlorine-ammonia system and resultant bad taste), chlorine dioxide, ozone, potassium permanganate, hydrogen peroxide, bromine, iodine, ferrate, high pH, and ultraviolet radiation. Of these, only chloramines, chlorine dioxide, and ozone have been considered feasible for large scale domestic water disinfection.

The major advantages of using alternative disinfection systems is the ability to lower trihalomethane concentrations to near detection limits. Of these three viable alternatives, chlorine dioxide and ozone are powerful disinfectants, while chloramines are weaker disinfectants which may be barely adequate to ensure sanitary quality.

The disadvantages of using alternative disinfectants is that they are all oxidants which will produce by-products which may be as undesireable as chloroform. Thus, while the trihalomethane level is lowered, the overall water quality may not be improved because the health hazard of the new organic by-products have yet to be evaluated.

BREAK-POINT CHLORINATION CURVE



mg/l = Milligram per liter

From point *A* to *B*, chlorine is in a combined form as chloramine.

At point *B* sufficient chlorine potential is present to break apart the combined form.

At point *C* the oxidation-reduction reaction is complete, most of the chlorine being consumed and no longer showing any appreciable residual.

At point *1* is the region of possible taste and odor difficulties.

Point *2* is in the region of chlorine utilization.

Point *3* represents optimum chlorine dosage after "break-point" at point *C*.

Note: The average concentrations of chloramines and free chlorine residual present in city drinking water.

	Chloramine mg/l	Free chlorine mg/l
American River plant	0.03	0.30
Sacramento River plant	0.03	0.35

Finally, none of these alternatives has the advantages of chlorine in terms of reliability and cost to safely disinfect drinking water. Additionally it may be extremely difficult to persuade the regulatory health agency (DOHS) to allow use of alternative disinfectants.

FINANCIAL

There is no financial liability or cost associated with this report.

RECOMMENDATIONS

I recommend that the current practice of break-point chlorination for disinfecting the City's drinking water be continued since it is the most cost effective and reliable method to achieve drinking water which is free from disease causing organisms. The by-products of the current disinfection process are well below the levels considered to be a health hazard.

Respectfully submitted

John F. Varozza
Director of Public Works

Recommendation Approved:

Walter J. Slipe, City Manager

LH:rg
attachment
bc: Mel Johnson
Robert C. Bitten
Robert W. Johnston
Larry Comarsh
Jim Sequeira
Lee Harry ✓
Ray Santin
files

14-R-010-00-0

August 30, 1983
All Districts

ATTACHMENT B

DEC 26 1984

Bennett T. Karoly

CL

DEPARTMENT OF HEALTH SERVICES

14 P STREET, SACRAMENTO, CA, 95814

NEWS NEWS

NUMBER: 143-84
FOR RELEASE: IMMEDIATE

DATE: December 21, 1984
CONTACT: Jim Morgan
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Dr. Kenneth W. Kizer, Chief of Public Health Program for the State Department of Health Services, today announced that the Department has requested that all public water systems in California using chloramines for disinfection of water discontinue their use for at least the next 90-days. This action has been taken in response to several recent incidents in Southern California in which kidney dialysis patients were adversely affected by chloramines in the water supply.

Dr. Kizer reported that in Los Angeles County there have been problems at several kidney dialysis centers. For example, at one center 10 patients suffered acute anemia and required blood transfusions due to chloramines in the center's water supply. As a result, on Thursday of this week, the Los Angeles Metropolitan Water District discontinued its use of chloramines.

While chloramines are of no health concern to the general population, kidney dialysis patients are especially susceptible to the effects of these chemicals. Unless adequately removed from the water supply, they can cause hemolytic anemia (rupture of red blood cells) in these patients. While these problems have not been reported in most of the State's water systems using chloramines, Dr. Kizer said he is taking this action now as a precaution until the safety of dialysis patients can be assured.

Dr. Kizer pointed out that at least 10 public water systems in California have recently switched from using free chlorine to chloramines in an attempt to reduce possible health risks from trihalomethanes. Trihalomethanes (THM's) are suspected cancer-causing compounds which may form in drinking water when free chlorine reacts with natural organic compounds in the water.

(more)

Use of chloramines is a generally accepted method for reducing THMs throughout much of the country, and when the use of chloramines was approved in California the Department of Health Services required extensive notification of all hospitals and dialysis centers. This notification included a letter to each water system directing them to alert all dialysis centers served, as well as a return letter from each dialysis center acknowledging receipt of the notification and implementation of safety measures.

Dr. Kizer indicated that the temporary suspension of chloramine treatment would beemin effect until a task force fully evaluates the situation.

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