DISINFECTION BY CHLORINATION
DESIGN
AND
OPERATION AND MAINTENANCE
GUIDELINES
AS RELATED TO THE
PL 92-500 CONSTRUCTION GRANT PROGRAM

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ENVIRONMENTAL PROTECTION AGENCY

REGION X

1200 SIXTH AVENUE

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1. INTRODUCTION

1.1 DISINFECTION REQUIREMENTS

Disinfection requirements have been and must continue to be directed at protecting the public health. State water quality standards which establish the need for disinfection shall as a minimum, include the following:

1. Protection of public water supplies.
2. Protection of fisheries and shellfish waters.
3. Protection of irrigation and agricultural waters.
4. Protection of water where human contact is likely.
5. Protection of interstate waters to which the above criteria apply.

In summarizing the best available design criteria and operational guidelines, several alternate disinfectants were considered. These disinfectants included: iodine, bromine, lime, ozone, ultraviolet light, pasteurization, and gamma radiation. In most cases, insufficient information was available to determine whether these are any better disinfectants or any less toxic than chlorine. While it is recognized that other disinfectants are available, these guidelines are directed to the use of chlorine. The intent is not to preclude the use of other disinfectants. EPA Region X proposes that the design guidelines which follow be used in obtaining adequate disinfection. The operational guidelines should assist the states in their monitoring responsibility and ensure adequate disinfection.

These design and operation guidelines are intended to obtain adequate and reliable disinfection with the lowest possible chlorine residual being discharged. The guidelines will be used by EPA Region X in the review of plans and specifications for construction and operation of wastewater treatment facilities.

DEVIATIONS FROM THESE DESIGN AND OPERATION GUIDELINES WILL BE ALLOWED ON A CASE-BY-CASE BASIS WHEN IT CAN BE SHOWN THAT SUCH DEVIATIONS WILL PROVIDE FOR EFFICIENT, EFFECTIVE, AND RELIABLE DISINFECTION.

1.2 ADEQUATE DISINFECTION

For the purpose of these guidelines adequate disinfection is achieved when:

1. The geometric mean of values for effluent samples collected in a period of 30 consecutive days does not exceed a fecal coliform concentration of 200 per 100 milliliters.
2. The geometric mean of values for effluent samples collected in a period of seven consecutive days does not exceed a fecal coliform concentration of 400 per 100 milliliters.

More strict effluent standards may be necessary for receiving waters where existing or potential uses depend upon maintenance of unusually high quality water.

1.3 SAMPLING FREQUENCY AND METHODS

The sampling frequency and methods shall be established on a case-by-case basis. Calculation of the geometric mean fecal coliform concentration shall be made utilizing all data obtained during the reporting period.

1.4 DECHLORINATION OF CHLORINATED EFFLUENTS

Dechlorination of chlorinated effluents will be required, on a case-by-case basis, when ecological conditions dictate the need. The design of all disinfection facilities, utilizing chlorine as the disinfectant, shall assure that the following criteria are met:

1. Preservation of the present and future beneficial uses of the receiving waters both upstream and downstream which may be affected by toxicity of chlorine compounds.
2. In freshwater, the concentration of total chlorine residual outside the mixing zone shall not exceed 0.002 mg/l.
3. In freshwater, for those situations which may result in fish blockage during the migration season, the concentration of total chlorine residual inside the mixing zone shall not exceed 0.02 mg/l.

4. In marine waters, the concentration of total chlorine residual shall not exceed 0.01 mg/l.

5. The total chlorine residual concentrations in fresh water shall be determined through calculation of dilution ratios utilizing the 10-year, 7-day low stream flow.

2. DESIGN

2.1 MIXING

Rapid initial mixing of the chlorine solution and wastewater should be accomplished within three seconds and prior to entering the contact chamber.

2.1.1 The hydraulic jump is considered the best method of obtaining rapid mixing in an open channel.

2.1.2 Mechanical mixers are considered second best in accomplishing rapid mixing. The mixer should be located at or immediately downstream from the point of chlorine injection and the mixing chamber should be as small as possible.

2.1.3 Injecting the chlorine solution into a full flowing pipe is probably the least efficient. When this method is used, the inner surface of the pipe shall be irregular so as to create a sufficient turbulence to accomplish complete mixing within a distance of 10 pipe diameters. This method will not be acceptable for pipe diameters of 76.2 cm (30 inches) and larger.

2.2 CONTACT CHAMBERS

Contact chambers shall be sized to provide a minimum of one hour detention at average design flow and 30 minutes detention at peak hourly flow, whichever is greater. During start-up the contact chamber detention time shall be verified by tracer testing and shall be reverified whenever there is a substantial increase in peak flow.

2.2.1. The contact chambers shall be baffled to minimize short circuiting and backmixing of the chlorine-wastewater to such an extent that plug flow is approached. The baffling will be considered adequate when tracer tests indicate a modal value of greater than 0.6. The modal time occurs at the highest point of the tracer residence time distribution curve. The modal value is the number derived when the modal time is divided by the theoretical time.

It is recommended that baffles be constructed parallel to the longitudinal axis of the chamber with a minimum length to width ratio of 40:1 (the total length of the channel created by the baffles should be 40 times the distance between the baffles). Shallow uni-directional contact chambers should also have cross baffles to reduce short-circuiting caused from wind currents.

2.2.2. Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent. To accomplish continous disinfection, the chlorine contact tank should be designed with duplicate compartments to permit draining and cleaning of individual compartments. A sump or drain within each compartment with the drainage flowing to a raw sewage inlet is necessary for dewatering, sludge removal, and maintenance. Unit drains must not discharge into the outfall sewer. Baffles shall be provided to prevent the discharge of floating material. A readily accessible sampling point shall be provided at the outlet end of the contact tank or basins.

2.2.3 In some instances outfall lines may be used as chlorine contact chambers provided that the conditions set forth in Section 2.1 through 2.2.2 are met. In addition, pipe design and construction must preclude infiltration and exfiltration and must be full flowing under all flow conditions.

2.3 CHLORINE SUPPLY

When 45.5, 68.1, or 907 kg (100, 150, or 2,000 pound) cylinders are used, the following shall apply:

1. Sufficient space provided in the supply area for at least one spare cylinder for each one in service.
2. Minimum allowable room temperature is 12.76 degrees C (55 degrees F).
3. Heat must never be applied directly to the cylinder.
4. Direct sunlight must never reach the cylinder.

5. The maximum withdrawal rate for 45.4 and 68.1 kg (100 and 150 pound) cylinders should be limited to 18.16 kg (40 pounds) per day per cylinder.
6. When gas is withdrawn from 907 kg (2,000 pound) cylinders, the withdrawal rate should be limited to 181.6 kg (400 pounds) per day per cylinder.
7. The chlorine supply area should be kept cooler than the chlorinator area, except when liquid chlorine is withdrawn from 907 kg (2,000 pound) cylinders.
8. Scales should be provided for each cylinder in service; one scale is adequate for a group of cylinders connected to a common manifold.

2.3.1 Handling equipment should be provided as follows for 45.4 and 68.1 kg (100 and 150 pound) cylinders:

1. A hand-truck specifically designed for cylinders.
2. A method of securing cylinders to prevent them from falling over.

2.3.2 Handling equipment should be provided as follows for 907 kg (2,000 pound) cylinders:

1. 1814 kg (two-ton) capacity hoist.
2. Cylinder lifting bar.
3. Monorail or hoist with sufficient lifting height to pass one cylinder over another.

4. Cylinder trunnions to allow rotating the cylinders for proper connection.

2.3.3 Automatic switchover of chlorine cylinders at facilities having less than continuous operator attendance is desirable and will be required on a case-by-case basis.

2.4 CONSTRUCTION MATERIALS

2.4.1 The Supply system; i.e., that portion of the system between the cylinder and the chlorinator inlet, should be constructed of Schedule 80 black seamless steel pipe with 907 kg (2,000 pound) forged steel fittings. Unions should be ammonia type with lead gaskets. All valves shall be Chlorine Institute approved. Gauges shall be equipped with a silver protector diaphragm.

Piping can be assembled by either welded or threaded connections. All threaded pipe must be cleaned with solvent, preferably trichlorethylene and dried with nitrogen gas or dry air. Teflon tape should be used for thread lubricant in lieu of pipe dope.

2.4.2 The chlorine solution lines can be either Schedule 80 PVC, rubber-lined steel, saran-lined steel, or fiber cast pipe approved for moist chlorine use. Valves shall be PVC, PVC-lined, or rubber-lined.

2.4.3 The injector vacuum line between the chlorinator and the injector should be Schedule 80 PVC or fiber cast pipe approved for moist chlorine use.

2.4.4 Nuts and bolts should be 316 stainless steel, galvanized, or cadmium plated steel.

2.5 CHLORINATORS, CONTROLS, AND SAFETY SYSTEMS

In order to properly size the chlorination facilities, the maximum and minimum chlorine dosage rates must be determined. The dosage needs will vary with the type of treatment provided.

For domestic waste with not more than 1-2 percent industrial waste, the following guidelines should apply:

1.	Secondary effluent	6-9 g/cu m	(50-75 lbs/MG)
2.	Secondary plus ponds	6 g/cu m	(50 lbs/MG)
3.	Tertiary (not nitrified)	3.6-6 g/cu m	(30-50 lbs/MG)

When significant amounts of industrial waste are present, laboratory estimation of chlorine demand may be necessary.

When initial start-up flows are extremely low as compared to design flows, additional measures may be necessary to prevent over chlorination.

2.5.1. For treatment facility designs of 18,925 cu m/day (5 mgd) and greater, continously modulated dosage control systems shall be used. The control system will adjust the chlorine dosage rate to accomodate fluctuations in effluent chlorine demand and residual caused by changes in waste flow and waste characteristics with a maximum lag time of five minutes. This type of control is commonly called a closed loop or feedback control circuit. These facilities shall also utilize continuous chlorine residual monitoring. Flow proportional control is preferred over manual control for smaller facilities and may be required on a case-by-case basis.

In all cases where dechlorination is required, a compound loop control system will be required.

2.5.2 All sample lines should be designed so that they can be easily purged of slimes and other debris.

2.5.3 Alarms and monitoring equipment that adequately alert the operators in the event of deficiencies, malfunctions, or hazardous situations related to chlorine supply metering equipment, leaks, and residuals will be required on a case-by-case basis.

2.5.4 Safety equipment should be provided as follows:

1. Breathing apparatus.
2. Emergency chlorine container repair kits.
3. Chlorine leak detector.
4. Expansion tanks (liquid chlorine only).

Canister type masks are limited in effectiveness to changing chlorine cylinders and normal maintenance work, but are inadequate for repairing leaks. Therefore, one of the following types should be furnished: the air tank type unit as manufactured by MSA or Scott Aviation Company, the oxygen breathing apparatus as manufactured by MSA Company, or equal. This equipment should be stored outside the chlorine rooms.

All installations utilizing one ton cylinders shall have Chlorine Institute Emergency Container Kits. All other installations should have access to kits stored at a central location.

All installations utilizing 907 kg (2,000 pound) cylinders and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors. Continuous chlorine leak detectors would be desirable at all other installations. Whenever chlorine leak detectors are installed, they will be connected to a centrally located alarm system and should automatically start exhaust fans.

It is desirable to color code all piping related to chlorine systems.

2.5.5 Injector systems include the following components:

1. The water supply to the injector.
2. The chlorine injector.
3. The chlorine vacuum line from the chlorinator.
4. The chlorine solution line.
5. The diffuser located at the point of application.

Approximately 151.41 (40 gallons) of water is needed per 0.454 kg (pound) of chlorine fed. The volume of water must be sufficient to maintain a chlorine solution concentration of less than 3,500 mg/l.

After the designer has determined back pressure to be expected from the solution line and diffuser, the pressure and volume of water needed for the specific injector being used can be obtained from the equipment manufacturer. The water source can be either fresh water or effluent taken from the chlorine contact chamber.

Gauges should be provided to show the injector operating water pressure and the chlorine solution pressure. The chlorine solution gauge must be a compound unit reading to 76.2 cm (30 inches) Hg vacuum and to a pressure greater than the anticipated operating pressure. The gauge must also be equipped with a silver diaphragm protector.

A solution line can be manifolded to two or more injectors but should not be manifolded to two or more points of application, except when only one point of application will be used at a time. This is due to problems related to chlorine solution flow proportioning systems.

2.5.6 Diffuser design and location are two of the prime elements to effective disinfection. There are two basic locations for discharging the chlorine solution into the treated wastewater for disinfection: into a pipeline flowing full and into an open channel.

Diffusers located in pipelines are generally of two types: one type, used in pipes up to 76.2 cm (30 inches) in diameter, discharges into the center of the pipe; the other, which is satisfactory for most sizes of pipes, except very small lines, discharges through perforations over the middle half of the diameter. To insure rapid mixing both types should be located in highly turbulent flows, or immediately followed by a mechanical mixer.

Diffusers located in open channels are of two general types: a series of nozzles suspended from a flexible hose and a perforated pipe across the channel; the latter being the preferred type. Both types must be located in a highly turbulent zone with a minimum water cover of 22.86 cm (9 inches).

The minimum recommended velocity through the diffuser holes is 3.0-3.6 m (10-12 feet) per second. All diffusers should be removable for cleaning.

2.6 HOUSING AND STORAGE

Housing is necessary to protect the equipment from adverse environmental elements and many of the design requirements relate to the safe use of chlorine and protection of personnel.

Areas housing chlorinators and chlorine cylinders in use should be located on or above ground level with the container area separated from the chlorinator and accessories. These facilities should be housed in a separate building or as a minimum in rooms completely separated from the remainder of the building with access only through outside doors. There must not be any means by which chlorine gas can enter other areas of a common building.

Chlorine cylinder storage area should be located on or above ground level and shaded from direct sunlight.

Chlorination systems should be protected from fire hazards and water should be available for cooling cylinders in case of fire.

There must be adequate room provided for easy access to all equipment for maintenance and repair. The minimum acceptable clearance around and in back of equipment is 0.6 m (2 feet), except for units designed for wall or cylinder mounting.

All rooms shall be force ventilated providing one air change per minute, except "package" buildings less than 1.48 sq m (16 square feet) of floor space, where an entire side opens as a door and sufficient cross ventilation is provided by a window. The room exhaust must be located near the floor and separated from other ventilation systems. Air inlets should be located so as to provide cross-ventilation.

When possible, a clear glass, gas tight, inspection window should be provided.

Chlorinator rooms shall have a means of heating and controlling the room air temperature above a minumum of 12.76 degrees C (55 degrees F). A temperature of 18.31 degrees C (65 degrees F) is recommended. The room housing chlorine clyinders in use must be maintained at a temperature equal to or slightly less than the chlorinator room, but in no case less than 12.76 degrees C (55 degrees F).

Chlorinators and some accessories require individual vents to a safe outside area. The vent should terminate not more than 7.62 m (25 feet) above the chlorinator or accessory and have a slight downward slope from the highest point. The outside end of the vent should bend down to preclude water entering the vent and be covered with a screen to exclude insects.

Electrical controls for lights and fans should operate automatically when entrance doors are opened. Manually controlled over-ride switches shall be located adjacent to and outside of all entrance doors with an indicator light at each entrance when there are two or more entrances. Electrical controls will be excluded, insofar as possible, from rooms plumbed for chlorine.

2.7 RELIABILITY

Reliability by design will afford dependable disinfection. Standby equipment will be required on a case-by-case basis. Routine reliability will include:

1. Means to prevent exhaustion of the chlorine supply.
2. Means to assure adequate water supply to the injector.
3. Means of cleaning the chlorine contact chamber while maitaining continuous disinfection.

Additional guidelines are provided in the following Technical Bulletins:

1. Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability, EPA-430-99-74-001.
2. Protection of Shellfish Waters, EPA 430/9-74-010.

3. FACILITY OPERATION

3.1 ANALYTICAL METHODS

Analytical methods of chlorine residual and fecal coliform concentrations shall be conducted in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater," prepared and published jointly by AWWA, the APHA, and the WPCF, and/or other methods approved by the states in Region X and EPA.

3.1.1 Data indicates that the Orthotolidine method of analysis for chlorine residual is highly erroneous and unreliable for wastewater analysis. Consequently, its use is not acceptable.

3.1.2 The amperometric method is considered to be the most accurate method of testing for chlorine when the indirect procedure (back titration) is used. The method will detect chlorine residuals less than 0.05 mg/l. Therefore, this method will be required when dechlorination is used.

3.1.3 The iodometric (starch iodide) titration method is comparable to the amperometric method except for extremely low concentration of chlorine residual. The indirect procedure (back titration) is recommended.

3.1.4 The N,N-diethyl-p-phenylenediamine (DPD) method has been established by EPA as an interim method for analysis of chlorine residual, pending further laboratory testing. It may be acceptable for use at smaller treatment plants on a case-by-case basis when dechlorination is not required with approval of the state regulatory agency.

3.2 CHLORINE DOSAGE

The chlorine dosage required for adequate disinfection will fluctuate over the 24-hour period, depending on changing flow and waste characteristics. A study to determine the relationship of bacterial kill to chlorine dosage and residual should be made soon after the new plant is placed into operation. Such a study should be repeated yearly or, preferably seasonally, to identify changes in disinfection requirements. A bacterial analysis should consist of fecal coliform determinations on at least six samples collected over a 12-hour period which includes the peak flow. All chlorine residual determinations should be taken concurrent to bacteriological samples and recorded in the plant log.

3.2.1 Total residual chlorine should be determined hourly until sufficient data are available to justify reducing the testing frequency. Individual values rather than averages should be recorded in the plant log. Chlorine residuals must be watched closely since a reduction in effluent quality or a sharp increase in flow may quickly cause inadequate disinfection.

3.3 CONTACT CHAMBER CLEANING

The advantages of clean chlorine contact chambers or basins have been well documented. Each facility will establish and adhere to a schedule of monitoring and removing settled solids and floating matter from contact chambers or basins.

3.4 RECORDS

Current records of daily chlorine residuals and failures shall be available for inspection at the plant. Copies of these records shall be submitted in accordance with the discharger's NPDES permit requirements. The appropriate State agency or EPA shall be notified immediately by telephone when emergency or other conditions prevent adequate disinfection of waste effluents.

3.5 EFFICIENCY OF DISINFECTION

Several parameters have an impact on the efficiency of disinfection. These include temperature, pH, suspended solids, BOD, chlorine demand, and others. Test for these parameters are described in "Standard Methods." Routine analysis of these parameters should be maintained in the plant laboratory records.

3.6 SAFETY PRECAUTIONS

All operation and maintenance personnel should be trained in safety precautions involving chlorine. Local fire departments and rescue squads should also be alerted to potential chlorine emergencies that exist at the wastewater treatment plant.

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