Chapter 5 Treatment

Editor's Note: For questions on updates, please call the MassDEP Drinking Water Program in Boston, MA at 617-292-5770, or e-mail the MassDEP Drinking Water Program Director at program.director-dwp@mass.gov. Subject line: Guidelines.

Acronyms used in this chapter:

ANSI – American National Standards Institute
AWWA - American Water Works Association
AIX – anion exchange
BAT's - Best Available Technologies
BWP - Bureau of Waste Prevention
CDC - US Centers for Disease Control and Prevention
CMR – Code of MA Regulations
COM - community
CT – contact time
DAF – dissolved air flotation
DO – dissolved oxygen
DWP – Drinking Water Program
DWW - Division of Wetlands and Waterways
EPA - US Environmental Protection Agency
ETV - Environmental Technology Verification
GAC – granulated activated carbon
GPD - gallons per day
GPM - gallons per minute
GFD - gallons per square foot per day
G Value - velocity gradient
GWR - Groundwater Rule
HA - Health Advisory
HPC - heterotrophic plate count
IESWTR – Interim Enhanced Surface Water Treatment Rule
ISO - Insurance Services Organization
IT – UV light intensity x time
IX – ion exchange
LP - low pressure
LPHO - low pressure high-output
LT1ESWTR – Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR – Long Term 2 Enhanced Surface Water Treatment Rule
MassDEP – MA Dept. of Environmental Protection
MassDPH – MA Dept. of Public Health
MA ORSGs – Office of Research and Standards Drinking Water Guidelines
MCL - maximum contaminant level

MDL - method detection limits
MRDL – maximum residual disinfectant level
MEPA – MA Environmental Policy Act
MF - microfiltration
MIB - methyl isoborneol
NA – novel adsorbents
NaF – sodium fluoride
Na2SiF6 - sodium silico-fluoride
ND – no-detect
NF – nanofiltration
NFL - National Sanitation Foundation
NIST - National Institute of Standards & Technology
NPDES – National Pollutant Discharge Elimination System
NRC - Nuclear Regulatory Commission
NSF – National Sanitation Foundation
NTNC - non-transient non-community
NTU – nephelometric turbidity unit
OSHA – Occupational Safety and Health Act
O&M - operation and maintenance
ORS - Office of Research and Standards
PAC - powdered activated carbon
PFAS - Per- and Polyfluoroalkyl Substances
PFAS6.- sum of PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA
PFDA - Perfluorodecanoic acid
PFHpA - Perfluoroheptanoic acid
PFHxS - Perfluorohexanesulfonic acid
PFNA - Perfluorononanoic acid,
PFOA - Perfluorooctanoic acid
PFOS - Perfluorooctanesulfonic acid
PTA - packed tower aeration
PVC – polyvinyl chloride
PSS - point source summation
PVDF - polyvinyl difluoride
POTW – publicly owned treatment works
PSI – pounds per square inch
PWS – public water system
QA/QC quality assurance/quality control
RCRA - Resource Conservation and Recovery Act
RED - reduction equivalent dose
RO – reverse osmosis
SDWA – Safe Drinking Water Act
SOC - synthetic organic chemicals
SWTR - Surface Water Treatment Rule
TCR - Total Coliform Rule
TCLP - toxicity characteristic leaching procedure
TNC - transient non-community
TOC - total organic carbon
THM – trihalomethane
UIC – underground injection control
UL - Underwriter Laboratory
um – micrometer or microns
USGS - US Geological Survey
UF - ultrafiltration
UV – ultra violet
VOC – volatile organic compounds
WMA - Water Management Act Program

WTP – water treatment plants

5.0 Treatment

Any treatment process not specifically covered in chapter 5.0 is likely considered New Technology and must follow the New Technology Approval Process (310 CMR 22.04(8) and DWP Policy 89-01).

5.1 General Information

5.1.1 Permits

Permit applications must be completed for all pilot proposals, pilot study reports, and final plans for water treatment and submitted to MassDEP for final approval. All final design plans must be stamped by a professional engineer (P.E.) registered in Massachusetts in the appropriate engineering field and submitted to MassDEP for final approval unless otherwise approved by MassDEP in writing. Inquiries regarding Drinking Water Program (DWP) permits should be directed to the appropriate regional office.

Permit applications and approvals may also be required from many non-DWP state programs such as waste handling and disposal (see Section 5.10). Inquiries regarding these types of programs should be directed to the appropriate regional office.

5.1.2 Engineer's Report

An initial engineering study documented in an engineer's report shall be submitted in conformance with Section 1.1, Engineer's Report. Where recycling of backwash water is proposed the report shall address the adverse impact of recycling backwash water due to solids, algae, trihalomethane formation and similar problems.

5.1.3 Engineer's Plans and Specifications

Unless otherwise requested by MassDEP in writing, it is only necessary to submit engineering plans and specifications for the equipment and materials directly related to the treatment process(es). (See Chapter 1, Sections 1.2 and 1.3.) MassDEP requests one hard copy and one electronic copy of the appropriate specifications and plans. The electronic copy must be submitted on a compact disk or other acceptable media and must be in PDF format.

5.1.4 Pilot Studies

A pilot proposal and a pilot study or in-plant demonstration study shall be conducted when requested by MassDEP. Permits are required for both the proposal and the study. Both the proposal and the study must be conducted in accordance with DWP Policy 90-04.

5.1.5 Water Treatment Facility Design

General Information

1. Facility design shall:

   a. Include a minimum of two units for each unit process unless otherwise approved by MassDEP in writing.

   b. Consider a design that would permit operation of the rapid mix and flocculation tanks in either series or parallel

   c. Permit units to be taken out of service without disrupting operation and with drains or pumps sized to allow dewatering in a reasonable period of time

   d. Include multiple-stage treatment facilities when required by MassDEP

   e. Minimize hydraulic head losses between units to allow future changes in processes without the need for repumping

   f. Include space and equipment for operators to conduct all necessary process and operational procedures such as jar testing. Results shall be used at the plant to assure that chemical feeds are adjusted and maintained in response to raw water changes in temperature, turbidity and other variations in quality.

   g. Include equipment and connections for disinfection of all water treatment facilities that are taken out of service for inspection, repairing, painting, cleaning or other activity that might lead to contamination of water. Disinfection must be conducted in accordance with AWWA Standard C-653.

   h. Include a Waste Disposal Plan as described in Section 5.10.1.2

   i. Include covered structures for all outdoor water treatment plant basins unless otherwise approved by MassDEP in writing.

   j. Be designed and constructed in such a manner as to prevent contamination of the water supply, by excluding any cross connections to the distribution system and by-passes of treatment units through interconnection of chemical feed or other piping. At all facilities treating surface water, pre- and post-chemical feed systems must be independent to prevent possible siphoning of partially treated water into the clearwell. Blow off outlets and drains must terminate and discharge at places satisfactory to MassDEP. Cross connection control must be included for the potable water lines used to back flush sludge lines.

k. Include equipment, controls, and alarms for maintaining the facility in accordance with applicable standards to prevent trespassing, vandalism, and sabotage.

l. Include weather resistant equipment where applicable and the appurtenances and equipment for maintaining the facility in good repair.

m. Include sufficient flow meters to allow for appropriate process control and determining a flow balance within the facility.

n. Indicate only chemicals proposed for use as chemical additions in the water treatment plant that have been thoroughly evaluated and approved by MassDEP. MassDEP may require the following as part of the evaluation: desk top study, bench scale study, pilot study, proposal, pilot testing, pilot report, or new technology approval.

o. See also 6.1.3 and 6.1.4.

5.1.6 Final Requirements for the Treatment Facility

1. Before the treatment facility goes on-line, the following items must be completed:

   a. Determination of Compliance

   The water supplier shall submit a Determination of Compliance letter to MassDEP that certifies the following:

   (1) The facility is fully operational, tested, and ready to go on-line.

   (2) The facility was constructed in accordance with MassDEP's approval letter.

   (3) All conditions of approval have been met.

   (4) All chemicals used in treatment meet the requirements of the guidelines.

   (5) The O&M manual has been prepared and staff has been trained in all O&M procedures.

   (6) The supplier shall provide a copy of the punch list as an attachment to the letter as well as timelines to complete the punch list items.

   (7) All alarms have been tested and are operating properly.

b. Water Quality Tests

In addition to the required monitoring to evaluate the efficacy of treatment, sampling must be conducted for volatile organic chemicals, inorganics (including lead and copper), bacteria, and secondary contaminants and if required by the regional office: radionuclides and synthetic organic chemicals.

c. Operation and Maintenance Manual

The O & M manual shall be prepared in compliance with DWP Policy 93-02; the manual shall be available at the facility at the time of final inspection and at all times after the facility is approved to go on-line by MassDEP. The PWS shall incorporate the following into the system's O&M manual:

(1) A stand-alone schedule of inspections, testing, and preventative maintenance recommendations shall be provided for all the components of the system.

(2) Calibration curves shall be provided for all chemical feed pumps.

(3) An annual or more frequent performance evaluation of all alarms and signals shall be conducted.

d. Emergency Response Procedures

Every water treatment facility shall incorporate, into their water system's emergency response plan, all details and procedures related to the operation of their facility as described in Chapter 12 of these guidelines.

e. Operator Staffing Plan

The plan must comply with 310 CMR 22.11B.

f. Operator Training

All treatment facilities shall be overseen by a certified operator that has been properly trained in the operation and maintenance of each piece of equipment. Such training shall be conducted by the design engineer or equipment manufacturer (or both), and shall be conducted on site after the equipment has been installed, but prior to placing the treatment facility on-line. Records of such training, signed by both the trainer and the operator, shall be maintained.

g. As-Built Plans

These plans should be available on site once the facility is completed.

h. Final Inspection

The inspection shall be conducted by MassDEP or its designee. (Refer to Policy # 88-19).

i. Written approval must be received from MassDEP to place the facility on-line.

2. Contact Time (CT) Tracer Study

When required by MassDEP, a contact time tracer study shall be conducted to determine available contact times (see Section 5.4.1.2). The study is needed to ensure that the Surface Water Treatment Rule (SWTR) requirement and all subsequent SWTR (i.e. Interim Enhanced Surface Water Treatment Rule (IESWTR), Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), and Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)) requirements pertaining to disinfection contact times and inactivation of selected pathogens will be met when using a chemical disinfectant. The study will consist of the following:

a. A pilot proposal for the contact time tracer study

b. The actual piloting of approved tracers

c. Submittal of a pilot study report of the contact time tracer study

d. To satisfy the SWTR the pilot proposal must be approved by MassDEP prior to final approval for the water treatment plant to go on-line either as a new facility or as a retrofitted facility. Included in the pilot proposal must be the identification of interim values to be used at startup to insure that the facility will comply with the inactivation requirements of the SWTR. The permit process allows 60 days for the review and approval of the proposal (Permit BRP WS 21-22).

e. Piloting, using approved tracer(s), will commence within 30 days of startup of the treatment facility. When piloting of the tracers has been completed, data will be incorporated into a pilot report on the contact time tracer study. The pilot report on the contact time tracer study shall outline the final methods and values the water system intends to use to comply with the SWTR.

f. The pilot study report of the contact time tracer study must be submitted within 60 days of commencing piloting as required by the permit process.

g. When using UV light for disinfection, the IT (ultraviolet light intensity X time) requirements for inactivation must be met (see Section 5.4.6).

5.1.7 Optimization of Water Treatment Facility Performance

1. Water treatment facilities designed to comply with the requirements of the SWTR, ESWTR, LT1ESWTR and LT2ESWTR must be optimized continuously for water to be

free of microbial pathogenic organisms such as *Giardia Lamblia, Cryptosporidium* and viruses. The following components should be incorporated into an optimization evaluation:

a. Minimum Data Monitoring Requirements

(1) Daily raw water turbidity

(2) Settled water turbidity at 4-hour time increments from each sedimentation basin

(3) On-line (continuous) turbidity from each filter

(4) One filter backwash profile each month from each filter

b. Individual Sedimentation Basin Performance Goals

(1) Settled water turbidity less than 1 NTU 95 percent of the time when annual average raw water turbidity is less than or equal to 10 NTU

(2) Settled water turbidity less that 2 NTU at 95 percent of the time when the annual average raw water turbidity is greater than 10 NTU

c. Individual Filter Performance Goals

(1) Filtered water turbidity less than 0.1 NTU at 95 percent of the time (excluding 15 minute period following backwashes) based on the maximum values recorded during 4-hour time increments

(1) Maximum filtered water measurement of 0.3 NTU

(2) Maximum filtered water turbidity following backwash of less than 0.3 NTU

(3) Maximum backwash recovery period of 15 minutes (e.g., return to less than 0.1 NTU)

d. Disinfection Performance Goal

CT values shall achieve required log inactivation of *Giardia, Cryptosporidium* and viruses. See also 5.4.

2. Continuous optimization of treatment plant performance to help insure control of pipeline corrosion so that the 90th percentile lead and copper concentrations are minimized (below action levels of .015mg/L for lead and 1.3mg/L for copper) at the customer's tap.

3. Continuous optimization of treatment plant performance is required for removal of disinfectant by-product precursors and for control of disinfection by-products is required so that disinfection byproduct concentrations are minimized below the MCLs.

4. Continuous optimization of treatment plant performance is required to help insure that secondary water quality standards (or any aesthetic standard) are not exceeded. Optimization should include the minimization of aesthetic contaminants.

5. Operational flexibility is required to handle a variety of water quality situations; jar testing should be conducted on a regular basis.

6. Establishment and implementation of management protocols designed to help insure that the water treatment plant is continuously optimized to the fullest extent possible is required.

5.2 Clarification

Plants designed to reduce suspended solids concentrations prior to filtration shall

1. Provide a minimum of two units each for coagulation, flocculation and solids removal;

2. Permit operation of the units either in series or parallel where softening is performed and should permit series or parallel operation where plain clarification is performed;

3. Be constructed to permit units to be taken out of service without disrupting operation, and with drains or pumps sized to allow dewatering in a reasonable period of time;

4. Provide multiple-stage treatment facilities when required by MassDEP;

5. Be started manually following shutdown;

6. Minimize hydraulic head losses between units to allow future changes in processes without the need for repumping.

5.2.1 Presedimentation

Waters containing high turbidity may require presedimentation either with or without the addition of coagulation chemicals. The feasibility and effectiveness of presedimentation should be specifically addressed in the engineer's report for review by MassDEP.

1. Basin Design:

Presedimentation basins should have hopper bottoms or be equipped with continuous mechanical sludge removal apparatus and provide arrangements for dewatering.

2. Inlet:

   Inlets shall be dispersed across the full width of the line of travel as quickly as possible; short circuiting must be prevented.

3. Bypass:

   Provisions for bypassing presedimentation basins shall be included.

4. Detention Time:

   Three hours detention is the minimum period recommended; longer or shorter detention may be required or allowed based on piloting or bench scale evaluations.

5.2.2 Microscreening

A microscreen is a mechanical supplement of treatment capable of removing suspended matter from the water by straining. It may be used to reduce nuisance organisms and organic loading. It shall not be used in place of:

1. Filtration - when filtration is necessary to provide a satisfactory water
2. Coagulation - in the preparation of water for filtration

Design shall give due consideration to:

1. Nature of the suspended matter to be removed
2. Corrosiveness of the water
3. Effect of chlorination, when required as pre treatment
4. Duplication of units for continuous operation during equipment maintenance
5. Automated backflushing operation when used in conjunction with microfiltration treatment (See Section 5.3.9 Membrane Filtration.)

Design shall provide:

1. A durable, corrosion resistant screen
2. By-pass arrangements
3. Protection against back siphonage when potable water is used for washing

4. Proper disposal of wash waters (See Section 5.10 *Waste Handling and Disposal*.)

5.2.3 Coagulation

Coagulation shall mean a process using coagulant chemicals and mixing by which colloidal and suspended material are destabilized and agglomerated into settleable or filterable flocs, or both. For surface water plants using direct or conventional filtration, the use of a primary coagulant is required at all times.

5.2.4 Rapid Mix

Rapid mix is the rapid and even dispersion of chemicals throughout the water to be treated, usually by violent agitation. The engineer shall submit the design basis for the velocity gradient (G Value) selected, considering the chemicals to be added, water temperature, color, and other related water quality parameters.

1. Equipment:

   Static or mechanical mixing devices may be approved along with any other method proven by piloting evaluations. Variable speed mechanical mixing devices should be considered.

2. Mixing:

   The detention period should not be more than 30 seconds and should yield a velocity gradient of at least 750 ft/sec/ft for mechanical mixing. The design engineer should determine the appropriate G value and detention time through jar testing.

3. Location;

   The rapid mix and flocculation basins shall be located as close together as possible.

4. Accessibility:

   Each rapid mix basin or device shall be constructed for easy observation and access.

5. Chemical Feed:

   Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water. Preliminary design documents, submitted with the piloting report should contain diagrams of proposed application points of all chemicals.

5.2.5 Flocculation

Flocculation is the agitation of chemically treated water at low velocities for periods of time to encourage formation of floc particles.

1. Basin Design

   Inlet and outlet design shall minimize short-circuiting between flocculation and sedimentation basins and also prevent the destruction of floc. Series compartments are recommended to further minimize short-circuiting and to provide decreasing mixing energy with time. Basins shall be designed for sludge removal by dewatering, pumping, gravity drainage or other methods. For details on residuals removal see Section 5.10.

2. Detention

   Detention time for floc formation should be at least 30 minutes with consideration to using tapered (i.e., diminishing velocity gradient) flocculation. Longer or shorter detention time may be allowed based on piloting. The flow-through velocity should be not less than 0.5 or greater than 1.5 feet per minute.

3. Equipment

   Agitators shall be driven by variable speed drives with the peripheral speed of paddles or walking beam flocculator ranging from 0.5 to 3.0 ft/sec. External, non-submerged motors are preferred.

4. Piping

   Flocculation and sedimentation basins shall be located as close together as possible. The velocity of flocculated water through pipes or conduits entering settling basins shall be not less than 0.5 or greater than 1.5 ft/sec. To maintain floc, allowances must be made to minimize turbulence at bends and changes in direction.

5. Other designs

   Baffling may be used to provide for flocculation in small plants only after consultation with MassDEP. The design should be such that the velocities and flows noted above will be maintained.

6. Cleaning

   A water supply of sufficient quantity shall be available in reasonable proximity to the flocculation and sedimentation basins.

7. Superstructure

   A cover or enclosure over the flocculation basins may be required to protect against weather and contamination. A watertight access hatch should be installed to allow access and observation. Hatches should be sized to allow installation and removal of basin equipment components.

8. Accessibility

   Each flocculation basin shall permit observation and easy access.

9. Safety

   Permanent ladders or handholds should be provided on the inside walls of basins and shall comply with latest OSHA regulations. Guard rails should be provided for any floors or walkways adjacent to open basins.

10. Chlorine Feed

    Installation of chlorine feed points in flocculation basins are recommended to allow for shock dosing for maintenance purposes.

11. Chemical Feed

    Maintain the proper application of all chemicals required for meeting primary MCLs when a treatment plant is in operation.

12. Underwater Light

    To assist in determining flocculant presence, effective size, and density, an underwater light should be installed in flocculation chambers approximately 12 inches below the normal water level of the basin.

5.2.6 Sedimentation

Sedimentation may follow flocculation. The detention time for effective sedimentation depends upon a number of factors related to basin design, hydraulic flows and the nature of the raw water. The following criteria apply to conventional sedimentation units:

1. Detention Time

   Detention time for settling shall provide a minimum of four hours of settling time at maximum flow rate depending on raw water quality and pre-treatment chemistry. Reduced detention time may be approved if equivalent effective settling is demonstrated during piloting or bench evaluations or when overflow rate is not more than 0.5 gpm per square foot.

2. Inlet Devices

   Inlets to sedimentation basins shall be designed to distribute the water equally and at uniform velocities. Open ports, submerged ports, and similar entrance arrangements are required. Baffles should be constructed across the basin close to the inlet end and should project several feet below the water surface to dissipate inlet velocities and provide uniform flows through the basin.

3. Outlet Devices

Outlet weirs or submerged orifices shall be designed to maintain velocities suitable for settling in the basin and to minimize short-circuiting. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow. Outlet weirs and submerged orifices shall be designed as follows:

a. Recommended weir rates are not to exceed 20,000 gal/day/ft of weir length. A higher number will be considered where justified.

b. Submerged orifices should not be located lower than three feet below the flow line.

c. The entrance velocity through the submerged orifices shall not exceed 0.5 feet per second.

4. Surface Overflow Rate

The overflow rate shall not exceed 800gal/day/ft^2. Higher rates may be allowed based on evaluation of water quality settling characteristics and filter loading rates.

5. Velocity

The velocity through sedimentation basins should not exceed 0.5 feet per minute. The basins must be designed to minimize short-circuiting. Baffles may be provided as necessary to control velocities and short-circuiting.

6. Overflow

An overflow weir (or pipe) should establish the maximum water level desired on top of the filters. Gravity discharge of overflow waters will be discharged or directed to reservoirs, lagoons or MassDEP approved locations.

7. Superstructure

A cover or enclosure over the sedimentation basins may be required to protect against weather and contamination. A watertight access hatch should be installed to allow access and observation. Hatches should be sized to allow installation and removal of basin equipment components.

8. Residuals Collection

Mechanical residuals collection equipment is recommended to prevent reintrainment of residuals. The residuals collection equipment should not disturb the settled solids. Acceptable collection means include traveling screens, sludge scrapers, or vacuum systems.

9. Residuals Removal

   Residuals removal design shall include:

   a. Sedimentation basin floors should be sloped to a central collection point or trough to facilitate drainage and residuals removal.

   b. Residuals removal should comply with general requirements of Section 5.10.

10. Flushing Lines

   Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to MassDEP.

11. Safety

   Permanent ladders or handholds should be provided on the inside walls of basins and shall comply with latest OSHA regulations. Guard rails should be provided for any floors or walkways adjacent to open basins.

12. Residuals Disposal

   Methods of residuals disposal should be identified. Residuals disposal shall be done in accordance with local, state, and federal requirements (see Section 5.10).

13. Chemical Feed

   The installation of chlorine feed points in sedimentation basins are recommended to allow shock dosing for maintenance purposes.

5.2.7 Tube or Plate Settlers

Tube settler units, consisting of variously shaped tubes or plates that are installed in multiple layers and at an angle to the flow, may be used for sedimentation following flocculation. Effectiveness of the settling unit should be demonstrated by piloting. General criteria are:

1. Inlet and Outlet Considerations

   Design shall maintain velocities suitable for settling in the basin and to minimize short-circuiting. Plate units shall be designed to minimize maldistribution across the units. Inlets and outlets shall conform to sections 5.2.6.2 & 5.2.6.3

2. Drainage

   Drain piping from the settler units must be sized to facilitate a quick flush of the settler units and to prevent flooding other portions of the plant.

3. Protection from Freezing

A cover or enclosure should be provided to protect against weather and contamination.

4. Application Rate for Tubes

   A maximum rate of 2 gpm per square foot of cross-sectional area (4.8 m/hr) for tube settlers, unless higher rates are successfully demonstrated through pilot plant or in-plant demonstration studies.

5. Application Rate for Plates

   Application rates for plates - A maximum plate loading rate of 0.5 gpm per square foot (1.2 m/hr), based on 80 percent of the projected horizontal plate area.

6. Flushing Lines

   Water and/or air flushing lines shall be provided to facilitate routine flushing of floc buildup in and/or above the tubes. Water lines in the basins must be properly protected against backflow or back siphonage.

7. Placement

   Modules should be placed:

   a. In zones of stable hydraulic conditions;

   b. In areas nearest effluent launders for basins not completely covered by the modules.

8. Support

   The support system should be able to carry the weight of the modules when the basin is drained plus any additional weight or accumulated residuals to support maintenance.

9. Residuals Removal

   Mechanical residuals removal should be provided (see Section 5.10).

5.2.8 Solids Contact Unit

Units are generally acceptable for clarification where: water characteristics especially temperature does not fluctuate rapidly, flow rates are uniform, and operation is continuous. Before such units are considered as clarifiers, approval of MassDEP shall be obtained. Clarifiers should be designed for the maximum uniform rate and should be adjustable for changes in flow that are less than the design rate and for changes in water characteristics. A minimum of two units are required for surface water treatment.

1. Chemical Feed

   Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water. Preliminary design documents submitted with the piloting report should contain diagrams of proposed application points of all chemicals.

2. Mixing

   A rapid mix device or chamber upstream of solids contact units may be required by MassDEP to assure proper mixing of the chemicals applied. Mixing devices shall:

   a. Provide good mixing of the raw water with previously formed residuals particles;

   b. Prevent deposition of solids in the mixing zone.

3. Flocculation Equipment:

   a. Shall be adjustable (speed and/or pitch);

   b. Must provide for coagulation in a separate chamber or baffled zone within the unit;

   c. Should provide a flocculation and mixing period of no less than 30 minutes.

4. Residuals Concentrators

   a. The equipment should be designed with either internal or external concentrators in order to obtain a concentrated residual with a minimum of wastewater.

   b. Large basins should have at least two sumps for collecting residuals with one sump located in the central flocculation zone for draining.

   c. See Section 5.10 for details on residuals.

5. Detention Time

   The detention time shall be established on the basis of the raw water characteristics and other local conditions that effect the operation of the unit. Based on design flow rates, the detention time within the mixing zone and settling zone should be between two and four hours. MassDEP may allow alternative detention times on the basis of successful pilot study results.

6. Suspended Slurry Concentrate

   Softening units should be designed so that continuous slurry concentrates of one percent or more by weight can be satisfactorily maintained.

7. Water Losses

    a. Units shall be provided with suitable controls for residuals withdrawal.

    b. Total water losses should not exceed five percent.

    c. Solids concentration of sludge bled to waste should be three percent by weight.

8. Weirs or Orifices

    The units should be equipped with either overflow weirs or orifices constructed so that water at the surface of the unit does not travel over 10 feet horizontally to the collection trough.

    a. Weirs shall be adjustable and at least equivalent in length to the perimeter of the tank.

    b. Weir loading shall not exceed 10 gal/min/ft of weir length for units used for clarifiers.

    c. Where orifices are used, the loading per foot of launder rates should be equivalent to weir loadings. Either shall produce uniform rising rates over the entire area of the tank.

9. Upflow Rates

    The upflow rates should be 1.0 gal/min/ft^2 of area at the sludge separation line for units used for clarifiers. MassDEP may allow higher upflow rates on the basis of successful pilot study results.

10. Pulsating or Upflow Units

    Pulsating or upflow settling units may be used for clarifying sedimentation of flocculated waters. The pilot study shall identify and justify this type of construction. These types of units shall contain all provisions outlined under the general requirements of solid contact units.

5.2.9 Dissolved Air Flotation

Dissolved air flotation (DAF) is a clarification process that is based on the transfer of particles to the surface of a liquid through attachment of bubbles to the particle surface. The particles are removed as floating solids by mechanical skimming. The piloting evaluation shall identify and justify this type of solids removal. Refer to Section 5.10 for details on residuals management.

1. DAF may be recommended when waters contain high levels of low-density particles such as algae.

2. The typical DAF process train consists of chemical and air injection, flocculation, flotation, and skimming.

3. A portion of the flotation tank effluent is recycled, pressurized, and saturated with air.

4. Surface loading rates ranging from three to five gal/min/ft^2 are recommended. Higher loading rates must be demonstrated through piloting.

5. Baffling is required at the tank influent to direct the incoming flow toward the tank surface while reducing its velocity to minimize disturbance of the floating residual layer.

6. In order for DAF Filtration system to receive 2.5 log credits for Giardia removal and 2.0 log credits for cryptosporidium, the following conditions must apply:

    a. In the modern DAF system, coagulation and flocculation must occur upstream of the DAF chamber.

    b. The DAFs that have separate sedimentation basins, otherwise referred to as the Dissolved Air Floatation Chamber to be credited as a conventional systems for the removal of Giardia and *Crytosporidium*.

    c. The existence of an Air Floatation Chamber on top of the filtration media is not acceptable for conventional log credits. This is the type with a build in filter. Specifically, those systems resembling the 1993 Krofta type design, configured as multiple compartments within the same tank, shall not be credited as a modern DAF system.

    d. The subnatant from the Air Floatation Chamber must be routed to the filtration unit. These two units must be physically separated, the floatation chamber preceding filtration. Therefore, the effluent from the Air Floatation Chamber will be piped or channeled to the filter chambers, as featured in the modern DAFs.

    e. The Air Floatation Chamber should have the ability to recycle to the head works, if needed.

    f. The new DAF system must comply with the requirements of "enhanced coagulation in order to meet the TOC requirements of the SWTR in reducing the amount of DBPs in the finished water.

5.2.10 Contact Adsorption Clarifier

Contact adsorption clarifiers combine coagulation, flocculation, and clarification processes into a single upflow adsorption clarifier that includes passage though media. The clarifier uses contact flocculation/adsorption to remove turbidity. Refer to Section 5.10 for details on residuals management. This type of combined arrangement is classified as a "package unit" or alternative technology.

1. A media loading rate should be determined based on piloting data.

2. Media size and bed depth should be determined based on piloting results.

3. Effective media size is typically four to six mm and media depth is generally four feet.

5.2.11 Other High Rate Clarification Processes

High rate clarification processes may be approved upon demonstrating satisfactory performance under on-site pilot plant conditions or documentation of full scale plant operation with similar raw water quality conditions as allowed by MassDEP. Reductions in detention times and/or increases in weir loading rates shall be justified.

5.3 Filtration

5.3.1 General Information

1. Acceptable Filters

   Acceptable filters shall include the following:

   a. Dual and mixed media

   b. Granular activated carbon

   c. Deep bed anthracite or coarse sand

   d. Diatomaceous earth

   e. Membranes

   f. Bag and Cartridge

2. Filtration Processes

   Many filtration processes should be considered and may include the following:

   a. Rapid rate gravity filters

   b. Direct filtration

   c. Diatomaceous earth filtration

d. Slow sand filtration

e. Pressure filters.

f. Suction and pressure membranes

g. Deep bed rapid rate gravity filters

h. Biologically active filters

The application of any filtration process shall be supported by water quality data representing a reasonable period of time to characterize variations in water quality. Pilot studies may be required to demonstrate the applicability of a proposed filtration process.

3. Surface Water Treatment Rule (SWTR)

To ensure compliance with the Surface Water Treatment Rule:

a. Filtration facilities shall include a continuous turbidimeter with recorder to monitor the effluent turbidity from each individual filter and in the composite filter effluent line. Access should be made for taking regular grab samples. If continuous monitoring is impractical, routine monitoring of individual filters is recommended as a minimum.

b. New treatment facilities shall have the capability of filter-to-waste whenever a filter is put on-line, initially and following backwash. Existing treatment facilities shall be retrofitted with this capability if possible.

c. Filters removed from service for extended periods of time should be backwashed upon start-up and where possible, an increased dosage of disinfectant shall be applied to the effluent.

d. Additional credit for log removal of up to 0.5 logs may be considered for filtration facilities other than conventional facilities. Credit will be given for the completion and maintenance of an approved watershed control program that reduces the potential for source water contamination. The Long Term 2, (SWTR) Tool-box contains other possible credit awards for surface water systems.

e. Filter media shall be regularly inspected for wear and replaced as necessary.

5.3.2 Rapid Rate Gravity Filters

The use of rapid rate gravity filters shall require pretreatment

1. Number of Filters

If the water system is dependent upon the proposed facility to meet the average daily demand, at least two separate filtering units with bypasses to one another shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service. Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters must be considered when determining the design capacity for the filters.

2. Rate of Filtration

Typical Filtration rates are from two to four gpm/ft2. Average filtration rates should not exceed three gal/min/ft^2 except that higher rates may be allowed through consideration of factors such as raw water quality control, monitoring for turbidity and other parameters, staffing, and other factors as required by MassDEP. In any case, the filter rate must be proposed and justified by the designing engineer to the satisfaction of MassDEP prior to the preparation of final plans and specifications.

3. Structural Details and Hydraulics

The filter structure design shall include the following:

a. Vertical walls within the filter

b. No protrusion of the filter walls into the filter media

c. over by superstructure

d. Head room to permit normal inspection and operation.

e. Minimum depth of filter box of 8.5 feet.

f. Maximum velocity of treated water in pipes and conduits to filters of two feet per second.

g. Trapped effluent to prevent backflow of air to the bottom of the filter

h. Prevention of floor drainage to filter with a minimum 4-inch curb around the filters

i. Prevention of flooding by providing overflow

j. Washwater drain capacity to carry maximum flow

k. Walkways around filters cannot be less than 24 inches wide

l. Safety handrails or walls around filter areas adjacent to normal walkways

m. Construction to prevent cross connections and permeable common walls between potable and non-potable water

n. Accessibility by the operator to obtain samples from the effluent channels or sampling pumps

4. Washwater Troughs

The washwater trough design should include the following:

a. The elevation of the bottom of the troughs shall be determined based upon the type of backwashing process i.e., air and water or water alone. In no instance shall the bottom of the trough interfere with the expansion of the media.

b. A level top edge

c. Two inch freeboard at maximum rate of wash

d. Spacing so that each trough serves the same number of square feet of filter area

e. Maximum horizontal travel of suspended particles to reach the trough not to exceed 3 feet

5. Filter Bottoms and Strainer Systems

Porous plate bottoms shall not be used where iron or manganese may clog them or with waters softened by lime. The design of manifold-type collection systems shall:

a. Minimize loss of head in the manifold and laterals

b. Assure even distribution of washwater and even rate of filtrate collection over the entire area of the filter

c. Provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003

d. Provide the total cross-sectional area of the laterals at approximately twice the total area of the final openings

e. Provide the cross-sectional area of the manifold at one and a half to two times the total area of the laterals

f. Provide that lateral perforations without strainers be directed downward

Note: Departures from these standards may be acceptable for high rate filters and for proprietary bottoms.

6. Surface Wash Facilities

Surface wash facilities are required except those used exclusively for iron, radionuclides, arsenic or manganese removal and may be accomplished by a system of fixed nozzles or a revolving type apparatus. All devices shall be designed with:

a. Provisions for operating water pressures of at least 45 psi;

b. A properly installed approved device to prevent back siphonage, if connected to the treated water system;

c. Minimum rate of flow of 2.0 gal/min/ft^2 of filter area with fixed nozzle or 0.5 gal/min/ft^2 with revolving arms.

7. Air Scouring

Air scouring can be considered in place of surface wash providing it meets the following conditions:

a. Air flow for air scouring the filter must be three to five standard ft^3/min/ft^2 when the air is introduced in the underdrain. A lower air rate must be used when the air scour distribution system is placed above the underdrains.

b. A method for avoiding excessive loss of filter media during backwashing must be provided.

c. Air scour distribution systems should be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles shall be designed to prevent media from clogging the nozzles or entering the air distribution system.

d. Piping for the air distribution system shall not be flexible hose which will collapse when not under air pressure and shall not be a relatively soft material which may erode at the orifice opening with the passage of air at high velocity.

e. Air delivery piping shall not pass down through the filter media nor shall there be any arrangement in the filter design which would allow short circuiting between the applied unfiltered water and the filtered water.

f. Concurrent washwater rates must not exceed eight gal/min/ft^2 unless a method of retaining the filter media is provided. The maximum rate should be determined based on the type of media used and the amount of time that is desirable for cleaning the media when using air and water in combination.

g. If dual or mixed media is used, air scouring must be followed by a fluidization wash sufficient to restratify the media.

h. Air must be protected against contamination from compressor or exhausts or other potential contaminants.

i. No air wash piping shall be placed in the filter media unless approval of piping and backsiphonage valving is obtained from MassDEP.

j. Underdrain and air manifold shall be designated to accommodate air and water backwash.

k. Provisions of Section 5.3.2.9 shall be followed.

8. Appurtenances

Every filter shall have:

a. Provisions for sampling and observation of influent and effluent waters, where applicable;

b. A gauge indicating loss of head;

c. A raw water flow meter indicating flow rate. A modified rate controller that limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow into the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with MassDEP.

d. A continuous turbidity monitoring recording device for surface water treatment plants;

e. Treatment plants filtering surface water or ground water under the direct influence shall have on-line turbidimeters installed on the effluent line from each filter. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 15 minutes. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level exceeds 0.3 NTU. Water systems serving less than 10,000 people and having less than three filters may conduct continuous monitoring of the combined filter effluent in lieu of individual filter effluent monitoring.

f. A 1 to 1-1/2 inch pressure hose and storage rack within the filter room for washing filter walls with hot water, if available;

g. Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing;

h. Provisions for draining the filter to waste when gravity drains are not installed (appropriate measures for backflow prevention such as an air gap should be used).

Note: Subsections b and c may not apply to automatic continuous backwash filters and shall be determined by MassDEP.

MassDEP also recommends that:

a. Particle monitoring equipment as a means to enhance overall treatment operations where used for surface water;

i. A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

9. Backwash

Provisions shall be made for backwashing filters as follows:

a. The backwash water delivery system must be capable of 15 gallons per minute per square foot of filter surface area (37 m/hr); however, when air scour is provided the backwash water rate must be variable and should not exceed 8 gallons per minute per square foot (20 m/hr) unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces A rate of flow to provide for a 50% expansion of a granular activated carbon filter bed and up to 30% expansion for other medias is recommended.

b. Filtered water shall be provided at the required rate by washwater tanks, a washwater pump, clearwell, or a combination of these. Use of a high service main may be allowed but only with a pressure-regulating valve to prevent high pressure damage to the underdrain system and disruption of the media. Distribution system pressures shall not fall below 30 psi.

c. Cashwater pumps in duplicate unless an alternate means of obtaining washwater is available

d. Sufficient storage of filtered water to backwash one filter at the maximum rate for not less than 15 minutes

e. A rate of flow controller or valving with totalizing capability as a minimum shall be provided on the main washwater line to obtain the desired rate of filter wash.

f. Rate of flow controls shall be designed to prevent rapid changes in backwash water flow.

g. Backwash shall be capable of being operator initiated. Where automated systems are used they shall be operator adjustable.

Note: Subsections a, c, d, and e may not apply to automatic, continuous backwash filters.

10. Filter Media

Filter media shall be clean silica sand or other natural or synthetic media free from detrimental chemical or bacterial contaminants and approved by MassDEP. Other media and media depths will be considered based on pilot test data, specifications, and operating data. Types of filter media include:

a. Anthracite - Clean crushed anthracite or a combination of anthracite and other media may be considered on the basis of pilot test data specific to the project and shall have an:

(1) Effective size of 0.45mm to 0.55mm when used alone;

(2) Effective size of 0.8 mm to 1.2 mm when used as a cap;

(3) Uniformity coefficient of not greater than 1.65 when used alone;

(4) Effective size for anthracite used as a single media on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies or other demonstration acceptable to MassDEP);

(5) Specific gravity greater than 1.4;

(6) Acid solubility less than five percent;

(7) A Mho's scale of hardness greater than 2.7.

b. Sand - Sand shall have:

(1) An effective size of 0.45 mm to 0.55 mm;

(2) An uniformity coefficient not greater than 1.65;

(3) A specific gravity greater than 2.5;

(4) An acid solubility less than five percent.

c. High Density Sand

(1) High density sand shall consist of hard durable, and dense grain garnet, ilmenite, hematite, magnetite, or associated minerals of those ores that will resist degradation during handling and use, and shall:

(2) Contain at least 95 percent of the associated material with a specific gravity of 3.8 or higher

(3) Have an effective size of 0.2 to 0.3 mm.

(4) Have a uniformity coefficient of not greater than 1.65.

(5) Have an acid solubility less than five percent

d. Granular activated carbon - Use of granular activated carbon (GAC) as a filter media, must be justified by the following criteria:

(1) During piloting or design, various types of granular activated carbon shall be tested for optimum effectiveness and absorption capacities on the water(s) being treated. Contract specifications should specify AWWA standards recommendations for iodine testing to determine activated levels of granular activated carbon prior to installation.

(2) Based on testing results, each bed of granular activated carbon should be tested annually, at a minimum, to determine adsorption capacity and filtering effectiveness.

(3) Particle size, specific gravity and adsorptive capacities of granular activated carbon shall be based on site-specific needs. Piloting and design evaluation should take into account the nature of the water to be treated, particular treatment process used and pre-filtering treatment processes.

(4) Effective size of granular activated carbon shall be from 0.35 mm to 1.30 mm.

(5) Surface loading rates and bed depth should be based on piloting results. For PFAS removal see Chapter 5.11.4.for General design recommendations

(6) Uniformity coefficient shall not exceed 1.65 if used alone.

(7) There must be provisions for a free chlorine residual and adequate contact time in the water following the filters and prior to distribution (See 5.4; 5.4.1#2; and 5.4.1#4a (1) (3).)

(8) There must be means for periodic treatment of filter material for control of bacterial and other growth.

(9) Virgin (new) GAC shall meet the requirements of AWWA Standard B604-05 *Granular Activated Carbon* or latest issue

(10) New Drinking Water Filtration Plants (DWFP) going on-line for the first time must use virgin GAC only.

(11) Provisions must be made for frequent replacement or regeneration as needed to produce water of the desired quality. The spent GAC can be disposed of and replaced with virgin GAC, or the spent GAC can be reactivated and reinstalled for additional use. Reactivation is a form of regeneration.

(12) Re-using spent Granular Activated Carbon .

GAC removes organic impurities from potable water sources. These impurities include compounds imparting taste and odors, algal toxins, synthetic organic compounds, endocrine disruptors, pharmaceutically active compounds, and disinfection by-product precursors. After continuous use the GAC becomes exhausted, its capacity to adsorb impurities decreases. When the GAC filter no longer produces water of the desired quality, a water utility faces the decision either to replace the GAC with virgin (new) carbon or to re-use the spent GAC. The spent GAC can be reused by one of two methods, regeneration and reactivation. Whether the spent GAC can be regenerated or reactivated depends on the type of contaminant(s) adsorbed to the media.

(a) Regeneration: The process involves various techniques—including thermal (low temperatures), chemical, and biological methods—designed to partially restore the adsorption capacity of adsorbents. These methods aim to rejuvenate the adsorbents to a fraction of their original capacity, enabling one or more additional adsorption cycles. This regeneration process extends the lifespan of the adsorbents and enhances the overall efficiency and sustainability of the adsorption system.

(b) Reactivation: This process is aimed at completely removing all the adsorbates from saturated activated carbon and desorb, devolatilize, or char in the carbon structure through a high-temperature thermal process (~1000 °C). The reactivation is usually performed at the centralized reactivation facility, and it is suited when the destruction of adsorbate is required although the carbon structure may vary from the virgin ones.

MassDEP requires that AWWA Standard B605-18 *Reactivation of Granular Activated Carbon* or latest issue, must be used by potable water utilities that intend to use reactivated granular activated carbon and to the suppliers who provide a thermal reactivation service. In addition to using the prescribed guidance, AWWA Standard B605 -18, MassDEP emphasizes the following conditions:

(i) The requirements of AWWA Standard B605-18 Reactivation of Granular Activated Carbon or latest issue

(ii) All contracts regarding the sampling, analyses, transportations, reactivation and storage of GAC, analytical results pertaining to the GAC, and affidavit of compliance from the supplier shall be kept by the PWS and available for MassDEP inspection for as long as the GAC is present or utilized by the water system.

(iii) After the reactivation process, the GAC must comply with the specifications approved by MassDEP such as, but not limited to, the effective size and uniformity coefficient.

(iv) DWFPs must only reuse the reactivated GAC provided to the re-activator for its renewal. Substituted or generic type reactivated GAC must not be used in DWFPs regardless of prior use or history of the reactivated GAC.

(v) Reactivated GAC losses due to processing must be made up with virgin GAC.

(vi) The PWS should accurately assess the effectiveness of the reactivated GAC as recommended in the Forward of the AWWA Standard B605-18 section 11-D Adsorptive Capacity or latest issue.

(vii) Reactivated GAC shall not impart any impurities to the water that could cause or potentially cause harm to the consumer.

(viii) When requested by the purchaser (PWS), the supplier shall provide:

1. A written plan detailing the specific reactivation process to be used for each facility where this process will be implemented.

2. The plan shall include (at a minimum) details of facility operation after media removal, the use of multiple medias (if rotating media), storage of media after regeneration, and any other details required by the MassDEP to properly document the reactivation process and operations during this process.

3. The plan shall include an affidavit of compliance stating that the activated services provided, and the product complied with the

applicable provisions of this standard and the purchaser's specifications; and, a tracking manifest that documents that a handling procedure is in place, assuring that the purchaser's spent GAC has been separated from other GACs from the time of removal, through the activation process and during storage, until it is received by the purchaser.

e. Support Media

(1) Torpedo sand- A three-inch layer of torpedo sand shall be used as a supporting media for filter sand where supporting gravel is used, and shall have:

(a) An effective size of 0.8 mm to 2.0 mm;

(b) A uniformity coefficient not greater than 1.7.

(2) Gravel - When used as the supporting media, shall consist of hard, rounded particles and shall not include flat or elongated particles. The coarsest gravel shall be 2-1/2 inches in size when the gravel rests directly on the strainer system, and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the following size and depth distribution when used with perforated laterals:

Size	**Depth**
2-1/2 to 1-1/2 inches	5-8 inches
1-1/2 to 3/4 inches	3-5 inches
3/4 to 1/2 inches	3-5 inches
1/2 to 3/16 inches	2-3 inches
3/16 to 3/32 inches	2-3 inches

Reduction of gravel depths may be considered upon justification to MassDEP when proprietary filter bottoms are specified.

f. Filter Bottoms and Strainer Systems

Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms shall not be used where iron or manganese may clog them or with waters softened by lime. The design of manifold-type collection systems shall:

(1) Minimize loss of head in the manifold and laterals;

(2) Ensure even distribution of washwater and even rate of filtration over the entire area of the filter;

(3) Provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003;

(4) Provide the cross-sectional area of the manifold at 1.5 to two times the total area of the laterals;

(5) Provide lateral perforations without strainers shall be directed downward.

g. Multi and Mixed Media

Filtration by other media, using types of multi media and mixed media as an innovative technology, will be considered based on pilot plant study data and operational experience in New England.

11. Miscellaneous

a. Roof drains shall not discharge into the filters, basins, or conduits within the water treatment facility.

b. It is recommended that granular activated carbon filters should have water jet carbon eductor hardware, including hoses for removal and replacement of media although manual replacement by the manufacturer will be accepted.

5.3.3 Pressure Filters

The most common use of these filters is for iron and manganese removal. The use of these filters is not recommended for surface supplies and is generally not approved since their effectiveness is easily reduced and their operation difficult to monitor. However, they may be approved on a case-by-case basis as conditions warrant.

1. General

c. Minimum criteria relative to number, rate of filtration, structural details and hydraulics, filter media, etc., provided for rapid rate gravity filters also apply to pressure filters where appropriate

d. The specific media shall be approved by MassDEP.

12. Rate of Filtration

The rate should not exceed the rate used in the pilot study. In any case the filter rate must be proposed and justified by the designing engineer to the satisfaction of MassDEP prior to the preparation of final plans and specifications.

13. Details of Design

The pressure filters design shall include:

a. Pressure gauges on the inlet and outlet pipes of each battery of filters;

b. A direct read flow indicator meter on each filtering unit and intake piping;

c. A piping and valving design which shall be arranged to allow for filtration, backwashing, air scouring, and drain downstream of the filter;

d. minimum side wall shell height of five feet. A corresponding reduction in side wall height is acceptable where proprietary bottoms permit reduction of the gravel depth and chemical contact times are acceptable.

e. The top of the washwater collectors shall be at least 18 inches above the surface of the media to minimize media discharge.

f. The underdrain system shall efficiently collect the filtered water and uniformly distribute the backwash water at a rate not less than 15 gallons per minute per square foot of filter area (37 m/hr) unless otherwise approved by MassDEP in writing.

g. Readable backwash flow indicators and solenoid valve and operating controls;

h. An air release valve on the highest point of each filter;

i. Two accessible manholes of sufficient size to allow human access to facilitate inspection and repair on filters greater than 36 inches in diameter. The manholes should be at least 36 inches in diameter where feasible.

j. Provisions to observe and sample the wastewater during backwash;

k. Construction to prevent cross-connection;

l. A pressure relief valve shall be installed for each filter and on the main effluent discharge line from the facility.

5.3.4 Diatomaceous Earth Filtration

The use of these filters may be considered on the basis of successful pilot test results. Diatomaceous earth filters are expressly excluded from consideration for the following conditions:

a. Bacteria removal

m. Color removal

n. Turbidity removal where either the gross quantity of turbidity is high or the turbidity exhibits poor filterability characteristics

o. Filtration of waters with high algae counts

1. Types of Filters

Pressure or vacuum diatomaceous earth filtration units will be considered for approval. However, the vacuum type is preferred for its ability to accommodate a design which permits observation of the filter surfaces for determining the following: proper cleaning, damage to a filter element, and adequate coating over the entire filter area.

14. Number of Filters

If the water system is dependent on the proposed facility to meet the average daily demand, at least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service.

15. . Precoat

a. A uniform precoat shall be applied hydraulically to each septum by introducing slurry to the tank influent line and by employing a filter-to-waste or recirculation system.

b. The recommended quantity of precoat is one kg/m^2 (0.2 lb/ft^2) of filter area, and the minimum thickness of the precoat filter cake is three mm to five mm (1/8 to 1/5 inch).

16. Body Feed

A body feed system by use of a slurry tank, demixer and hopper shall be provided to apply additional amounts of diatomaceous earth slurry during the filter run to avoid short filter runs or excessive head losses.

a. Quantity - Rate of body feed is dependent upon raw water quality and characteristics and must be determined in the pilot plant study.

b. Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines with provisions for flushing.

c. Continuous mixing of the body feed slurry is required.

d. Coagulant to coat body feed to improve removal rates for viruses, bacteria and turbidity is required.

17. Filtration

a. Rate of Filtration

The recommended nominal filtration rate is 1.0 gal/min/ft^2 of filter area with a recommended maximum of 1.5 gal/ min/ft^2. Alternative rates may be accepted based on results from the pilot plant study.

b. Head Loss

The head loss shall not exceed 30 psi for pressure diatomaceous earth filters or a vacuum of 15 inches of mercury for a vacuum system.

c. Recirculation

A recirculation or holding pump shall be used to maintain differential pressure across the filter when the unit is not in operation in order to prevent the filter cake from dropping off the filter elements. A minimum recirculation rate of 0.1 gal/min/ft^2 of filter area shall be provided.

d. Septum or Filter Element

The filter elements shall be structurally capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles, and shall be spaced such that not less than one inch is provided between elements or between any element and a wall.

e. Inlet Design

The filter influent shall be designed to prevent scouring of diatomaceous earth from the filter element.

18. Backwash

Two air compressors, one as backup, shall be provided to thoroughly remove and dispose of spent filter cake during periods of backwash. A satisfactory method to thoroughly remove and dispose of spent filter cake shall be provided

19. Appurtenances

The following shall be provided for every filter:

a. Sampling taps for raw and filtered water

b. Loss of head or differential pressure oil filled gauges

c. Rate-of-flow indicator, preferably with totalizer

d. A manual and automatic controlled throttling valve to control flows

e. Body feed, recirculation, and any other pumps required to insure the operation of the treatment system

f. Provisions for filtering to waste with appropriate measures for backflow prevention

g. The following appurtenances are recommended:

(1) A 1 to 1.5 inch pressure hose and storage rack at the operating floor for washing the filter

(2) Access to particle counting equipment as a means to enhance overall treatment operations

(3) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation

(4) A continuous monitoring turbidimeter with recorder on each filter effluent for plants treating surface water

20. Treated water storage capacity in excess of normal requirements shall be provided to:

a. Allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate, and

b. Guarantee continuity of service during adverse raw water conditions without by-passing the system.

21. Diatomaceous Earth Pilot Study

Installation of a diatomaceous earth filtration system shall be preceded by a pilot plant study on the water to be treated.

a. Conditions of the study such as duration, filter rates, head loss accumulation, slurry feed rates, turbidity removal, bacteria removal, and etc. must be approved by MassDEP prior to the study.

b. Satisfactory pilot plant results must be obtained prior to preparation of final construction plans and specifications.

c. The pilot plant study must demonstrate the ability of the system to meet applicable drinking water standards at all times.

5.3.5 Slow Sand Filtration

The use of this filtration technology shall require a pilot study to demonstrate the adequacy and suitability of this method of filtration for the raw water supply to be treated, unless waived by MassDEP.

Slow rate gravity filtration shall be limited to waters having maximum turbidities of 10 units and maximum color of 15 units; such turbidity must not be attributable to colloidal clay. Microscopic examination of the raw water must be made to determine the nature and extent of algae growths and their potential adverse impact on filter operations.

1. Number of Filters

   At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service.

22. Structural Details and Hydraulics

    a. Slow rate gravity filters shall have:

    b. A cover

    c. Headroom to permit normal movement by operating personnel for scraping and sand removal operations

    d. Adequate manholes, ladders and access ports for handling of sand

    e. Valving and piping to allow for filtration to waste

    f. An overflow to an approved location (installed at the maximum filter water level elevation)

23. Rates of Filtration

    The permissible rates of filtration shall be determined by the quality of the raw water and shall be on the basis of pilot plant study data derived from the water to be treated. The nominal rate may be 45 to 150 gal/day/ft^2 of sand area, with somewhat higher rates accepted based on piloting results.

24. Underdrains

Each filter unit shall be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water. The underdrains shall be spaced so that the maximum velocity of the water in the lateral underdrain will not exceed 0.75 ft/sec. The maximum spacing of the laterals shall not exceed 12 feet.

25. Filtering Material

a. Filter sand shall be placed on graded gravel layers for a minimum depth of 30 inches.

b. The effective size shall be between 0.15 mm and 0.30 mm.; larger sizes may be considered by MassDEP; a pilot study may be required.

c. The uniformity coefficient shall not exceed 2.5.

d. The sand shall be clean and free from foreign matter.

e. The sand shall be rebedded when scraping has reduced the bed depth to no less than 19 inches. Where sand is to be reused in order to provide biological seeding and shortening of the ripening process, rebedding shall utilize a “throw over” technique whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

26. Filter Gravel

The supporting gravel shall conform to the size and depth distribution provided for rapid rate gravity filters (see Section 5.3.2.10c.

27. Depth of Water on Filter Beds

Design shall provide a depth of at least 6 feet of water over the sand. Influent water shall be distributed by use of weirs or inlets designed to prevent scouring of the sand surface during filling.

28. Operating Requirements

Maintenance of a slow sand filter involves two periodic tasks:

a. Removal of the top two to three cm (0.8 to 1.2 inches) of the surface of the sand bed when the headloss exceeds 1 to 1.5 m.;

b. Replacement of the sand when repeated scrapings have reduced the depth of the sand to approximately one-half of its design depth. (See 5.e above.)

29. Control Appurtenances

a. Influent and effluent sampling taps

b. An indicating loss of head gauge or other means to measure head loss

c. An indicating rate-of-flow meter. A modified rate controller that limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the reviewing authority.

d. Provisions for filtering to waste with appropriate measures for cross connection control

e. An effluent pipe designed to maintain the water level above the top of the filter sand

5.3.6 Direct Filtration

Direct filtration refers to the filtration of surface water without prior settling. The nature of the treatment process will depend upon the raw water quality. A full scale direct filtration plant shall not be constructed without prior pilot studies that are acceptable to MassDEP. In-plant demonstration studies may be appropriate where conventional treatment plants are converted to direct filtration. Where direct filtration is proposed, an engineering report shall be submitted prior to conducting pilot plant or in-plant demonstration studies.

Prior to the initiation of design plans and specifications, a final report including the engineer's design recommendations shall be submitted to MassDEP. In addition to items considered in section 1.1, the report should include a historical summary of meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The following raw water parameters should be evaluated in the report:

a. Color

f. Turbidity

g. Bacterial concentration

h. Microscopic biological organisms

i. Temperature

j. Total solids

k. General inorganic chemical characteristics

l. Additional parameters as required by MassDEP

m. The report should also include a description of methods and work to be done during a pilot plant study or, where appropriate, an in-plant demonstration study.

1. Pretreatment: Rapid Mix and Flocculation

   The final rapid mix and flocculation basin design should be based on the pilot plant or in-plant demonstration studies augmented with applicable portions of Sections 5.2.2 and 5.2.3.

2. Filtration

   a. The final filter design should be based on the pilot plant or in-plant demonstration studies augmented by applicable portions of Section 5.3.

   b. Surface wash shall be provided for the filters in accordance with Sections 5.3.2.6 and 7.

3. Control and Operation

   a. A continuous recording turbidimeter should be installed on each filter effluent line and on the combined filter effluent line.

   b. Additional continuous monitoring equipment may be required by MassDEP.

   c. Provisions of Section 5.3 also apply.

4. Siting Requirements

   The plant design should allow for the installation of conventional sedimentation basins when necessary.

5.3.7 Deep Bed Rapid Rate Gravity Filters

1. Deep bed rapid rate gravity filters, as used herein, generally refers to rapid rate gravity filters with filter material depths equal to or greater than 48 inches. Filter media sizes are typically larger than those listed in Section 5.3.2.

2. Deep bed rapid rate filters may be considered based on pilot studies approved by MassDEP.

3. The final filter design shall be based on the pilot plant studies and shall comply with all applicable portions of Section 5.3.2. Careful attention shall be paid to the design of the backwash system which usually includes simultaneous air scour and water backwash at subfluidization velocities.

5.3.8 Biologically Active Filters

1. Biologically active filtration, as used herein, refers to the filtration of a surface water (or a ground water with iron, manganese or significant natural organic material) which includes the establishment and maintenance of biological activity within the filtration media.

2. Objectives of biologically active filtration may include control of disinfection byproduct precursors, increased disinfectant stability, reduction of substrates for microbial regrowth, breakdown of small quantities of synthetic organic chemicals, reduction of ammonia-nitrogen, and oxidation of iron and manganese. Biological activity can have an adverse impact on turbidity, particle and microbial pathogen removal, disinfection practices; head loss development; filter run times and distribution system corrosion. Design and operation should ensure that aerobic conditions are maintained at all times. Biologically active filtration often includes the use of ozone as a pre-oxidant/disinfectant which breaks down natural organic materials into biodegradable organic matter and granular activated carbon filter media which may promote denser biofilms.

3. Biologically active filters may be considered based on pilot studies pre-approved by MassDEP. The study objectives must be clearly defined and must ensure the microbial quality of the filtered water under all anticipated conditions of operation.

4. The pilot study shall be of sufficient duration to ensure establishment of full biological activity; often greater than three months is required. Also, the pilot study shall establish empty bed contact time, biomass loading, and/or other parameters necessary for successful operation as required by MassDEP.

5.3.9 Membrane Filtration: Ultrafiltration (UF), Microfiltration (MF), and Nanofiltration (NF)

5.3.9.1 General Information

Membrane filtration is defined as a pressure or vacuum driven separation process in which particulate matter larger than one micrometer (um) is rejected by an engineered barrier, primarily through a size exclusion mechanism, and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test. This definition includes MF, UF, NF, and reverse osmosis (RO). RO is discussed in section 5.3.10.

Membrane processes are water conditioning processes by which dissolved minerals, or ions, are removed from water by the use of semi-permeable membranes. Membrane processes can be used to remove excess dissolved solids, a variety of organic contaminants, and, to a lesser extent, radionuclides from drinking water. Membrane processes can be used specifically for the removal of particulate material, including microorganisms such as protozoa (Giardia and Cryptosporidium), bacteria, and viruses. UF, MF, and NF are membrane processes which are considered filtration processes. In applications where the removal of dissolved minerals, total organic carbon (TOC), or trihalomethane (THM) precursors is not critical, UF and MF technology may be appropriate. These membrane processes can effectively remove from solution species such as larger organics, colloids, and microorganisms including bacteria, and cysts. However, UF and NF will remove viruses and dissolved organics, while MF does not. In addition, NF will remove salts while UF and MF does not.

As a general rule, the lower membrane pore size in um (microns) is 0.0001 um for (RO), 0.001 um for NF, 0.005 um for UF, and 0.1 um for MF.

5.3.9.2 Pilot Testing

The use of this filtration technology shall require three operational cycles of at least 30 days (minimum 90-day) duration pilot testing study to demonstrate the adequacy and suitability of this method of filtration for the raw water supply to be treated, unless otherwise approved by MassDEP. The pilot study must take into consideration:

1. Quantity and quality of the raw water
2. Pre-treatment and post-treatment processes
3. Bypass ratio
4. Amount of reject water
5. Process efficiency
6. Particulate/organism removal efficiencies
7. Cold and warm water flux
8. Useful life of the membranes
9. Fouling potential
10. Corrosiveness of the finished water
11. Concentrate disposal

See “Pilot Study Requirements for Proposed Treatment”, Policy # 90-04 (year 2000 printing) and EPA manual 815-R-06-009 dated November 2005 titled: “Membrane Filtration Guidance Manual”, and Section 6.0 Pilot Testing for more information.

MassDEP will utilize the requirements and recommendations of the EPA manual 815-R-06-009 as the basis for assigning removal credit for Cryptosporidium for all membrane systems piloted after January 1, 2011. This includes membrane systems that may be used to treat sources that are categorized as being in Bin #1 per 301 CMR 22.0G and are required to inactivate or remove only 2 logs of Cryptosporidium.

Similarly the MassDEP will assign the log credit for the removal of Giardia based on challenge test and direct integrity testing. MassDEP may, at MassDEP discretion, consider pilot test data in lieu of challenge tests for membrane systems piloted or installed prior to January 1, 2011.

5.3.9.3 Materials

Materials and system components used in construction of UF or MF or NF treatment processes shall be in conformance with ANSI/NSF Standard 61 (Drinking Water System Components – Health Effects – National Sanitation Foundation). MF and UF membranes currently are constructed in a hollow fiber configuration using polypropylene, polyvinyl difluoride (PVDF), polysulfone, polyethersulfone, and cellulose acetate membranes. Some membranes may be proprietary polymers. The MF or UF is operated either as an "inside-out", or "outside-in" flow mode.

All membrane modules installed after January 1, 2011for the purposes of receiving credit for the removal of Cryptosporidium and Giardia must include a certification from the manufacturer to have passed a nondestructive performance test to assure that the modules comply with minimum standards for Cryptosporidium removal. The methodology for demonstrating these minimum standards must be acceptable to MassDEP. The MassDEP may consider other documentation for replacement of membranes installed prior to January 1, 2011.

5.3.9.4 Backwashing

Backwashing of MF and UF membranes using reverse flow of water and/or pressurized air is needed to remove contaminants. NF membranes use chemical cleaning to remove contaminants, as NF can not be backwashed due to a spiral wound design.

5.3.9.5 Direct and Indirect Integrity Testing

Direct integrity testing may include pressure and vacuum decay tests for MF and UF, and marker-based tests for NF. These are usually conducted at least once per day. For membranes treating surface waters or groundwater under the direct influence of a surface water, Cryptosporidium log removal credit refer to MassDEP "Guidelines and Policies for Public Water Systems Appendix N – Requirements for Microbial Toolbox Options for Meeting Cryptosporidium Treatment Requirements under the Long Term 2 Enhanced Surface Water Treatment Rule dated August 1, 2007" for more information on challenge testing, direct integrity testing, and indirect integrity monitoring. MassDEP will also apply the operating requirements of Appendix N, including reporting requirements, to those systems that are categorized as being in Bin #1. MassDEP reserves the right to review the integrity testing protocol and assign a lower log removal than the manufacturer states.

Verification testing must be performed during operation in order to assess log removal of Giardia.

Where particle counters or particle monitors are installed, the water system must collect data and establish, on a schedule approved by MassDEP, a means of using these instruments as a more sensitive method of indirect integrity testing. MassDEP may consider other documentation for replacement of membranes installed prior to January 1, 2011.

5.3.9.6 Design and Operation

1. Raw Water Source

   One of the most important aspects of membrane treatment plant selection and design is the source and character of the proposed raw water. The main water quality parameters that affect membrane production are turbidity, total organic carbon (TOC), and algae content. Membrane processes can be used to treat turbid waters but may result in higher operation and maintenance costs and possibly more frequent replacement of some membrane types.

2. Pre-Treatment

   Pre-treatment should include disinfection. Chlorine and its by-products have often proven to be a major cause of membrane failures. System designers must know the properties of the specific membranes to be used in the system to prevent this type of problem.

   For applications involving removal of various organics, disinfection by-product precursors, and SOCs, pre-treatment shall include the addition of activated carbon or coagulation, or other treatment systems as approved by MassDEP. Alum coagulation shall not be used as pre-treatment for UF because the alum will readily foul the membrane.

   Generally, pre-treatment for MF and UF may include strainers or bag filters, and disposable cartridge filters for NF systems.

3. Design Criteria

   a. At least two UF or MF or NF units shall be provided, with each unit capable of meeting the plant's design capacity. When more than two units are provided, the units shall be capable of meeting the plant's design capacity with the largest unit removed from service.

b. A maximum thirty-six month membrane life should be assumed until satisfactory on-site data is generated.

c. The design shall include the ability to measure plant flow rate of permeate and concentrate water.

d. All units shall be equipped with a feed water and concentrate pressure gauge. The units should also be equipped with a permeate water pressure gauge.

e. Taps for sampling feed (raw) water, permeate, concentrate, and finished water shall be provided. Sample taps shall have a quill that extends into the center of the pipe to obtain a more representative sample. In addition, if a microorganism is used as the challenge particulate, it is prudent to use a metal or heat resistant sampling valve to allow the tips of the valve to be flame sterilized.

f. A 90% water recovery is recommended.

g. On-line instrumentation for hydraulic and water quality characteristics should be provided for membrane feed water, permeate, and concentrate.

h. On-line instrumentation with recorders should be considered for the following: flow, pH, and temperature every 4 hours. On line instrumentation with recorders for raw and finished water should be considered for the following: turbidity, conductivity, and particle count (particles / ml) every 4 hours.

i. Automatic controls should be provided to shut down the system during high effluent turbidities, high pressure differential, or failure of the membrane integrity.

j. Redundancy of critical components including, but not limited to, valves, air supply, and computers shall be required.

k. Roof drains shall not discharge into the filters, basins, or conduits within the water treatment facility.

4. Post-Treatment

For applications in which UF and MF processes are used to directly produce drinking water, post-treatment may include removal of toxic gases, improvement of taste and odor, and protection of the distribution system from corrosion and bacteria growth where necessary.

For pre-treatment applications of UF and MF for reverse osmosis (RO), the product water from the UF or MF process may be fed directly to the RO system.

5. Membrane Cleaning

   UF and MF systems should be cleaned periodically to maintain flux (flow per unit of membrane area usually expressed as gallons per square foot per day (gfd)) levels.

   Detailed information concerning the manufacturer's cleaning requirements and types of cleaning chemicals should be submitted to MassDEP as part of the permit application. Proper disposal of cleaning chemicals is required and must comply with the latest state, local and federal regulations. See section 5.10.2. Chemicals and lubricants that may come in contact with the water or affect the quality of the water shall be certified to be in conformance with ANSI/NSF Standard 60 (Drinking Water Treatment Chemicals – Health Effects).

   In addition to routine cleaning, regular flushing of all membrane based systems is recommended.

6. Cross Connection Control of Feed or Filtrate Streams

   a. In order to protect the feed or filtrate streams from cleaning process chemical contamination a suitable double block and bleed valve arrangement is the preferred method.

   b. An alternate method of cross connection control for un-automated chemical cleaning systems is the removable spool method with the spool removed during the chemical cleaning.

   c. Air gaps could also be used as cross connection control measures, where applicable, especially on the drain lines.

7. Operator Training

   A minimum of 24 hours of operator training provided by the membrane filter supplier is required during construction and start-up phase for systems serving more than 3,300 people, and eight hours of operator training for systems serving 3,300 people or fewer. For very small systems additional operator training requirements are at the discretion of MassDEP. Written training documentation to MassDEP is required for one primary operator.

5.3.10 Membrane Filtration - Reverse Osmosis (RO)

5.3.10.1 General

Reverse osmosis is a pressure-driven process that retains virtually all ions (including salts, dissolved organics, viruses, colloids, bacteria, and cysts). The pressure applied exceeds the osmotic pressure of the salt solution against a semi-permeable membrane, thereby forcing water through the membrane and leaving salts behind. RO units may utilize either spiral wound or rarely hollow fiber membranes. RO units are very effective for seawater desalting, brackish water desalting, and fresh water treatment.

5.3.10.2 Pilot Testing

The use of this filtration technology shall require three operational cycles of at least 30 days (minimum 90-day) duration pilot testing study to demonstrate the adequacy and suitability of this method of filtration for the raw water supply to be treated, unless otherwise approved by MassDEP. The pilot study must take into consideration:

1. Quantity and quality of the raw water
2. Pre-treatment and post-treatment processes
3. Bypass ratio
4. Amount of reject water
5. 5. Process efficiency
6. Particulate/organism removal efficiencies
7. Cold and warm water flux
8. Useful life of the membranes
9. Fouling potential
10. Corrosiveness of the finished water
11. Concentrate disposal

See "Pilot Study Requirements for Proposed Treatment", MassDEP Policy # 90-04 (year 2000 printing) and EPA manual 815-R-06-009 dated November 2005 titled: "Membrane Filtration Guidance Manual" section 6.0 Pilot Testing for more information.

5.3.10.3 Backwashing

RO membranes use chemical cleaning to remove contaminants, as RO can not be backwashed due to spiral wound design type membranes.

5.3.10.4 Materials

Materials and system components used in construction of RO treatment processes shall be in conformance with ANSI/NSF Standard 61 (Drinking Water System Components –

Health Effects – National Sanitation Foundation). RO membranes currently are constructed using cellulose acetate based and polyamide composites.

5.3.10.5 Direct Integrity Testing

Direct integrity testing may include marker-based tests for RO. These are usually conducted at least once per day. For membranes treating surface waters or groundwater under the direct influence of a surface water, refer to Guidelines and Policies for Public Water Systems Appendix N – Requirements for Microbial Toolbox Options for Meeting Cryptosporidium Treatment Requirements under the Long Term 2 Enhanced Surface Water Treatment Rule (dated August 1, 2007) for more information on challenge testing, direct integrity testing, and indirect integrity monitoring.

5.3.10.6 Total Dissolved Solids

The RO process should not be used to treat waters with a total dissolved solids concentration exceeding 12,000 mg/L for low pressure (400 psi) membranes or 30,000 mg/L for high pressure (1,000 psi) membranes without justification. Detailed information outlining the required feed water quality and anticipated performance capabilities of the RO process shall be submitted with the permit application.

5.3.10.7 Design and Operation

1. Pre-Treatment

   Pre-treatment systems should be capable of producing feed water of a quality recommended by the manufacturer of the RO unit. Detailed information, including the manufacturer's feed water requirements, proposed pre-treatment equipment, and evidence that the proposed pre-treatment system is capable of producing the desired feed water quality, shall be included in the permit application. Generally, disposable cartridge filtration immediately prior to the membrane is recommended.

   a. Pre-treatment for groundwaters should include acid and antiscalants to inhibit the formation of scale precipitates.

   b. Pre-treatment for surface waters should include disinfection for microbiological contaminants and some form of coagulation-flocculation and filtration for removal of suspended and colloidal matter. Ultrafiltration (UF) and microfiltration (MF) processes may be used as pre-treatment to extend membrane life.

   c. Pre-treatment of the feed water shall be provided to remove suspended matter or iron and manganese if the feed water contains 5 NTU or more turbidity or 0.3 mg/L or more of iron and manganese. Adjustment of the feed water pH to 5.5 is recommended when cellulose acetate (spiral wound) modules are used.

Softening or pH adjustment is satisfactory pre-treatment for hollow fiber modules.

d. Where the feed water pH is altered, stabilization of the finished water is mandatory. Stabilization is optional in other cases.

2. Design Criteria

a. For community water systems, two RO units should be provided with each unit capable of meeting the system's design capacity. For non-community water systems, only one unit is required, provided it is equipped with appropriate lock-out to insure that all water consumed has been properly treated.

b. MassDEP may vary the design criteria for very small systems.

c. Appurtenant equipment which shall be considered in the design of the RO system includes the following:

(1) A polishing membrane filter (less than or equal to eight microns for hollow fiber modules, or less than or equal to twenty-five microns for spiral wound modules) should be provided before the RO unit. Pressure gauges shall be provided on the upstream and downstream side of the filter. The filter shall be located to facilitate changes of the filtering membrane.

(2) All units shall have feed water and permeate pressure gauges and have the capability to measure flow rates of permeate and concentrate water.

(3) Taps for sampling permeate, concentrate, and blended (if practiced) flows shall be provided. Sample taps shall have a quill that extends into the center of the pipe to obtain a more representative sample. In addition, if a microorganism is used as the challenge particulate, it is prudent to use a metal or heat resistant sampling valve to allow the tips of the valve to be flame sterilized.

(4) A conductivity meter shall be provided at each installation. A continuous conductivity meter, if installed, shall be constructed so that it may be disconnected from the piping system for calibration with standard solutions.

(5) An in-line laser type or equivalent turbidity meter should be provided on each stage.

(6) A maximum 36- month membrane life should be assumed until satisfactory on-site data is generated.

(7) An automatic high temperature alarm or cut-off switch shall be provided if the feed water is heated. The maximum temperature setting is generally between 80°-90° F depending on the membrane used.

(8) All units shall be equipped with alarms or automatic controls to shut down the system during high effluent turbidities, high pressure differential or membrane failure (low pressure differential).

(9) Cleaning in place is usually accomplished at lower pressures but at two to three times the normal flow velocity on the concentrate side. Chelating agents as well as citric acid are acceptable provided the unit is adequately flushed following cleaning.

(10) Since RO permeate will be virtually demineralized, the design should provide for a portion of the raw water to bypass the unit to maintain stable water within the distribution system as long as the raw water does not contain unacceptable contaminants. Alternate filtration/treatment complying with surface water treatment rule is required for bypassed surface or ground water under the direct influence of surface water.

(11) Redundancy of critical components including, but not limited to, valves, air supply, and computers shall be required.

(12) Roof drains shall not discharge into the filters, basins, or conduits within the water treatment facility.

3. Post-Treatment

Treated effluents from the RO process are usually low in pH and solids, high in carbon dioxide, and normally corrosive. Detailed information shall be submitted with the permit application concerning the anticipated corrosiveness of the product water and the methods proposed for stabilizing this water.

4. Operator Training

A minimum of 24 hours of operator training provided by the membrane filter supplier is required during construction and start-up phase for systems serving more than 3,300 people, and 8 hours of operator training for systems serving 3,300 people or less. For very small systems additional operator training requirements are at the discretion of MassDEP. Written training documentation to MassDEP is required for one primary operator.

5. Power Consumption

   Electrical power consumption may be a significant cost factor for reverse osmosis plants. Power consumption shall be evaluated during the pilot plant study or from other relevant data.

6. Membrane Cleaning

   Chemicals and lubricants that may come in contact with the water or affect the quality of the water shall be certified to be in conformance with ANSI/NSF Standard 60- Drinking Water Treatment Chemicals – Health Effects.

7. Residuals

   For proper residuals management see Section 5.10.

5.3.11 Bag and Cartridge Filtration

5.3.11.1 General

Bag and cartridge filtration technologies are usually designed to meet low flow requirements typical of small water supplies. Bag and cartridge filters can effectively remove particles from water in the size range of Giardia cyst (five to ten microns) and Cryptosporidium (two to five microns). For Cryptosporidium removal the following sequence is recommended: a 10 micron (nominal) rated preliminary filter, a five micron (nominal) intermediate filter, and a one micron (absolute) final filter.

Bag and cartridge filters must be discarded once the particular loading capacity of the filters is expended. The life expectancy of a filter is dependent on many factors, including the quality and volume of water being treated and the type of cartridge. The manufacturer's recommended guidelines for bag and cartridge filters should be closely followed. Bag and cartridge filters are usually pressure type filters consisting of a membrane, fabric or string medium with particle size removal, ranging from 0.2 microns up to 10 microns.

With this type of treatment there is no alteration of water chemistry. So, once the technology has demonstrated the required removal efficiency, no further pilot demonstration may be necessary. The demonstration of filtration is specific to a specific housing and a specific bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency.

Some additional factors to be considered in the design and operation of bag and cartridge filters include the following:

5.3.11.2. Materials

The materials in contact with the water shall not impart undesirable taste, odor, color and/or toxic materials into the water as a result of the presence of toxic constituents in materials of construction.

System components such as housing, cartridges, gaskets, and O-rings shall be certified for performance with ANSI/NSF Standard 61. The filter housing shall be constructed to withstand a hydrostatic pressure of 125 psi.

5.3.11.3. Design

a. The source water or pre-treated water should have a turbidity level of less than 3 NTU.

b. Flow rates should be maintained at less than 1.0 gal/min/ft^2 of filter area, preferably 0.5 gal/min/ft^2, to minimize pressure loss and increase efficiency. The flow rate through the bag and cartridge filter must not exceed 20 gpm, unless documentation exists to prove the cartridge filters will meet the requirements for removal of particulates at high flow rates. An automatic fix flow rate control shall be provided as an integral part of the unit to prevent an influent flow rate in excess of the filtering capabilities at any time during its effective life. A totalizing meter should be provided to record daily flow.

c. When various types of bag or filter cartridges or elements with different purposes and performances are available from the manufacturer, they shall bear differentiating identifications that are easily identified and clearly visible. Such identification shall be explained on the package containing the element or cartridge.

d. Waste connections or outlets, if provided, should be through an air gap of not less than 1 inch. Special attention must be given to prevent cross connection between untreated and treated water.

e. The dispenser spout, faucet, or outlet for treated water shall be designed, constructed and located such that when the unit is installed in conformance with the manufacturer's instructions, it is directed downward and readily accessible for use.

f. It is recommended that chlorine or another disinfectant be added at the head of the treatment process to reduce or eliminate the growth of algae, bacteria, etc., on the filters. The impact on disinfection by-product formation should be considered. Disinfection of the filtered water may be required after filtration (see Disinfection Section 5.4.1).

g. A filter-to-waste component is required for any pre-treatment pressure sand filters. At the beginning of each filter cycle and/or after every backwash a set amount of water shall be discharged to waste before flow begins into the bag filter.

h. A labeled sampling tap shall be provided ahead and after any treatment so that a water sample can be collected.

i. A bag or cartridge filter should be constructed or equipped to preclude operation beyond the effective life of the bag or cartridge filter. The effective life definition shall be covered in the posted SOP. This may be accomplished by one of the following means:

    (1) The unit becomes inoperable when the effective life of the bag filter or cartridge is reached

    (2) The unit is provided with an easily visible and readily interpretable means of guiding the operator in determining the effective life of the bag or cartridge.

j. Frequent start and stop operations of the bag and cartridge filter should be avoided. One of the following operations is recommended in order to avoid frequent start / stop cycles:

    (1) Slow opening and closing of valve ahead of the filter to reduce flow surges

    (2) Reduce the flow through the cartridge filter to as low as possible to lengthen filter run times

    (3) Install a recirculating pump that pumps treated water back to the head of the cartridge filter. Care must be taken to make sure there is no cross connection between the finished water and raw water.

k. A pressure relief valve should be incorporated into the bag and cartridge filter housing.

l. Pressure gauges must be provided before and after each bag and cartridge filter to properly monitor system pressure loss in psi.

m. An automatic air release valve should be installed on top of the filter housing.

n. A minimum of two bags or cartridge housings in parallel shall be provided for water treatment systems that must provide water continuously.

5.3.11.4. Installation

a. All units shall be readily accessible for maintenance, service inspection, and cleaning. The cartridges filter elements and other replacements shall be readily removable and easily replaced.

b. Spare cartridges, pressure gauges, filter elements, and other replacement components are to be provided to allow prompt replacement and / or repair by a qualified person properly instructed in the operation and maintenance of the equipment.

5.3.11.5. Operation

a. Complete automation of the water treatment plant is not required. Automation of the treatment plant should be incorporated into the ability of the water system to monitor the finished water quality. A properly certified operator shall be available to run the treatment plant.

b. A plan of action in the SOP shall be in place should the water quality parameters fail to meet MassDEP regulations or Office of Research and Standards (ORS) standards.

c. The filter and the back wash rates shall be monitored so that the prefilters are being used optimally. The bag and cartridge filter must be replaced when a pressure difference of 30 psi or other pressure difference recommended by the manufacturer is observed. It should be noted that bag filters do not load linearly.

d. Additional observation of filter runs is required near the end of filter runs.

e. Maintenance (O-ring replacement) shall be performed in accordance with the manufacturer recommendations.

f. The following parameters should be monitored:

    (1) Instantaneous flow rate in gpm

    (2) Total flow rate in gallons

    (3) Operational pressure in psi

    (4) Pressure differential in psi

    (5) Turbidity in NTU

g. Sterile rubber gloves and a disposable face mask covering the nose and mouth should be worn when replacing the cartridge or bag filters.

h. The filter system shall be properly disinfected, and water shall be flushed or run to waste each time the cartridge or bag filter vessels are opened for maintenance.

5.3.12 Treated Water Storage - Clearwell

The water supply works (including all treatment facilities and sources of supply) shall be capable of delivering, in connection with the storage on the distribution system, the maximum daily consumption plus the required fire flow. Accordingly, required clearwell storage shall be sized taking into account the present storage needs to meet the aforementioned requirement as recommended by AWWA and the Insurance Services Organization (ISO).

The following shall apply for sizing and operation:

1. The operator shall be able to safely shut down the treatment train and/or facility during periods of mechanical failure and/or during periods of allowed unoperated supervision.

8. The clearwell shall allow the system to have continuity of flow through the filters for each treatment train at uniform rates during all conditions of system demand at or below the approved filtration rate.

9. The clearwell shall be able to guarantee continuity of service during adverse raw water conditions without bypassing the system.

10. Baffling is recommended to increase plug flow zone in the basin and minimize short-circuiting to meet CT requirements of the Surface Water Treatment Rule.

11. Overflows may be discharged directly back to surface waters and shall be equipped with the appropriate level of instrumentation. Overflow elevations shall be designed to prevent flooding of the water treatment facility.

12. Design shall conform to the requirements in Chapter 8.

5.4 Disinfection

5.4.1 General Information

1. Applicability

   Disinfection requirements of the Surface Water Treatment Rules, the Ground Water Rule (GWR) and MassDEP's disinfection regulations, guidelines and policies must be met when applicable. All disinfection byproduct MCLs and MRDLs shall not be exceeded while meeting disinfection requirements. Continuous disinfection is an important barrier to contamination and is recommended for all water supplies with treatment.

Disinfection may be permanent, temporary, or optional.

a. Permanent Disinfection

Permanent disinfection shall be required:

(1) At all terminal surface water sources.

(2) At ground water sources determined by MassDEP to be under the influence of surface water.

(3) At ground water sources required to disinfect in compliance with the Ground Water Rule.

(4) At ground water sources determined by MassDEP to be in compliance with the Ground Water Rule but of questionable sanitary or bacterial quality. This determination can be made at any time including during a pump test.

(5) After exposed treatment processes on ground water sources; for example, exposed filtration and exposed aeration and also after exposed chemical treatment when required by MassDEP.

(6) After enclosed treatment processes on ground water sources where MassDEP determines that there are significant pathogens present in the treated water based on routine and additional monitoring described below in 5.4.1.1.f. These systems shall be classified as being of questionable sanitary or bacterial quality and shall meet MassDEP disinfection guidelines for water systems. Examples of enclosed treatment include pressure filters and enclosed aeration (e.g., venturi, forced draft, pressure, diffused bubble, etc.). MassDEP considers the following as indicative of significant pathogen presence:

(a) Two or more coliform bacteria MCL exceedances in a twelve month period which can be traced to treated water coliform bacteria detects

(b) Confirmed presence of coliform bacteria immediately after treatment two or more times within a twelve-month period

(c) Confirmed presence of coliform bacteria in a system immediately after new treatment during pilot testing

(d) Any other related circumstance as identified by MassDEP

(7) For any other treatment as determined by MassDEP

b. Temporary Disinfection

MassDEP may require any system to install disinfection on a temporary basis to address an immediate short-term bacteria problem at a ground water source or immediately after treatment. New groundwater sources must demonstrate that they have the necessary funding and infrastructure to install and monitor disinfection treatment if required.

Temporary disinfection shall be required after the cleaning of a component of an enclosed treatment system such as a pressure filter or clearwell and in any other circumstance as required by MassDEP.

c. Optional Disinfection

Any water system wishing to install disinfection when not required to do so must apply to MassDEP for approval. Care shall be taken to ensure that no MCLs or MRDLs are exceeded and that required monitoring and reporting is satisfied.

d. Discontinuing Disinfection

An existing ground water system not subject to the guidelines in 5.4.1.1.a. with only disinfection for treatment or with disinfection in an enclosed treatment system that wishes to discontinue disinfection shall submit a written request to MassDEP. This request shall be in report format and contain the following minimum information:

(1) Raw water coliform bacteria results for at least two years of continuous monitoring in accordance with their MassDEP approved sampling schedule. Additionally, those systems on MassDEP approved quarterly monitoring for raw water bacteria must sample monthly for one year and submit results to MassDEP if wishing to obtain approval to discontinue disinfection.

(2) Date groundwater source was placed online.

(3) The reason(s) why the system installed disinfection, e.g., whether the system was required by MassDEP to disinfect in the past and if not required, then why it was being done.

e. Distribution System Disinfection

MassDEP may require permanent or temporary disinfection for coliform bacteria detects occurring as a result of distribution system problems such as biofilm and cross-connections.

f. Required Pathogen Monitoring for Ground Water Sources with Enclosed Treatment-No Disinfection

MassDEP will use these monitoring criteria to determine if there are significant pathogen presences in raw water or immediately after treatment.

(1) Monitoring

Triggered monitoring for the Ground Water Rule fecal indicator shall be required at the raw water source(s). Monitoring for total coliform and/or Ground Water Rule fecal indicators shall be required immediately after enclosed filtration or enclosed aeration. Monitoring immediately after other enclosed treatment such as chemical addition shall be at the discretion of MassDEP. Frequency of monitoring after treatment shall be as determined by MassDEP. Where there are no significant presences of pathogens, disinfection is optional (see Section 5.4.1.1.a. (6)).

(2) Additional Monitoring

MassDEP shall require additional coliform bacteria monitoring for the following:

(a) For one or more MCL violations over a twelve-month period in either source water or treated water

(b) For treated water after installation of new treatment

(c) In a new ground water source which has experienced coliform detects during a pump test

(d) In any other related circumstance as required by MassDEP

(3) Frequency shall be as determined by MassDEP.

2. Contact Time (CT)

Satisfactory disinfection contact time is required at facilities treating surface water or ground water under the direct influence of surface water or groundwaters treating to comply with the Groundwater Rule. Due consideration shall be given to the contact time of the disinfectant in water with relation to pH, ammonia, taste-producing substances, temperature, bacteria quality, disinfection byproduct formation potential and other pertinent factors. All basins used for disinfection must be designed to minimize short circuiting. Additional baffling can be added to new or existing basins to minimize short circuiting and increase contact time.

The amount of contact time provided will depend on the type of disinfectant used along with the parameters mentioned in 5.4.1(2) (a) in the next paragraph. As a minimum, for surface water and groundwaters under the direct influence of surface water, the system must be designed to meet CT standards set by MassDEP. If primary disinfection is accomplished using ozone, ultraviolet light, or some other chemical that does not provide a residual disinfectant for treating surface water or groundwater under the direct influence, then chlorine must be added to provide a residual disinfectant as noted in 5.4.1(4)(a)(1) *Demonstration of Maintaining a Residual*. Disinfection for groundwater shall be as determined by MassDEP.

a. To demonstrate that a water supply maintains disinfection conditions that inactivate *Cryptosporidium*, *Giardia lamblia* and viruses, the system must monitor and record the disinfectant(s) used, disinfectant residual(s), disinfectant contact time(s), pH, and water temperature. This data is used to determine if minimum total inactivation requirements of the Surface Water Treatment Rules are being met.

b. The CT value(s) for a system's disinfection conditions are calculated during peak hourly flow once each day that the system is delivering water to its customers. CTs during all flow conditions shall be sufficient to achieve the amount of inactivation of Cryptosporidium, *Giardia* and viruses required by 310 CMR 22.20A for all water that is delivered to its customers unless otherwise determined in writing by MassDEP.

c. Residual disinfectant concentration is the concentration of the disinfectant (in mg/L) at a point before or at the first customer.

d. Contact time in pipelines must be calculated based on plug flow by dividing the internal volume of the pipeline by the peak hourly flow rate through that pipeline.

e. Contact time within mixing basins, settling basins, storage reservoirs, and any other tankage must be determined by tracer studies or an equivalent method, as determined by MassDEP. The contact time determined from tracer studies to be used for calculating CT is T_{10}. T_{10} is the detention time corresponding to the time for which 90% of the water has been in contact with the residual concentration. Guidance for determining contact times for basins is provided in Appendix C of the *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*, the latest relevant EPA Rules and guidance manuals, and MassDEP regulations 310 CMR 22.20A.

f. Contact Time Tracer Study Protocol- (see Section 5.1.6.2)

g. For systems that disinfect with ultraviolet light, refer to tables listing UV dosages necessary to meet inactivation requirements for Cryptosporidium, Giardia and viruses published in EPA's LT2ESWTR and guidance manual. Log credit is based on validated UV dose in relation to UV dose table, reactor validation testing required to establish UV dose and associated operating conditions. See specific criteria in 141.720(d) of the LT2ESWTR and guidance manual (see Section 5.4.6).

3. Point of Application

   Provisions shall be made for applying the disinfectant to the raw water, settled water, filtered water, and water entering the distribution system.

   The application of a disinfectant shall be designed and constructed in such a manner as to prevent contamination of the water supply, by excluding any cross connections to the distribution system and by-passes of treatment units through interconnection of chemical feed or other piping. All disinfectant systems, pre- and post-treatment, must be independent of one another to prevent possible siphoning of partially treated water into the finished water.

   The application point of chlorine shall be designed and constructed in a manner to allow immediate downstream sampling of the disinfected water to monitor and control residuals. Application should not be made directly to large vessels or tanks. One time disinfection of large vessels or tanks shall comply with AWWA Standard C652-19 or latest edition *Disinfection of Water Storage Facilities*.

4. Demonstration of Maintaining a Residual

   a. Facilities disinfecting surface water or ground water under the direct influence of surface water (except those using ultraviolet light):

      (1) A minimum disinfectant residual of 0.2 mg/L entering the distribution system must be maintained.

      (2) The disinfectant residual cannot be less than 0.2 mg/L for more than four hours

      (3) A detectable residual must be maintained throughout the distribution system. Alternatively, this requirement can be met through heterotrophic plate count (HPC) sampling. Note that actual measurement of the residual is still required under the Stage 1 Disinfectant/Disinfection Byproduct Rule to demonstrate compliance with the MRDL.

      (4) Where chloramination is practiced, a minimum chloramine residual should be 1.0 mg/L at the distant points in the distribution system.

      (5) Higher residuals may be required depending on pH, temperature, and other characteristics of the water.

b. Facilities chlorinating groundwater of questionable sanitary quality not triggered into disinfection by the Ground Water Rule:

   (1) A minimum free chlorine residual of 0.2 mg/L after a 10-minute contact time shall be maintained entering the distribution system. Contact time in this application is determined by taking a sample of water at a tap immediately after the point of chlorine addition, letting the sample stand for ten minutes then adding the proper reagents and immediately measuring the free chlorine residual using an approved analyzer. However, if a water system can meet the 10-minute contact time and required free chlorine residual through storage at the treatment plant then the previous methodology would not apply.

   This minimum requirement may be significantly enhanced when determined by MassDEP to be necessary (e.g. a conventional water filtration plant treating ground water utilizing many different unit processes to remove iron, manganese, color etc.).

   (2) In those cases where a chloramine residual is desired in the distribution system, a minimum free residual of 0.2 mg/L must be maintained for at least ten minutes prior to the addition of ammonia.

   (3) Higher disinfectant residuals may be required depending upon pH, temperature and other characteristics of water.

   (4) Maintenance of a detectable chlorine or chloramine residual in all parts of the distribution system is desirable.

c. Facilities disinfecting with UV see Section 5.4.6.1.

d. Facilities disinfecting in compliance with the Ground Water Rule refer to the rule specifics for maintaining a residual in the distribution system and/or entry point to the distribution system.

e. All community public water systems using chlorine disinfection, that do not fall under the disinfection requirements noted above, shall maintain a minimum free chlorine residual of 0.2 mg/L leaving the treatment facility at all times. MassDEP may set minimum free chlorine residual requirements for other water systems as necessary.

5. Disinfection Methods

   Approved Methods:

a. Chlorination

b. Chloramination

c. Ozonation

d. Chlorine dioxide

e. Ultraviolet light

f. Other methods approved by MassDEP

5.4.2 Chlorination

Chlorination may be accomplished with calcium or sodium hypochlorite or chlorine gas solution.

1. Chlorination Equipment

   a. Type

      Solution-feed-gas chlorinators or hypochlorite feeders of the positive displacement type must be provided (see Chapter 6).

   b. Capacity

      The chlorinator capacity shall be such that a free chlorine residual of at least 2 mg/L can be attained in the water after contact time of at least 30 minutes when maximum flow rates coincide with anticipated maximum chlorine demands. The equipment shall be designed to operate accurately over the desired feeding range.

   c. Standby Equipment

      Where chlorination is required for protection of the supply, complete standby equipment of sufficient capacity shall be available to replace the largest unit during shutdown. Emergency or standby power shall also be available. Whenever gas chlorination is used, if there is a large difference in feed rates between routine and emergency dosages, a gas metering tube should be provided for each dose range to ensure accurate control of the chlorine feed.

   d. Automatic Proportioning

      Automatic proportioning chlorinators will be required where the rate of flow or chlorine demand is not reasonably constant.

   e. Automatic Switch-over

Whenever gas chlorine is used, automatic changeover equipment to switch from one cylinder or bank of cylinders to another cylinder or bank of cylinders must be provided to ensure that unchlorinated water is not allowed into the distribution system. Spare parts shall be made available to replace parts subject to wear and breakage.

f. Alarms

Visual and audio alarms must be provided for detection of chlorine gas leaks or overfeed.

g. Injector/diffuser

The chlorine solution injector/diffuser must be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point.

h. Eductor

Whenever gas chlorine is used each eductor must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector water flow, the total discharge back pressure, the injector operating pressure, and the size of the chlorine solution line. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.

i. See Section 6.4 for chlorine gas installation.

2. Testing Equipment

a. Chlorine residual test equipment recognized in the latest edition of *Standards Methods for the Examination of Water and Wastewater* shall be provided and should be capable of measuring residuals to the nearest 0.1 milligrams per liter. MassDEP requires that all systems, as a minimum, use an instrument employing the DPD colorimetric method with a digital readout and a self-contained light source unless otherwise approved by MassDEP.

b. In addition to (2a) above, the MassDEP will allow the use of EPA Method 334.0 (The Determination of Residual Chlorine in Drinking Water Using On-Line Chlorine Analyzer). This method can be used with any type of on-line instrument since it is a "performance based" method. This method can be obtained from the EPA website:
http://water.epa.gov/scitech/drinkingwater/labcert/upload/met334_0.pdf

c. Users of EPA Method 334.0 must be strictly guided by criteria established under this method with regards to reagents and standards; sample collection and preservation and storage; quality control; calibration and start-up of the on-line equipment; routine procedures; pollution prevention; and, waste prevention.

d. Under EPA Method 334, MassDEP reserves the right to inspect plant records with regards to implementation of this method.

e. Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time.

f. All surface water, or groundwater under the direct influence, treatment plants that serve a population greater than 3,300 must have equipment to measure chlorine residuals continuously entering the distribution system.

g. Systems that rely on chlorination for inactivation of bacteria or other microorganisms present in the source water shall have continuous chlorine residual analyzers and other equipment that automatically shut down the facility when chlorine residuals are not met unless otherwise approved by MassDEP.

h. MassDEP recommends that continuous chlorine residual analyzers be installed as near the point of chemical application as possible to provide representative sample results. Continuous chlorine residual analyzers used for inactivation credit monitoring (or other monitoring) may be used at a point substantially downstream of chemical application. However, in these cases, providing an additional analyzer at a location near the point of chemical application will allow the operator to identify any problems before they become issues downstream. Analyzers should not draw from large vessels or tanks.

3. Chlorination Piping

a. The piping system for the injection of chlorine into the water should be of suitable material and should be as short and direct as possible to the point of application. The pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use PVC). Pipes and fittings carrying chlorine solution must be made of rubber, PVC, polyethylene or other materials recommended by the Chlorine Institute. Nylon products are not acceptable for any part of the chlorine solution piping system.

b. An installation whereby chlorine may be applied to the water from each unit independently is preferred. However, under special conditions, the chlorinators may be manifolded together and a single line run to the point of injection. If only one line is run from the chlorinators to the point of injection, an extra corporation cock should be installed for emergency use.

c. The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, or groundwater under the direct influence, pre and post-chlorination systems must be independent to prevent possible siphoning of partially treated water in the finished water. The water supply to each eductor shall have a separate shut-off valve. No master shut-off valve will be allowed.

4. Housing

   Adequate housing shall be provided for the chlorination equipment and for storing the chlorine (see Chapter 6).

5.4.3 Chloramination

1. General Information

   a. Chloramines are useful for controlling trihalomethane formation, maintaining a disinfectant residual in water distribution systems, and other related applications. Chloramines tend to remain active for longer periods and at greater distances from the plant than free chlorine. Chloramine concentrations should be maintained higher than free chlorine to avoid nitrifying bacterial activity.

   b. Patients on kidney dialysis machines may be particularly affected by chloramines especially monochloramine. Public water systems using chloramines as the terminal disinfectant shall advise area hospitals, health clinics and the local board(s) of health annually of the presence of monochloramine in the tap water. Notification shall be made to the parties noted above in public notice format or as approved by MassDEP.

   c. Chloramines in water are considerably more toxic to fish and other aquatic organisms than free chlorine. Consideration must therefore be given to potential for leaks to contaminate and damage natural water course ecosystems. Public water systems should inform pet stores with fish tanks and aquariums.

   d. Chloramines are a much weaker oxidant than free chlorine, chlorine dioxide, or ozone and are not recommended as a primary disinfectant. When using chloramination as a secondary disinfectant, unless specifically approved otherwise in writing by MassDEP, chlorine shall be added and thoroughly mixed in the water prior to the addition of ammonia.

      (1) Where chloramination is required for protection of the supply, complete standby equipment of sufficient capacity shall be available to replace the largest unit during shutdown. Emergency or standby power shall also be available.

      (2) Visual and audio alarms shall be provided for detection of chlorine and ammonia gas leaks.

(3) Alarming and continuous analyzers are recommended to prevent overfeeding

e. Chloramination Impacts

(1) When chloramines are used in water treatment as a residual disinfectant, it can change the chemical properties of the water which subsequently can impact lead and copper corrosion. Certain conditions related to pH, alkalinity, and dissolved inorganic carbonate levels in the water can cause lead to dissolve from pipe material.

(2) Chloramination, if not properly optimized, can result in nitrification (conversion of ammonia into nitrite and then nitrate) in the presence of bacteria. Nitrification can lower the pH of the water, which can increase corrosion of lead and copper. The following are recommended:

(a) Water systems planning to use chloramination must review *US EPA Simultaneous Compliance Guidance Manual*.

(b) Water systems using chloramination must perform an optimal corrosion control treatment study prior to introducing chloramines into the distribution system.

(c) Water systems using chloramination may need to add chemicals to the finished water to form a protective coating on the pipes, such as an orthophosphate corrosion inhibitor.

(d) Water systems using chloramination shall optimize the chloramination process to minimize the possibility of nitrification that can reduce pH and increase corrosion.

f. Where chloramination is required for protection of the supply, complete standby equipment of sufficient capacity shall be available to replace the largest unit during shutdown. Emergency or standby power shall also be available.

g. Visual and audio alarms shall be provided for detection of chlorine and ammonia gas leaks.

h. Alarming and continuous analyzers are recommended to prevent overfeeding.

2. Forms of Ammonia

a. Ammonia for chloramine formation may be added to water either as a water solution of ammonium sulfate or, as aqua ammonia, (ammonia gas in water solution) or as anhydrous ammonia (purified 100% ammonia in liquid or gaseous form). Special provisions required for each form of ammonia are listed below:

(1) Ammonium sulfate

A water solution is made by addition of ammonium sulfate solid to water with agitation.

(a) The tank and dosing equipment contact surfaces should be made of corrosion resistant non-metallic materials.

(b) Provision should be made for removal of the agitator after dissolving the solid.

(c) The tank should be fitted with a lid and vented outdoors.

(d) Injection of the solution should take place in the center of treated water flow at a location where there is high velocity movement.

(2) Aqua ammonia (ammonium hydroxide)

Aqua ammonia feed pumps and storage shall be enclosed and separated from other operating areas. The aqua ammonia room shall be equipped as in Section 6.4 with the following changes:

(a) A corrosion resistant, closed, unpressurized tank shall be used for bulk storage. The tanks shall be vented through an inert liquid trap to a high point outside and an incompatible connector or lockout provisions shall be made to prevent accidental addition of other chemicals to the storage tank.

(b) The storage tank shall be fitted either with cooling/refrigeration and/or with provisions to dilute and mix the contents with water without opening the system. Those provisions are required to avoid conditions where temperature increases cause the ammonia vapor pressure over the aqua ammonia to exceed atmospheric pressure.

(c) An exhaust fan shall be installed to withdraw air from high points in the room and makeup air shall be allowed to enter at a low point.

(d) The aqua ammonia feed pump, regulators, and lines shall be fitted with pressure relief vents discharging outside the building away from any air intake and with water purge lines leading back to the headspace of the bulk storage tank.

(e) The aqua ammonia shall be conveyed direct from storage to the treated water stream injector without the use of a carrier water stream unless the carrier stream is softened.

(f) The point of delivery to the main water stream should be placed in a region of rapid, preferably turbulent, water flow.

(g) Provisions should be made for easy access for removal of calcium scale deposits from the injector.

(h) Provision of a modestly-sized scrubber capable of handling occasional minor emissions should be considered.

(3) Anhydrous ammonia

Anhydrous ammonia is readily available as a pure liquefied gas under moderate pressure in cylinders or as a cryogenic liquid boiling at -15 Celsius at atmospheric pressure. The liquid causes severe burns on skin contact.

(a) Anhydrous ammonia and storage feed systems (including heaters where required) shall be enclosed and separated from other works areas and constructed of corrosion resistant materials.

(b) Pressurized ammonia feed lines should be restricted to the ammonia room.

(c) An emergency air exhaust system, as in Section 6.4 but with an elevated intake, shall be provided in the ammonia storage room.

(d) Leak detection systems shall be fitted in all areas through which ammonia is piped.

(e) Special vacuum breaker/regulator provisions must be made to avoid potentially violent results of backflow of water into cylinders or storage tanks.

(f) Carrier water systems of soft or pre-softened water may be used to transport ammonia to the finished water stream and to assist in mixing.

(g) The ammonia injector should use a vacuum eductor or should consist of a perforated tube fitted with a closely fitting flexible rubber tubing seal punctured with a number of small slits to delay fouling by lime deposits.

(h) Provision should be made for the periodic removal of scale/lime deposits from injectors and carrier piping.

(i) Consideration shall be given to the provision of an emergency gas scrubber capable of absorbing the entire contents of the largest ammonia storage unit whenever there is a risk to the public as a result of potential ammonia leaks.

5.4.4 Ozonation

1. General

   a. Ozone treatment systems are generally used for the purpose of disinfection, oxidation and microfiltration, and may be used as a predisinfectant and as flocculation enhancement for water treatment facilities using surface water supplies. When applied, all of these reactions may occur but typically only one is the primary purpose for its use. The other reactions would become secondary benefits of the installation.

   b. Effective disinfection occurs as demonstrated by the fact that the CT values for ozone for inactivation of viruses and Giardia cysts, are considerably lower than the CT values for other disinfectants. In addition, recent research indicates that ozone can be an effective disinfectant for the inactivation of cryptosporidium. Microflocculation and enhanced filterability has been demonstrated for many water supplies but has not occurred in all waters. Oxidation of organic compounds such as color, taste, and odor, and detergents and inorganic compounds such as iron, manganese, heavy metals, and hydrogen sulfide has been documented. The effectiveness of oxidation has been varied, depending upon pH and alkalinity of the water.

   c. These parameters affect the formation of highly reactive hydroxyl radicals, or conversely the scavenging of this oxidant. High levels of hydroxyl radicals cause lower levels of residual ozone. Depending on the desired oxidation reaction, it may be necessary to maximize ozone residual or maximize hydroxyl radical formation. For disinfection, residual ozone is necessary for development of CT.

   d. As a minimum, bench scale studies shall be conducted to determine minimum and maximum ozone dosages for disinfection CT compliance and oxidation reactions. Piloting evaluations are required to determine ozone effectiveness and sizing for the proposed water treatment facility equipment. More involved pilot studies may be necessary to document the benefits and DBP precursor removal effectiveness. Ozone piloting may be used in the pilot process or by contactor columns, based upon MassDEP determinations. The time frame for piloting of ozone treatment systems shall be the same as that approved for water treatment evaluations.

e. The use of ozone requires a higher degree of operator maintenance skills and training. The ability to obtain qualified operators must be evaluated in selection of this treatment process. The necessary operator training shall be provided prior to plant start-up.

f. The production of ozone is an energy intensive process: substantial economies in electrical usage, reduction in equipment size, and waste heat removal requirements can be obtained by using oxygen enriched air or 100% oxygen as feed, and by operating at increased electrical frequency.

g. Use of ozone may result in increases in biologically available organics content of the treated water. Consideration of biologically active filtration may be required to stabilize some treated waters. Ozone may also lead to increased chlorinated byproduct levels if the water is not stabilized and free chlorine is used for distribution protection.

h. Following the use of ozone, the application of a disinfectant which maintains a measurable residual will be required in order to ensure a bacteriologically safe water is carried throughout the distribution system. See Section 5.4.1(4) (a) (1) "Demonstration of Maintaining a Residual"

2. Piloting evaluations should address the following:

   a. The required contact time of ozone for maximum disinfection during period of high algal and bacteriological content should be addressed. EPA's *Surface Water Treatment Rule Guidance Manual* and the latest applicable EPA rules and guidance manuals shall be consulted for determining contact time values for inactivating pathogens including *Cryptosporidium*. The ozone decay rate for various application points shall also be evaluated.

   b. The effects of micro-flocculation from ozone on the treatment process (i.e., filter loading, flocculation, and settling characteristic changes) should be addressed. This evaluation shall include effects on disinfection by-products, filter turbidity effluent, and coagulant dose levels.

   c. Ozonation effects on constituents present in the raw water such as color, iron and manganese, volatile organic compounds, and organics (pesticides)

   d. Potential health effects of escaping ozone

e. Corrosive effects of excess oxygen on facility internal piping

f. Emergency power generator sizing due to ozone equipment addition

g. Required ozone feed rate in milligrams per liter (mg/L). Maximum required gas application rates shall be determined during time periods with the least desirable water quality. Extreme care must be taken during bench and pilot scale studies to ensure accurate results. Particularly sensitive measurements include gas flow rate, water flow rate, and ozone concentration.

h. The feasibility and design requirements for applying ozone at other points in the treatment process

i. The most appropriate application points. Ozone may be applied at one point or at multiple points in the process. Consideration shall be given to multiple points of ozone application.

3. Equipment - General

   a. Facilities using ozonation shall be designed to house all ozonation equipment in a separate room and to provide access for unit maintenance.

   b. The ozone treatment system shall be sized to provide sufficient capacity to provide a minimum dosage rate of 1.5 mg/L for the required flow unless piloting confirms a lesser rate.

   c. Equipment shall be provided to meet existing design standards for application of this chemical and to ensure that adequate duplication is provided.

   d. Ozonation equipment not used for disinfection may not need all of the following criteria as approved by MassDEP.

   e. Spare parts for each component, including a complete set of dielectric tubes for at least one ozone generator

4. Feed Gas Preparation

   a. Air preparation equipment shall be designed to minimize humidity during worst-case conditions. As a minimum, two towers should be included in the air-drying process. Air handling equipment on conventional low pressure air feed systems shall consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some "package" ozonation systems for small plants may work effectively operating at high pressure without the refrigerant dryer and with a "heat-less" desiccant dryer. In all cases the design engineer must ensure that the maximum dew point of -76°F (-60°C) will not be exceeded at any time.

b. Ozone gas preparation systems shall be designed to provide low, medium, or high pressure delivery systems. Heat generated in the gas stream during compression will be required to be within parameters determined by the manufacturer with use of an after cooler (if required).

c. Feed gas can be air, oxygen enriched air, or high purity oxygen. Sources of high purity oxygen include purchased liquid oxygen; on site generation using cryogenic air separation; or temperature, pressure or vacuum swing (adsorptive separation) technology. For high purity oxygen-feed systems, dryers typically are not required.

5. Air Compression

   a. a. Air compressors shall be of the liquid-ring or rotary lobe, oil-less, positive displacement type for smaller systems or dry rotary screw compressors for larger systems.

   b. The air compressors shall have the capacity to simultaneously provide for maximum ozone demand, provide the air flow required for purging the desiccant dryers (where required) and allow for standby capacity.

   c. Air feed for the compressor shall be drawn from a point protected from rain, condensation, mist, fog and contaminated air sources to minimize moisture and hydrocarbon content of the air supply.

   d. A compressed air after-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.

   e. A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a breakdown.

6. Air Drying

   a. Refrigerated air dryers with condensed water drains with excess capacity. Units shall be sized to handle maximum humidity conditions during worst-case summer periods.

   b. Dry, dust-free and oil-free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation and to prevent damage to the generator dielectrics. Sufficient drying to a maximum dew point of -76°F (-60°C) must be provided at the end of the drying cycle.

   c. Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure systems, a refrigeration air dryer in series with heat-reactivated desiccant dryers shall be used.

d. A refrigeration dryer capable of reducing inlet air temperature to 40°F (4°C) shall be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type.

e. For heat-reactivated desiccant dryers, the unit shall contain two desiccant filled towers complete with pressure relief valves, two four-way valves and a heater. In addition, external type dryers shall have a cooler unit and blowers. The size of the unit shall be such that the specified dew point will be achieved during a minimum adsorption cycle time of 16 hours while operating at the maximum expected moisture loading conditions.

f. Multiple air dryers shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

g. Each dryer shall be capable of venting "dry" gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are on-line.

7. Air Filters

a. Air filters shall be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators.

b. The filter before the desiccant dryers shall be of the coalescing type and be capable of removing aerosol and particulates larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be of the particulate type and be capable of removing all particulates greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

8. Preparation Piping

Piping in the air preparation system can be common grade steel, seamless copper, stainless steel or galvanized steel. The piping must be designed to withstand the maximum pressures in the air preparation system.

9. Ozone Generator

a. Ozone generator shall be provided with sufficient replacement tubes to ensure continued operation.

b. The production rating of the ozone generators shall be stated in pounds per day and kWhr per pound at a maximum cooling water temperature and maximum ozone concentration.

c. The design shall ensure that the minimum concentration of ozone in the generator exit gas will not be less than 1 percent (by weight).

d. Generators shall be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time. This can result in premature breakdown of the dielectrics.

e. The production rate of ozone generators will decrease as the temperature of the coolant increases. If there is to be a variation in the supply temperature of the coolant throughout the year, then pertinent data shall be used to determine production changes due to the temperature change of the supplied coolant. The design shall ensure that the generators can produce the required ozone at maximum coolant temperature.

f. Appropriate ozone generator backup equipment must be provided.

g. The generators can be low, medium or high frequency type. Specifications shall require that the transformers, electronic circuitry and other electrical hardware be proven, high quality components designed for ozone service.

h. Adequate cooling shall be provided. The required water flow to an ozone generator varies with the ozone production. Normally unit design provides a maximum cooling water temperature rise of 5°F (2.8°C). The cooling water must be properly treated to minimize corrosion, scaling and microbiological fouling of the water side of the tubes. A closed loop cooling water system shall be used to insure proper water conditions are maintained unless otherwise approved in writing by the MassDEP. Where cooling water is treated cross connection control or its equivalent as approved in writing by MassDEP shall be provided to prevent contamination of the potable water supply

i. To prevent corrosion, the ozone generator shell and tubes shall be constructed of type 316L stainless steel.

10. Ozone Contactors

a. The application of ozone shall take place in a contact tank sized to provide the maximum required CT as determined by piloting. Chambers shall consist of two dissolution chambers and a reaction chamber. A minimum of 2 feet of free clearance between the bottom of the chamber cover and the baffle wall shall be included. Gas will be placed in the contactor by fine bubble porous tube or dome diffusers or by turbine dissolution. Other contactors, such as the venture or aspirating turbine mixer contactor, may be approved by MassDEP provided adequate ozone transfer is achieved and the required contact time and residuals can be met and verified.

b. Chambers shall be designed to provide a minimum of 10 minutes contact time at facility design flow. A shorter contact time may be approved by MassDEP if justified by appropriate design and CT considerations.

c. If iron and manganese oxidation is the primary purpose of ozone use, two chambers may be acceptable.

d. Where disinfection is the primary application a minimum of two contact chambers each equipped with baffles to prevent short circuiting and induce countercurrent flow shall be provided. Ozone shall be applied using porous-tube or dome diffusers.

e. Chambers shall have gasketed stainless steel access hatches for periodic inspection.

f. Contactors should be separate closed vessels that have no common walls with adjacent rooms. The contactor must be kept under negative pressure and sufficient ozone monitors shall be provided to protect worker safety. Placement of the contactor where the entire roof is exposed to the open atmosphere is recommended.

g. Large contact vessels should be made of reinforced concrete. All reinforcement bars shall be covered with a minimum of 1.5 inches of concrete. Smaller contact vessels can be made of stainless steel, fiberglass or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level.

h. For ozone applications in which precipitates are formed, such as with iron and manganese removal, porous diffusers should be used with caution.

i. Where taste and odor control is of concern, multiple application points and contactors shall be considered.

j. Where necessary a system shall be provided between the contactor and the off-gas destruct unit to remove froth from the air and return the other to the contactor or other location acceptable to MassDEP. If foaming is expected to be excessive, then a potable water spray system shall be placed in the contactor head space.

k. All openings into the contactor for pipe connections, hatchways, etc. shall be properly sealed using welds or ozone resistant gaskets such as Teflon or Hypalon.

l. Multiple sampling ports shall be provided to enable sampling of each compartment's effluent water and to confirm CT calculations.

m. A pressure/vacuum relief valve shall be provided in the contactor and piped to a location where there will be no damage to the destruction unit.

n. The diffusion system should work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel.

o. The depth of water in bubble diffuser contactors should be a minimum of 18 feet. The contactor should also have a minimum of 3 feet of freeboard to allow for foaming.

p. All contactors shall have provisions for cleaning, maintenance and drainage of the contactor. Each contactor compartment shall also be equipped with an access hatchway.

q. Aeration diffusers shall be fully serviceable by either cleaning or replacement.

r. Every ozone treatment train utilized for disinfection or other similar purposes shall have a means for determining if diffusers are properly operating. Acceptable methods may include:

   (1) Observation windows with sufficient lighting within the chamber to allow daily visual inspection of ozone diffusion

   (2) Provision to monitor the ozone transfer efficiency such as by continuous measurement of ozone off-gases and comparison with applied dose.

   (3) Visual and audio alarms shall be provided and would be activated when ozone off-gas set points are exceeded.

   (4) Other methods as approved in writing by MassDEP.

11. Ozone Destruction Unit(s)

a. A system for treating the final off-gas from each contactor must be provided in order to meet safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units.

b. In order to reduce the risk of fires, the use of units that operate at lower temperatures is encouraged, especially where high purity oxygen is the feed gas.

c. The maximum allowable ozone concentration in the discharge is 0.1 ppm (by volume).

d. At least two units shall be provided which are each capable of handling the entire gas flow.

e. Exhaust blowers shall be provided in order to draw off-gas from the contactor into the destruct unit and then to atmosphere through a vent stack system.

f. Catalysts must be protected from froth, moisture and other impurities which may harm the catalyst.

g. The catalyst and heating elements shall be located where they can easily be reached for maintenance.

h. Flow of ozone gas to each chamber shall be by manual flow control valves. Excess and unused ozone gas shall be directed to a gas destruction system. The ozone gas destruction shall discharge to the atmosphere through a blower and vent stack system.

12. Ozone Gas Piping Material

Only low carbon 304L and 316L stainless steels shall be used for ozone service with 316L the preferred.

13. Joints and Connections

a. Connections on piping used for ozone service are to be welded where possible.

b. Connections with meters, valves or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon or Hypalon. Screwed fittings shall not be used because of their tendency to leak.

c. A positive closing plug or butterfly valve plus a leak-proof check valve shall be provided in the piping between the generator and the contactor to prevent moisture reaching the generator.

14. Sampling and Instrumentation

a. The laboratory shall be specifically equipped with the necessary equipment for the operator to test and sample waters containing ozone gas. Sampling equipment shall be stainless steel, as required. Laboratory equipment shall consist of air sample diaphragm pumps, gas-washing bottles and absorbers, wet-test gas meters, a wall-mounted barometer, and equipment required for ozone determination as outlined in the latest edition of *Standard Methods for the Examination of Water and Wastewater.*

b. Pressure gauges shall be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet to the ozone generators and contactors and at the inlet to the ozone destruction unit.

c. Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator shall have a trip which shuts down the generator when the wattage exceeds a certain preset level.

d. Dew point monitors shall be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture entering the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors shall be used.

e. Air flow meters shall be provided for measuring air flow from the desiccant dryers to each of other ozone generators, air flow to each contactor and purge air flow to the desiccant dryers.

f. Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generator feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water.

g. Water flow meters shall be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply.

h. Ozone monitors shall be installed to measure zone concentration in both the feed-gas and off-gas from the contactor and in the off-gas from the destruct unit. For disinfection systems, monitors shall also be provided for monitoring ozone residuals in the water. The number and location of ozone residual monitors shall be such that the amount of time that the water is in contact with the ozone residual can be determined.

i. A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactor and a minimum of one shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.

j. Vibration switches shall be provided.

k. Level and flow indicators shall be provided.

15. Alarms

The following alarm/shutdown systems shall be provided at each installation unless otherwise approved in writing by the MassDEP:

a. Dew point shutdown/alarm - This system shall shut down the generator in the event the system dew point exceeds -76^{o}F (-60^{o}C).

b. Ozone generator cooling water flow shutdown/alarm - This system shall shut down the generator in the event that cooling water flows decrease to the point that generator damage could occur.

c. Ozone power supply cooling water flow shutdown/alarm - This system shall shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply.

d. Ozone generator cooling water temperature shutdown/alarm - This system shall shutdown the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.

e. Ozone power supply cooling water temperature shutdown/alarm - This system shall shutdown the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.

f. Ozone generator inlet feed-gas temperature shutdown/alarm - This system shall shutdown the generator if the feed-gas temperature is above a preset value.

g. Ambient ozone concentration shutdown/alarm - The alarm shall sound when the ozone level in the ambient air exceeds 0.1 ppm or a lower value chosen by the water supplier. Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor.

h. Ozone destruct temperature alarm - The alarm shall sound when temperature exceeds a preset value.

i. All alarms shall be audio-visual unless otherwise approved in writing by MassDEP.

16. Safety and Training

a. Approval of ozonation treatment systems by MassDEP shall be contingent on the public water supplier providing a written plan that outlines classroom and training instruction for personnel on the ozone treatment system operation. The plan shall provide for training of operation and maintenance for the proposed ozone treatment plant prior to start-up.

b. Safety equipment shall be provided as required by the manufacturer and the local fire department.

c. Safety equipment shall consist of two ambient low-concentration ultraviolet absorption ozone photometer analyzers within the separate ozone building and at the contact chamber to measure atmospheric air. Gas masks and pressure-demand tanks shall be provided along with hand-operated gas detector devices.

d. Large signs indicating the presence of an irritant gas shall be located at all entrances to the ozone building. A sign shall be posted indicating "No Smoking – Oxygen In Use" at all entrances to the facility. In addition, no flammable or combustible materials shall be stored within the oxygen generating area.

e. Exhaust of ozone gas after the ozone destruct unit shall be below the accepted 8-hour exposure level at a point away from all building entrances. OSHA and industry standards shall be consulted for acceptable exhaust levels. Appropriate warning signs shall be placed at the exhaust point. The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume).

f. Emergency exhaust fans shall be provided in the room containing the ozone generators to remove ozone gas if leakage occurs.

g. Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation.

h. A portable purge air blower that will remove residual ozone in the contactor prior to entry for repair or maintenance shall be provided.

i. High voltage and high frequency electrical equipment must meet current electrical and fire codes.

17. Construction Considerations

a. Prior to connecting the piping from the desiccant dryers to the ozone generators the air compressors should be used to blow the dust out of the desiccant.

b. The contactor should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactor and checking for pressure losses.

c. Connections on the ozone service line should be tested for leakage using the soap-test method.

5.4.5 Chlorine Dioxide

Chlorine dioxide may be considered as a primary and residual disinfectant, a pre-oxidant to control tastes and odors, to oxidize iron and manganese, and to control hydrogen sulfide and phenolic compounds. It has been shown to be a strong disinfectant which does not form THMs or HAAs. When choosing chlorine dioxide, consideration must be given to formation of the regulated byproducts and chlorite.

Notification of a change in disinfection practices and the schedule for the changes shall be made known to the public; particularly to hospitals, kidney dialysis facilities and fish breeders, as chlorine dioxide and its byproducts may have similar effects as chloramines. (See section 5.4.3(1)b, c *Chloramination – General Information*.)

1. Chlorine Dioxide Equipment

Chlorine dioxide equipment is similar to chlorine equipment. However, chlorine dioxide is produced in a chemically controlled manner on site due to its explosive nature. Chlorine gas, sodium chlorite and sodium hypochlorite feed and storage facilities shall comply with section 5.4.2 “Chlorination and Chapter 6 of these guidelines respectively.

a. The following pieces of equipment are required for chlorine dioxide generation:

(1) Reactor (Pyrex glass)

(2) Diaphragm metering pump

(3) Solution tank

(4) Mixer

(5) Chlorine dioxide generating tower

(6) Electrical controls, as needed

(7) PVC/Tygon and/or polyethylene piping

b. To prevent periods without disinfection or inadequate disinfection, automatic change-over equipment is necessary to switch chlorine gas supply as well as any of the associated reactants in use.

c. Chlorine dioxide may be tested by using the DPD or amperometric methods of analysis.

d. Where chlorine dioxide is required for protection of the supply, complete standby equipment of sufficient capacity shall be available to replace the largest unit during shutdown. Emergency power shall also be available.

2. On-Site Generation of Chlorine Dioxide

a. In liquid media, chlorine dioxide's production involves either of the following reactants:

(1) Chlorine and sodium chlorite

(2) Chlorite and hydrochloric acid

b. In gas phase generation, chlorine gas reacts with liquid sodium chlorite under vacuum. Chlorine dioxide is then removed by a gas ejector.

c. Chlorine dioxide generation equipment shall be factory assembled, pre-engineered units with a minimum efficiency of 95%. The excess free chlorine shall not exceed 3% of the theoretical stoichiometric concentration required.

3. Dosage

   a. The typical dosage of chlorine dioxide in drinking water varies from 0.1 mg/L to 0.5 mg/L with a maximum of 0.8 mg/L as ClO_2.

   b. Continuous analyzers should be installed for monitoring and alarming of chlorine dioxide overfeeds.

4. Safety

   Chlorine dioxide should be handled similarly to chlorine. The following precautions should be followed:

   a. Chlorine dioxide cellular detectors should be installed in the area for continuous monitoring of chlorine dioxide leaks, if any. The drawtube of the equipment should be placed close to the floor.

   b. In the event of an emergency, use self-contained breathing apparatus.

   c. Chlorine dioxide mixtures should not be greater than five percent.

   d. Due to the corrosive nature of sodium chlorite, the explosive nature of chlorine dioxide, and the fact that chlorine supports combustion in the event of a chlorine gas explosion, the chlorine dioxide facility (particularly the reactors) should be isolated from the rest of the facility, including supportive chlorinators.

   e. The storage room should be adequately ventilated. Upon opening the door of the storage room, the exhaust fan should be automatically energized.

   f. Chlorine dioxide leak detection equipment should be tested periodically for proper functioning.

   g. Ammonia gas can be used to detect chlorine.

   h. A formal safety program should be in place for personnel.

   i. Audio and visual alarms shall be provided for detection of chlorine gas leakage.

5.4.6 Ultraviolet Disinfection

1. General

   a. Ultraviolet (UV) light produced by UV lamps has been shown to be effective at inactivating protozoa (*Cryptosporidium* and *Giardia*) and bacteria (*Escherichia coli* and *Staphylococcus aureus*). It is less effective at inactivating certain types of viruses (adenovirus). UV light can be used as a disinfectant to meet the requirements of the SWTR (and all subsequent surface water treatment rules IESWTR, LT1SWTR, and LT2SWTR) and the Groundwater Rule (GWR).

b. MassDEP may on a case-by-case basis allow the use of UV light for disinfection of any type of source.

c. Unless otherwise approved by MassDEP, UV disinfection cannot be used alone when the source of microbial contamination is believed to be related to a problem in the distribution system. UV light may be used in conjunction with other acceptable forms of disinfection. Supplemental disinfection for additional virus inactivation or to provide a residual in the water distribution system may be required by MassDEP. When UV light treatment devices are used for non-health related purposes the UV device may provide doses less than indicated in the following criteria.

d. The information in this section establishes the minimum set of requirements for all systems using UV disinfection. Systems utilizing UV reactors for compliance with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR shall meet EPA's UV dose requirements (see Table 5.4.6-1 below) and perform reactor validation testing as summarized in Section 5.4.6.3 and detailed in the most recent EPA UV guidance document (November 2006, or the most recent subsequent revisions).

Table 5.4.6-1 - UV Dose Requirements (mJ/cm^2)

Type of Pathogen	**0.5 Log**	**1 Log**	**1.5 Log**	**2 Log**	**2.5 Log**	**3 Log**	**3.5 Log**	**4 Log**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

e. These guidelines are for low pressure mercury vapor lamps (LP), low pressure high-output mercury vapor lamps (LPHO), and medium pressure mercury vapor lamps (MP). Other types of UV treatment (e.g., pulsed and eximer lamps) not covered in this section may be considered by MassDEP on a case-by-case basis and may require new technology approval.

2. Water Quality

a. UV disinfection effectiveness can be impacted by certain water quality parameters. Table 2 summarizes the minimum amount of monitoring that shall be conducted for systems utilizing UV reactors for compliance with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR. For all other situations, MassDEP may allow less frequent monitoring (e.g. one sample/year for any type of source). The samples shall be collected at a location that is immediately prior to where the UV reactor is to be installed. Water quality monitoring shall represent storm events, reservoir turnover, seasonal changes, source blending, and any variation in upstream treatment.

Table 5.4.6-2 Minimum monitoring parameters for systems utilizing UV reactors

Parameter	**Frequency** [(1)]	**Recommended Limits**
pH (field measurement)	Monthly	6.5 – 9.5
Temp. (field measurement)	Bi-weekly for 1 year	NA
Dissolved iron (mg/L)	Quarterly for 1 year	0.1
Dissolved manganese (mg/L)	Quarterly for 1 year	0.05
Turbidity (NTU)	Bi-weekly for 1 year	1.0
Color (color units)	Monthly	15
Total Hardness (mg/L as $CaCO_3$)	Quarterly for 1 year	120
Hydrogen Sulfide[(2)] (mg/L)	Quarterly for 1 year	0.2
Alkalinity (mg/L as $CaCO_3$)	Quarterly for 1 year	NA
Suspended Solids (mg/L)	Quarterly for 1 year	10.0
UV Transmittance @ 254nm	Bi-weekly for 1 year	0.155 cm-1
Spectral Absorbance[(3)]	Bi-weekly for 1 year	NA
Algae Counts (cells/mL)[(4)]	Bi-weekly for 1 year	NA[5]

Notes:

(1)In some cases MassDEP may allow the use of historical data that was not collected at the frequency defined.

(2)Groundwater only

(3)For the use of medium pressure reactors only. Absorbance to be measured at 200 – 300 nm.

(4)Unfiltered supplies only.

(5)At algae concentration > 70,000 cells/mL additional piloting may be required as part of the UV validation testing.

b. MassDEP, the design engineer or the UV reactor manufacturer, may require additional treatment for waters that do not meet the recommended limits specified in Table 2.

3. Validation

The purpose of validation testing is to determine the operating conditions under which a UV reactor delivers the validated dose. The validated dose must be greater than or equal to the required dose (Table 1) to receive log inactivation credit for a target pathogen. Validation testing also establishes the operational set points used during reactor operations to confirm delivery of the validated dose. UV reactors being installed in order to comply with the disinfection requirements of the SWTR, IESWTR, LT1ESWTR, LT2ESWTR or GWR, shall be validated.

a. The proponent shall submit a Validation Test Plan to MassDEP for review and approval. The Validation Test Plan shall be accompanied by the appropriate MassDEP permit (BRP WS 21, Approval to Conduct Pilot Study) and a completed Validation Test Plan Checklist (See Checklist 5.2 in EPA's UV Guidance Manual, November 2006, or the most recent subsequent revision). At a minimum, the Validation Test Plan shall include the following:

   (1) Description of UV reactor to be validated (wetted dimension, baffles, lamps, UV sensors, optical properties)

   (2) Justification for the type of UV reactor to be validated

   (3) Description of the validation test

   (4) Description of the treatment process train where the UV reactor(s) is to be installed

   (5) Key personnel, laboratories and institutions/companies overseeing the testing and preparation of the reports

   (6) Validation testing schedule

   (7) Discussion of the standard testing approach to be used (e.g. intensity set point approach, calculated dose approach)

   (8) Operating parameters and ranges to be tested (flow, UV transmittance, lamp aging, and fouling factors)

   (9) Method of accounting for non-uniform lamp aging

   (10) Description of all equipment (including analyzers and sensors) to be used

   (11) Schematic of all equipment and piping (including pipe sizes, sample tap locations, meter(s), in-line analyzers, pump(s), valve locations)

(12) Description and justification of the non-pathogenic challenge organism(s) to be used

(13) Parameters to be monitored (flow, UV intensity, UV transmittance, lamp status, electrical power consumption, challenge organism concentration), and frequency of monitoring

(14) Wastewater disposal plan (for on-site validation testing only)

b. A full scale UV reactor validation test shall be done in accordance with EPA's latest *UV Guidance Manual November 2006* (or the most recent subsequent revisions). MassDEP may, pending EPA guidance, allow validation methods other than challenge organism biodosimetry techniques (e.g., computational fluid dynamics, microspheres).

c. UV reactors can be validated either off-site or on-site. Typically, off-site validation is done before installation at an approved testing facility. Reactors that are tested at an approved off-site facility that receive MassDEP validation approval for a specific installation are considered as 'prevalidated'.

d. The primary steps for the UV reactor validation test shall consist of the following:

(1) Bench-scale collimated beam test using the approved challenge microorganism(s)

(2) Full scale UV reactor test using the approved challenge microorganism(s)

(3) Determination of the reduction equivalent dose (RED)

(4) Derivation of the validation factor (VF)

(5) Calculation of the UV reactor's validated dose

e. UV reactor validation testing shall be overseen by a third party that is independent of the UV manufacturer and shall be competent in UV technology.

f. Once validation testing begins any changes or revisions are prohibited unless prior approval is obtained from MassDEP.

g. A validation report shall be submitted by a third party to MassDEP for review and approval. The report shall be written and/or reviewed by the third party overseeing the validation testing. (See paragraph 'e' above). The report shall be accompanied by the appropriate MassDEP permit (BRP WS 22, Approval of Pilot Study Report) and a completed Validation Report Checklist (See Checklist 5.3 in EPA's UV

Guidance Manual, November 2006, or the most recent subsequent revisions). At a minimum, the validation report shall include the following:

(1) Executive summary stating the log credit achieved for the validated dose and range of operating conditions

(2) Summary of all test results, including collimated beam results

(3) All validation calculations (e.g., RED, VF)

(4) QA/QC checks

(5) Description of any variations in the actual validation test from MassDEP approved validation test plan

(6) Discussion on any potential impacts to or from upstream and downstream treatment processes

(7) Proposed schedule for final UV design submittal to MassDEP and anticipated installation date

h. Unless otherwise approved in writing by MassDEP, the final UV design and installation shall be done with equipment and in a configuration identical to that which was used in the validation test. MassDEP reserves the right to require a UV reactor revalidation test should actual installed conditions vary significantly from that of the original validated test conditions.

4. Hydraulics

   a. The minimum, maximum, and average flow rates shall be provided.

   b. The expected pressure drop through the reaction chamber at maximum flow rate shall be provided.

   c. The UV reactor chamber shall be fully enclosed and be plug flow. The reactor shall be flowing full under all hydraulic conditions. No open channel units shall be allowed.

5. Materials

   a. The UV housing shall be stainless steel 304 or 316L.

   b. The materials exposed to UV irradiation, including the piping and isolation valves immediately upstream and downstream of the reactor unit, shall be constructed of materials that are resistant to UV light. They shall not impart undesirable taste, odor, color, and/or toxic materials into the water as a result of the presence of toxic constituents in materials of construction or as a result of physical or chemical changes resulting from exposure from UV energy.

c. All components shall be constructed of materials suitable to withstand the temperatures generated during normal operation.

6. Design Criteria

a. For systems utilizing UV reactors for compliance with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR, the minimum UV dose (reduction equivalent dose) shall be dictated by the corresponding desired log inactivation as defined in EPA's UV dose requirements (see Table 1 in Section 5.4.6.1.d). The reactor shall operate within the validated range 95% of the time each month in order to be in compliance.

b. All other UV reactors shall provide a minimum dosage of 40,000 microwatt-seconds per square centimeter (40 mJ/cm^2) unless a higher dosage is required by MassDEP. The reactor must be certified to NSF/ANSI - Ultraviolet Microbiological Water Treatment Systems, Standard 55 for Class A units or other standards acceptable to MassDEP.

c. The required minimum dosage shall be achieved by the unit at the manufacturer's specified end of lamp life. This minimum dosage shall be applied throughout the reaction chamber.

d. The selected UV reactor shall be capable of providing the required dosage under all hydraulic and water quality conditions

e. The UV reactor shall be designed to provide the specified minimum dosage at the peak instantaneous flow rate to be expected through the reactor. Automatic flow control devices may be required by MassDEP to ensure that the maximum design flow rate is not exceeded.

f. The estimated power consumption of the unit(s) under the design operating conditions shall be provided.

g. At least one redundant UV reactor shall be provided unless otherwise approved in writing by MassDEP.

h. The well or booster pump(s) shall have adequate pressure capability to maintain minimum water pressure after the water treatment device.

i. Each UV reactor shall be equipped with a minimum of one inline (duty) sensor and one spare (reference) sensor. The UV reactor shall be designed so that the duty sensor(s) can be readily removed and checked against the reference sensor(s). The UV sensor(s) shall meet the following criteria:

(1) The duty sensor shall be installed in the wall of the disinfection chamber at the point of greatest distance from the lamps.

(2) Documentation shall be provided that demonstrates that all sensors meet the National Institute of Standards & Technology (NIST) traceable measurements with an uncertainty of ± 15% or less at an 80% confidence level.

(3) The duty sensor shall continuously measure the UV intensity produced by the lamp(s) and be provided with a unit mounted UV intensity meter. For units equipped with more than one sensor, the meter shall display the average percent intensity based upon the point source summation (PSS) method.

(4) Intensity meters shall display numerical UV intensity values ranging from zero to one hundred. Intensity meters that indicate low, medium, or high UV intensity are *not* acceptable.

(5) Sensors and intensity meters shall be properly calibrated to account for lamp geometry.

j. At least one inline UV transmittance monitor shall be installed upstream of the UV treatment for all systems that are complying with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR. MassDEP may allow grab samples in lieu of a continuous monitor in situations where water quality does not vary.

k. The system shall have ground fault interrupt circuitry and it shall be installed on a designated electrical circuit.

l. The reactor shall be designed to prevent short-circuiting.

m. Lamps shall be enclosed in quartz sleeves in order to maintain the lamp surface near its optimum operating temperature.

n. Lamp assemblies shall be insulated from direct contact with the influent water.

o. Lamp sleeves shall be annealed to remove internal stress.

p. The UV reactor shall be designed to permit either mechanical or physical cleaning of the quartz sleeve.

q. Each UV reactor shall be provided with an elapsed time meter, which accurately monitors the hours that the unit's lamp is on.

r. Power and/or voltage interruptions shall be avoided. The UV reactor shall be designed with an electrical interlock such that it will automatically stop water flow in the event of a power failure and/or voltage interruption. The unit shall go back on line only when adequate UV intensity has been restored.

s. A flow or time delay mechanism wired in series with the well or service pump shall be provided to permit a sufficient time for lamp warm up per manufacturer's recommendations before water flows from the unit upon start up. Where there is extended no-flow periods and fixtures are located a short distance downstream of the unit, consideration should be given to UV unit shutdown between operating cycles to prevent heat build-up in the water due to the UV lamp.

t. The UV reactor shall be provided with an audible and visual alarm set to go off and trigger flow shut-down during the following scenarios:

    (1) The UV intensity monitor indicates that insufficient UV light (as specified in item 1 or 2 above is reaching the sensor.

    (2) Lamp or ballast failure

    (3) Mechanical wiper failure (if applicable)

    (4) The hour meter indicates that the useful life of the bulb as recommended by the manufacturer has expired.

    (5) High reactor temperature

u. An early warning alarm shall be provided for both the intensity meter and hour meter, to notify the operator when either the minimum design dosage (as specified in item 1 or 2 above) or the useful life of the bulb is within 10% of the shut down set points. This alarm is not required to shut the system down.

v. In situations where gravity flow through the unit exists, the system shall either have provisions for automatic emergency power or automatic flow shut down in the event of power failure.

w. If the UV reactor is installed for reasons other than compliance with the SWTR, IESWTR, LT1SWTR, LT2ESWTR and GWR, and it is the only form of disinfection used in a community system, redundancy may be required by MassDEP. This secondary or back-up form of disinfection should be installed and ready for operation if the primary UV reactor fails or is taken off-line.

x. UV water treatment devices that are operated on a seasonal basis shall be inspected and cleaned prior to use at the start of each operating season. The UV water treatment system, including filters, shall be disinfected prior to placing the water treatment system back into operation. A procedure for shutting down and starting up the UV treatment system shall be developed and submitted to MassDEP for approval. (See also Section 5.4.6 (9) "Maintenance").

7. Installation

a. The UV reactor design must be approved by MassDEP prior to reactor installation.

b. The UV reactor shall be installed in a protected enclosure not subject to extremes of temperature that could cause malfunction.

c. Each UV reactor shall have the capability of being easily isolated or taken out of service for replacement or repair. Bypass lines around the reactor are not allowed.

d. Any UV reactor that is installed, and is in a 'standby' mode shall be either physically disconnected from the process piping or be equipped with an open drain vent so as to prohibit any flow from a leaking valve to pass through the reactor.

e. If the UV reactor is installed in an area that is normally unattended (i.e., basement, utility room, etc.) the alarm (see Section 5.4.6.6.s) should be located in an area that is occupied by personnel familiar with the alarm and the procedures to report the alarm.

f. Unless otherwise approved by MassDEP, there shall be a minimum of 5 pipe diameters of straight pipe upstream and downstream of each UV reactor.

g. Unless otherwise approved by MassDEP, validated reactors must be installed in an identical configuration at the facility as was tested during validation.

h. A smooth-nosed sampling tap shall be installed upstream and downstream of each UV reactor.

i. Unless otherwise approved by MassDEP, each UV reactor shall be equipped with a dedicated flow meter.

j. The UV reactor is installation configuration should allow ease of access for visual inspection, disassembly, repairs, and replacement.

8. Spare Parts

a. All UV reactors installed for compliance with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR shall have spare parts as described in section 6.3.3 of EPA's UV Guidance Manual, November 2006, or most recent revisions.

b. All other reactors consisting of only a single unit shall be supplied with a spare lamp, spare electrical ballast, and a spare reference sensor.

c. Spare lamps shall conform to the original lamp specifications.

9. Maintenance

a. An operation and maintenance manual including a parts list and parts order form shall be supplied to the owner/operator of the UV reactor. The operations and maintenance manual shall be submitted to MassDEP for approval before the UV reactor goes on-line. The manual shall conform to MassDEP Policy 93-02 (*Operation and Maintenance Manual*) and these guidelines (see Section 5.1.6.1.c).

b. At a minimum, the operation and maintenance manual shall address the following:

(1) Procedures for routine cleaning of the quartz sleeve and sensor window (manual or automatic sleeve cleaning, with or without chemicals)

(2) Procedures and recommended frequency for calibrating the intensity meter for proper intensity

(3) Procedures and recommended frequency of UV transmittance monitor calibration

(4) Procedures for changing lamps, sleeves, and sensors

(5) Procedures and recommended frequency of sensor calibration

(6) Procedures and recommended frequency of dedicated flow meter calibration

(7) Guidance on the proper care and handling of lamps to prevent injury and inadvertent lamp breakage

(8) Method of lamp disposal

(9) Procedures for storage and disposal of quartz sleeve cleaning chemicals. (if using chemical cleaning method)

(10) Emergency procedures should a lamp break while in service

c. Public water systems installing UV reactors in order to comply with the requirements of the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR shall perform routine maintenance as outlined in Section 6.3 of EPA's UV Guidance Manual, November 2006, or most recent revisions. For all other UV reactors, the following minimum maintenance shall be performed:

   (1) The duty sensor shall be checked against the reference sensor at least every six months.

   (2) The quartz sleeve shall be checked every month and cleaned/replaced as necessary.

   (3) The lamps shall be replaced at least every year.

   (4) Quartz sleeves shall be replaced every 5 years.

d. The operation and maintenance manual shall include a separate section that describes the actions required to insure the delivery of treated water in the event of a failure of the UV reactor.

10. Reporting Requirements

a. All UV reactors installed for compliance with the SWTR, IESWTR, LT1ESWTR, LT2ESWTR and GWR, shall submit the necessary monthly reports to MassDEP that demonstrates that 95% of the water treated (by volume) was within the approved validated specifications. At a minimum, the following data for each UV reactor must be submitted:

   (1) Required UV dose

   (2) Daily run time

   (3) Daily volume of water treated

   (4) Daily maximum flow rate

   (5) Minimum UV transmittance

   (6) Minimum UV intensity

   (7) Actual validated dose

   (8) Volume of water that was off-specification

b. For any UV reactor installed for compliance with the SWTR, IESWTR, LT1E SWTR, LT2ESWTR and GWR that was off-specification for any period during a month, an additional monthly report must be submitted that calculates the total monthly volume of treated water that was off specification as a percentage of the total volume of treated water for the month.

c. All other systems with UV reactors must submit a monthly report that includes the daily volume of water treated and a daily UV intensity reading.

d. Records regarding routine equipment calibration and maintenance must be maintained at the treatment facility and be made available to MassDEP upon request.

5.5 Aeration

5.5.1 General information

1. Uses

Aeration may be used to help remove offensive tastes and odors due to dissolved gases from decomposing organic matter, or to reduce or remove objectionable amounts of carbon dioxide, hydrogen sulphide, etc., and to introduce oxygen to assist in iron and/or manganese removal. Aeration may be used for other treatment needs, such as to remove volatile organic compounds, to remove carbon dioxide for pH control, and to remove radon. If total VOC emissions from aeration treatment at a facility will exceed 1 ton per year the facility must obtain an Air Quality Permit from the MassDEP Bureau of Waste Prevention (BWP), pursuant to 310 CMR 7.02(4). If a BWP permit is required the applicant shall contact BWP in the applicable regional MassDEP office. Off-gas controls, such as vapor-phase granular activated carbon, may be required as a condition of the BWP Air Quality Permit. See also DWP Policy 90-04 – *Pilot Study Requirements for Proposed Treatment* for piloting requirements for VOC removal through aeration. Please note that in addition to Drinking Water Program and BWP Permits, other MassDEP permits as well as other agency permits may be required. The public water system should contact the applicable programs for further information.

2. Protection of Aerators

All new aerators shall be protected from contamination from birds and insects, windblown debris, rainfall, and water draining from the exterior of the aerators. Existing aerators lacking this protection shall be retrofitted on a schedule as approved by MassDEP.

3. Disinfection

   Groundwater supplies exposed to the atmosphere by aeration shall be properly disinfected (see section 5.4.1 – *Disinfection – General Information*).

4. Bypass

   A bypass should be provided for all aeration units, except those installed to comply with MCLs.

5. Corrosion Control

   The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary.

6. Quality Control

   Equipment should be provided to test for DO, pH, and temperature to determine proper functioning of the aeration device. Equipment to test for iron, manganese, and carbon dioxide should also be considered.

7. Redundancy

   Redundant equipment shall be provided for units installed to comply with Safe Drinking Water Act primary contaminants, unless otherwise approved by MassDEP.

5.5.2 Natural Draft Aeration

The design shall provide:

1. For distribution of water uniformly over the top tray
2. Construction of durable material resistant to aggressiveness of the water and dissolved gases
3. Protection from loss of stray water by wind carriage by enclosure with louvers sloped to the inside at an angle of approximately 45 degrees
4. Perforations in the distribution pan 3/16 to 1/2 inches in diameter, spaced 1 to 3 inches on centers to maintain a six inch water depth,
5. Discharge through a series of three or more trays with separation of trays not less than 12 inches
6. Loading at a rate of one to five gallons per minute for each square foot of total tray area
7. Trays with slotted, heavy wire (1/2 inch openings) mesh or perforated bottoms

8. Protection from insects by 24-mesh screen

9. Provisions for continuous disinfection feed shall be provided after aeration (See Section 5.4.1 – Disinfection – General Information).

5.5.3 Forced or Induced Draft Aeration

Devices shall be designed to:

1. Include a blower with a weatherproof motor in a tight housing and screened enclosure;

2. Ensure adequate counter current of air through the enclosed aerator column;

3. Exhaust air directly to the outside atmosphere;

4. Include a down-turned and 24-mesh screened air outlet and inlet;

5. Introduce air in the column that shall be as free from obnoxious fumes, dust, and other contaminants as possible;

6. Allow sections of the aerator to be easily reached or removed for maintenance of the interior or be installed in a separate aerator room;

7. Provide distribution of water uniformly over the top tray;

8. Be of durable material resistant to the aggressiveness of the water and dissolved gases;

9. Provide loading at a rate of 1 to 5 gallons per minute for each square foot of total tray area to insure effective removal of targeted contaminants;

10. Insure that the water outlet is adequately sealed to prevent unwarranted loss of air;

11. Discharge through a series of five or more trays with separation of trays not less than six inches or as approved by MassDEP;

12. Provide for continuous disinfection feed after aeration.

5.5.4 Pressure Aeration

Pressure aeration may be used for oxidation purposes only if pilot plant study indicates the method is applicable; it is not acceptable for removal of dissolved gases. Filters following pressure aeration must have adequate exhaust devices for release of air. Pressure aeration devices shall be designed to:

1. Give thorough mixing of compressed air with water being treated

2. Provide screened and filtered air free of obnoxious fumes, dust, dirt, and other contaminants

5.5.5 Spray Aeration

Design shall provide:

1. A hydraulic head of between 5 - 25 feet;

2. Nozzles, with the size, number, and spacing of the nozzles being dependent on the flow rate, space, and the amount of head available;

3. Nozzle diameters in the range of 1 to 1.5 inches to minimize clogging;

4. An enclosed basin to contain the spray. Any openings for ventilation, etc. must be protected with a 24-mesh screen.

5. For continuous disinfection feed after aeration.

5.5.6 Packed Tower Aeration

Packed tower aeration (PTA) which is also known as air stripping involves passing water down through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic chemicals, trihalomethanes, carbon dioxide, and radon. Generally, PTA is feasible for compounds with a Henry's Constant greater than 100 atm mol/mol at 12^0C, but not normally feasible for removing compounds with a Henry's Constant less than 10. For values between 10 and 100, PTA may be feasible, but should be extensively evaluated using pilot studies.

Process Design

Process design methods for PTA involve the determination of Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. The applicant shall provide justification for the design parameters selected (i.e., height and diameter of unit, air to water ratio, packing depth, surface loading rate, etc.). Pilot plant testing may be required.

The pilot test shall evaluate a variety of loading rates and air to water ratios at the peak contaminant concentration. Special consideration should be given to removal efficiencies when multiple contaminations occur. Where there is considerable past performance data on the contaminant to be treated and there is a concentration level similar to previous projects, MassDEP may approve the process design based on use of appropriate calculations without pilot testing. Proposals of this type must be discussed with MassDEP prior to submission of any permit applications.

a. The tower shall be designed to reduce contaminants to below the maximum contaminant level (MCL) and to the lowest practical level.

b. The ratio of the column diameter to packing diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full scale tower. The type and size of the packing used in the full scale unit shall be the same as that used in the pilot work.

c. The minimum volumetric air to water ratio at peak water flow should be 25:1. The maximum air to water ratio for which credit will be given is 80:1.

d. The design should consider potential fouling problems from calcium carbonate and iron precipitation and from bacterial growth. It may be necessary to provide pretreatment. Disinfection capability shall be provided prior to and after PTA.

e. The effects of temperature should be considered since a drop in water temperature can result in a drop in contaminant removal efficiency.

6. Materials of Construction

a. The tower can be constructed of stainless steel, concrete, aluminum, fiberglass or plastic. Uncoated carbon steel is not recommended because of corrosion. Towers constructed of light-weight materials should be provided with adequate support to prevent damage from wind.

b. Packing materials shall be resistant to the aggressiveness of the water, dissolved gases and cleaning materials, and shall be suitable for contact with potable water.

7. Water Flow System

a. Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 30 in^2 of tower cross-sectional area is recommended.

b. A mist eliminator shall be provided above the water distributor system.

c. A side wiper redistribution ring shall be provided at least every 10 feet in order to prevent water channeling along the tower wall and short circuiting.

d. Sample taps shall be provided in the influent and effluent piping.

e. The effluent sump, if provided, shall have easy access for cleaning purposes and be equipped with a drain valve. The drain shall not be connected directly to any storm or sanitary sewer.

f. A blow-off line should be provided in the effluent piping to allow for discharge of water/chemicals used to clean the tower.

g. The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it shall be maintained under positive pressure.

h. The water flow to each tower shall be metered.

i. An overflow line shall be provided which discharges 12 to 14 inches above a splash pad or drainage inlet. Proper drainage shall be provided to prevent flooding of the area.

j. Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air entrainment.

k. Means shall be provided to prevent flooding of the air blower.

l. The water influent pipe should be supported separately from the tower's main structural support.

8. Air Flow System

a. The air inlet to the blower and the tower discharge vent shall be downturned and protected with a non-corrodible 24-mesh screen to prevent contamination from extraneous matter. It is recommended that a four-mesh screen also be installed prior to the 24-mesh screen on the air inlet system.

b. The air inlet shall be in a protected location.

c. An air flow meter shall be provided on the influent air line or an alternative method to determine the air flow shall be provided.

d. A positive air flow sensing device and a pressure gauge must be installed on the air influent line. The positive air flow sensing device must be a part of an automatic control system which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling buildup.

e. A backup motor for the air blower must be readily available.

9. Other features that shall be provided

a. A sufficient number of access ports with a minimum diameter of 24 inches to facilitate inspection, media replacement, media cleaning and maintenance of the interior.

b. A method of cleaning the packing material when fouling may occur. Any wastewater or residuals generated from cleaning shall be handled in accordance with Section 5.10 *Waste Handling and Disposal*.

c. Tower effluent collection and pumping wells constructed to clearwell standards.

d. Provisions for extending the tower height without major reconstruction.

e. An acceptable alternative supply must be available during periods of maintenance and operation interruptions. No bypass shall be provided unless specifically approved by MassDEP.

f. Disinfection application points both ahead of, and after the tower to control biological growth.

g. Disinfection and adequate contact time after the water has passed through he tower and prior to the distribution system. Disinfection may be discontinued in accordance with the requirements of Section 5.4.1.1.d – General Information, Discontinuing Disinfection.

h. Adequate packing support to allow free flow of water and to prevent deformation with deep packing heights.

i. Operation of the blower and disinfectant feeder equipment during power failures.

j. Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading.

k. Fencing and locking gate to prevent vandalism.

l. An access ladder with safety cage for inspection of the aerator, including the exhaust port and de-mister.

m. Electrical interconnection between blower, disinfectant feeder and well pump.

10. Environmental Factors

a. The applicant must contact MassDEP's Air Quality section to determine if permits are required under the Clean Air Act.

b. Noise control facilities should be provided on PTA systems located in residential areas.

5.5.7 Other Methods of Aeration

Other methods of aeration may be used if applicable to the treatment needs. Such methods include but are not restricted to diffused air, cascades and mechanical aeration. The treatment process shall be designed to meet the particular needs of the water to be treated and shall be subject to the approval of MassDEP.

5.6 Iron And Manganese Control

5.6.1 General Information

Iron and manganese control, as used herein, refers solely to treatment processes designed specifically for this purpose unless otherwise approved by MassDEP. The treatment process used will depend upon the character of the raw water. The selection of one or more treatment processes must consider specific local conditions as determined through engineering investigations, including chemical analysis of representative samples of water to be treated, and must receive the approval of MassDEP. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Consideration should be given to adjusting pH of the water to optimize the chemical reaction.

For manganese, the SMCL is 0.05 mg/L, in accordance with EPA, and a Health Advisory (HA) set at 0.3 mg/L (Table 5.6.1). The MA ORSG closely follow EPA HA at 0.3 mg/L with manganese removal required when this level is exceeded (for COM and NTNC PWS).

The MassDEP Office of Research and Standards (MassDEP ORS) has concurred with EPA that Iron's SMCL in drinking water should not exceed 0.3 mg/L to prevent taste, odor, aesthetics and staining problems and a health-based limit set at 2.0 mg/L (Table 5). MassDEP recommends iron removal when levels exceed 1.0 mg/L.

If iron, manganese, or a combination exceeds 1.0 mg/L, it may be necessary to receive an assessment by MassDEP ORS will be necessary to determine if removal shall be required.

Table 5.6.1-1. Available Guidance for Iron and Manganese in Drinking Water

Chemical	Type of Guidance	Base of Guidance	Value (mg/L)	Source
Fe	SMCL	Taste, odor, aesthetics, staining	0.3	US EPA
Fe	No designation	Health-based	2	World Health Organization1
Mn	SMCL	Taste, odor, aesthetics, staining	0.05	US EPA
Mn	Long-term Health Advisory	Health-based	0.3	US EPA
Mn	MA ORSG	Health-based	0.3	MA ORS

For more information on the Iron and Manganese Drinking Water Guidelines see: Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda. Geneva: World Health Organization; 2022.

Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent and each treatment unit effluent.

For those Iron and Manganese treatment processes that produce residuals, the residuals should be handled in accordance with Section 5.10 – *Waste Handling and Disposal*.

5.6.2 Removal by Oxidation, Detention, and Filtration

1. Oxidation

   Oxidation may be by aeration, as indicated in Section 5.5 or by chemical oxidation with chlorine or potassium permanganate, sodium permanganate, ozone, chlorine dioxide, or other MassDEP approved chemical.

2. Detention

   a. Reaction - A minimum detention of 30 minutes shall be provided following aeration in order to insure that the oxidation reactions are as complete as possible. Shorter detention times may be allowed based on pilot plant study results. The detention basin shall be designed as a holding tank with no provisions for sludge collection but with sufficient baffling to prevent short circuiting.

   b. Sedimentation - Sedimentation basins shall be provided when treating water with high iron and/or manganese content, or where chemical coagulation is used to reduce the load on the filters, or where indicated by pilot plant study. Provisions for sludge removal shall be made.

3. Filtration

   Filters shall be provided and shall conform to Section 5.3 - Filtration.

5.6.3 Removal by Manganese Coated Media and Greensand Filtration

This process is more applicable to the removal of manganese than to the removal of iron. This process consists of a continuous or batch feed of potassium permanganate to the influent of a manganese coated media filter.

1. Provisions should be made to apply the permanganate as far ahead of the filter as practical and to a point immediately before the filter.

2. Other oxidizing agents or processes such as chlorination or aeration may be used prior to the permanganate feed to reduce the amount of the chemical oxidant needed.

3. Anthracite media cap of at least six inches shall be provided over manganese coated media or greensand.

4. Normal filtration rate is three gal/min/ft^2.

5. Normal wash rate is eight to 10 gal/min/ft^2 with manganese greensand and 15 to 20 gal/min/ft^2 with manganese coated media.

6. Air washing should be provided.

7. Sample taps shall be provided:

   a. prior to application of permanganate (raw water)

   b. immediately ahead of filtration

   c. at a point between the anthracite media and the greensand or manganese coated media

   d. at the filter effluent

5.6.4 Removal by Ion Exchange

This process of iron and manganese removal should not be used for water containing more than 0.3 mg/L of iron, manganese, or a combination thereof unless otherwise approved by MassDEP. This process is not acceptable where either the raw water or wash water contains dissolved oxygen or other oxidants, unless otherwise approved by MassDEP. Care should be taken to avoid producing water containing high sodium concentrations. Reference latest Office of Research and Standards (ORS) guidance for sodium concentrations (see Section 5.8.5 – Corrosion Control – Other Treatment and Sodium Levels).

5.6.5 Biological Removal

Biofiltration to remove manganese and/or iron requires on-site piloting to establish effectiveness. The final filter design shall be based on the on-site pilot plant studies and shall comply with all applicable portions of Section 5.3.8 – *Biologically Active Filters*. Continuous disinfection shall be provided for the finished water.

5.6.6 Sequestration by Polyphosphates

This process shall not be used when iron, manganese, or a combination thereof exceeds 1.0 mg/L. If the manganese concentrations in raw water exceed 0.3 mg/L but is less than or equal to one mg/L, an assessment by MassDEP Office of Research and Standards will be necessary to determine if removal is required. The total phosphate applied shall be related to the amount of iron and manganese to be sequestered. It shall not exceed four mg/L as PO_4, except 10 mg/L may be allowed until the system becomes stabilized as evidenced by presence of four mg/L at the extremity of the system. Flushing of the distribution system prior to initial treatment is recommended to accelerate the stabilization. Where phosphate treatment is used, satisfactory chlorine residuals should be maintained in the distribution system. Possible adverse effects on corrosion must be addressed when phosphate addition is proposed for iron sequestering. Polyphosphate treatment may be less effective for sequestering manganese than for iron.

1. Feeding equipment shall conform to the requirements in Section 6.0 – *Chemical Application*.

2. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual in the phosphate barrel. This guideline applies unless it can be shown that the pH or the chemical composition of the phosphate prevents microbiological growth, and the phosphate is being fed from the covered shipping container. Chlorine should not be added to the phosphate barrel when the phosphate contains zinc.

3. Polyphosphates shall not be applied ahead of iron and manganese removal treatment. The point of application shall be prior to any aeration, oxidation, or disinfection if no iron or manganese removal treatment is provided.

4. Phosphate chemicals must be food grade and approved by MassDEP.

5. Plans for the specific installation must be approved by MassDEP prior to installation.

6. A phosphate proposed for use as a sequestering agent must be evaluated with respect to its impact on corrosion control (see Section 5.8 – *Corrosion Control*).

7. Changes in chemicals used for sequestering require MassDEP approval and may require submittal of a pilot proposal and pilot report for MassDEP approval (see Section 5.1.5.1.o – Water Treatment Facility Design – General Information).

8. Phosphate feed points shall be located as far ahead of the oxidant feed point as possible.

5.6.7 Sequestration by Sodium Silicates

Sodium silicate sequestration of iron and manganese is appropriate only for groundwater supplies prior to air contact. On-site pilot tests are required to determine the suitability of sodium silicate for the particular water and the minimum feed needed. Rapid oxidation of the metal ions such as by chlorine or chlorine dioxide must accompany or closely precede the sodium silicate addition. Injection of sodium silicate more than 15 seconds after oxidation may cause detectable loss of chemical efficiency. Dilution of feed solutions much below five per cent silica as SiO_2 should also be avoided for the same reason. Sodium silicate treatment may be less effective for sequestering manganese than for iron.

1. Sodium silicate addition is applicable to waters containing up to one mg/l of iron, manganese or combination thereof, unless otherwise approved by MassDEP.

2. Chlorine residuals shall be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron, unless otherwise approved by MassDEP.

3. The amount of silicate added shall be limited to 20 mg/l as SiO_2, but the amount of added and naturally occurring silicate shall not exceed 60 mg/l as SiO_2.

4. Feeding equipment shall conform to the requirements of Section 6 – *Chemical Application*.

5. Sodium silicate shall not be applied ahead of iron or manganese removal treatment.

5.6.8 Testing Equipment

1. The equipment should have the capacity to accurately measure the iron content to a minimum of 0.1 mg/L and the manganese content to a minimum of 0.05 mg/L.

2. Where polyphosphate sequestration is practiced, appropriate phosphate testing equipment shall be provided.

3. Testing equipment shall be provided for all plants or arrangements made for testing by a Massachusetts or EPA certified lab as required by MassDEP.

5.7 Fluoridation

5.7.1 Plans, Specifications, and Coordination with MassDPH

(MassDPH – Massachusetts Department of Public Health)

MassDEP will review and approve all engineering plans and specifications for fluoride feed equipment. The appropriate permit application, along with the plans and specifications must be completed and submitted to the appropriate MassDEP regional office for approval. Construction of the facility shall begin within three years of the date of the permit approval. After this date a new permit application must be resubmitted to MassDEP for a new approval. Included within the permit approval letter (MassDPH, Office of Oral Health copied) will be a requirement that a MassDPH (Office of Oral Health) approved fluoride monitoring plan be submitted to the water supplier and MassDEP (see Section 5.7.7) before MassDEP will consider allowing the facility to go on-line.

After construction has been completed the MassDEP regional office will inspect the completed facility while the facility is pumping to waste with approved fluoridation works and appurtenant works in operation. Initial sampling and analysis for fluoride concentration of fluoridated water while pumping to waste will be conducted by the water supplier under observation by MassDEP. The water supplier shall use calibrated approved fluoride analyzers. The target fluoride concentration is 0.7 ppm. 4.0 ppm is the Maximum Contaminant Level Goal (MCLG), the level below which there is no known or expected risk to health. If the facility is operating properly and initial sampling for fluoride concentration is within the acceptable range, the facility will be conditionally placed on line. Immediate follow-up sampling and analysis of water entering the distribution system will then be conducted by the water supplier under observation by MassDEP. If fluoride concentrations are still within the acceptable range, MassDEP will give written approval within five days to place the facility permanently on-line; MassDPH approved monitoring plan will be implemented without delay. If the test results are not within the acceptable range, the facility will not be allowed to go permanently on-line until test results show they are in the acceptable range. MassDPH (Office of Oral Health) will be copied on this approval letter.

5.7.2 Fluoride Compound Storage

Fluoride chemicals should be isolated from other chemicals to prevent contamination.

Compounds shall be stored in covered or unopened containers and should be stored inside a building. Unsealed storage units for hydrofluosilicic acid should be vented to the atmosphere at a point outside the building. The vents to the atmosphere shall be provided with a corrosion resistant 24 mesh screen. Bags, fiber drums and steel drums should be stored on pallets.

5.7.3 Fluoride Chemicals, Chemical Feed Equipment, and Methods

Commercial sodium fluoride, sodium silicofluoride, and hydrofluosilicic acid shall conform to the applicable AWWA standards and NSF 60. Other fluoride compounds which may be available must be approved by MassDEP.

In addition to the requirements in Chapter 6, fluoride feed equipment shall meet the following requirements:

1. General

    a. Scales or loss-of-weight recorders shall be provided for sodium silico-fluoride dry chemical feeders and hydrofluosilicic acid day tanks.

    b. To avoid loss of fluoride, the fluoride compound shall not be added before filtration if aluminum coagulants are used. If a clearwell is provided, the fluoride compound should be added to the filter effluent or clearwell influent for better mixing and to guard against overfeeding.

    c. Adequate anti-siphon devices shall be provided for all fluoride feed lines.

d. If a protected water flush or carry water tee is provided, it shall only be teed in on the metering pump discharge line within 10 feet of the final fluoride injection point to help avoid slug feeding. An interlock solenoid valve is required.

e. Also see Chapter 6.

2. Fluoride Metering Pumps

a. Feeders shall be accurate to within 5% of any desired feed rate.

b. The fluoride feeder must be paced in proportion to flow.

(1) If lagoon supernatant is recycled to the rapid mix or static mixer, a special pacing control must be implemented to ensure optimum fluoride concentration is maintained.

c. Two diaphragm-type anti-siphon valves shall be installed in the fluoride feed line when a metering pump is used. The anti-siphon device should have a diaphragm that is spring-loaded in the closed position. All anti-siphon devices shall be dismantled and visually inspected at least once a year and replaced if necessary. Schedules of repairs or replacements should be based on the manufacturer's recommendations.

d. All fluoride-metering pumps shall be constructed so that the pumps cannot remain in "hand or manual" mode unless the switch is held in place by an operator.

e. All new or modified fluoride-metering pumps shall be electrically interlocked with respective raw or treated water pump or a thermal type flow switch drilled into the pipeline. Any newly installed hard wired interlocked circuit shall include a pilot light located near the fluoride pump that indicates when the interlocked circuit is activated. The electrical outlet used for the fluoride feed pump should have a twist lock receptacle.

f. A fluoride solution shall be applied by a positive displacement pump having a stroke rate not less than 20 strokes per minute and at a feed rate not less than 10% of the rated capacity of the feed pump.

g. Secondary control systems for fluoride chemical feed devices shall be provided as a means of reducing the possibility for overfeed; these may include flow or pressure switches, break boxes or other devices.

3. Sodium Fluoride Saturators

a. The service water solution shall be metered for sodium fluoride saturators.

b. The water make-up line to an upflow saturator shall be equipped with a backflow prevention device approved by MassDEP.

c. An external saturator overflow prevention system shall be installed on the water make-up line to avoid overflows. A non-electrical hydraulic type float valve placed in a fixed six-gallon overflow container is acceptable.

d. The fluoride feeder should be located on a shelf or saturator top not more than 3 feet higher than the saturator or day tank. The suction line shall be as short as possible and slope continuously upward with no false loops. A flooded suction line is not recommended in water fluoridation to guard against possible siphoning.

e. Saturators shall be of the upflow type.

f. The water used for sodium fluoride dissolution shall be softened if hardness exceeds 75 mg/l as calcium carbonate.

g. The dilution water pipe shall terminate at least two pipe diameters above the solution tank.

h. Refer to Figure 5.7.8-1 titled: *Typical Saturator with Overflow Prevention System* on last page of section 5.7.

4. Hydrofluosilicic Acid

a. The point of application of hydrofluosilicic acid, if into a horizontal pipe, shall be in the lower half of the pipe.

b. A day tank is required where bulk storage of hydrofluosilicic acid is provided.

c. When hydrofluosilicic acid is transferred from a bulk storage tank to a day tank using a transfer pump, the following guidelines shall be implemented:

(1) To prevent siphoning, the transfer pump discharge line must extend up to a point above the height of the top of the bulk tank and must be teed back at its highest point to the bulk tank; a second choice is to add a back-pressure valve at the highest point of the discharge line.

(2) The fill switch shall be momentary type (spring loaded switch) so as not to pump continuously and shall be hand-held in “on” position or else it would stop pumping.

(3) The daytank cover shall be fitted with a high level probe to shut off the transfer.

d. When hydrofluosilicic acid is transferred from a bulk storage tank to a daytank, the preferred method of transfer is by means of a transfer pump, but if gravity feed is utilized then two spring-loaded ball valves shall be installed in series in the line between the two tanks.

e. Consideration shall be given to providing a separate room for fluorosilicic acid and feed.

5. Sodium Silico-Fluoride Dry Feeders

a. Dissolving tank with baffles shall be sized to allow a minimum of 15 minutes of detention time based on winter water temperatures.

b. The dissolving tank shall include a mechanical mixer and tank.

c. The water make-up line to a fluoride dry feeder dissolving tank shall be equipped with a backflow prevention device approved by MassDEP.

d. The water make-up line shall have a rotameter or water meter to view and set the desired water feed rate in gpm. Normally a feed rate of one pound per hour of Na_2SiF_6 requires one gallon per minute of make-up water.

e. Acceptable dry feeder fluoride chemicals are either sodium fluoride (NaF) or sodium silico-fluoride (Na_2SiF_6).

f. The hopper inlet shall include a suitable mesh filter to keep any fluoride bag paper particles out to prevent clogging.

g. A hopper mechanical vibrator should be used to prevent chemical arching and under feeding.

h. Gravity feeding of fluoride solution to the clearwell influent using an air gap and cleanout tee is the preferred method of fluoridation which does not use any metering pumps or eductors.

i. Some surface water plants utilize warmed make-up water or switch to NaF in winter to help prevent under feeding.

j. Dry feeders may either be gravimetric or volumetric type design and accurate to within 5% of desired feed rate.

k. Dry feeder must be electrically interlocked and paced in proportion to flow.

l. Provisions for easy filling of fluoride chemical into hopper by operator must be included such as stairway with rails or a vacuum filling process.

m. Make-up water shall be softened using ion-exchange softener if total hardness exceeds 75 ppm.

n. A continuous weight recorder (pounds) with recording chart should be used for volumetric type dry feeders.

5.7.4 Protective Equipment and Reporting

1. Personal protective equipment shall be provided for operators handling fluoride compounds. At least one pair of rubber gloves, a respirator certified by the National Institute for Occupational Safety and Health for toxic dusts or acid gas (as necessary), an apron or other protective clothing, and goggles or face masks shall be provided for each operator. Deluge showers and eye wash devices shall be provided at all fluorosilicic acid installations. Other protective equipment must be provided as necessary.

2. Any fluoride chemical operator accident requiring overnight hospitalization must be reported by the close of the next business day to the appropriate MassDEP Regional Office and MassDPH Office of Oral Health.

5.7.5 Dust Control

1. Provision shall be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed. The enclosure shall be provided with an exhaust fan and dust filter which maintains the hopper under a negative pressure. Air exhausted from fluoride handling equipment shall discharge through a dust filter to the outside atmosphere of the building.

2. Provision shall be made for disposing of empty bags, drums, or barrels in a manner which will minimize exposure to fluoride dusts. A floor drain or vacuum cleaner shall be provided to facilitate the cleaning of floors.

5.7.6 Testing Equipment

Equipment shall be provided for measuring the fluoride concentration in the finished water. Public water system operators using their own fluoride analyzers must use analytical equipment and methodologies approved by MassDEP in compliance with the latest MassDEP fluoridation guidelines and 310 CMR 22.06(16)(b) and 310 CMR 22.10. Analytical equipment such as specific ion or colorimetric, used by operators should be portable and must be calibrated on a daily basis prior to use.

5.7.7 Fluoride Monitoring

Public water systems are required to monitor for fluoride by MassDEP Drinking Water Program and MassDPH Office of Oral Health.

1. MassDEP Role

   MassDEP/DWP oversees and enforces all SDWA requirements pertaining to the public water system SDWA fluoride monitoring program. MassDEP requires monitoring for fluoride in both fluoridated and non-fluoridated public water systems at points of entry to the distribution system at a frequency of once every three years for ground water systems and annually for surface water systems.

   SDWA compliance monitoring for fluoride is required only for community systems, however, MassDEP reserves the right to assess and take action on fluoride levels of concern in any public water system. Community systems must be in compliance with the relevant portions of 310 CMR 22.00 and in particular 310 CMR 22.06, 22.06C and 22.16(4).

   MassDEP approves the sampling locations at the point(s) of entry into the distribution system and frequency of sampling. Samples are collected by public water system operators according to MassDEP approved sampling schedule and sent to laboratories certified by MassDEP for fluoride analysis. Reports containing fluoride results are sent to MassDEP within 10 days of the end of the reporting month.

   MassDEP also requires, as part of the New Source Approval process, monitoring for fluoride concentrations in all new public water supply sources.

2. MassDPH Role:

   MassDPH, Office of Oral Health, following the US Centers for Disease Control and Prevention (CDC**)** recommendations, supervises the non SDWA fluoride monitoring program. MassDPH requires monitoring for fluoride in fluoridated PWSs *and* PWSs with naturally occurring fluoride concentrations at optimum levels or higher. MassDPH may also require baseline monitoring for NTNCs such as schools.

   MassDPH requires the following monitoring protocol for PWSs that fluoridate:

   a. Daily monitoring is required at MassDEP approved entry points to the distribution system. The PWS operator(s) may use their own fluoride analyzers to monitor or collect samples and send to a Massachusetts certified laboratory certified for fluoride analysis.

   b. Weekly monitoring must be conducted a minimum of four times a month at MassDPH approved sampling locations in the distribution system. Monitoring shall be conducted by the PWS operator(s) using their own fluoride analyzers or the PWS can send samples to a Massachusetts certified laboratory certified for fluoride analysis. These distribution sites shall be rotated as approved by MassDPH. Distribution sampling locations shall include a site near a school and, if applicable, sites selected or otherwise approved by MassDPH in the distribution system or a consecutive system.

c. Monthly monitoring of monthly split sample(s) must be collected by the PWS operator(s) from MassDPH approved designated distribution locations and then sent to a Massachusetts certified laboratory certified for fluoride analysis. If the PWS used a Massachusetts certified laboratory for its daily samples, it must send the required monthly split sample to a different Massachusetts certified laboratory.

All MassDPH required fluoride monitoring reports from PWS operators and certified labs must be sent to the Office of Oral Health, MassDPH within 10 days of the end of the reporting month on MassDPH approved forms.

5.7.8 Fluoride Metering Equipment Shut-Downs

(Removal or Change to MassDEP Approved Treatment)

1. In accordance with 310 CMR 22.04 (4) (b), public water systems must provide MassDEP with advance notification to any changes in MassDEP approved treatment or removal of approved devices unless the change or removal is required because of an emergency. This requirement also applies to fluoridation treatment and equipment.

2. In accordance with 310 CMR 22.04 (4) (b), if the change or removal is the result of an emergency, the public water system must notify MassDEP within 24 hours of the change or removal.

3. Public water systems with MassDEP approved fluoridation treatment must also notify Mass DPH Office of Oral Health in writing within the same timeframe as their MassDEP notification of the shutdown, removal, or change.

Figure 5.7.8-1: Typical Saturator with Overflow Prevention System

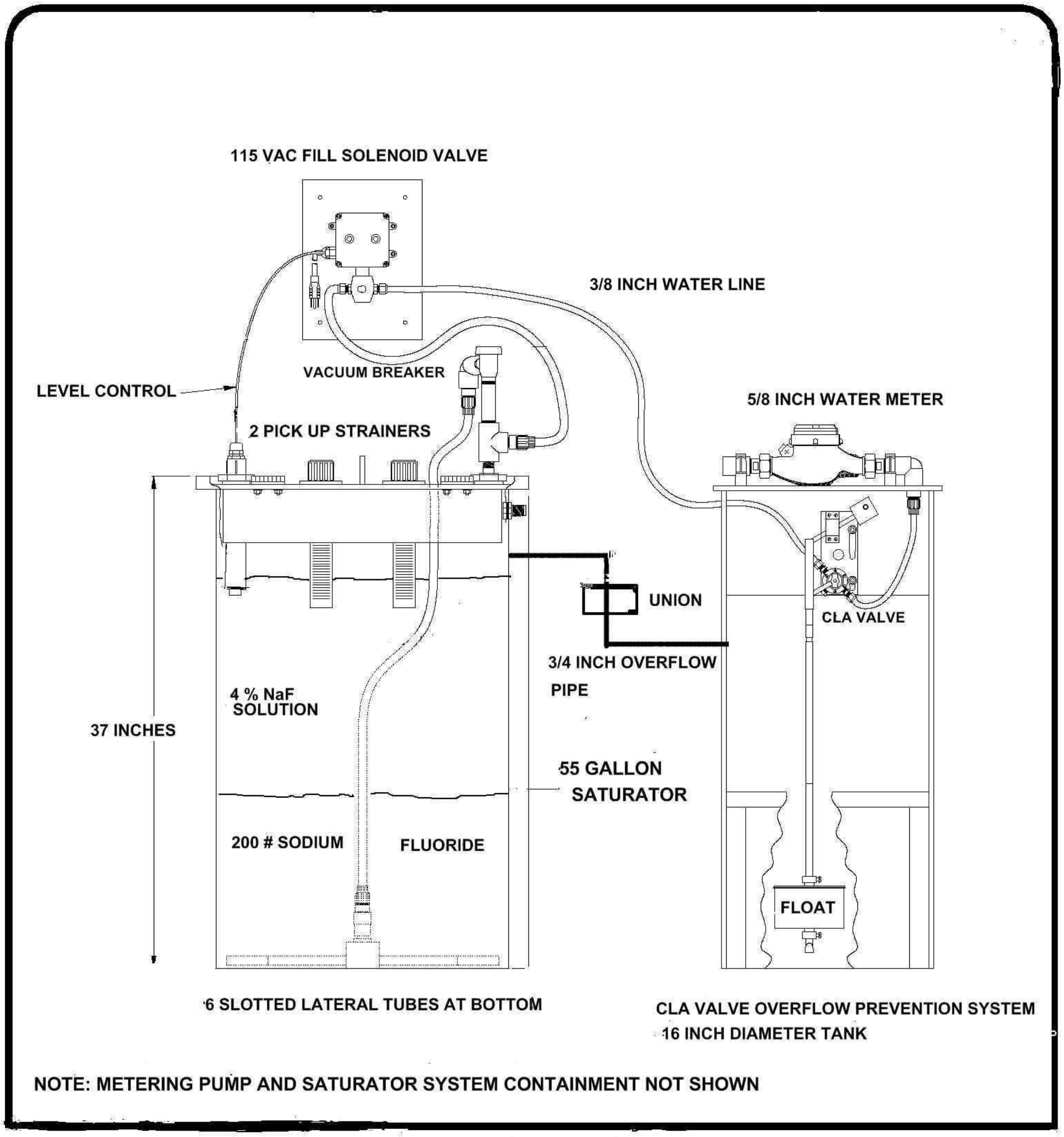

FIGURE 1 TYPICAL SATURATOR WITH OVERFLOW PREVENTION SYSTEM

REPRINTED WITH APPROVAL OF NPI

5.8 Corrosion Control

5.8.1 General Information

Water systems that exceed the lead and/or copper action levels shall install and operate optimal corrosion control treatment in accordance with 310 CMR 22.06B of the Massachusetts Drinking Water Regulations. Chemicals proposed for use in corrosion control must be thoroughly evaluated and are subject to MassDEP review and approval before use. With the application of chemicals MassDEP may require some or all of the following: desk top study, bench scale study, pilot study proposal, pilot testing, pilot report, or new technology approval (see Sections 5.1.5.1.o and 5.6.5.6.)

Laboratory equipment or laboratory service shall be provided to maintain adequate control.

Smooth-nosed sampling taps shall be provided for control purposes. Taps shall be located on each raw water source, each treatment unit influent, and each treatment unit effluent.

Corrosion of pipes can be controlled primarily through use of corrosion inhibitors and/or adjustment of pH and alkalinity; alternatively, other means such as calcium hardness adjustment may be utilized. Some approaches for controlling corrosion follow in 5.8.2; 5.8.3; and 5.8.4.

5.8.2 Corrosion Inhibitors – Phosphates & Silicates

The feeding of phosphates and silicates may be applicable for corrosion control.

1. Feed equipment shall conform to the requirements in Chapter 6.

2. Phosphate and silicate must be certified by NSF 60 and approved by MassDEP.

3. Stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual in the phosphate tank. This guideline applies unless it can be shown that the pH or the chemical composition of the phosphate prevents microbiological growth. Chlorine should not be added to the phosphate tank when the phosphate contains zinc.

4. Some phosphate applications may require water to have a pH restricted to a narrow range for its most effective use, e.g. pH 7.2 - 7.8.

5. Presence of other chemicals in water like disinfection by-products may compromise the effectiveness of phosphates in controlling pipeline corrosion.

6. Consideration shall be given to maintaining a satisfactory chlorine residual in the distribution system when phosphates are used.

5.8.3 pH & Alkalinity Adjustment – Chemical

The use of lime, soda ash, sodium hydroxide, potassium hydroxide, sodium bicarbonate, potassium carbonate and carbon dioxide may be applicable for adjustment of pH and alkalinity for corrosion control (see Section 5.8.1).

5.8.4 pH Adjustment - Aeration

Aeration of water containing significant concentrations of carbon dioxide may be an effective means of reducing carbon dioxide levels thereby raising pH and reducing chemical costs (see Section 5.5.1.1).

5.8.5 Other Treatment & Sodium Levels

Other treatment for controlling corrosive waters may be used where appropriate and approved by MassDEP. The public water supplier shall evaluate the total sodium level of the water delivered to the customer when considering adding a corrosion control chemical.

Chemicals that have not been previously used in Massachusetts public drinking water supplies may require new technology approval and must receive approval from MassDEP before use (see Section 5.1.5.1.o).

5.9 Taste and Odor Control

5.9.1 General Information

Space should be allocated for the future addition of taste and odor control chemicals at all surface water treatment plants; space should also be provided at all ground water treatment plants if needed. These chemicals should be added sufficiently ahead of other treatment processes to assure contact time for an effective and economical use of the chemicals.

5.9.2 Flexibility

Plants treating water that is known to have taste and odor problems should be provided with equipment that makes several control processes available so that the operator will have flexibility in operation.

5.9.3 Chlorination

Chlorination can be used for the removal of some objectionable odors. Adequate contact time must be provided to complete the chemical reactions involved. Excessive potential disinfection byproduct production shall be investigated by bench scale testing prior to design.

5.9.4 Chlorine Dioxide

Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. However, chlorine dioxide can be used in the treatment of any taste and odor that is treatable by an oxidizing compound. When used provisions shall be made for proper storing and handling of the sodium chlorite so as to eliminate any danger of explosion (See Section 5.4.5 *Chlorine Dioxide*).

5.9.5 Activated Carbon

1. Powdered Activated Carbon

    a. Powdered activated carbon may be added prior to coagulation to provide maximum contact time. Facilities that allow the addition at several points are preferred. Activated carbon should not be applied near the point of chlorine or other oxidant application.

    b. The carbon can be used as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly wetted.

    c. Agitation is necessary to keep the carbon from depositing in the slurry storage tank.

    d. Provisions shall be made for adequate dust control.

    e. The required rate of feed for carbon in a water treatment plant depends upon the tastes and/or odors involved, but provision should be made for adding from 0.1 mg/L to at least 40 mg/L.

    f. Powdered activated carbon shall be handled as a potentially combustible material. It shall be stored in a building or compartment as nearly fireproof as possible. A separate room should be provided for carbon feed installations, unless otherwise approved in writing by MassDEP. Carbon feeder rooms shall be equipped with explosion proof electrical outlets, lights, and motors.

2. Granular Activated Carbon

    a. Replacement of anthracite with GAC may be considered as a control measure for geosmin and methyl isoborneol (MIB) taste and odors from algae blooms. Demonstration studies may be required by MassDEP.

    b. See Section 5.3.2 *Rapid Rate Gravity Filters*, subsection 10.d. *Filter Media*.

5.9.6 Copper Compounds and Other Algaecides

The application of algaecides including copper containing compounds (such as copper sulfate), to a surface water body can be used to control taste and odor causing algae. All algaecide applications must be done by a Massachusetts licensed pesticide applicator in accordance with the USEPA Federal Insecticide, Fungicide and Rodenticide Act of 1996. In addition, MassDEP must be notified in writing prior to the application of such algaecides (310 CMR 22.20B(8)). For non-copper containing algaecides, a MassDEP permit must be issued. Copper containing compounds shall be controlled to prevent copper concentrations in excess of 1.0 mg/L in the plant effluent. Care shall be taken to assure an even distribution of the chemical within the treatment area.

5.9.7 Aeration

See Section 5.5 *Aeration*.

5.9.8 Potassium Permanganate

Application of potassium permanganate may be considered, providing the treatment shall be designed so that the products of the reaction are not present in the finished water.

5.9.9 Ozone

Ozonation can be used as a means of taste and odor control. Adequate contact time must be provided to complete the chemical reactions involved. Ozone is generally more desirable for treating water with high threshold odors (See Section 5.4.4 *Ozonation*).

5.9.10 Other Methods

The decision to use any other methods of taste and odor control should be made only after careful laboratory and/or pilot plant tests and on consultation with MassDEP.

5.10 Waste Handling and Disposal

5.10.1 General Information

1. Most water treatment facilities will produce one or more of the following wastes:

    a. Sanitary waste from areas such as kitchens, bathrooms and locker rooms

    b. Process and instrumentation waste from things such as continuous analyzers and sampling sinks

    c. Sediment and debris from periodic cleaning of intake structures or holding/equalization tanks

    d. Clarification process waste

e. Filter backwash waste

f. Membrane cleaning waste

g. Filter media waste from periodic scraping or removal of media

h. Building floor drain waste

i. Hazardous chemical spill containment area waste

j. Radioactive waste

k. Arsenic waste

l. Any waste not listed above but which MassDEP requires be addressed

Some of these wastes, such as that from the clarification and filter backwash process, are commonly referred to as ‘residuals’ or ‘sludge’ and can be further processed and disposed of (either off-site or on-site) in a number of ways discussed further in this section.

2. All water treatment plants (WTP) must submit a Waste Disposal Plan that describes how each applicable waste stream listed in (1) above will be handled. The Waste Disposal Plan shall minimize the generation of material by emphasizing reuse, reduction, or recycling whenever feasible. The Waste Disposal Plan must minimize any potential contamination of the water supply by not proposing for waste disposal at a site which would be out of compliance with MassDEP regulations, policies, or guidelines governing protective areas of drinking water sources. The Waste Disposal Plan shall provide for appropriate backflow protection on waste discharge piping as needed to protect the water supply. The Waste Disposal Plan must be submitted as part of the WTP design and must be approved in writing by MassDEP concurrently with the WTP design.

3. For WTPs producing residuals, the Waste Disposal Plan must contain a detailed Residuals Management Plan. The Residuals Management Plan must use information obtained during the pilot study to identify and quantify the type, and amount, of residuals to be produced. The Residuals Management Plan must also provide a feasibility analysis of all temporary and final disposal options.

   The Residuals Management Plan must address the following:

   a. The plan must include a schedule of inspections, preventative maintenance, and data collection sufficient to assure that the collection and processing of residuals occurs in a manner that does not interfere with optimal treatment of water to customers and that the processing of residuals occurs in a manner consistent with all regulations and permits.

b. The plan must include criteria which would trigger the water system to take actions such as when to dispose of collected residuals and outline what steps must be taken in order to effect that disposal including options for such disposal. This may include sampling and analyses of residuals, costs associated with residuals management, and residual disposal options available.

4. Residuals removal from basins/tanks shall provide that:

   a. Residuals withdrawal lines should be adequately sized for proper use. It is recommended they be at least 4 inches in diameter and arranged to facilitate cleaning.

   b. Entrance to residuals withdrawal piping shall minimize clogging.

   c. Valves shall be located outside the tank for accessibility.

   d. The operator may observe and sample residuals being withdrawn from the unit.

5. When wastes are discharged to sanitary sewers, design shall prevent cross connections and there shall be no common walls between potable and non potable water, unless otherwise approved in writing by MassDEP.

6. All waste discharges, either to the sewer, ground, or surface water, are governed by one or more of the applicable federal, state, and local regulatory agency requirements. All necessary federal, state, and local permits must be obtained prior to the WTP going on line. The guidelines outlined herein are considered to be the minimum requirements as federal and local authorities may have more stringent requirements.

7. MassDEP approved alternative methods of water treatment and chemical use should be considered as a means of reducing waste volumes and the associated handling and disposal problems.

5.10.2 Sanitary Waste

The sanitary waste from water treatment plants, pumping stations, etc., may be discharged directly to a sanitary sewer system when feasible or to another disposal facility approved in writing by MassDEP or the appropriate wastewater permitting authority.

5.10.3 Brine Waste

Brine waste shall be discharged in a manner and a location approved by MassDEP or the appropriate wastewater permitting authority. Brine waste shall not be discharged in the Zone 1 or Zone A of a public water supply unless otherwise approved in writing by the MassDEP.

Waste from ion exchange plants, demineralization plants, or other plants which produce brine, may be disposed of by controlled discharge to a stream if adequate dilution is available. Surface water quality requirements of the regulatory agency will control the rate of discharge. Except when discharging to large waterways, a holding tank of sufficient size should be provided to allow the brine to be discharged over a twenty-four hour period. Where discharging to a sanitary sewer, a holding tank may be required to prevent the overloading of the sewer and/or interference with the waste treatment processes. The effect of brine discharge to sewage lagoons might depend on the rate of evaporation from the lagoons.

5.10.4 Process and Instrumentation Waste

Process and instrumentation waste from things such as continuous analyzers and sampling sinks may be discharged to sewer or other method as approved in writing by MassDEP.

In locations where sewer is unavailable, such as remote pump stations, such discharges normally do not require a Groundwater Discharge Permit, but must discharge to a UIC Class V well. The Class V well must be registered using registration form BRP WS 06, selecting well type “c” for a 5G30 well. See DWP/SOP #08-01 "Registration of Discharges to the Ground from Pump Houses and Other Public Water System Facilities Including Discharges from In-line Analyzers."

5.10.5 Alum Residuals

Handling of alum residuals may be carried out by one or more of the following methods:

1. Lagoons

   Lagoons should be designed to produce an effluent satisfactory to MassDEP and should provide:

   a. location free from flooding;

   b. where necessary, dikes, deflecting gutters, or other means of diverting surface water so that it does not flow into the lagoon;

   c. a minimum usable depth of five feet;

   d. adequate freeboard of at least two feet;

   e. adjustable decanting device;

   f. effluent sampling point;

   g. adequate safety provisions (such as fencing);

   h. a minimum of two cells, each with appropriate inlet/outlet structures to facilitate independent filling/dewatering operations;

   i. accessibility for residual removal (by providing ramps);

j. existing lagoons should be lined if located in the Zone I of a groundwater source or Zone A of a surface water source. All new lagoons within a Zone I of a groundwater source or a Zone A of a surface water source shall be lined;

k. An NPDES permit shall be required for the effluent of any lagoon that discharges to surface water;

l. A groundwater discharge permit may be required by the MassDEP or appropriate wastewater permitting authority.

2. Mechanical dewatering

   a. A pilot study is required before the design of a mechanical dewatering installation unless it can be demonstrated that sufficient information exists to allow the proposed system to be properly designed.

   b. The successful use of mechanical dewatering depends on the characteristics of the alum sludge produced, as determined by site specific studies.

   c. Mechanical dewatering shall be preceded by sludge concentration and chemical pre-treatment.

3. Land application

   Alum sludge may be disposed of by land application either alone, or in combination with other wastes where an agronomic value has been determined and disposal has been approved by MassDEP. See 310 CMR 32:00: "Land Application of Sludge and Septage ".

4. Beneficial Use Determination

   Alum Sludge may be disposed of through a Beneficial Use Determination when approved by MassDEP. See 310 CMR 19.000: *Solid Waste Management Facility Regulations*.

5. Sanitary Sewer Discharge

   When residuals are discharged to sanitary sewers, a holding or receiving basin is recommended to allow settling of residuals and for the decanting and recycling of supernatant waters. Approval from the POTW receiving the flow from the sewer may be required for the discharge of water treatment residuals to a sanitary sewer. The amount of material to be discharged to a sewer system and the authority to do so should be determined prior to the design phase of the facility.

6. Holding Tanks / Recycling Supernatant

   See Section 5.10.7 *Residuals Supernatant / Filter Backwash Water.*

7. Freeze-Dry Beds

   Freezing changes the nature of alum residuals so that it can be used for fill.

8. Acid Treatment

   Acid treatment of residuals for alum recovery may be a possible alternative.

9. Other Methods

   Other methods may be utilized as approved in writing by MassDEP.

5.10.6 Iron and Manganese Waste

For treatment plants utilizing ferric coagulants, see Section 5.10.5 Alum Residuals. Waste filter wash water from iron and manganese removal plants can be disposed of as follows:

1. Sand filters

   Sand filters should have the following features:

   a. Total filter area shall be sufficient to adequately dewater applied solids. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required.

   b. The filter shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing all of the production filters in the plant, unless the production filters are washed on a rotating schedule and the flow through the production filters is regulated by true rate of flow controllers. Then sufficient volume shall be provided to properly dispose of the wash water involved.

   c. Sufficient filter surface area should be provided so that, during any one filtration cycle, no more than two feet of backwash water will accumulate over the sand surface.

   d. The filter shall not be subject to flooding by surface runoff or flood waters. Finished grade elevation shall be established to facilitate maintenance, cleaning and removal of surface sand as required. Flash boards or other non watertight devices shall not be used in the construction of filter side walls.

   e. The filter media should consist of a minimum of twelve inches of sand, three to four inches of supporting small gravel or torpedo sand, and nine inches of gravel in graded layers. All sand and gravel should be washed to remove fines.

f. Filter sand should have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5. The use of larger sized sands shall be justified by the designing engineer to the satisfaction of MassDEP.

g. The filter should be provided with an adequate under drainage collection system to permit satisfactory discharge of filtrate.

h. Provision shall be made for the sampling of the filter effluent.

i. Overflow devices shall not be permitted.

j. Where freezing is a problem, provisions should be made for covering the filters during the winter months.

k. A Groundwater Discharge Permit, NPDES Permit, and/or UIC Registration may be required.

2. Lagoons

Lagoons shall have the following features:

a. Be designed with a volume 10 times the total quantity of wash water discharged during any 24 hour period

b. A minimum usable depth of three feet

c. A length four times width, and the width at least three times the depth, as measured at the operating water level

d. Outlet to be at the end opposite the inlet

e. A weir overflow device at the outlet end with weir length equal to or greater than depth

f. Velocity to be dissipated at the inlet end

g. Subsurface infiltration lagoons may be acceptable if approved by MassDEP

h. Accessibility for residual removal (by providing ramps)

i. Existing lagoons should be lined if located in the Zone I of a groundwater source or Zone A of a surface water source. All new lagoons within a Zone I of a groundwater source or a Zone A of a surface water source shall be lined

j. An NPDES permit shall be required for the effluent of any lagoon that discharges to surface water.

k. A groundwater discharge permit may be required by the MassDEP or appropriate wastewater permitting authority.

3. Discharge to sanitary sewer

When residuals / filter backwash water are discharged to sanitary sewers, a holding or receiving basin is recommended to allow settling of residuals and for the decanting and recycling of supernatant waters. Approval from the POTW receiving the flow from the sewer may be required for the discharge of water treatment residuals to a sanitary sewer. The amount of material to be discharged to a sewer system and the authority to do so should be determined prior to the design phase of the facility. Design shall prevent cross connections and there shall be no common walls between potable and non potable water.

4. Holding Tanks / Recycling Supernatant or Filtrate

See Section 5.10.7 *Residuals Supernatant / Filter Backwash Water*.

5.10.7 Residuals Supernatant / Filter Backwash Water

1. Residuals supernatant and filter backwash water may be recycled or discharged to one or more of the following, where appropriate:

   a. Sand Filters- see 5.10.6, iron and manganese waste (sand filters)

   b. Lagoons **/**Freeze-Dry Beds- see 5.10.5, alum residuals

   c. Equalization Tanks / Holding Tanks- see 5.10.7.1(4), residuals supernatant (holding tanks)

   d. Recycling

   e. Sewer (permits required)- see 5.10.1.6, waste discharges to sewer (general)

   f. Surface or Groundwater (permits required)

2. Recycling

   a. General

   Returning a residuals supernatant stream or filter backwash water to a water treatment plant's primary treatment process is a conditionally acceptable alternative for both ground and surface water treatment plants.

   (1) All recycled flows shall be metered and the chemical feed rates adjusted to reflect the recycle flow rate.

(2) A variable pumping rate (approximately five percent of treatment rate) that provides a continuous flow based on the treatment rate of the plant is preferable. If the recycle return rate is high (compared to the treatment rate), hydraulic surges within the facility may result causing a significant disruption of the treatment process and ultimately leading to a degradation of the finished water quality. The recycle return rate should be low compared to actual treatment rate to minimize hydraulic surges.

(3) When proposing recycling, consideration shall be given to adjustment of chemical feed practices during recycling, hydraulic surges, and potential to disrupt the chemistry of the treatment process or impair the treatment performance.

(4) If recycling backwash water stored in holding tanks, the tanks shall meet the following construction criteria:

(a) Shall be covered unless otherwise approved in writing by MassDEP

(b) Shall contain the anticipated volume of waste water produced by the plant when operating at design capacity

(c) A plant that has two filters should have a holding tank that will contain the total waste wash water from both filters calculated by using a 15 minute wash at 20 gallons per minute per square foot.

(d) In plants with more than two filters, the size of the holding tank will depend on the anticipated hours of operation.

b. All Treatment Plants:

(1) That recycle residuals supernatant and/or filter backwash water from open lagoons or open basins (tanks) shall be subject to the Surface Water Treatment Rule, the Filter Backwash Recycling Rule if applicable and MassDEP's design guidelines for water treatment plants;

(2) Should not recycle filter waste water when the raw water contains excessive algae, when finished water taste and odor problems are encountered, when disinfection byproduct levels in the distribution system may exceed allowable levels, or when any water quality problems are encountered as determined by MassDEP. Particular attention must be given to the presence

of protozoans such as *Giardia* and *Cryptosporidium* concentrating in the waste water stream.

(3) May need to treat filter waste water prior to recycling to reduce pathogen population and improve coagulation or avoid reclaiming filter wash water given the increased risk to treated water quality.

c. Surface Water/Groundwater Under Influence Treatment Plants: Facilities treating water from such sources that recycle backwash water shall conform to the requirements of the Filter Backwash Recycling Rule.

d. For the purpose of compliance with the Filter Backwash Recycling Rule, the recycling of any flow shall be returned to a point prior to the addition of any chemical feed or other treatment used to meet the removal/inactivation requirements of the Surface Water Treatment Rules, unless otherwise approved in writing by MassDEP.

3. Disposal to ground and surface waters

   a. A NPDES permit will be required for discharging any lagoon effluent to surface water.

   b. A groundwater discharge permit may be required by MassDEP or appropriate wastewater permitting authority.

5.10.8 Membrane Cleaning Waste Water Disposal

Wash water containing cleaning chemicals shall be discharged to a tight tank (holding tank), sewer, or other method as approved in writing by MassDEP. For discharge to a tight tank a certification will be required; for discharge to a sewer, a permit will be required.

5.10.9 Radioactive / Radionuclide Waste

Radioactive materials include, but are not limited to:

1. Granulated activated carbon (GAC) used for radon removal;

2. Ion-exchange regeneration waste from radium removal;

3. Manganese greensand backwash solids from manganese removal systems, precipitative softening sludges, and reverse osmosis concentrates where radiological constituents are present.

The buildup of radioactive decay products of radon shall be considered, and adequate shielding and safeguards shall be provided for operators and visitors.

A PWS shall comply with the latest guidance from MassDEP, USEPA, Nuclear Regulatory Commission (NRC), and MassDPH Radiation Control Program as follows:

1. For BATs (Best Available Technology) for radionuclide removal in drinking water see MassDEP 310 CMR 22.09A, Tables C, D, and E.

2. Calculations shall be performed to estimate the removal efficiency of the treatment process (radionuclide concentration of the backwash water and the residual left in the media).

3. Exemption: A system is exempt from NRC and MassDPH licensing if the radionuclide residual does not exceed 0.05% by weight. PWSs that are either treating for radionuclides or generating a radioactive residual as a result of other treatment, with a concentration less than 0.05% by weight must notify the MassDEP Drinking Water Program in writing. Notice must be provided within 15 days of making the determination and include supporting documentation and calculations.

4. General License: A system must apply for and receive a general license if the treatment process generates 15 pounds or less of uranium or radium per month and not more than 150 pounds per year and exposes individuals to 100 mRem or less. Under the general license, disposal options are identified. These usually involve shipping media back to the media vendor. MassDPH Radiation Control Program issues general licenses.

5. Specific License: A system shall apply for and receive a specific license if any treatment process exceeds the limits permitted under a general license or if eligible for a general license but the PWS does not apply for the license within the required time. MassDPH Radiation Control Program issues specific licenses.

6. Discharge to Sewer: A system may apply to the local sewer commission for a permit to discharge to the sewer.

5.10.10 Arsenic Waste

Arsenic-bearing wastes from an arsenic treatment facility may be considered hazardous. Under the Resource Conservation and Recovery Act (RCRA), a residual from an arsenic water treatment facility may be defined as being hazardous waste if it exhibits a Toxicity Characteristic Leaching Procedure (TCLP) result of 5.0 mg/l. Arsenic residuals shall be disposed of in accordance with applicable federal, state and local regulations. MassDEP must be contacted for written approval prior to disposal of arsenic residuals.

5.10.11 Final Disposal of Waste Residuals

Final disposal of residuals generated by a water treatment facility may be accomplished by one of the following methods provided the appropriate authority obtains the required approvals/permits:

1. Landfill
2. Land applications
3. Reuse
4. Incineration
5. Sewage collection system
6. Wastewater facility

5.10.12 Approval of Water Treatment Facilities

Water treatment facilities requiring an NPDES Permit, a Sewer Connection/Extension Permit or Groundwater Discharge Permit shall not be approved to go on line until MassDEP issues the Permit(s).

5.10.13 Sodium Fluoride Saturator Waste

1. Sodium fluoride (NaF) sludge waste from a drinking water plant saturator is classified as a special waste, and eligible for disposal at a Massachusetts licensed landfill that is regulated under MassDEP regulations 310 CMR 19.061.

2. Sodium fluoride waste shipped directly to a facility outside of Massachusetts is not regulated by MassDEP.

3. The public water supplier shall store cleaned out non liquid NaF sludge waste in a labeled and covered container on site until disposal.

4. The recycling of "clean" saturated solution is encouraged. This can be accomplished by removing the saturated liquid water from the saturator, straining and placing that liquid into the cleaned out new saturator.

(For the purpose of 310 CMR 19.130 liquid wastes means any material that drains freely or contains free draining liquids, as determined by MassDEP using the Paint Filter Liquids Test, Method 9095 as described in USEPA Publication SW-846, as may be amended.)

5.11 PFAS

5.11.1. General Information

Per- and Polyfluoroalkyl Substances (PFAS) are an important group of emerging contaminants of national concern. PFAS are man-made chemicals, widely used since the 1950s. Some sources of PFAS that have been released into the environment include firefighting foams, manufacturing sites, landfills, spills, air deposition from factories, consumer products (e.g. personal care products), and residential and commercial wastewater. Because PFAS are water-soluble and persistent in the environment, they can leach into groundwater or surface water and contaminate drinking water.

On October 2, 2020, MassDEP, under the Massachusetts Drinking Water Regulations 310 CMR 22.07G, published its PFAS public drinking water standard, called the Massachusetts Maximum Contaminant Level (MMCL or MCL) of 20 ng/L or parts per trillion (ppt) for community (COM) and non-transient non-community (NTNC) public water systems (PWS) for the sum of the concentrations of six specific PFAS compounds: PFOS, PFOA, PFHxS, PFNA, PFHpA, and PFDA. MassDEP abbreviates this set of six PFAS compounds as "PFAS6." Transient non-community (TNC) PWS are not subject to the MCL but may require an individual ORS health assessment to determine if the levels pose an unacceptable health risk to consumers.

On April 10, 2024, the United States Environmental Protection Agency (EPA) issued National Primary Drinking Water Regulations (NPDWR) for PFAS establishing Maximum Contaminant Levels (MCLs) for six PFAS compounds. However, on May 13, 2025, EPA announced changes to NPDWR and the Maximum Contaminant Levels (MCLs) for PFAS. For more information on federal standards, see the US EPA: Per- and Polyfluoroalkyl Substances (PFAS) Final PFAS National Primary Drinking Water Regulation.

States are required to adopt regulations that are no less stringent than the federal standards within two years of the promulgation of the federal rule. Massachusetts will be revising the state regulations and MCLs. For more information on Massachusetts standards, see the Massachusetts PFAS Drinking Water Standard (MCL).

5.11.2. Technologies Capable of Removing PFAS Compounds

EPA has identified Granular Activated Carbon (GAC), Anion Exchange Resins (AIX), Nanofiltration (NF) and Reverse Osmosis (RO) as the Best Available Technologies (BATs) that remove PFAS from drinking water. EPA acknowledges that not every BAT represents the best treatment option for an individual system and that site-specific considerations can limit BAT selection.

Powder Activated Carbon (PAC) can also be used for PFAS removal, although it is not considered a BAT. Additionally, there are emerging technologies that appear to be capable of removing PFAS from drinking water, namely new adsorptive medias made of materials such as modified clay or common starches such as potatoes or corn.

Elements to consider when choosing the type of PFAS treatment can include, but are not limited to:

1. The size of the new drinking water treatment plant or the type and extent of modifications needed to an existing treatment plant, and the available space (building footprint).

2. The amount of water to be treated (daily flow and peak demands), contact time, storage capacity, backwash capacity, simultaneous compliance with other contaminant limits and rules; chlorination, treatment classification and operations, media lifespan/availability/frequency of replacement, monitoring frequency, and chemical addition.

3. Existing water quality parameters. Pre-treatment of the influent water prior to entering the PFAS treatment system may be needed. Water quality parameters such as TOC, sulfates, and nitrites can impact media performance and must be evaluated when selecting a type of media to ensure an economically efficient lifespan.

4. Waste disposal options: Backwash and any residuals generated from PFAS removal treatment processes must be handled according to MassDEP Guidelines (Section 5.10, Waste Handling and Disposal), solid waste regulations, and applicable discharge standards for surface water and/or groundwater.

5. The cost of installation of the treatment system, ongoing maintenance and monitoring costs, and the cost and availability of media replacement and disposal.

Prior to choosing to install a treatment system, check if the manufacturer has independently verifiable monitoring results demonstrating that the treatment can reduce PFAS levels below the federal and Massachusetts MCLs or, optimally, capable of reducing PFAS to non-detect (ND) levels.

Any product in contact with drinking water requires ANSI/NSF certification. Additionally, MassDEP maintains a statewide list of approved technologies and products that includes some which are suitable for PFAS removal through the New Technology Approval Program. For more information, see the MassDEP Drinking Water New Technology Approval Program and the Massachusetts Statewide List of Approved Technologies.

5.11.3. Removal by GAC

1. General Design

   GAC is a type of media that uses an adsorption mass-transfer process to remove PFAS. Treatment plants that use surface water as their primary source typically employ gravity filtration units, while those that rely on groundwater use pressure vessels.

   GAC media can also be used in the filtration process and is described in Section 5.3.2 for gravity filters and Section 5.3.3 for pressure filters. Table 5.11.3-1 describes general design recommendations for PFAS removal using GAC media:

Table 5.11.3-1 General design recommendations for PFAS removal by GAC

Design Criteria	**Design/Operational Recommendations**
For pressure vessel configuration	At least two vessels configured in series: lead/lag
Sample collection	• Sample taps and pressure gauges shall be installed before and after each vessel and configured so pre-vessel, midpoint between vessels, and post-vessel can be sampled with varying lead-lag configurations. • Sample taps shall be located at the 25%, 50%, and 75% tank levels, or at the discretion of the MassDEP regional office. No PFAS-containing materials shall be used to install sample taps.
Pressure and flow control	• Pressure relief fail-safes should be installed. • Each train shall have rupture discs or pressure blowoff valves designed to prevent damage to the vessel components (e.g. internal cone underdrains can only handle a certain amount of pressure). The design engineer shall ensure that the pressure entering the vessel is below the rupture disc pressure.
Operation to waste	• The treatment system design should include flow control capabilities for conditioning and backwashing, including forward rinse and backwash to waste, with appropriate backflow prevention and sample taps. • Backwash flows and pressures should not exceed the vessels design standards. • Provisions should be included to monitor and record backwash flow rates and pressure across the filters during backwashing. • When system pressure is used for backwashing, surge control measures and/or pressure reduction should be provided. • Refer to Section 5.3.2.9 for other backwash information.
Empty Bed Contact Time (EBCT) (minimum)	20 minutes total (two vessels, lead-lag, 10-minute EBCT per vessel)
Surface Loading Rate (gpm/sq.ft.)	2 – 8
Influent Water Quality Consideration to Avoid fouling or Head Loss Issues	TOC < 2 mg/L Iron < 0.3 mg/L Manganese < 0.05 mg/L Cl2 < 0.5 mg/L Langelier saturation index (LSI) <0.5

Design Criteria	Design/Operational Recommendations
Vessel Design	• Vessels shall be rated for at least 1.5 times the normal working pressure. • Vessel interior shall be protected against corrosion. • Influent shall be designed to ensure even flow across the vessel. • Vessels shall be sized to allow for a minimum of 30% bed expansion. • Vessels shall have access ports. • Filter systems with multiple treatment trains shall have means to control flow to each train to assure minimum EBCT is always met. • Pressure differential gauges shall be provided for each vessel. • A pressure relief valve, vacuum breaker, and air release valve should be provided at high point of the vessel.

2. Media

GAC media mesh size of 12 x 40 (~0.5 - 0.7 mm particle size) has been shown to be more efficient at PFAS removal with a minimum Iodine Number of 850 mg/g. However, MassDEP strongly recommends testing various types of granular activated carbon during piloting or design to compare effectiveness and absorption capacities on the water(s) being treated. For more specifications on GAC see Guidelines Section 5.3.2.10.d and AWWA B604-18 *Granular Activated Carbon*.

To ensure that GAC media meets the minimum health effects requirements for chemicals used in drinking water treatment and therefore is safe for drinking water use, the media must be reviewed and approved by a third party (NSF, UL, ETV, or AWWA). In addition, for GAC media used to remove PFAS and intended for statewide use in Massachusetts, the media must receive MassDEP New Technology Approval. If the media has not been approved statewide, a system may apply for a pilot under Specific Site Location approval; however, such approval limits the use of the technology to a single location. For more information, see the MassDEP Drinking Water New Technology Approval Program.

An SOP for the media must be prepared and submitted at the time of the permit application to MassDEP and must include, but is not limited to, the following list:

a. Monitoring frequency

b. Treatment breakthrough targets to determine when to remove vessels from service

c. Change-out procedures

d. Source of rinse water for conditioning the media

e. Rinse water and potential backwash discharge handling

f. Optimal parameters such as pH that indicate conditioning of the media is complete

g. Provisions for disinfection of media in case of biological growth.

3. Conditioning

GAC Media Conditioning refers to the preparation process carried out before the new GAC media is placed into service for water treatment. Proper conditioning ensures that the media performs optimally, does not introduce contaminants, and minimizes operational issues such as pressure spikes or turbidity. Whenever new media is installed in the treatment vessel, it must be treatment-ready (cleaned, flushed, and conditioned) per the manufacturer's instructions.

One important concern during GAC conditioning is the potential leaching of arsenic. Elevated arsenic levels have been observed in water that initially comes into contact with virgin GAC—sometimes exceeding the Maximum Contaminant Level (MCL) for arsenic of 0.010 milligrams per liter (mg/L). ANSI/AWWA Standard B604 states that GAC media shall not have impurities capable of producing deleterious or injurious effects to the health of those consuming water that has been properly treated with GAC. Therefore, water suppliers should reference the ANSI/AWWA Standard B604 when ordering GAC media.

It is important to pay close attention to arsenic flushing and monitoring during the conditioning process to ensure regulatory compliance and protect public health.

4. Pre-treatment

Pre-treatment may be necessary to remove competing contaminants and protect the performance of GAC. In addition to adsorption, GAC also acts as a filtration medium. Consequently, solids in the influent water can accumulate in the GAC bed, leading to excess pressure drop, increased backwash frequency, and potential fouling of the media. Therefore, depending on source water quality, pre-filtration is recommended.

Cartridges or bag filters are recommended ahead of the PFAS pressure vessels, with sample taps and pressures gauges located included before and after the filters to monitor performance.

5. Replacement

Media replacement is recommended when a regulated PFAS is detected at the effluent water sample of the lead vessel. The replacement of media shall occur in a timely fashion to ensure that treatment is operated as designed, maintaining treated finished water PFAS levels reliably and consistently below applicable MCLs, optimally at no detection (ND) to the MRL.

6. Reactivation

If planning to use reactivated GAC media at a treatment facility, the reactivated GAC must originate from spent GAC from that specific water treatment facility. Therefore, a management plan should be included to have media in service at all times. For more description refer to Section 5.3.10.d.(12)(a) Reactivation.

Spent GAC media that was used for PFAS treatment shall be reactivated in a facility permitted by the Resource Conservation and Recovery Act (RCRA) to destroy the PFAS on the media. Refer to *the EPA's Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances — Version 2 (2024), Section 3.a.i.2*.

5.11.4. Removal by Anion Exchange (AIX)

1. General Design

Ion exchange (IX) is a treatment process that uses resin material (small beads) to remove either negatively charged ions (anions) or positively charged ions (cations) from water. For PFAS removal, anion exchange resins are used because PFAS are negatively-charged ions. The PFAS molecules become bound to the AIX, which contain positively-charged sites that attract and retain the negatively charged PFAS particles. Table 5.11.4-1 describes general design recommended for PFAS removal using AIX resin.

Table 5.11.4-1 General design recommendations for PFAS removal by AIX

Design Criteria	Design/Operational Recommendations
Pressure vessel configuration	Lead/lag
Sample collection	• Sample taps and pressure gauges shall be installed before and after each vessel and configured so pre-vessel, midpoint between vessels, and post-vessel can be sampled with varying lead-lag configurations. • Sample taps shall be located at the 25%, 50%, and 75% tank levels, or at the discretion of the MassDEP regional office. No PFAS containing materials shall be used to install sample taps
Pressure and flow control	• Pressure relief fail-safes should be installed • Each train shall have rupture discs or pressure blowoff valves designed to prevent damage to the vessel

Design Criteria	Design/Operational Recommendations
	components (e.g. internal cone underdrains can only handle a certain amount of pressure). The design engineer shall ensure that the pressure entering the vessel is below the rupture disc pressure. • Ion exchange systems work better when running at steady state. Cycle times should be maximized as much as possible • If the hydraulic grade line of the treatment facility is below the top of the ion exchange vessel(s), provisions should be made to prevent vessel draining. • Flow control mechanisms shall be provided for multiple treatment trains in parallel.
Empty Bed Contact Time (minimum)	4 to 6 minutes total (two vessels, lead-lag, 2-3 minutes EBCT per vessel)
Surface Loading Rate (gpm/sq.ft.)	6-18
Flow rate per vessel	8 to 40 bed volumes per hour
Bed Depth	30 in. to 12 ft
Bed Depth: Vessel Diameter	0.2:1 to 2:1
Influent Water Quality Consideration to Avoid fouling or Head Loss Issues	TOC < 4 mg/L Iron < 0.3 mg/L Manganese < 0.05 mg/L Non-detect chlorine residual (for gel-based resins) or less than 1 mg/L chlorine residual (for macroporous-based resins)
Vessel Design	• Vessels shall be rated for at least 1.5 times the normal working pressure. • Vessel interior shall be protected against corrosion. • Influent shall be designed to ensure even flow across the vessel. • Vessels shall have access ports. • Filter systems with multiple treatment trains shall have means to control flow to each train to assure minimum EBCT is always met.

Design Criteria	Design/Operational Recommendations
	• Pressure differential gauges shall be provided for each vessel. • A pressure relief valve, vacuum breaker, and air release valve should be provided at high point of the vessel.

2. Media

The use of PFAS-selective anion exchange resin is recommended as it will generally have longer life spans than general IX resins. MassDEP strongly recommends onsite pilot testing of AIX media and testing various types of AIX media during piloting to evaluate the effectiveness and adsorption capacities on the water(s) being treated. For more specifications on IX see Section 5.6.4, ANSI/AWWA B104-*24 Single-Use Ion Exchange Treatment for Trace Contaminant Removal* and *Ion Exchange for Drinking Water*.

To ensure that AIX resins meet the minimum health effects requirements for chemicals used in drinking water treatment and therefore are safe for drinking water use, the resins must be reviewed and approved by a third party (NSF, UL, ETV, or AWWA). In addition, for AIX resins intended for statewide use in Massachusetts, the resins must receive MassDEP New Technology Approval. If the resins have not been approved statewide, a system may apply for a pilot or Specific Site Location approval; however, such approval limits the use of the technology to a single location. For more information, see the MassDEP Drinking Water New Technology Approval Program.

An SOP must be prepared and submitted at the time of the permit application to MassDEP and must include a PFAS Management plan detailing, but not limited to, the following:

a. Monitoring frequency

b. Treatment breakthrough targets to determine when to remove vessels from service

c. Change-out procedures

d. Source of rinse water for conditioning the media

e. Rinse water discharge handling

f. Optimal parameters such as pH that indicate conditioning of the media is complete

Additionally, if the ion exchange system includes a standby vessel not in typical use, the Standard Operating Procedure (SOP) shall include procedures for returning the standby vessel back to service.

3. Conditioning

   a. Whenever new media is installed in the treatment vessel, it must be treatment-ready (cleaned, flushed, and conditioned) per the manufacturer's instructions.

   b. Anion exchange system vessels, piping, and appurtenant equipment shall be disinfected in accordance with ANSI/AWWA C563 prior to resin installation. The equipment shall be thoroughly rinsed to remove all chlorine residuals to avoid destruction of the ion exchange resin.

   c. Anion exchange resin shall be pre-rinsed in accordance with NSF/ANSI 61 requirements. Pre-rinsing can be performed on-site at the time of installation, off-site prior to installation, or a combination of the two.

   d. Anion exchange resins tend to uptake sulfates and release chloride for approximately 1,000 bed volumes of treatment during start-up. Refer to the manufacturer's recommendations for start-up procedures related to the number of bed volumes to rinse and/or the duration of start-up rinsing. Rinsewater generated during start-up should be properly dechlorinated or disposed of to prevent damage to the surrounding environment by corrosive water. Purchasing buffered resins may also minimize the risk of corrosive rinsewater.

4. Pre-treatment

   a. Pre-treatment of the raw water with bag or cartridge filters is recommended to prevent fouling of the resin (if needed due to the source water quality). Bag filters are recommended ahead of the ion exchange pressure vessels. Sample taps and pressures gauges shall be included before and after the bag filters.

   b. 5-micron filters are recommended for most bag or cartridge filters. If a particle size distribution analysis indicates that the particle size is significantly below 5 microns, consider stacked prefiltration (i.e. coarser filters followed by finer filters to prevent filter clogging).

   c. Residual oxidants may decay the resin quality over time. The impact of residual oxidants on the AIX resin shall be evaluated in a pilot study or desktop calculations or in technical studies provided by the manufacturer to demonstrate to MassDEP that dechlorination is not necessary prior to AIX treatment. Sufficient analyzers or other instruments shall be installed during pilot testing to monitor the effectiveness of dechlorination or other pretreatment processes.

d. If any disinfectant that can produce anionic byproducts is in practice prior to an ion exchange system, the system must be dechlorinated before water passes through the anion exchange system to eliminate competing ions. If dechlorination is necessary prior to the anion exchange system, the anion exchange system effluent water may need to be rechlorinated to meet distribution system requirements.

e. Backwashing of AIX media is highly discouraged as the uniform-sized media will generally mix and may cause premature breakthrough. Refer to the manufacturer's recommendations for backwashing if backwashing is absolutely necessary.

5. Replacement

   Media replacement is recommended when a regulated PFAS is detected in the effluent water sample of the lead vessel. The replacement of media shall occur in a timely fashion to ensure that treatment is operated as designed, maintaining treated finished water PFAS levels reliably and consistently below applicable MCLs, optimally at no detection (ND) to the MRL.

5.11.5. Other Treatment Methods

5.11.5.1 Nanofiltration (NF) and Reverse Osmosis (RO) for PFAS Removal

1. General Information:

   NF and RO are among the BATs identified by EPA for the treatment/removal of PFAS from drinking water. NF/RO systems can provide consistent PFAS removal through the lifespan of the membrane system, unlike GAC and AIX systems, which experience decreasing PFAS removal efficiency over time.

   NF/RO systems can be viable treatment options if PFAS concentrations are high enough to make GAC or AIX media replacement too frequent and cost prohibitive.

   Both treatment methods are detailed in this guidance under Sections 5.3.9 and 5.3.10, respectively. However, below are some additional treatment considerations specific to PFAS removal.

2. Facility Design:

   Membrane fouling, water quality entering the NF/RO system, and water temperature can impact the efficacy of the NF/RO system to remove PFAS. NF/RO systems are operationally very complex. They are highly sensitive to inorganic and organic fouling and cannot tolerate exposure to free chlorine. Adequate pretreatment and routine membrane cleaning should be implemented to maintain the NF/RO system.

Pretreatment with bag or cartridge filters and scale inhibitors and acids are recommended to prevent membrane fouling and scaling.

Water treated by NF/RO systems is often stripped of alkalinity, resulting in a pH of 5.5 to 6.5. Post-treatment will likely be required to prevent corrosion instability in the distribution system. Desktop evaluations, bench-top (coupon) evaluations, and/or pipe loop testing would be recommended to confirm stability in the distribution system.

NF/RO systems generate brine waste that contains high concentrations of PFAS. Refer to the manufacturer's recommendations and the Waste Disposal sections of the Guidelines for information about managing PFAS-concentrated brine waste from the NF/RO system.

5.11.5.2 Powdered Activated Carbon (PAC) for PFAS Removal

1. General Information

   PAC is not considered one of the BATs for PFAS removal. PAC has specific and specialized usage. While there are several types of PAC that are commercially available (bituminous coal, wood, and coconut), only some types of PAC are effective for PFAS treatment. For continuous operation GAC is preferred over PAC. PWS may face challenges related to compliance and the long-term effectiveness of PAC as a treatment option. For general design guidelines, refer to Section 5.9.5.1 for Powdered Activated Carbon. Table 5.11.5-1 describes general design recommended for PFAS removal using PAC media.

   Table 5.11.5-1 General design recommendations for PFAS removal by PAC

Design Criteria	**Design/Operational Recommendations**
Hydraulic Loading Rate	Dosed into water, no flow limit
Dosage	Determined via bench scale or pilot testing; often much higher than PAC doses for taste and odor removal
Contact Time	10-30 minutes
Ease of use	Simple dosing but needs removal downstream
Reusability	Single use only, not reusable

2. Operational considerations:

   a. Adsorption Efficiency: PAC is moderately effective at removing long-chain PFAS compounds but is not as effective at removing short-chain PFAS compounds.

   b. Cost-Effectiveness: Compared to other advanced treatment technologies (like reverse osmosis or advanced oxidation processes), PAC can be more affordable in terms of both capital and operational costs.

c. Ease of Implementation: PAC can be integrated into existing water treatment systems with relative ease. It can be used in batch or continuous processes, making it flexible for various treatment setups.

d. Integration: PAC systems should be added upstream of other treatment processes. In order to implement a PAC process, there must be a mechanism in place to capture the used PAC downstream, as PAC is very fine and can easily make its way into a distribution system if not filtered.

e. Removal of Other Contaminants: In addition to PFAS, PAC can also adsorb other organic contaminants and certain taste and odor compounds, improving the overall quality of drinking water.

f. Rapid Results: PAC treatment can often achieve quick results in contaminant reduction, making it suitable for emergency response situations and short-term use.

g. Limited Selectivity: While PAC can adsorb a variety of PFAS, its effectiveness can vary significantly between different compounds and may not remove all PFAS equally well.

h. Saturation and Regeneration: The PAC can become saturated quickly, meaning it needs to be replaced frequently. This can lead to increased operational costs and waste disposal concerns.

i. Production of Secondary Waste: The spent PAC containing adsorbed PFAS can produce secondary waste that must be managed and disposed of, which can complicate treatment processes.

j. Monitoring and Control: Effective performance of PAC requires careful monitoring and control of operating conditions, including contact time and dosage, which can increase operational complexity.

k. Residuals: PAC cannot be regenerated.

5.11.5.3 Novel Adsorbents (NA):

As the need for PFAS treatment grows, new PFAS treatment media, referred to as “Novel Adsorbents” (NA), are coming on the market to compete with traditional GAC and AIX media.

Clay-Based Adsorption Media are becoming more widely used as this novel adsorbent has shown benefits of not being impacted by certain water quality parameters that may impact other types of media. Some clay-based media are surface-modified with multiple platelets. As these platelets adsorb PFAS, they expand, allowing for enhanced sorption kinetics and increased capacity. Basic design considerations for this type of media include lead-lag adsorption vessels and a minimum EBCT of 3 minutes per vessel. Follow the manufacturer's instructions for proper loading and conditioning of the media.

Any NA for PFAS treatment must meet minimum health-effects requirements for chemicals used in drinking water treatment and be safe for drinking water use; therefore, the product must be reviewed and approved by a recognized third party (e.g., NSF, UL, ETV, or AWWA). In addition, if the NA media is intended to be used statewide in Massachusetts, the media must receive MassDEP New Technology Approval. If the media has not been approved statewide, a system may apply for a pilot under Specific Site Location approval; however, such approval limits the use of the technology to a single location.