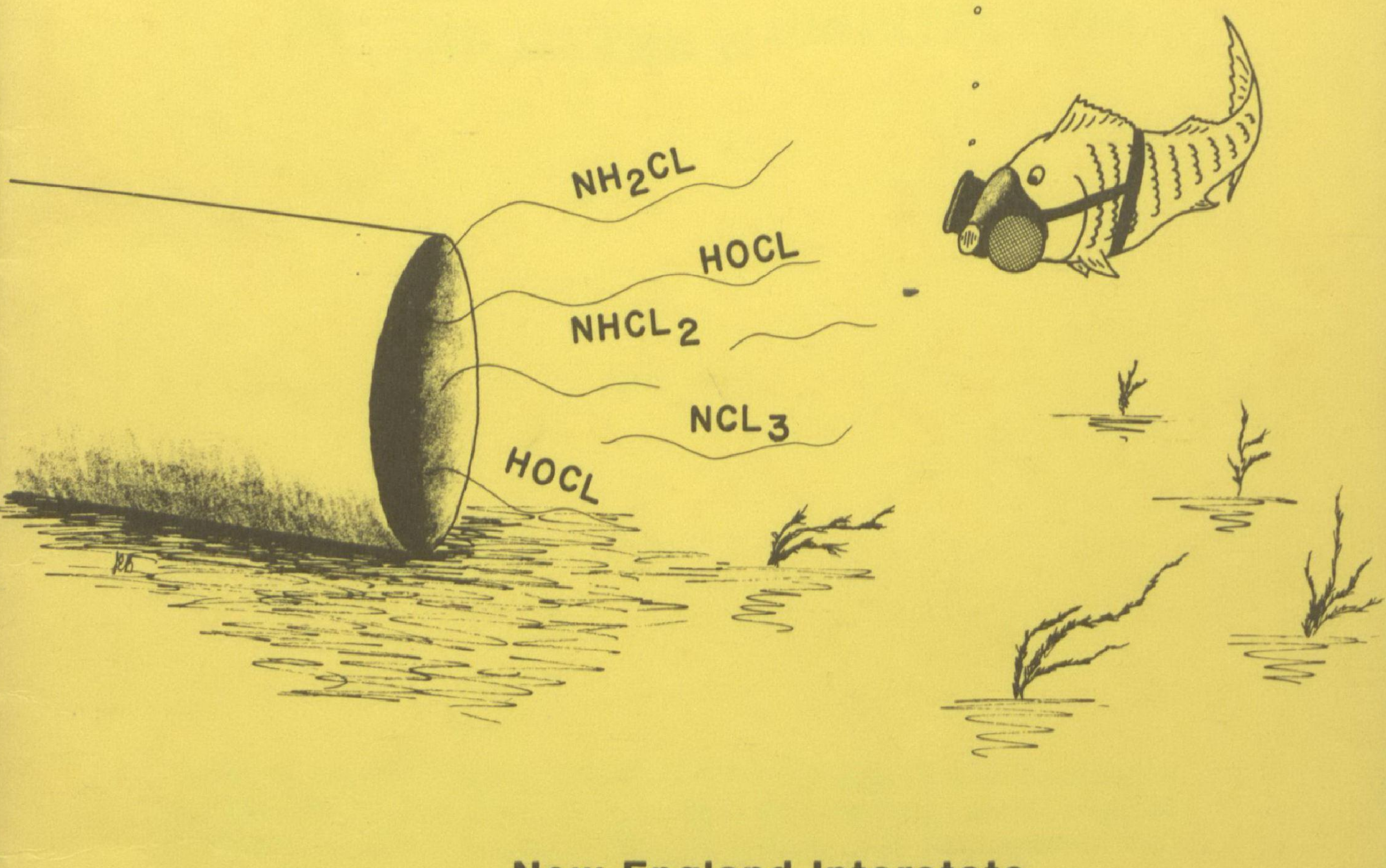
# Methods To Minimize and Optimize the use of Chlorine in Wastewater Disinfection




**New England Interstate Water Pollution Control Commission**

**United States**
Environmental Protection Agency
**Region I -- New England**

# METHODS TO MINIMIZE AND OPTIMIZE THE USE OF CHLORINE IN WASTEWATER DISINFECTION

April 1984

Edited by the New England Interstate Water Pollution Control Commission and the New England Regional Wastewater Institute from material prepared by Metcalf & Eddy, Inc. in cooperation with the U.S. Environmental Protection Agency.

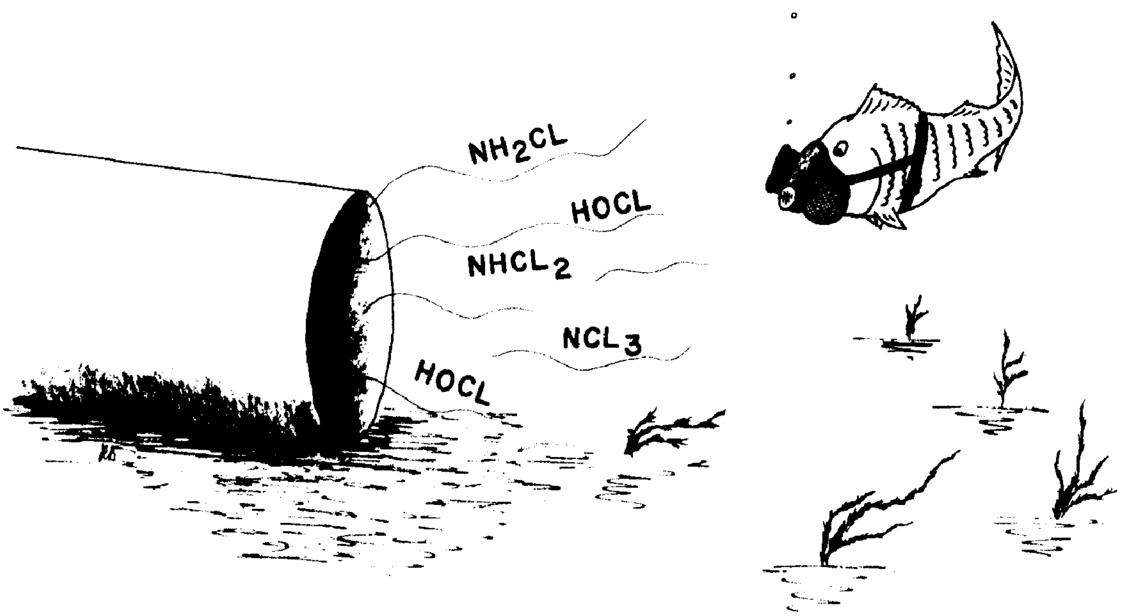
## WHY DISINFECT?

The purpose of disinfection is to destroy disease-causing organisms (pathogens) before the wastewater is discharged to the receiving water. The organisms of specific concern include protozoans, bacteria and viruses which are generated by humans and discharged with their waste products into the wastewater collection and treatment system. These organisms must be destroyed or rendered harmless to minimize the transfer of disease or infection from one individual to another. In the United States, wastewaters have generally been disinfected with chlorine since it is effective and has been less costly than other disinfection methods.

## CONCERN OVER CHLORINATION

In recent years, traditional wastewater disinfection practices have been the subject of increasing public concern due to the toxic effects of chlorine by-products on aquatic life and human health. Residual chlorine compounds, such as chloramines, are toxic to fish and other aquatic organisms. Chlorine can also combine with organics in the wastewater effuent to form chlorinated hydrocarbon compounds which are suspected of causing cancer. These compounds are a concern for downstream users who reuse the receiving water for a drinking water supply.

For these reasons, many States, including Maine, New Hampshire and Vermont, are encouraging seasonal chlorination where possible to reduce the discharge of chlorine compounds to the environment during the winter months and to reduce operating costs at treatment plants.



## HOW CHLORINATION WORKS

Chlorine is a potent oxidizing agent which reacts with substances in wastewater such as suspended solids and organics as well as with disease-causing organisms. Since the suspended solids and organics consume the chlorine, or have a chlorine demand, chlorine dosage must be sufficient to satisfy this demand and provide a residual for disinfection.

## FACTORS AFFECTING CHLORINE DISINFECTION

The effectiveness of chlorine as a disinfectant, therefore, depends on the quality and characteristics of the wastewater, the chlorine concentration, the degree of mixing and the contact time between chlorine and the wastewater. Greater organism kill will generally be possible with wastewater low in suspended solids, organics, and ammonia-nitrogen content, and at lower pH's (6.0 to 7.0). Disinfection is also enhanced by higher temperatures, higher chlorine dosages, greater mixing and longer contact times.

## OPTIMIZING DISINFECTION

The first and most important step in minimizing the introduction of chlorine products to the environment is to optimize the efficiency of the entire treatment system to improve the quality of the effluent prior to disinfection. Reducing the solids and organics in the effluent will reduce the chlorine demand and chlorine by-products.

This booklet will focus on other steps in optimizing disinfection including: chlorine FEED RATE CONTROL, INITIAL MIXING of chlorine and wastewater, and CHLORINE CONTACT TIME.

## MEASURING DISINFECTION EFFECTIVENESS

Two measurements which give information on the effectiveness of chlorine disinfection are chlorine residual and the number of coliform bacteria (MPN/100 ml or colonies/100 ml) in a sample volume of disinfected plant effluent.

Effluent permits usually specify a number for minimum chlorine residual (mg/1 or ppm) which is assumed to be available for disinfection after the wastewater is discharged to a receiving water.

Although this booklet will focus on residual analysis as a control parameter, the use of coliform analysis (both total and fecal) to optimize disinfection is of growing interest to many operators. Destruction of fecal or total coliforms indicates that the disease-causing organisms have also been destroyed. Many States require total coliform analysis, but fecal coliform bacteria are better indicators of the sanitary quality of water because these organisms originate only in the digestive tract of warmblooded animals and are more resistant to the effect of disinfectants than most pathogens.

## WHY BOTHER?

Optimizing the disinfection process using the information in this booklet should achieve a desired coliform (and pathogen) kill using less chlorine. The benefits are twofold: the quantity of potentially harmful chlorine products introduced to the environment will be reduced, and treatment plants will save money as less chlorine is used.

## FEED RATE CONTROL

The concentration of chlorine in the disinfection process can be controlled by adjusting the chlorine feed rate either manually or automatically, based on wastewater flow and/or analyses of residual chlorine concentrations. If chlorine feed rate is not adjusted to both flow and residual concentrations, over- or under-chlorination may occur frequently. This is particularly true at treatment plants where the feed rate is adjusted manually.

At all treatment plants, the chlorine control and feed systems should be checked daily for leaks, blockages, and to maintain proper settings. Operators using manual chlorine feed systems should check the residual concentration several times each day, particularly during low or high flow periods, and adjust the feed rate accordingly.

An automatic control system can be used to maintain continuous control of the chlorine residual concentrations. This system includes a residual analyzer which continually measures residual concentrations, a compound loop chlorinator and a flow signal. The chlorine feed rate is set (paced) according to the wastewater flow rate and adjusted (trimmed) by a signal from the residual analyzer. For example, if the residual analyzer measures an effluent residual concentration above the predetermined set point, the chlorine feed rate is automatically adjusted to reduce the residual concentration usually by closing a motorized valve in the chlorinator. This level of control is important because a change in flow rate will always alter the amount of chlorine required for disinfection, but the chlorine demand can also change without a change in flow rate.

Other types of automatic control systems pace chlorine on the basis of wastewater flow rate only. In other words, as the flow rate increases or decreases, the chlorine feed rate increases or decreases accordingly. These flow-proportional systems do not use a residual analyzer so the chlorine feed rate does not automatically change as the chlorine demand changes. These systems, which only pace chlorine feed rate to wastewater flow, do not give as close control as systems where feed rate is also trimmed by residual analyzer feedback.

Automatic control systems should be calibrated to the range of flow rates which are presently occurring rather than the design flow rates. If, during periods of extremely high or low flow, the automatic control system does not provide the correct dosage rate, the operator should switch to manual chlorination.

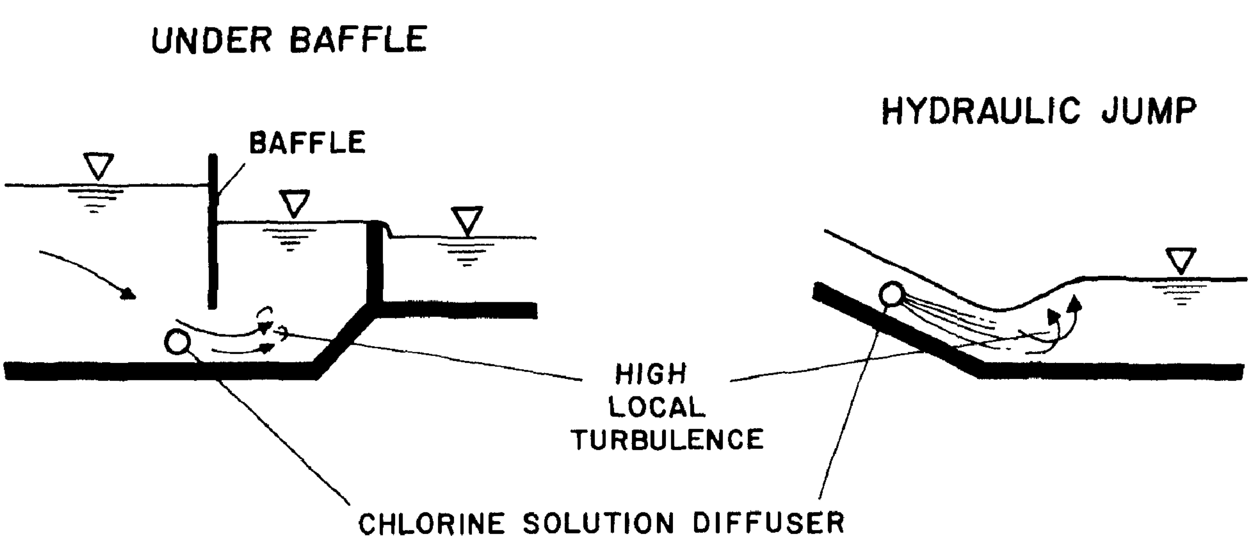
At all treatment plants, the chlorine rotameter should be properly sized for the actual daily chlorine dose required. When rotameters are oversized, it is difficult to maintain chlorine dosage in the desired range and over- or under-chlorination can occur frequently. For example, if a plant has a required dosage rate of 20 lb/day, a rotameter with a maximum capacity of 50 lb/day would provide more sensitive control and waste less chlorine than a rotameter with a capacity of 200 lb/day.

Rotameters are inexpensive (less than $500) and can be installed easily by the operator. An operator can obtain a new rotameter that is closer to the range of the facility's normal chlorine dosage rate by contacting the chlorinator service representative. The operating records should be studied to determine the present average and peak chlorine usage. The new rotameter(s) should be selected to supply these chlorine requirements.

## INITIAL MIXING

Rapid and thorough mixing of chlorine with the wastewater is critical, since chlorine must come in contact with the pathogens, often hidden in minute clumps of solids, if disinfection is to occur. Initial mixing is best accomplished by injecting the chlorine solution through diffusers at a point where the wastewater flow is turbulent. Mechanical mixers, parshall flumes, and hydraulic jumps are commonly used to create turbulence. Mixing should be completed before the flow enters the contact tank in order to avoid wasting chlorine.

## METHODS OF MIXING CHLORINE SOLUTIONS WITH WASTEWATER



If the area of initial mixing is visible, the efficiency of mixing may be checked by inspection. If the mixing area is not visible or mixing appears to be inefficient, operators can also check the efficiency of mixing systems by collecting a series of grab samples at several points downstream of the point of chlorine addition. The sample points should be located in a line which forms a right angle with the line of flow. These samples should be analyzed for residual chlorine concentration in the plant lab. If the samples contain approximately the same amount of chlorine, this indicates the mixing system is effective. If the chlorine concentrations vary widely between samples, this indicates that initial mixing is inefficient. The efficiency of initial mixing should be tested periodically.

It is also important to minimize the release of chlorine gas to the atmosphere (chlorine stripping). Chlorine stripping not only wastes chlorine but it is also dangerous because chlorine gas is toxic and corrosive. It can endanger the plant staff and damage equipment and structures. If the operator notices excessive chlorine odor, equipment and/or structural corrosion near the point of chlorine injection, this may indicate chlorine stripping. Chlorine stripping can be reduced by ensuring the chlorine diffuser is at least two feet below the minimum wastewater level and preventing any additional turbulence after mixing (such as dropping into an effluent pump station wet well).

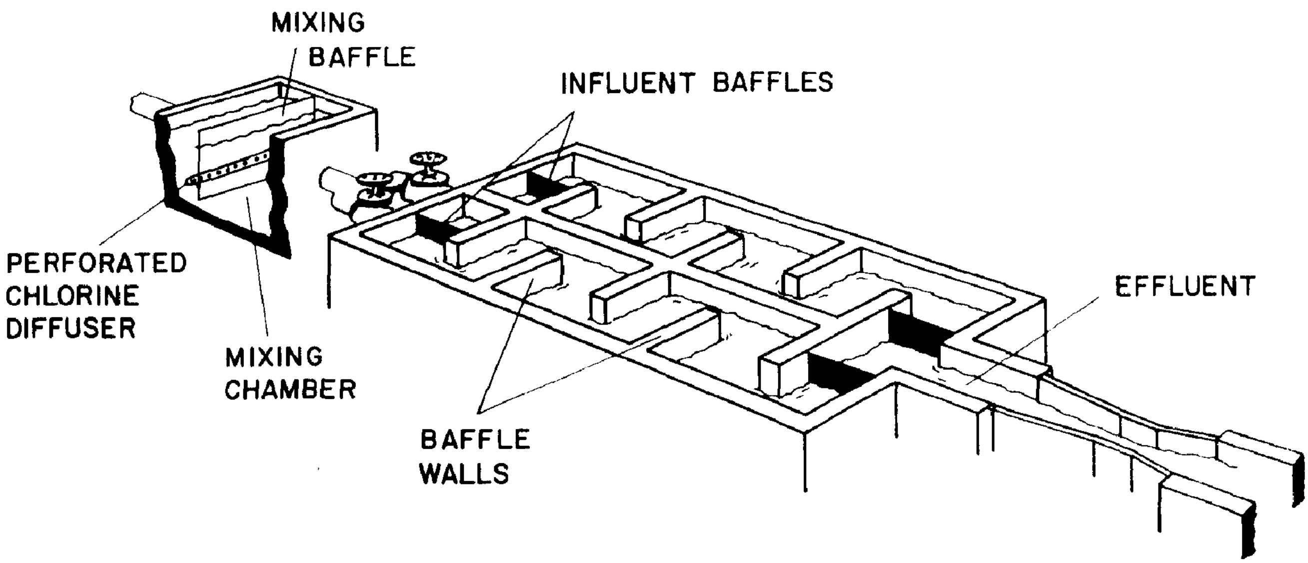
Several modifications can be made to improve initial mixing. If space and hydraulics permit, constructing a hydraulic jump, over-and-under baffles, a submerged weir or venturi flume will improve initial mixing. Initial mixing can also be improved by installing a mechanical mixer at the point of chlorine injection. To obtain a mixer, the operator should contact a manufacturer's representative and provide him with the requirements of the service, including dimensions of the mixing area. Normally, mechanical mixers have a low power requirement (on the order of 3 hp), but it is important to check that the plant can provide this additional power if a mixer is installed. Engineering assistance will generally be needed to effectively improve initial mixing.

## CHLORINE CONTACT

The contact system should provide a minimum of 15 minutes contact time at peak wastewater flows. Plants discharging to a shellfishing area are required to provide 30 minutes contact time at peak flows. It is important that all portions of the flow receive equal contact time (plug flow). Short-circuiting, which occurs when some of the flow passes through the tank more quickly than other portions of the flow, decreases the effectiveness of disinfection and may require the use of extra chlorine.

The operator can evaluate the contact tank quickly by adding confetti to the influent end of the tank. By watching the movement of the confetti, flow patterns and/or dead spots on the water surface can be observed.

## CHLORINE CONTACT TANK




The operator can evaluate the contact tank more accurately for both flow patterns and contact times by conducting a dye test. Rhodamine WT is a fluorescent dye which is typically used. The dye is added to the wastewater at the point of chlorine injection (or at the next convenient upstream point). If the dye is obtained in solid form, it should be dissolved in water prior to use.

By watching the flow of dye through the tank, the operator can identify flow patterns. If the dye test results show dead spots or eddies which disturb the flow pattern, additional longitudinal baffles can be constructed to divide the tank into long narrow channels. The construction of channels will improve the flow pattern and may increase the contact time. The baffling should be installed to form channels with a total length at least 40 times more than the channel width. If chlorine solution is thoroughly mixed with the wastewater upstream of the contact tank, the baffles can be constructed of wood, fiberglass or PVC. However, it will be necessary to take the tank out of service during installation. If chlorine solution is added directly to the chlorine contact tank, the baffles should be constructed of concrete.

The dye test can also be used to determine the minimum chlorine contact time provided in the tank by measuring the length of time between chlorine addition and the first appearance of dye in the contact tank effluent. Alternatively, a fluorometer (device which measures dye concentration) can be used to measure dye concentrations in the effluent at periodic intervals. By making a graph of the measured dye concentrations versus elapsed time, the average contact time can be estimated as the time at which the largest dye concentration is measured.

The contact time(s) determined through these tests are highly dependent on the specific wastewater flow rates occurring at the time of testing. The contact time will decrease as the wastewater flow rate increases. Dye testing should be conducted at times of high wastewater flow rates to determine the contact time at peak flow rates. If the contact time at peak flow is less than fifteen minutes (or thirty minutes if discharging to a shellfishing area) then the contact time determined by the dye test should be compared to the theoretical or design detention time.

If the tank is not theoretically capable of providing a minimum detention time at the peak flows actually occurring (peak flow is exceeding maximum design flow), then consider some design modifications. For example, consider relocating chlorine diffusers upstream to provide additional contact time. The long term and expensive solution to inadequate contact time due to design deficiency would be construction of an additional contact tank.

If, on the other hand, a comparison of actual and theoretical contact times indicates that the contact tank is designed to provide longer detention times than are actually occurring, then certain operational problems such as plugged baffles may be, in effect, changing the design of the tank and reducing contact times. Similar problems are caused when chlorine reacts with suspended solids in the wastewater, causing the solids to settle out of solution and accumulate on the bottom of the tank. Besides altering the effective volume of the tank, these solids will exert a chlorine demand and reduce efficiency of disinfection. Chlorine also causes suspended oils and greases to coagulate and accumulate on the tank's surface. For these reasons, the contact tank(s) should be checked frequently for solids, slime, or scum buildup and cleaned if any occur.

## RESIDUAL ANALYSIS

Chlorine residual analysis provides important information which can be used to control the chlorine feed rate and it is important for compliance with effluent permits. To maintain effluent chlorine residuals at the desired level and effluent coliform concentrations at or below the desired level, residual measurements (analysis) should be more frequent. It is important to check the chlorine residual at times when the wastewater flow rate is changing, particularly as flows decrease. Residuals should be measured more frequently at primary plants than at secondary plants.

If analyses indicate chlorine residual concentrations are exceeding the desired levels and if effluent coliform concentrations are less than the permit levels, the chlorine feed rate should be turned down.

An automatic chlorine analyzer is advantageous because residual concentrations are continually monitored. However, daily calibration of the analyzer is important. A grab sample should be collected from the effluent and tested in the lab using the amperometric titration procedure for total chlorine. If the lab results differ significantly from the analyzer reading, the analyzer should be recalibrated.

If an automatic analyzer is not available, the iodometric method with amperometric titration to determine the end point is reliable, convenient and capable of accurately determining very low residual concentrations. Although amperometric titration systems cost about $1,000, this cost can easily be recovered if the chlorine use is reduced with more accurate information on residual chlorine levels. The DPD colorimetric test also provides good results although turbid effluent may interfere with the results. The orthotolidine method should not be used for determining residual concentrations. The orthotolidine solution is carcinogenic, presenting a health hazard to the operator. Furthermore, this method cannot accurately determine low residuals, it is unreliable and is adversely affected by many conditions.

## OPERATING RECORDS

Operating records not only satisfy State requirements, they also provide the operator with important information which can be used to identify and correct potential problems. Plant operating logs should contain such information as residual chlorine measurements, wastewater flows, time of day these measurements are taken, any corrective adjustments made, and the total amount of chlorine used each day.

By keeping records of such information, the operator will be in a better position to spot trends away from normal operating conditions, to identify the problem, and determine an effective solution to maintain a high quality, properly disinfected effluent.

## SAFETY

Chlorine is a potential killer when people become careless or when chlorine handling equipment becomes defective. REMEMBER — during the handling of chlorine equipment, gas or liquid, SAFETY should be the utmost concern at all times.

# CHLORINE

1. TRADE NAMES

   Chlorine gas, liquid chlorine

2. USES

   Disinfection, slime control, taste and odor control

3. AVAILABLE FORMS

   Cylinders — 100, 150, 200, 2,000 lb.

   Tank cars — 16, 30, 55 tons

4. COMMERCIAL STRENGTH

   99.8% $CL_2$

5. STORAGE

   Pressure cylinders

6. FEEDERS

   Gas chlorinator

7. APPROXIMATE 1984 COST

   | | | |
   |---|---|---|
   | Cylinders: | 1 ton | 13-17 cents/lb. |
   | | 150 lb. | 21-26 cents/lb. |
   | Hypochlorite solution (15%): | drum | 65 cents/gal. |
   | | bulk | 50 cents/gal. |

8. HANDLING MATERIALS

   Gas — copper, iron, steel
   Liquid — glass, rubber, lead, silver

9. SAFETY CONSIDERATIONS

Pungent, noxious, corrosive gas, health hazard. Prevent contact with ammonia, acetylene, all petroleum gases, hydrogen, turpentine, and benzene.

10. MAJOR MANUFACTURERS

Allied Chemical Corp., P.O. Box 1139R, Morristown, NJ 07960
Ashland Chemical Co., P.O. Box 2219, Columbus, Ohio 43216
Pennwalt Corp., Organic Chemicals Div., Three Parkway, Philadelphia, PA 19102
PPG Industries, Inc., Chemical Div., One Gateway Center, Pittsburgh, PA 15222
Dixie Chemical Co., 3635 W. Dallas St., Houston, TX 77019

Adapted from "Chemical Aids Manual for Wastewater Treatment Facilities", EPA Publication # 43019-79-018, December 1979.

OCLC 1141745968 Held by EHA - no other holdings

| | | | | | |
|---|---|---|---|---|---|
| **Rec stat** n | **Entered** 20200224 | | **Replaced** 20200224 | | |
| **Type** a | **ELvl** K | **Srce** d | **Audn** | **Ctrl** | **Lang** eng |
| **BLvl** m | **Form** | **Conf** 0 | **Biog** | **MRec** | **Ctry** mau |
| | **Cont** | **GPub** f | **LitF** 0 | **Indx** 0 | |
| **Desc** i | **Ills** a | **Fest** 0 | **DtSt** s | **Dates** 1984 , | |

| | |
|---|---|
| 040 | EHA ‡b eng ‡e rda ‡c EHA |
| 088 | EPA 901-R-84-006 |
| 099 | EPA 901-R-84-006 |
| 049 | EHAD |
| 245 0 0 | Methods to minimize and optimize the use of chlorine in wastewater disinfection / ‡c New England Interstate Water Pollution Control Commission ; United States Environmental Protection Agency, Region I. |
| 264 1 | [Boston, MA] : ‡b United States Environmental Protection Agency, Region I, ‡c 1984. |
| 300 | 10 pages : ‡b illustrations, ; ‡c 26 cm |
| 336 | text ‡b txt ‡2 rdacontent |
| 337 | unmediated ‡b n ‡2 rdamedia |
| 338 | volume ‡b nc ‡2 rdacarrier |
| 500 | "April 1984." |
| 650 0 | Water ‡x Purification ‡x Chlorination ‡x Environmental aspects ‡z United States. |
| 710 2 | Metcalf & Eddy, ‡e author. |
| 710 2 | New England Interstate Water Pollution Control Commission, ‡e editor. |
| 710 2 | New England Regional Wastewater Institute, ‡e editor. |
| 710 1 | United States. ‡b Environmental Protection Agency. ‡b Region I, ‡e issuing body. |

Delete Holdings- Export- Label- Produce- Submit- Replace- Report Error- Update Holdings-C Validate-C Workflow-In Process