DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Point and Nonpoint Source Management

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TITLE: Design Standards for Sequencing Batch Reactors

EFFECTIVE DATE: Upon final publication in the *Pennsylvania Bulletin*

AUTHORITY: The Clean Streams Law (35 P.S. §§691.1-691.1001) 25 Pa. Code Chapter 91.

POLICY: Pennsylvania's water quality management permitting guidance will be updated to ensure statewide consistency in permit processing and to improve and preserve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life and for recreation.

PURPOSE: Pennsylvania's wastewater permitting design standards have not been updated since 1997. This document establishes design standards for a new technology - sequencing batch reactors - that had no design standards in 1997. These changes will improve the ability of the Department to be consistent in the permitting of domestic wastewater facilities statewide.

APPLICABILITY: This policy is applicable to persons submitting and reviewing permitting documents for the design of sequencing batch reactors.

DISCLAIMER: The policies and procedures outlined in this guidance document are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of DEP to give these rules that weight or deference. This document establishes the framework, within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 14 pages

DEFINITIONS: Maximum day dry weather flow - the largest volume of flow to be received during a continuous 24 hour period during dry weather, expressed as a volume per unit time.

PREFACE

The Commonwealth of Pennsylvania provides for the regulation of wastewater disposal “to preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life, and for industrial consumption and recreation.”

These design standards have been prepared as a guide to those persons responsible for the design and permitting of sequencing batch reactors. These standards have been developed as an addition to the Domestic Wastewater Facilities Manual, and have been numbered to allow insertion into the Manual when the Manual is updated.

DEP considers the registered professional engineer whose seal is affixed to facility design documents to be fully responsible for the adequacy of all aspects of the facility design and compliance with the state standards and requirements. DEP approval or issuance of permit does not, in any way, relieve the design engineer of this responsibility.

The design of wastewater facilities should not be limited by minimum requirements, but must meet the needs of the particular situation. It is not the purpose of this document to set forth data which can be used without due regard for the requirements of the particular project under design. The judgment of the skilled professional engineer is still required to apply these data. DEP will apply more stringent criteria when, in its judgment, their use is justified. With the foregoing qualifications definitely understood, DEP considers the standards set forth in this document as generally representative of good engineering practices.

New processes and variations of processes are proposed from time to time. Lack of description or criteria for a process does not suggest a process should not be used, but only that consideration by DEP will be on the basis of information submitted with a specific design. The Domestic Wastewater Facilities Manual explains the requirements for experimental processes in a section entitled “Applications for New Processes.” Data on newly proven processes are usually not sufficiently developed and final standards cannot be adopted immediately or included in a revised document. Tentative standards for such processes will be available as information is submitted and reviewed. DEP reserves the right to amend this document if and when necessary to incorporate such new processes. Any such amendments will be posted on DEP’s website and incorporated into the document then reprinted at a later date.

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88.1 General

The sequencing batch reactor (SBR) process is a fill and draw mode of the activated sludge process in which all major steps occur in the same tank in sequential order - Fill, React, Settle, Decant, and Idle. The SBR may be used where wastewater to be treated is amenable to aerobic biological treatment. This process may be used to accomplish carbonaceous and/or nitrogen and phosphorus removal. The design should be based on experiences at other facilities and should meet the applicable requirements under Domestic Wastewater Facilities Manual (362-0300-001) Sections 40, 60, and 80.

88.2 Pretreatment

a. Pre-Screening Devices

One of the following should be provided:

- A bar screen with maximum opening of 5/8 of an inch meeting the other applicable requirements of Section 51.1 of the Domestic Wastewater Facilities Manual, or
- A comminutor with automatic reversing controls meeting the other applicable requirements of Section 52 of the Domestic Wastewater Facilities Manual.

For applicable design provisions, refer to Section 50 of the Domestic Wastewater Facilities Manual.

b. Screens

1. Automatically cleaned fine screens or medium fine screens capable of removing material of ¼ inch diameter or larger should be provided.

2. Screens should be removable for maintenance.

3. Screens should incorporate an automatic washdown system or other means to reduce organic material in the screening load.

4. Other provisions of Section 51.2 of the Domestic Wastewater Facilities Manual apply to the design of a fine screen.

c. Grit Removal

1. Permanent grit removal facilities meeting the requirements of Section 53 of the Domestic Wastewater Facilities Manual should be provided for combined sewer systems and sewer systems receiving substantial amount of grit.

2. If a plant serving a separate sewer system is designed without grit facilities, consideration should be given to possible damaging effects on pump, comminutors, other preceding equipment, and the need for additional storage capacity in treatment units where grit is likely to accumulate.

d. Alkalinity

Piping for chemicals to allow for alkalinity adjustment (if necessary) should be provided to the influent flow equalization tank and/or SBR tanks. The minimum alkalinity should be kept between 40-70 mg/L at the decant phase.

88.3 Flow Equalization

a. Influent flow equalization must be considered for all SBR systems. Systems not using flow equalization should utilize a means of allowing the SBR system to operate with a tank offline.

b. Flow equalization should meet requirements of Section 55 of the Domestic Wastewater Facilities Manual.

88.4 Tank (Reactor) Design

a. The basic parameters for the tank design include the hydraulic, organic, nitrogen and phosphorus loading. These parameters should be in accordance with Section 82.32 of the Domestic Wastewater Facilities Manual. These are used to determine the tank size, cycle frequency, rate of draw and discharge of treated effluent and total oxygen demand. Temperature is an important consideration when dealing with nitrogen removal.

b. The effective part of the tank (the volume between the lowest operating level and the highest level, allowing for at least 18" of freeboard) should be sized to contain the volume of the peak hourly flow received during that portion of the SBR(s) cycle time when there will be no forward flow or the volume of one batch, whichever is larger. In addition to this, side stream/recycle flows should be included in the sizing.

c. The plant hydraulic capacity should be based on treating 100% of the maximum month average flow.

d. The basins should be sized to treat 100% of the maximum day dry weather flows without advancing cycles. Cycles may be advanced to process maximum day wet weather peak flows to assure biomass retention and treatment stability.

e. Consideration should be given to dividing the required aeration tank volume into two or more units at all plants. For plants designed to receive maximum monthly average flow of 50,000 gpd or more, total aeration tank volume should be divided among two or more units capable of independent operation to meet applicable effluent limitations and reliability guidelines.

f. A single SBR reactor may be provided with a pre-equalization tank. The pre-equalization tank should be sized for the peak flow that may occur over the non-fill portion of one cycle.

g. Flow division control facilities preceding the SBR tanks should be designed for greatest operating and maintenance convenience, flexibility, continuity of maximum effluent quality, and ease of installation of future units. Automatic influent valves or dedicated influent pumps should be provided for each basin, if more than one basin is provided. A means of isolation and /or bypass should be provided for each of these valves to allow for servicing.

h. The aeration tank volumetric loading should not exceed 15 lb BOD_5/day/1000 ft^3 [0.24 kg $BOD_5/(m^3 \cdot d)$] based on the maximum daily BOD_5 load to the aeration tank. Higher loadings may be acceptable with proper justification and calculations.

i. Reactor design MLSS concentration at low or minimum water level should be in the range of 2,000 mg/L to 5,000 mg/L. Other values may be accepted, if justified.

j. A means of completely emptying each reactor of all grit, debris, liquid, and sludge should be provided.

k. Automatic influent valves should be used for normal operation as a means to control fill to tanks in or out of service.

l. Influent baffling should be included to provide physical separation of the influent from the decanter in single tank SBR design or if the peak wet weather flows are anticipated to cause advancement of the design cycle. In lieu of this, an influent manifold may be utilized to distribute the influent without disturbing the sludge blanket.

    1. Average horizontal velocities through each baffle wall or manifold opening should not exceed 1 ft/sec at design peak hourly flow.

    2. The baffling or manifold should direct the influent wastewater into the sludge blanket.

m. SBR systems should be designed to interrupt flow during the SETTLE and DECANT phases, but may choose to operate as a continuous influent feed system. In this case, the reactor should have a minimum length to width ratio of 3:1 with inlet and outlet separation maximized.

n. Each reactor should be provided with inter-reactor overflow to another SBR tank or a storage tank.

o. The detention time at minimum water level at maximum monthly average flow should be at least 12 hours.

p. The hydraulic grade line calculations should consider decanter system head requirements, operating depth changes, operation during stream flooding elevations, future plant expansions, and potential for treatment units or pumps to be out of service.

q. As a minimum the following mechanical requirements shall be considered:

1. SBR with one or two basins should be provided with equipment that is accessible for inspection, routine maintenance, and operation from the top or side of the basin without dewatering the basins.

2. A detailed description of how the in-basin equipment can be serviced while still processing a minimum of 75% of the maximum monthly average flow and peak daily load with a basin out of service is required. If more than two basins are required to achieve this requirement, an independent blower and mixing system should be provided for each basin.

r. Tank bottoms should be sloped towards a drain or sump. Circular basins should be sloped towards the middle for maintenance. For rectangular basins slightly slope to one corner to allows for hosing down the unit.

s. Structures using a common wall should be designed to accommodate the stresses generated when one basin is full and an adjacent basin is empty.

t. Every wall of the SBR should be water tight and resist buoyant uplift when empty.

u. The minimum side water depth of a tank should be 9 feet.

v. The tank should have a minimum freeboard of 18 inches at the maximum liquid level.

88.5 Mixing and Aeration Systems

Mechanical mixing independent of aeration should be provided for all plants designed to provide biological phosphorus removal or denitrification. The aeration and mixing equipment should not interfere with settling.

a. Mixing Systems

1. Mixing equipment should be of the number, size, and location to provide adequate complete suspension of the MLSS in order to prevent accumulation of settled solids throughout react phases and to ensure sufficient distribution of dissolved oxygen during aerobic events throughout the basin. This determination should be based on manufacturer supplied test data on tanks of similar geometry.

2. The mixing system should be sized to thoroughly mix the entire basin from a settled condition within 5 minutes without aeration, regardless of

tank geometry. Specifications should require verification of the mixing effectiveness at system startup.

3. Mixing equipment should be provided in multiple units, so arranged and in such capacities as to meet the maximum mixing demand with the single largest unit out of service unless the equipment is serviceable without basin dewatering and the motor incorporates design enhancements that provide for three (3) years of operation without routine maintenance. Backup mixing may take the form of the diffused aeration system, if sized sufficiently to provide complete mix conditions and in accordance with prior requirements within this document.

4. The mixing equipment should provide for a mixing pattern that is unobstructed.

5. Floating mixers should be accessible, adequately moored to assure that they operate in the design location without interfering with, or stressing, any other tank or process function, and protected from excessive icing.

6. Provisions should be included to lift equipment for removal, installation, maintenance, and repair. In the case where a crane may be needed to lift equipment, access for the crane should be considered.

7. Mixing systems that are fixed to the floor (rather than floating and removable) should provide provisions for additional equalization or storage as necessary to dewater and inspect the fixed equipment.

b. Aeration Systems

1. The aeration equipment should be suitable for varying water depths and cyclical operation in a sequencing batch reactor based on experience with installations handling similar wastes and loadings. The discharge pressure of the blowers should be established at the maximum water depth.

2. Oxygen transfer rates from the aerators based on average water depth between the low-water level and the maximum water level for the critical flow conditions, should be considered to provide a dissolved oxygen concentration of 2.0 mg/L during aeration.

3. The blowers should be sized to deliver the total oxygen demand in a shorter period of time than allocated to the FILL/REACT and REACT phases of the cycle if oxic and anoxic conditions are required during these phases. A standby blower with complete system may be required in case of emergency.

4. The blowers should be provided in multiple units, so arranged and in such capacities as to meet the maximum air demand in the oxic portions of the FILL/REACT phases of the cycle with the single largest unit out of service. Variable frequency drives should be considered.

5. The aeration blower should be designed to provide 100% of the total air requirement with one unit out of service. The remaining components of the aeration system should be capable of providing a minimum of 100% of total air requirement to the basin during aeration system servicing.

6. The nitrogenous oxygen demand should be based on 4.6 lbs. of O_2/lb. of maximum daily TKN to the aeration tanks.

7. The minimum oxygen requirement should be based on 1.25 lbs. of O_2 / lb. of maximum daily BOD_5 applied to the aeration tanks at working conditions.

8. Diffused air systems should meet requirements of Section 82.332 of the Domestic Wastewater Facilities Manual. Mechanical aeration system should meet requirements of Section 82.333 of the Domestic Wastewater Facilities Manual.

9. Motors, gear housing, bearings, grease fittings, etc. associated with mechanical aeration systems should be easily accessible and protected from inundation and spray as necessary for proper functioning.

10. The aerator mechanism and associated structures for mechanical aeration system should be protected from freezing and ice accumulation.

11. The SBR design should allow for the removal of air diffusers or mechanical aeration devices without dewatering the tank or inhibiting the operation of other equipment.

12. If a jet aeration system used, the jet motive pumps should be either located in a dry pit, or furnished with a means to remove submersible jet pumps without dewatering the tank.

88.6 Decant Mechanism

a. Design should allow the decanter to withdraw decant fluid from beneath the liquid surface, regardless of liquid depth, down to the minimum allowable water level specified. The decanter should not pass through the water surface before or after decant where scum, foam and floatable may enter the weir.

b. The decantable volume of the SBR system should be sized for at least 100% of the maximum day dry weather peak flow without changing the cycle times.

c. The decanter capacity of the SBR system with the largest reactor out of service should be sized to pass at least 75 percent of the peak daily flow without changing cycle times.

d. The decanter design should take into account the depth of the settled liquid and solids, and should be located to allow even withdrawal throughout the tank. Decant overflow velocity should be generally kept to less than 1.0 ft/sec.

e. An adequate zone of separation between the sludge blanket and the decanter(s) should be maintained at all times during the decant phase.

f. Decant inlet velocities should be limited throughout the decant phase to prohibit vortexing, entry of scum or other floating material, or disturbance of settled sludge layer.

g. For reactors where simultaneous fill and decant occur, the location and design of the influent and effluent ports should prevent short-circuiting through the tank.

h. The decanter should draw decant fluid from below the water surface and a means of excluding solids, especially floating solids and scum, from entering the decanter during any phase of the cycle besides the decant phase.

i. Two independent means of controlling effluent discharge should be provided for each decanter device.

j. Protection against ice build-up on the decanter(s) and freezing of the discharge piping and decant valves should be provided.

k. Decanters should be moored at enough points to allow adequate movement of the mechanisms as necessary to accommodate all liquid levels.

l. The design should eliminate the potential for the decanters to get stuck at a level where they are not intended to operate.

m. The design should include a mechanical restraint to prevent the decanter from falling below the sludge blanket level.

n. A fixed decanter should not be used in a basin where simultaneous fill and decant may occur.

o. Additional settling time before a discharge may begin must be considered for systems with fixed decanters.

p. Fixed decant equipment and decant volumes that do not accommodate the maximum monthly average flow should be provided with an equalization basin.

q. An SBR system utilizing more than two basins should allow the decanting of at least two tanks simultaneously. If the systems are using two tanks, the downstream equipment should be sized based on the maximum number of tanks decanting at the same time.

r. The decanter should be accessible from the side of the basin.

88.7 Decant Flow Equalization

a. Decant flow equalization facilities should be considered for all facilities, and may be required for discharges having potential for stream bed scouring and/or other water quality impacts.

b. The basin should be of sufficient size to store the differential between the average decant rate and the maximum discharge rate from the equalization basin times the decant time and time between decant available.

c. These basins should also have a means of removing solids from the bottom of the unit, such as a sloped bottom with a drain or sump.

d. If decant flow equalization is not provided, downstream units should be sized to handle peak decant rates.

e. If decant flow equalization is not provided, effluent limits will need to be determined based on decant rate to ensure that toxic effects of ammonia and chlorine do not impact aquatic life in the receiving stream.

88.8 Sludge Removal

a. A sludge removal system separate from decant piping should allow sludge to be wasted during the DECANT and/or IDLE phases.

b. The sludge wasting points should be away from the decanters if wasting can occur during the DECANT phase.

c. Sludge withdrawal should be at a location and in a manner that will insure consistent and even withdrawal from the sludge layer and not disrupt any of the other settled layers.

d. Where there is a possibility for siphoning of the sludge to occur, siphon breaks should be installed.

e. Automatic wasting controls should be provided in all designs to insure that over wasting of sludge will not occur; however, manual controls for adjustment by the operator should also be included. The controls should allow for operator adjustments for the duration of the wasting period.

f. The capability to transfer sludge from each reactor to another should be provided to allow for seeding of other reactors if needed or to allow for the use of off-line reactors.

g. If decant pumps are used for sludge transfer, all solids in the decant piping should be flushed and recycled back to the SBR.

h. All sludge transfer and wasting pumps should be accessible for maintenance without dewatering the tank.

88.9 Process Control Equipment

a. Programmable Logic Controllers (PLC) or microprocessors should be provided with surge protector and programmed to meet the treatment requirements for the design loadings with limited operator adjustment.

   1. The design and installation should consider all factors affecting the flow and organic loading for each cycle, such as diurnal, first flush, industrial, etc.

   2. Where automatic process control is used, hard-wired manual backup controls for operation of the entire system should also be provided at the control panel.

   3. Each control panel should be provided with a remote access such a modem so the program can be modified or reloaded in a short period of time.

b. Both automatic and manual controls should be designed and installed to allow independent operation of each tank.

c. An Uninterruptible Power Supply (UPS) or other similar equipment should be provided for each PLC or microprocessor to retain program memory (process control program, last known set points, and measured process/equipment status) through a power loss.

d. A means of recording and displaying all activities of the SBR process, including the time and status of each cycle stage and batch change and all alarms should be provided.

   1. The current process cycle stage and time remaining should also be recorded and displayed.

   2. This information should be available in a visual display as well as a historical record if a SCADA system is provided.

e. A scroll-through display that identifies each cycle's length and time remaining in the current cycle should be provided.

f. There should be an operator interface provided for operator adjustment of all cycle settings and other control logic.

g. A fail-safe timer control which cannot be adjusted by the operator, allowing not less than 20 minutes between the REACT and DECANT phases, should be provided.

h. All designs should include a "high flow" mode with a program that will recognize flow above the diurnal peak flow. All equipment and controls should be designed to accommodate this high flow mode and to optimize the treatment processes. A description of this control logic should be included in the Design Engineer's report and O & M Manual.

i. All designs should include programming and operational capabilities for lower than average startup flows and loadings that may be realized during new system startup and/or other prolonged periods where the plant may experience flows and loadings less than the design criteria.

   1. The programming and controls should at least be able to provide for consistent, reliable treatment and operation at 25%, 50%, 75%, and 100% of the maximum monthly average flow and/or peak daily loading.

   2. A description of this control logic should be included in the Design Engineer's report and O & M Manual.

j. Control panel switches should be installed for all of the following:

   1. Pumps: manual/off/auto

   2. Valves: open/close/auto

   3. Blowers and mixers: manual/off/auto

   4. Selector switch for tank(s) in operation/standby

k. Control panel visual displays or indicating lights should be installed and similar to those that are provided for flow-through systems and should include the following:

   1. Mimic diagram of the process that shows the status and position of any pumps, valves, blowers or aerators, and mixers;

   2. Process cycle and time remaining;

   3. Instantaneous and totalized flow to the facility and of the final discharge;

   4. Tank level gauges or levels;

   5. Sludge pumping rate and duration; and

   6. Airflow rate and totalizer.

l. Annunciator panel or display screen to indicate alarm conditions should include the following:

   1. High and low water levels in each tank;

   2. Failure of all automatically operated valves;

3. Decanter failure;

4. Blowers, if used – failure;

5. Mechanical aerator, if used – failure;

6. Pump – failure; and

7. Mixers, if used – failure

m. A tank level system should include floats or pressure transducers.

1. A float system should be protected from prevailing winds and freezing.

2. A bubbler system should not be used in a tank level system.

3. An ultrasonic system or sensor should not be used where foam is anticipated.

88.10 Disinfection

a. When chlorination is used for disinfection, the chlorine contact tank should be sized to assure a minimum contact period of 15 minutes at maximum decant rate unless decant equalization is provided. The dosage should confirm to Section 103.32 of the Domestic Wastewater Facilities Manual.

b. When other means of disinfection is used, the facilities should be designed to provide required disinfection at maximum decant rate unless decant equalization is provided.

88.11 Sampling

a. Composite samplers should be provided that allow for at least three equal-sized samples from each batch of effluent discharged from the reactors.

b. Sampling and flow measurement equipment should allow monitoring of the operation of each reactor separately.

c. All effluent sampling for compliance reporting should be conducted using an automatic sampler controlled by an effluent flow meter.