ICP-206

January 1981 (Rev.)

RESIDUAL CHLORINE IN THE TIDEWATER POTOMAC: PROBLEMS AND REMEDIES

Paul W. Eastman
Executive Director
Interstate Commission on the Potomac River Basin

Introduction

Chlorine is widely used in the United States for treatment of water supplies, wastewaters, swimming pools, and cooling water systems.

Elemental chlorine is a greenish-yellow gas which dissolves easily in water. It is highly reactive and combines in a variety of ways with both organic and inorganic compounds. For water treatment, it is applied in the gaseous form or in the form of a powdered chlorine compound. Its function is to kill or inhibit growth of animal and plant organisms in water, including bacteria, which cause human diseases or foul water systems with slimy growths that reduce their flow and heat transfer capacity. Unfortunately chlorine does not discriminate in performing this disinfectant and biocidal function. It also can kill useful species of aquatic life and organisms in their food chain.

Most of the chlorine production in the U.S. is used in various industrial applications. Only about five percent, or roughly 500,000 tons per year, is used for disinfection and biocidal purposes in water or wastewater. Thus, chlorination of water, for whatever purpose, consumes only a small portion of the production and is not a vital part of the market.

Chlorination of Drinking Water

Although the upper freshwater portion of the tidewater Potomac has not been used in the past as a drinking water source, it could be in the future. In 1979 the Washington Aqueduct Division of the Army Corps of Engineers completed construction of an intake on the tidewater Potomac for emergency use to supplement upstream sources during extreme droughts. The Washington Aqueduct supplies treated water to public water supply systems in the District of Columbia and part of the Northern Virginia suburbs.

Chlorination of drinking water unquestionably has been beneficial as public health measure. With the introduction of chlorine for disinfection of community water supplies, deaths due to waterborne diseases dropped dramatically in the U.S. As an example, in Detroit, Michigan, which takes its water from the adjacent lake, annual deaths per 100,000 population dropped from 25 to less than 5 after chlorination was started shortly after 1900, and to virtually zero after filtration was added.[1/]

Use of chlorine for disinfection of community water supplies also has some problems, but they are not related to residual chlorine in the Potomac River. The most significant problem is the recent concern about chloroform and other chloro-organics in drinking water and their relationship to cancer. However, the evidence is substantial that these are formed during the use of chlorine in the drinking water treatment and distribution process and that they do not enter water supply systems from chlorinated municipal and industrial wastewater discharges into surface or ground waters.[2/]

Chlorination of Effluents from Sewage Treatment Plants and Power Plants Affecting the Potomac Tidewater

Sewage Treatment Plants

Chlorination of sewage treatment plant effluents traditionally has been practiced to reduce the numbers of disease-causing organisms discharged to receiving waters. The required amount of chlorine and the length of contact time in the chlorination chamber is determined by the reduction to be achieved in the concentration of fecal coliform bacteria in the effluent. Fecal coliform bacteria do not cause disease, but because their source is humans and other warm-blooded animals, they are indicators of the possible presence of disease-causing organisms, for example typhoid bacteria, from the same source. A reduction in fecal coliform bacteria implies a reduction in disease-causing organisms.

Fecal coliform bacterial densities in the effluents of well-operated secondary treatment plants usually fall in the range of 50,000 to 1,000,000 organisms per 100 milliliters of sample (organisms/100 ml).[3/] On the other hand, a thirty-day average of 200 fecal coliforms/100 ml is the usual limit in permits for sewage treatment plants discharging into waters which are used for water contact recreation, for example the Metropolitan Washington Blue Plains regional sewage treatment plant in the District of Columbia. This requires addition of sufficient chlorine to maintain a residual of around 0.5 to 2 milligrams per liter (approximately 500 to 2,000 parts per billion parts of water) in the treated wastewater for 30 minutes or more in a chlorine contact chamber before discharge. However, the discharge permit for the Blue Plains plant limits the total residual chlorine in the effluent to not more than 0.7 milligrams per liter (approximately 700 parts per billion). Lower levels will be required in the future and in 1981 or earlier the District of Columbia will start a study of dechlorination and alternatives to chlorination for disinfection.

Power Plants

Chlorine is used in power plants primarily to control biofouling by slimes and other organisims of condenser tubes and condenser water intake delivery conduits of once-through cooling systems and to control organisms such as algae in cooling towers of closed-cycle systems. Application of chlorine varies according to the temperature, other quality characteristics, and volume of water flowing through the cooling system. Pepco operates three power plants in the Washington Metropolitan Area and a fourth, its largest along the Potomac estuary, at Morgantown near the Highway 301 bridge. Chlorination starts at all of them when the water temperature reaches 50-55 degrees fahrenheit. Chlorine is injected intermittently at the three Metro Area plants and continuously at the Morgantown plant.4/

Vepco operates the only other power plant along the estuary at Possum Point near the mouth of Quantico Creek. Vepco does not practice regular chlorination of the once-through cooling water for four of its units and removes biofouling organisms by mechanical means. Vepco's fifth unit is cooled by a closed-cycle system with cooling towers in which chlorine is used for biofouling control. The occasional blow-down from the cooling towers is discharged to Quantico Creek.5/

Effects of Residual Chlorine on Aquatic Life

I have been unable to find any documentation of adult fish or shellfish kills due to residual chlorine in the Potomac tidewater. However, this may only mean that kills have not been observed, that the subject has not been studied and documented, that finfish avoid chlorinated discharges, that the damaging effect of residual chlorine is to spawning and to the food organisms, or that my search has not been sufficiently exhaustive. It is wellknown that chlorine and its ammonia derivatives are toxic to both freshwater and estuarine species.6/

However, chlorine-caused fish kills on the lower James River have been documented.7/ In May and June of 1973 between 5 and 10 million fish were killed, including spot, croaker, bluefish, sea trout, eels, and menhaden. Chlorine residuals from sewage treatment plants were determined to be the cause.

Subsequently, scientists from the Virginia Institute of Marine Science performed bioassays on fish and other organisms from the James and analyzed the river water for chlorine residuals.8/ They tested clam and oyster larvae, zooplankton, spot, grass shrimp, pipe fish and algae in varying concentrations of residual chlorine in river water. Fifty percent of the organisms were killed in concentrations of total residual chlorine ranging from about 0.001 mg/l (1 part per billion) to less than 1.0 mg/l (1,000 parts per billion). Clam and oyster larvae were the most sensitive and algae were the least sensitive.

Based on the previously mentioned data, Virginia reduced its requirements for chlorine residuals in sewage effluent during the 1974 oyster spawning season. Although the results were circumstantial, the James River had a better oyster set that year than it had in the previous 10 years, while other sets in Virginia were about the same as during the previous year.

Chlorine Related Water Quality Criteria and Standards

The USEPA's 1976 publication Quality Criteria for Water, or "Red Book", recommends no more than 2 micrograms per liter (parts per billion or ppb) of total residual chlorine in water for salmonid fish, for example trout, and 10 ppb for other freshwater and marine organisms.9/ A committee of scientists under the auspices of the American Fisheries Society reviewed the "Red Book" in 1979, and with the benefit of more recent information recommended a single criterion of 3 to 5 parts per billion total residual chlorine as more appropriate for freshwater life.10/ The committee recommended 20 parts per billion as the best criterion available at present for marine organisms. They also emphasized the importance of measuring chlorine residual in water with equipment that is sensitive and precise because of the very small concentrations and of possible interferences, but more about that later.

Maryland, as is generally the case in all states, includes a statement in its receiving water quality standards regulations that the waters of the state shall be free from toxic substances attributable to wastewater discharges in concentrations which are harmful to human, animal, plant, or aquatic life. In the revised standards effective in July 1980, Maryland included a specific limit in natural and recreational trout waters that total residual chlorine shall be less than 0.002 mg/liter or approximately 2 parts per billion. That limit corresponds to the USEPA recommendation in the 1976 "Red Book" and is more stringent than the more recent American Fisheries Society recommendations.

Residual Chlorine in the Tidewater Potomac

Agencies responsible for water quality monitoring and special studies do not routinely measure residual chlorine in the tidewater Potomac or other water bodies. Normally such measurements are made only when someone speculates that chlorine may be the culprit in a fish kill, such as the James River episode mentioned previously.

In searching around, however, I found that U.S. Geological Survey (USGS) scientists performed a few analyses for chlorine residuals in July 1979 during field investigations on phytoplankton (free-floating plants) in the Washington Metro Area and submerged vegetation in the estuary and creeks near the Highway 301 bridge. Dr. Ronald Cohen of the USGS emphasized that the accuracy of the data was very uncertain because they were using color comparison kits, results from which are imprecise, especially at low concentrations. Not only are they unreliable at low concentrations, they measure other oxidants as well as chlorine. The USGS measurements were taken in the tidal section from near Hains Point above the regional Blue Plains sewage treatment plant (STP) and the power plants in the Metro Area downstream about ten miles to Fort Washington. The range of results were approximately 50 ppb to 90 ppb. The results were presumed to be primarily residual chlorine because the higher concentrations were in the vicinity of the Blue Plains STP and the Pepco power plant on the opposite Virginia shore near Alexandria, both of which have chlorine in their effluents.

Maintaining a chlorine residual in the Blue Plains STP effluent, of course, has been a major cause for the low fecal coliform densities in the upper Potomac tidewater, densities which are within the limits for water contact recreation during dry weather. However, the chlorine not only reduces bacterial levels, it also decreases phytoplankton productivity. Dr. Cohen mentioned that in some laboratory tests he found that 50 ppb of residual chlorine decreased productivity by about one-half, which is not surprising since chlorine is a biocide.

In Washington, D.C., Mr. David Conlin of the Bureau of Air and Water Quality has the water monitoring responsibilites. He provided me with the results of residual chlorine analyses from a sampling run on August 8, 1980, using borrowed but more precise measuring equipment, an amperometric titrator. He warned me, however, that the results might be either too high or too low because of the organic content of the samples, and that he had not verified the accuracy of the equipment with any quality control comparisons.

Mr. Conlin's samples were taken from six cross-sections downstream from just above the Blue Plains STP and the power plants to about two and one-half miles below Wilson Bridge, the Southern Washington, D.C. boundary. The results ranged from a high of about 1,000 ppb one-half mile below Wilson Bridge to a low of 300 ppb just above Wilson Bridge. If accurate, these concentrations are high enough to be damaging to at least some forms of aquatic life.

During the same day that the samples were taken and the day before the total residual chlorine in the Blue Plains STP effluent was about 200 ppb. No information was available concerning the chlorine in the effluents from the power plant cooling systems in the same vicinity, which also could have contributed chlorine to that part of the estuary on the day the samples were taken and analyzed.

Because of the general lack of residual chlorine data, I was encouraged by Mr. Conlin's advice that the District of Columbia has purchased equipment to analyse routinely for residual chlorine in the estuary in the future.

Reduction of Chlorine in Waste Discharges or Alternatives to Chlorine for Disinfection and Control of Biofouling

Sewage Treatment Plants

Considerable controversy exists among health and fisheries authorities about the extent of the need, if any, for disinfection of discharges from sewage treatment plants for protection of waters used for body-contact recreation or completely treated domestic water supplies. The latter of course is of no concern now because the freshwater portion of the tidal Potomac is not now used as a source for domestic water supply. Body-contact recreation is the concern. With this in mind, possibilities of eliminating or reducing the damaging effects of chlorination of sewage treatment plant discharges are as follows:

1. Regardless of the position one takes relative to the need for sewage treatment plant effluent disinfection for protection of body-contact recreation, it seems obvious that the need, if any, exists only during the summer recreation season, from about June through September. Therefore seasonal chlorination during the period June through September is a viable method for diminishing the damages to aquatic life in the tidewater Potomac, particularly during the spawning season for many fish species. It would also reduce expenditures for chlorination.

2. Dechlorination could be added to sewage treatment plants which practice chlorination at the present time. Reliable dechlorination technology and equipment, for example using sulphur dioxide, is available. According to recent estimates of a task force of the Great Lakes Water Quality Board, the total annual operating costs, including amortization of capital costs, would range from about $15,000 for a one million gallons per day (mgd) plant to $216,000 for a 240 mgd plant.3/ According to these estimates, the total annual cost for the Blue Plains STP which treats around 300 mgd, would be on the order of $270,000 and for seasonal dechlorination about two-thirds to three-quarters of that amount. It has become a standard practice among municipal waste dischargers to San Francisco Bay in California to remove chlorine residuals (dechlorinate) before final discharge.1/

3. Even without dechlorination, the efficiency of present chlorination practices could be improved to decrease the amounts and frequency of excursions above permitted limits of residual chlorine in effluents. Also, sewage treatment plant outfall diffusion structures could be improved or installed so as to disperse the chlorine in discharges and provide for better mixing and dissipation of residual chlorine in the receiving waters, thus lessening the adverse impact on aquatic life.

4. Disinfection of sewage treatment plant effluents could be eliminated altogether, although this is recognized as the most controversial alternative. This alternative might require raising the bacterial density limits for body-contact recreation and raw water supply sources. Disinfection of discharges to the Thames River in the United Kingdom has never been required even though the river is intensively used for recreation and water supply purposes.

5. Alternatives to chlorination for disinfection of sewage treatment plants effluents could be installed. The use of ozone and ultraviolet radiation technologies appear to be the most feasible alternatives to chlorination.

Although the effectiveness of retrofitting old plants with ozone or ultraviolet radiation is uncertain according to the Great Lakes Water Quality Board task force, the effectiveness would be enhanced when applied in new plants or where plants are expanded or upgraded.

Power Plants

Chlorination, usually practiced intermittently, is necessary to maintain cleanliness of condenser tubes for efficient heat transfer at power plants, not for health purposes. Possibilities for diminishing the impact of residual chlorine from power plants include the following:

1. Site-specific studies could be undertaken to determine the minimum amounts of chlorine required for biofouling control and to reduce the impact of discharges by better mixing and dissipation of residual chlorine in the effluents in receiving waters. Also, water from other condensers could be used to both dilute and react with residual chlorine discharged from the condenser under chlorination when intermittent chlorination is practiced.

2. Automated mechanical cleaning could be installed without chlorination or supplemented by chlorination. The practicability of retrofitting existing plants would have to be investigated on a case by case basis. However, Vepco practices mechanical cleaning in the four units at its Possum Point power plant with once-through cooling water systems, thus eliminating the need for regular chlorination.

3. Facilities could be installed for dechlorination of discharges from once-through cooling water systems where chlorination is practiced for biofouling control. Costs of dechlorination would vary depending on plant capacity, unit arrangements, and cooling water system features. Nevertheless, they should be in about the same range as chlorination costs.

Conclusions

It is clear from the James River incident and numerous bioassay investigations that many important fresh water, estuarine and marine organisms are harmed by residual chlorine discharged to receiving waters from sewage treatment plants, power plants, or other sources. The harm can occur to fish and shellfish life forms and to food chain organisms in concentrations as low as a few parts per billion. I have described briefly a number of alternatives for reducing or eliminating these harmful effects. The question is what can be done now and in the longer range.

First, I suggest that Maryland, Virginia the District of Columbia, and the USEPA authorities temporarily defer during the period November of this year (1980) through May 1981 their practice or requirement of chlorination of sewage treatment plant effluents to the tidewater Potomac and its embayments or lower portions of its tributaries. Or if that is deemed impracticable, defer the requirement through much of the spawning season, for many species say February through May, 1981. Maryland gave serious consideration to this possibility in the spring of this year (1980) and I think many would share the view that it would involve little if any human health risks.

Second, I suggest that representatives of these same authorities join together to arrive at a consensus on a policy for the future beyond 1981 concerning the use of chlorine for disinfection of sewage treatment plant effluents and also for biofouling control in power plant effluents. I am confident that ICPRB would assist the regulatory and management authorities in every way possible to develop a common policy on this subject which would protect both human health and the extremely valuable biological resources of the estuary, and also other waters of the Potomac basin.

Third, and last but not least, I suggest that all agencies involved in water quality monitoring or special studies include analyses for chlorine residuals in these activities, depending, of course, on the liklihood that the waters being monitored are receiving chlorinated discharges. Care must be taken, however, to insure that the chlorine analysis equipment is accurate and adequately precise for determinations of the low level concentrations that may be encountered.

References

1/Goldman, J.C., Chlorine in the Marine Environment, Oceanus, Woods Hole Oceanographic Institution, Woods Hole, MA, 1979.

2/Morris, J.C., Formation of Halogenated Organics by Chlorination of Water Supplies, U.S. Environmental Protection Agency, 1975, (EPA-600/1-75-002).

3/Donnan, J.A., et.al., Alternatives for Managing Chlorine Residuals: A Social and Economic Assessment, Final Report of the Chlorine Objective Task Force to the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario, Canada, April 1980.

4/Guiland, L.S., Potomac Electric Power Co., Wash., D.C., letter to Maryland Department of Natural Resources, Power Plant Siting Program, Annapolis, MD, April 7, 1980.

5/Brehmer, M.L., Virginia Electric and Power Co., Richmond, VA, letter to Maryland Department of Natural Resources, Energy Administration, Annapolis, MD, August 6, 1980.

6/Brungs, W.A., Effects of Residual Chlorine on Aquatic Life, Journ. Water Pollution Cont. Fed. 45(10):2180-2193, Oct. 1973.

7/Bellanca, M.A. and D.S. Bailey, Effects of Chlorinated Effluents on Aquatic Ecosystem in the Lower James River, Journ. Water Pollution Con. Fed. 49(4):639-645, April 1977.

8/Huggett, R.J. and M.E. Bender, "Methods of Measuring Ecosystem Stress" in The Potomac Estuary Biological Resources Trends and Options, W.T. Mason and K.C. Flynn, eds., Interstate Commission on the Potomac River Basin, April 1976.

9/U.S. Environmental Protection Agency, Quality Criteria for Water, USEPA, 1976, pp 61-68.

10/Thurston, R.V., et.al., eds., A Review of the EPA Red Book: Quality Criteria for Water, American Fisheries Society, Bethesda, MD, 1979.