Package Treatment Plant Operation and Management

System Troubleshooting

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Plant Performance

- With adequate operation, supervision and maintenance most package treatment plants will perform reliably under normal operating conditions
- Most are robustly designed and utilise processes that have been developed and refined over time to cope with typical effluent characteristics and flow regimes
- However, sometimes things go wrong and often the first sign of a problem is…………………

Troubleshooting *Suspended Growth Processes*

- Activated sludge processes are most common:
  - Extended Aeration plants, SBR's, Oxidation Channels, IDEA plants, Hybrid Plants, BNR plants
- Remember, any activated sludge process is a biological process and any corrective action may take several days to weeks to show results (good or bad)
- While the following presents a review of common problems, do not exclude the possibility of a toxic event or other conditions not considered here

Suspended Growth Processes Common Problems

- Carryover of solids or high effluent turbidity
  - Return Activated Sludge (RAS) systems (pickup/skimmer) may be disabled or the rate of return may be too low
  - Poor settling in the clarification chamber may be resulting from sludge bulking or problematic foam generation
  - Over or under aeration can result in poor settling and gas buildup in solids (anaerobic digestion / denitrification)
  - The retained solids level in the system may be too high (WAS) and pump out required

Sludge Return Ratio

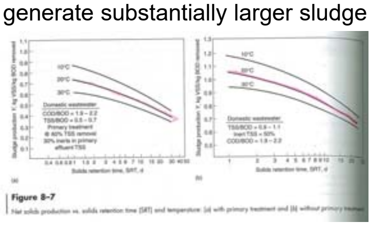
- MLSS concentration maintained in reactor vessel to maximise biological metabolism of organic wastes
- Recycling rate dependent on system characteristics (typically 50%-75% design flow)
- Target MLVSS concentration **2,000 to 5,000** mg/L for:
  - Extended Aeration
  - Oxidation Channel
  - SBR / IDEA
- Some systems may operate at significantly higher MLSS

Sludge Generation

- Sludge generation a function of organic loading (BOD/COD), solids retention time (SRT), reactor temperature (°C) and influent quality (raw or primary)
- Typical yield (kg.Cell / kg.COD) – 0.3-0.5 (primary) and 0.5-0.7 (raw)
- Sludge inventory will continue to increase in reactor at a rate controlled by process efficiency (high – logarithmic, low – endogenous)

Sludge Generation

- If not managed it will present as other system problems (poor settleability, effluent clarity)
- Systems with high rbCOD (simple sugars etc.) will generate substantially larger sludge volumes



from Metcalf & Eddy (2003)

Sludge Generation (Example)

- If a PTP treats 30,000L of raw wastewater per day
- Average COD concentration of 360mg/L
- Daily load of COD =

  30,000L x 360mg/L = 10,800,000mg or 10.8kg
- With a sludge yield ratio of 0.6
- Daily sludge production =

  10.8kg x 0.6 (kg.Cell / kg.COD) = 6.48kg
- If the reactor has a volume of 60kL and a MLSS concentration of 2,000mg/L, a wasting rate of **~6% per day** is required just to maintain equilibrium

Poor Settling

- Poor settling can result from a number of physical and biological conditions. Physical conditions include:
  - Excessive overflow (rise) rates in the clarifier can limit the settling rate of even well behaved AS systems
    - Check system sizing or design volumes (over capacity)
    - Identify other sources of agitation within secondary clarifiers that may hinder settling performance (uncontrolled/excessive air delivery, water sprays, deflections from fittings / equipment or wildlife??)

Poor Settling (Overflow)

- Higher than design surface loading rates or rise velocities in the clarifier can impede settling
- This is particularly problematic in demand 'spike' loaded systems with no flow balancing
- The following generally accepted (design) values are used to determine clarifier sizing:

	Overflow rate		Rise Rate
≤50kL/day	14,000L/m²/day	or	0.6m/hr
>200kL/day	22,000L/m²/day	or	0.9m/hr

Example (Overflow Rate)

- Example Clarifier Overflow Rate (OR)
- Clarifier surface area – $1.2m^2$
- System daily flow (peak) – 15,000L/day

$$OR = \frac{15{,}000 L/day}{1.2 m^2} = 12{,}500 L/m^2/day$$

$$\text{Rise Rate} = \frac{15 m^3/day\ (15{,}000L)}{1.2 m^2} = 12.5\ m/day$$

0.52 m/hr

Poor Settling (Bulking)

- Sludge bulking can occur via development of filamentous bacterial activity (common) or hydrophilic extracellular biopolymer accumulation (less common). Commonly associated with:
  - Low DO (<1mg/L)
  - Low substrate (food) concentration (F/M ratio)
  - Unbalanced Nutrient availability (C:N:P ratio)
  - High temp or high (simple) sugar or fatty acid wastes
  - Excessive aeration can also cause (non-filamentous) bulking (floc-shearing)

Example (F/M ratios)

- F/M = Q (flow) x BOD / Reactor m^3 x MLVSS
- Q = $30m^3$/d with BOD = 220mg/L
- Reactor Volume = $20m^3$ and MLVSS = 3,000mg/L

$$F/M = \frac{30{,}000\ L/day \times 220\ mg/L}{20{,}000\ L \times 3{,}000\ mg/L} = \frac{6{,}600{,}000\ mg/d}{60{,}000{,}000\ mg/d}$$

F/M = 0.11

Typical F/M ranges:
AS 0.4 – 0.10, High Rate 0.25 – 0.45

Poor Settling (Rising Sludge)

- Sludge with otherwise good characteristics may 'rise' in clumps to the clarifier surface
- This can cause solids carryover in systems with discharge weirs etc.
- Most common cause is denitrification within the sludge blanket.
- Look for:
  - Low DO in clarifier resulting from long SRT (increase RAS/WAS)
  - Higher than normal wastewater temperature

Poor Settling (Settleability Test)

- The Sludge Volume Index (SVI) is an empirical test used to examine the settling characteristics of MLSS
- The SVI is reported as the volume of 1 gram of MLSS after 30 minutes of settling
- The test takes the form of :

$$SVI = \frac{\text{settled volume of sludge (mL/L) x 1000}}{\text{mixed liquor suspended solids (mg/L)}} = \text{ mL/g}$$

- Although arguably flawed, the test is useful for comparing treatment system performance
- An SVI of <100 is considered good-settling, above 150 we look for bulking/foaming causes

Example (Settleability Test)

- Example Sludge Volume Index (SVI)

$$SVI = \frac{100mL/L \times 1000}{2{,}000 \text{ mg/L}} = \frac{100{,}000}{2{,}000} = 50mL/g$$

- Multiplying the top line of the equation by 1,000 converts milligrams to grams on the bottom of the equation

Reactor Foaming

- Foaming can result from a number of factors and is typically more of a nuisance than a performance problem
  - Excessive foaming can be the direct result of detergent inputs from influent wastewater
    - Educate system owners on appropriate detergent usage
  - Low F/M can also promote the growth of particular filamentous micro-organisms (principally Nocardia) that froth in the aerobic reactor vessel and clarifier
    - Water sprays can be successful in knocking down foams
    - In problematic situations a dilute chlorine spray can be directly applied to the foams to knock them over

Aeration (Over or Under)

- AS processes (BOD and nitrification) require significant oxygen inputs
- Nitrification requires 3-4 x oxygen than BOD only systems
- Typically a nitrifying AS plant will require:
  - BOD – 1.1kg O_2 / kg BOD converted
  - NO_x – 4.6kg O_2 / kg NO_3-N produced
- Also, in many systems air delivery serves not only to aerate but also to mix the reactor vessel
  - Over aeration can contribute to foaming, poor settling, dispersed bulking, energy wastage
  - Under aeration causes septicity, unwanted denitrification (rising sludge), filamentous bulking

Aeration (Over or Under)

- In aerobic (AS) reactors we should be aiming for reliable DO concentration of **2-3mg/L** for good BOD/nitrification performance
- Not just volume of air, but efficiency of delivery
- Typical 'Actual Oxygen Transfer Efficiency" (AOTE) values
  - BOD only systems – 4-6% (coarse bubble) to 8-12% (fine bubble)
  - Nitrifying systems – 4-8% (coarse bubble) to 8-14% (fine bubble)
- So, how much air do we need to deliver the appropriate amount of oxygen for the system processes we are trying to facilitate?

How much Air?

BOD only for 100 EP system

- BOD generation rate (g/EP/day) = 45
- EP (equivalent population) = 100
- BOD loading to plant (kg/day) = 4.5 (4,500g)
- Oxygen required (kg.O_2/kg.BOD) = 1.1
- Oxygen required (kg/day) = 4.95
- Air Density (kg/m^3 @ 20°C) = 1.2
- O_2 per m^3 of air (23.18%) (kg) = 0.278
- O_2 transfer efficiency – AOTE (%) = 8 (fine)
- Air Requirement (m^3/day) = 222 (155Lpm)

How much Air?

BOD and nitrification for 100 EP system

- BOD loading to plant (kg/day) = 4.5
- NH_3 loading to plant (kg/day) = 0.9
- Oxygen required (kg.O_2/kg.BOD) = 1.1
- Oxygen required (kg.O_2/kg.NO_3) = 4.6
- Oxygen required (combined) (kg/day) = 9.09
- O_2 transfer efficiency – AOTE (%) = 8
- Air Requirement (m^3/day) = 408 (285Lpm)

Other Common Problems

- Odours
  - Incomplete nitrification – ammonia smell (check for 'blue' tinge to reactor/clarifier water colour
  - In combination with dark-coloured and turbid effluent it may suggest under aeration or poor mixing (dead zones)
  - Excessive sludge buildup may be occurring – increase wasting rate (WAS)
  - Poor housekeeping – check for other odour generating substances (dead animals) or areas of stagnant water

Other Common Problems

- Poor Effluent Quality
  - Particularly in relation to higher the expected BOD and TSS
    - Check air delivery systems or aeration timings
    - Low DO may be contributing to poor performance
  - Check sludge wasting regime to ensure micro-organisms in MLSS remain at higher end of growth curve
  - Check system pH to ensure optimal growth conditions – toxic shock loading

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Troubleshooting *Attached Growth Processes*

- Attached growth systems such as:
  - Biological filters, RBC's, and other fixed or floating media reactors
- Subject to a range of operational problems as with all biological systems
- Specific problems relate to media or substrate properties, while others are a consequence of external conditions

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Attached Growth Processes Common Problems

- Ponding
  - Primarily in down flow biological filters
  - Clogging of the filter bed due to poor media selection (permeability) or excessive biofilm growth (high organic loading?)
  - Accumulation of debris on filter surface (leaves etc.)
  - Hydraulic overloading or undersized filter bed design
  - Localised infestation of insects (snails) or vermin
  - Freezing (less common)

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Attached Growth Processes Common Problems

- Odours
  - Excessive organic loading to filter bed
  - Poor oxygen (air) transfer to media or substrate surfaces (remember aerobic processes)
  - Excessive biofilm development causing bridging of voids and dead zones in filter

Attached Growth Processes Common Problems

- Carryover of solids or high effluent turbidity
  - Poor primary treatment (check septic tank)
  - Excessive organic loading to treatment system
  - Poor oxygen transfer to media and substrate
  - Excessive biofilm sloughing due to:
    - die-off
    - excessive rotational velocity or hydraulic loading
    - toxic shocks
    - temperature problems (influent and atmospheric)

?? Discussion ??