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| Minnesota Pollution Control Agency (MPCA), 520 Lafayette Road North, St. Paul, MN 55155-4194 | Chlorine Disinfection Review ChecklistNPDES/SDS Permit ProgramNational Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS)Doc Type: Plan/Specification Review Summary |

**Purpose:** This checklist is intended for use by design engineers, to assist Minnesota Pollution Control Agency (MPCA) review engineers in the efficient review of planning and design documents. The information requested is the minimum technical data necessary for MPCA staff to review proposed designs and to determine whether there is reasonable assurance that the treatment system, when constructed, will comply with permit conditions, regulations, and criteria of the MPCA.

**Instructions:** The information in this checklist is based on the ***Recommended Standards for Wastewater Facilities published by the Great Lakes Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (Ten State Standards) 2014 Edition,*** other accepted engineering references, and MPCA recommendations. Specific references, other than Ten State Standards, are listed where appropriate. The checklist is organized according to the numbering sequence found in Ten State Standards to allow for ease in locating the entire content and text of the recommendations.

The checklist is designed so that a “**yes**” answer indicates compliance with Ten State Standards et al.

A “**no**” answer indicates a deviation from Ten State Standards et al. Answering “no” to any question will require justification that can be provided at the end of the checklist and possibly supporting information, from wastewater treatment plant operational data, to demonstrate how the intent of the recommendation will be met. Additional information may be requested based on site specific conditions.

A “**N/A**” answer means not applicable because the equipment associated with the question is not included in the design.

Wastewater Treatment Facility information

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| **Date** (mm/dd/yyyy): |       | **MPCA Project No:**  |       |
| **Title of project:** |       |

Permittee information

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| --- | --- |
| Facility name: |       |
| Contact name and title: |       | NPDES/SDS Permit No: | MN  |       |
| Email: |       | Phone number: |       |

Design Engineer information

|  |  |  |  |
| --- | --- | --- | --- |
| Contact name: |       | Contact phone number: |       |
| Email: |       |  |  |

**Phase:** [ ]  Planning Phase [ ]  Design Phase

**Type of disinfection:** [ ]  Chlorination [ ]  Chlorination/Dechlorination

Influent Characteristics

|  |  |  |
| --- | --- | --- |
| Peak hourly flow rate: |       | MGD |

100. Disinfection

*(Only use a “NA” answer if the equipment associated with the question is not included in the design)*

| ***101. General*** | **Yes** | **No** | **N/A** |
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| Does the design consider meeting both the bacterial standards and the disinfectant residual limit in the effluent? | [ ]  | [ ]  |  |
| Was the disinfection process selected after due consideration of waste characteristics, type of treatment process provided prior to disinfection, waste flow rates, pH of waste, disinfectant demand rates, current technology application, cost of equipment and chemicals, power cost, and maintenance requirements? | [ ]  | [ ]  |  |

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| ***102. Chlorine Disinfection*** |
| ***102.1 Type*** | **Yes** | **No** | **N/A** |
| Was the type of chlorine carefully evaluated during the facility planning process? | [ ]  | [ ]  |  |
| Were both monetary cost and the potential public exposure to chlorine considered when making the final determination on the type of chlorine to use? | [ ]  | [ ]  |  |
| Identify type of chlorine to be used: |       |
| ***102.2 Dosage*** |
| Is the capacity adequate to produce an effluent that will meet the applicable bacterial limits specified by the regulatory agency for that installation? | [ ]  | [ ]  |  |
| Will the required disinfection capacity vary, depending on the uses and points of application of the disinfection chemical? | [ ]  | [ ]  |  |
| Is the chlorination system designed on a rational basis and calculations justifying the equipment sizing and number of units submitted for the whole operating range of flow rates for the type of control to be used? | [ ]  | [ ]  |  |
| Do system design considerations include the controlling wastewater flow meter (sensitivity and location), telemetering equipment and chlorination controls? | [ ]  | [ ]  |  |
| Are the following used as a guide in sizing chlorination facilities for normal domestic wastewater? | [ ]  | [ ]  |  |
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| **Type of Treatment** | **Dosage** |
| Trickling filter plant effluent | 10 mg/L |
| Activated sludge plant effluent | 8 mg/L |
| Tertiary filtration effluent | 6 mg/L |
| Nitrified effluent | 6 mg/L |
|  |

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| ***102.3 Containers*** |
| **102.31 Cylinders** |
| Are one hundred fifty pound cylinders used where chlorine gas consumption is less than 150 pounds per day? | [ ]  | [ ]  | [ ]  |
| Are cylinders stored in an upright position with adequate support brackets and chains at 2/3 of cylinder height for each cylinder? | [ ]  | [ ]  | [ ]  |
| **102.32 Ton Containers** |
| Are the use of one-ton containers considered where the average daily chlorine consumption is over 150 pounds? | [ ]  | [ ]  | [ ]  |
| **102.33 Tank Cars** |
| At large installations, are the use of tank cars, generally accompanied by evaporators, considered? | [ ]  | [ ]  | [ ]  |
| Is area wide public safety evaluated? | [ ]  | [ ]  | [ ]  |
| Will no interruption of chlorination be permitted during tank car switching? | [ ]  | [ ]  | [ ]  |
| Will the tank car being used for the chlorine supply be located on a dead end, level track that is a private siding? | [ ]  | [ ]  | [ ]  |
| Will the tank car be protected from accidental bumping by other railway cars by a locked derail device, a closed locked switch or both? | [ ]  | [ ]  | [ ]  |
| Will the area be clearly posted “DANGER-CHLORINE”? | [ ]  | [ ]  | [ ]  |
| Will the tank car be secured by adequate fencing that includes gates provided with locks for personnel and rail access? | [ ]  | [ ]  | [ ]  |
| Will the tank car site be provided with a suitable operating platform at the unloading point for easy access to the protective housing or the tank car for the connection flexible feedlines and valve operation and maintenance? | [ ]  | [ ]  | [ ]  |
| **102.34 Liquid Hypochlorite Solutions** |
| Will storage containers for hypochlorite solutions be of sturdy, non-metallic lined construction and be provided with secure tank tops and pressure relief and overflow piping? | [ ]  | [ ]  | [ ]  |

|  | **Yes** | **No** | **N/A** |
| --- | --- | --- | --- |
| Will storage tanks be either located or vented outside? | [ ]  | [ ]  | [ ]  |
| Will provisions be made for adequate protection from light and extreme temperatures? | [ ]  | [ ]  | [ ]  |
| Will tanks be located where leakage will not cause corrosion or damage to other equipment? | [ ]  | [ ]  | [ ]  |
| Will a means of secondary containment be provided to contain spills and facilitate cleanup? | [ ]  | [ ]  | [ ]  |
| Due to deterioration of hypochlorite solutions over time, will containers not be sized to hold more than one month’s needs? | [ ]  | [ ]  | [ ]  |
| At larger facilities and locations where delivery is not a problem, will on-site storage be limited to one week? Refer to Section 57. | [ ]  | [ ]  | [ ]  |
| **102.35 Dry Hypochlorite Compounds** |
| Will dry hypochlorite compounds be kept in tightly closed containers and stored in a cool, dry location? | [ ]  | [ ]  | [ ]  |
| Will some means of dust control be considered, depending on the size of the facility and the quantity of compound used? Refer to Section 57. | [ ]  | [ ]  | [ ]  |
| ***102.4 Equipment*** |
| **102.41 Scales** |
| Will scales for weighing cylinders and containers be provided at all plants using chlorine gas? | [ ]  | [ ]  | [ ]  |
| Will scales of the indicating and recording type be provided? | [ ]  | [ ]  | [ ]  |
| At a minimum, will a platform scale be provided? | [ ]  | [ ]  | [ ]  |
| Will the scale be of corrosion-resistant material? | [ ]  | [ ]  | [ ]  |
| **102.42 Evaporators** |
| Where manifolding of several cylinders or ton containers will be required to evaporate sufficient chlorine, is consideration given to the installation of evaporators to produce the quantity of gas required? | [ ]  | [ ]  | [ ]  |
| **102.43 Mixing** |
| Will the disinfectant be positively mixed as rapidly as possible, with a complete mix being effected in less than one second? (M&E 2014 and MOP 8 1998) | [ ]  | [ ]  |  |
| Will mixing be accomplished by either the use of turbulent flow regime or a mechanical flash mixer? | [ ]  | [ ]  |  |
| Identify point of application for the disinfectant chemical: |       |
| **102.44 Contact Period and Tank** |
| For a chlorination system, will a minimum contact period of 15 minutes at design peak hourly flow or maximum rate of pumpage be provided after thorough mixing? | [ ]  | [ ]  |  |
| For a chlorination system, will a minimum contact period of 30 minutes at average wet weather flow be provided after thorough mixing? (MOP 8 1998) | [ ]  | [ ]  |  |
| Identify detention time at peak hourly flow rate: |       | minutes |
| Identify detention time at average wet weather flow: |       | minutes  |
| When evaluating existing chlorine contact tanks, will field tracer studies be performed to assure adequate contact time? | [ ]  | [ ]  | [ ]  |
| Will the chlorine contact tank be constructed so as to reduce short-circuiting of flow to a practical minimum? | [ ]  | [ ]  | [ ]  |
| Identify length-to-width ratio: |       | L/W | Recommended L/W ratio greater than 40:1 (M&E 2014 and MOP 8 1998) |
| Identify volume of tank: |       | gallons |
| Will tanks that are not provided with continuous mixing be provided with “over-and-under” or “end-around” baffling to minimize short-circuiting? | [ ]  | [ ]  | [ ]  |
| Will the tank be designed to facilitate maintenance and cleaning without reducing effectiveness of disinfection? | [ ]  | [ ]  | [ ]  |
| Will duplicate tanks, mechanical scrapers, or portable deck-level vacuum cleaning equipment be provided? | [ ]  | [ ]  | [ ]  |
| Has consideration been given to providing skimming devices on all contact tanks? | [ ]  | [ ]  | [ ]  |
| Is the use of a covered tank avoided? | [ ]  | [ ]  | [ ]  |
| **102.45 Piping and Connections** |
| Will piping systems be as simple as possible, specifically selected and manufactured to be suitable for chlorine service, with a minimum number of joints? | [ ]  | [ ]  |  |
| Will piping be well supported and protected against temperature extremes? | [ ]  | [ ]  |  |
| Due to the corrosiveness of wet chlorine, will all lines designated to handle dry chlorine be protected from the entrance of water or air conditioning water? | [ ]  | [ ]  | [ ]  |
| Will low pressure lines be made of hard rubber, saran-lined, rubber-lined, polyethylene, polyvinylchloride (PVC), or other approved materials that are satisfactory for wet chlorine or aqueous solutions of chlorine? | [ ]  | [ ]  | [ ]  |
| Will the chlorine system piping be color coded and labeled to distinguish it from other plant piping? Refer to Paragraph 54.5. | [ ]  | [ ]  |  |
| Where sulfur dioxide is used, will the piping and fittings for chlorine and sulfur dioxide systems be designed so that interconnection between the two systems cannot occur? | [ ]  | [ ]  | [ ]  |
| **102.46 Standby Equipment and Spare Parts** |
| Will standby equipment of sufficient capacity be available to replace the largest unit during shutdowns? | [ ]  | [ ]  |  |
| Will spare parts be available for all disinfection equipment to replace parts which are subject to wear and breakage? | [ ]  | [ ]  |  |
| **102.47 Chlorinator Water Supply** |
| Will an ample supply of water be available for operating the chlorinator? | [ ]  | [ ]  |  |
| Where a booster pump is required, will duplicate equipment be provided and when necessary, standby power as well? | [ ]  | [ ]  | [ ]  |
| Does protection of a potable water supply conform to the requirements of Paragraph 56.2? | [ ]  | [ ]  |  |
| Is adequately filtered plant effluent considered for use in the chlorinator? | [ ]  | [ ]  |  |
| **102.48 Leak Detection and Controls**  |
| Will a bottle of 56 percent ammonium hydroxide solution be available for detecting chlorine leaks? | [ ]  | [ ]  | [ ]  |
| Is a leak repair kit approved by the Chlorine Institute provided where one-ton containers or tank cars are used? | [ ]  | [ ]  | [ ]  |
| Was consideration given to the provision of caustic soda solution reaction tanks for adsorbing the contents of leaking one-ton containers where such containers are in use? | [ ]  | [ ]  | [ ]  |
| Was consideration given to the installation of automatic gas detection and related alarm equipment? | [ ]  | [ ]  | [ ]  |
| ***102.5 Housing*** |
| **102.51 Feed and Storage Rooms** |
| If gas chlorination equipment or chlorine cylinders are to be in a separate building used for other purposes, will a gas-tight room separate this equipment from any other portion of the building? | [ ]  | [ ]  | [ ]  |
| Will the connection of floor drains from the chlorine room to floor drains from other rooms be avoided? | [ ]  | [ ]  |  |
| Will doors to this room open only to the outside of the building and be equipped with panic hardware? | [ ]  | [ ]  |  |
| Will rooms be at ground level and permit easy access to all equipment? | [ ]  | [ ]  |  |
| Will storage areas for one-ton cylinders be separated from the feed area? | [ ]  | [ ]  | [ ]  |
| Will the storage area have designated areas for “full” and “empty” cylinders? | [ ]  | [ ]  | [ ]  |
| Will chlorination equipment be situated as close to the application point as reasonably possible? | [ ]  | [ ]  |  |
| **102.52 Inspection Window** |
| Will a clear glass, gas-tight, window be installed in an exterior door or interior wall of the chlorinator room to permit the units to be viewed without entering the room? | [ ]  | [ ]  |  |
| **102.53 Heat** |
| Will rooms containing disinfection equipment be provided with a means of heating so that a temperature of at least 60 degreesFahrenheit be maintained? | [ ]  | [ ]  |  |
| Will the room be protected from excess heat? | [ ]  | [ ]  |  |
| Will cylinders be kept at essentially room temperature? | [ ]  | [ ]  | [ ]  |
| If liquid hypochlorite solution is used, will the containers be located in an unheated area? | [ ]  | [ ]  | [ ]  |
| **102.54 Ventilation** |
| With chlorination systems, will forced, mechanical ventilation be installed which will provide one complete fresh air change per minute when the room is occupied? | [ ]  | [ ]  |  |
| Will the entrance to the air exhaust duct from the room be near the floor? | [ ]  | [ ]  |  |
| Will the point of discharge be located as not to contaminate the air inlet to any buildings or present a hazard at the access to the chlorinator room or other inhabited areas? | [ ]  | [ ]  |  |
| Will air inlets be located to provide cross ventilation with air and at such temperature that will not adversely affect the chlorination equipment? | [ ]  | [ ]  |  |
|  Will the outside air inlet be at least three feet above grade? | [ ]  | [ ]  |  |
| Will the vent hose from the chlorinator discharge to the outside atmosphere above grade? | [ ]  | [ ]  |  |
| Will scrubbers be used on ventilation discharge where public exposure may be extensive? | [ ]  | [ ]  | [ ]  |
| **102.55 Electrical Controls and Ambient Gas Detectors** |
| Will switches for fans and lights be outside of the room at the entrance? | [ ]  | [ ]  |  |
| Will a labeled signal light indicating fan operation be provided at each entrance, if the fan can be controlled from more than one point? | [ ]  | [ ]  | [ ]  |
| Will an ambient chlorine gas detector be provided in the chlorine storage room? | [ ]  | [ ]  |  |
| Will a gas detector be interlocked with the fan and audible or visual alarms? | [ ]  | [ ]  |  |
| Will electrical fixtures be gastight and corrosion resistant? (MOP 8 1998) | [ ]  | [ ]  |  |
| **102.56 Protective and Respiratory Gear** |
| Will respiratory air-pac protection equipment that meets the requirements of the National Institute for Occupational Safety and Health (NIOSH) be available where chlorine gas is handled, and be stored at a convenient location, but not inside any room where chlorine is used or stored? | [ ]  | [ ]  | [ ]  |
| Will instructions for using the equipment be posted? | [ ]  | [ ]  | [ ]  |
| Will the units use compressed air, have at least 30-minute capacity and be compatible with the units used by the fire department responsible for the plant? | [ ]  | [ ]  | [ ]  |
| ***102.6 Sampling and Control***  |
| **102.61 Sampling** |
| Will facilities be included for sampling disinfected effluent after the contact chamber as monitoring requirements warrant? | [ ]  | [ ]  | [ ]  |
| In large installations, or where stream conditions warrant, will provisions be made for continuous monitoring of effluent chlorine residual? | [ ]  | [ ]  | [ ]  |
| **102.62 Testing and Control**  |
| Will equipment be provided for measuring chlorine residual using accepted test procedures? | [ ]  | [ ]  |  |
| Will the installation of demonstrated effective facilities for automatic chlorine residual analysis, recording, and proportioning systems be considered at all large installations? | [ ]  | [ ]  | [ ]  |
| Will equipment be provided for measuring bacterial organisms using accepted test procedures as required by the regulatory agency? | [ ]  | [ ]  |  |
| ***103. Dechlorination*** |
| ***103.1 Types*** |
| Will dechlorination of wastewater effluent be necessary to reduce the toxicity due to chlorine residuals? | [ ]  | [ ]  |  |
| For small facilities, will tablet dechlorination systems be used? | [ ]  | [ ]  | [ ]  |
| Identify type of dechlorination chemical will be used: |       |
| Was the type of dechlorination system carefully selected considering criteria including: type of chemical storage required, amount of chemical needed, ease of operation, compatibility with existing equipment, and safety? | [ ]  | [ ]  |  |
| ***103.2 Dosage*** |
| Does the dosage of dechlorination chemical depend on the residual chlorine in the effluent, the final residual chlorine limit, and the particular form of the dechlorinating chemical used? | [ ]  | [ ]  |  |
| Will one of the following forms of the compound be used and yield sulfite (SO2) when dissolved in water? | [ ]  | [ ]  |  |
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| **Dechlorination Chemical** | **Theoretical mg/L Required to Neutralize 1 mg/L Cl2** |
| Sodium thiosulfate (solution) | 0.56 |
| Sodium sulfite (tablet) | 1.78 |
| Sulfur dioxide (gas) | 0.9 |
| Sodium meta bisulfite (solution) | 1.34 |
| Sodium bisulfite (solution) | 1.46 |
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 |
| Were theoretical values used for initial approximations, to size feed equipment with the consideration that under good mixing conditions 10% excess dechlorinating chemical is required above theoretical values? | [ ]  | [ ]  |  |
| Was it considered that excess sulfur dioxide may consume oxygen at a maximum of 1.0 mg dissolved oxygen for every 4 mg SO2? | [ ]  | [ ]  |  |
| Was consideration given to the liquid solutions of various strengths and the potential need to further dilute these solutions to provide the proper dose of sulfite? | [ ]  | [ ]  |  |
| ***103.3 Containers*** |
| Will storage containers consist of gas cylinders or 50 gallon drums for liquid or dry compounds? | [ ]  | [ ]  |  |
| Will dilution tanks and mixing tanks be provided when using dry compounds and liquid compounds to deliver the proper dosage? | [ ]  | [ ]  | [ ]  |
| Will solution containers be covered to prevent evaporation and spills? | [ ]  | [ ]  | [ ]  |
| ***103.4 Feed Equipment, Mixing, and Contact Requirements*** |
| **103.41 Equipment** *In general, the same type of feeding equipment used for chlorine gas may be used with minor modifications for sulfur dioxide gas. However, the manufacturer should be contacted for specific equipment recommendations. No equipment should be used alternatively for the two gases.* |
| Will the type of dichlorination feed equipment utilizing sulfur compounds include a vacuum solution feed of sulfur dioxide gas and a positive displacement pump for aqueous solutions of sulfite or bisulfite? | [ ]  | [ ]  | [ ]  |
| Will the selection of the type of feed equipment utilizing sulfur compounds include consideration of the operator safety and overall public safety relative to the wastewater treatment plant’s proximity to populated areas and the security of gas cylinder storage? | [ ]  | [ ]  | [ ]  |
| Will the selection and design of sulfur dioxide feeding equipment take into account that the gas reliquefies quite easily? | [ ]  | [ ]  | [ ]  |
| Will special precautions be taken when using ton containers to prevent reliquefaction? | [ ]  | [ ]  | [ ]  |
| Where necessary to meet the operating ranges, will multiple units be provided for adequate peak capacity and to provide a sufficiently low feed rate on turn down to avoid depletion of the dissolved oxygen concentrations in the receiving waters? | [ ]  | [ ]  | [ ]  |
| **103.42 Mixing Requirements** |
| Will the dechlorination chemical be introduced at a point in the process where the hydraulic turbulence is adequate to assure thorough and complete mixing? | [ ]  | [ ]  |  |
| If a point in the process where the adequate hydraulic turbulence does not exist, will mechanical mixing be provided? | [ ]  | [ ]  | [ ]  |
| **103.43 Contact Time** |
| Will a minimum of 30 seconds for mixing and contact time be provided at the design peak hourly flow or maximum rate of pumpage? | [ ]  | [ ]  |  |
| Will a suitable sampling point be provided downstream of the contact zone? | [ ]  | [ ]  |  |
| Was consideration given to a means of reaeration to assure maintenance of an acceptable dissolved oxygen concentration in the stream following sulfonation? | [ ]  | [ ]  | [ ]  |
| **103.44 Standby Equipment and Spare Parts** |
| Will standby equipment of sufficient capacity be available to replace the largest unit during shutdowns? | [ ]  | [ ]  |  |
| Will spare parts be available for all disinfection equipment to replace parts which are subject to wear and breakage? | [ ]  | [ ]  |  |
| **103.45 Sulfonator Water Supply** |
| Will an ample supply of water be available for operating the sulfonator? | [ ]  | [ ]  |  |
| Where a booster pump is required, will duplicate equipment be provided and when necessary, standby power as well? | [ ]  | [ ]  | [ ]  |
| Does protection of a potable water supply conform to the requirements of Paragraph 56.2? | [ ]  | [ ]  |  |
| Is adequately filtered plant effluent considered for use in the sulfonator? | [ ]  | [ ]  |  |
| ***103.5 Housing Requirements*** |
| **103.51 Feed and Storage Rooms** |
| If SO2 equipment or cylinders are to be in a separate building used for other purposes, will a gas-tight room separate this equipment from any other portion of the building? | [ ]  | [ ]  | [ ]  |
| Will the connection of floor drains from the SO2 room to floor drains from other rooms be avoided? | [ ]  | [ ]  |  |
| Will doors to this room open only to the outside of the building and be equipped with panic hardware? | [ ]  | [ ]  |  |
| Will rooms be at ground level and permit easy access to all equipment? | [ ]  | [ ]  |  |
| Will storage areas for one-ton cylinders be separated from the feed area? | [ ]  | [ ]  | [ ]  |
| Will the storage area have designated areas for “full” and “empty” cylinders? | [ ]  | [ ]  | [ ]  |
| Will SO2 equipment be situated as close to the application point as reasonably possible? | [ ]  | [ ]  |  |
| When using solutions of the dechlorinating compounds, will the solutions be stored in a room that meets the safety and handling requirements set forth in Section 57? | [ ]  | [ ]  | [ ]  |
| Are the mixing, storage, and solution delivery areas designed to contain or route solution spillage or leakage away from traffic areas to an appropriate containment area? | [ ]  | [ ]  |  |
| **103.52 Protective and Respiratory Gear** *For additional safety considerations, see Section 57.* |
| Will respiratory air-pac protection equipment that meets the requirements of the National Institute for Occupational Safety and Health (NIOSH) be available where SO2 gas is handled, and be stored at a convenient location, but not inside any room where SO2 is used or stored? | [ ]  | [ ]  | [ ]  |
| Will instructions for using the equipment be posted? | [ ]  | [ ]  | [ ]  |
| Will the units use compressed air, have at least 30-minute capacity and be compatible with the units used by the fire department responsible for the plant? | [ ]  | [ ]  | [ ]  |
| Are leak repair kits available for use of the type used for chlorine gas that are equipped with gasket material suitable for service with sulfur dioxide gas (refer to The Compressed Gas Association Publication CGA G-3: Sulfur Dioxide, June 2023)? | [ ]  | [ ]  | [ ]  |
| ***103.6 Sampling and Control*** |
| **103.61 Sampling** |
| Are facilities included for sampling the dechlorinated effluent for residual chlorine? | [ ]  | [ ]  |  |
| Are provisions made to monitor for dissolved oxygen concentration after sulfonation when required by the regulatory agency? | [ ]  | [ ]  | [ ]  |
| **103.62 Testing and Control** |
| Are provisions made for manual or automatic control of sulfonator feed rates based on chlorine residual measurement or flow? | [ ]  | [ ]  |  |

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| Justification for all questions answered with a “no |
|       |
| Additional comments: |
|       |

**References**

GLUMRB (2014 Edition) *Recommended Standards for Wastewater Facilities* (Ten State Standards), Health Research, Inc., Health Education Services Division, Albany NY.

Metcalf & Eddy, Inc. (2014) *Wastewater Engineering, Treatment and Resource Recovery*, 5th ed., McGraw-Hill, New York. (M&E 2014)

WEF (1998) *Design of Municipal Wastewater Treatment Plants, Manual of Practice No. 8*, Water Environment Federation, Alexandria, VA. (MOP 8 1998)

**Acronym definitions**

mg milligrams

mg/L milligrams per liter

MGD million gallons per day