IFM OPS MEETING

NITRIFICATION AND PACKAGE PLANT OPERATIONS

GENERAL MICROBIOLOGY REVIEW

- ALL WASTEWATER TREATMENT RELIES ON VARIOUS FORMS OF BIOLOGY
- HETEROTROPHS – BACTERIA THAT RELY ON ORGANIC CARBON FOR PRIMARY FOOD SOURCE
- AUTOTROPHS – BACTERIA THAT RELY ON INORGANIC CARBON FOR

GENERAL MICROBIOLOGY REVIEW

- MICROORGANISMS RELY ON RATIO OF NUTRIENTS
- CARBON:NITROGEN:PHOSPHOROUS = 100:5::1 (NITROGEN MUST BE INORGANIC)
- OFTEN INDUSTRIAL ARE LOW IN NITROGEN
- PACKAGE PLANTS ARE EXCESSIVELY HIGH IN AMMONIA

GENERAL MICROBIOLOGY REVIEW

- ENERGY / MATTER IS NEITHER CREATED OR DESTROYED
- ORGANICS (CBOD5) ARE CONSUMED BY HETEROTROPHS
  - AS ORGANICS ARE CONSUMED, SOLIDS ARE PRODUCED (MULTIPLYING BACTERIA)
- HETEROTROPHS MULTIPLE EVERY 20 MINUTES

GENERAL MICROBIOLOGY

- NITRIFIERS ARE AUTOTROPHS
- RELY ON CARBONATE FOR SOURCE OF CARBON
- NITRIFICATION IS A 2 STEP CONVERSION, NOT A CONSUMPTION
- NH_3-N ULTIMATELY CONVERTED TO NITRATE
- NITRIFIERS MULTIPLY 1X / 24 HOURS
- DON’T LIKE UNSTABLE ENVIRONMENT
- TEMPERATURE SENSITIVE

GENERAL MICROBIOLOGY REVIEW

- THEORETICAL EXAMPLE BASED ON RATIO
- INFLUENT CBOD5 OF 500 MG/L
- AMMONIA (1 FORM OF INORGANIC NITROGEN) SHOULD BE NEAR 25 MG/L
- PHOSPHOROUS – 5 MG/L
- PILOT 16 CBOD5 = 240 MG/L, NH_3-N = 155 MG/L

Process Control Monitoring, the other half of field sample collection

- All systems require some level of routine process control monitoring
- Larger the facility, higher frequency of sample collection and monitoring
- Smaller the facility, lesser frequency of sample collection….but other test methods may be required to ensure the best treatment

Process Control Monitoring

- 30 minute settling – activated sludge process control monitoring method that helps an operator determine the settling characteristics of the biomass under aeration
- With experience, one can get an idea of sludge age and possible treatment changes

30 minute settling

- During test, operator can observe
- Clarity of water “decant” above the settled sludge during and after 30 minutes.
  - Dark Water – excess BOD5, septicity /underaeration
  - Presence of stragglers (young sludge) or pin floc (old sludge)
  - Physical structure of the floc, i.e. big and fluffy, small and granular, light brown to dark brown
  - These physical observations can help determine effluent variability. Need increased aeration, wasting that may improve effluent. Adequate aeration / overaeration?
  - Observe denitrification – popping sludge

30 minute settling (on the road)

Other Process Control Measures

- Spin test
- Alkalinity
- Ammonia test kits
- These are recommended tests for process control monitoring by OEPA Compliance Assistance Group for package plant operation

Process Control Monitoring

- MLSS – mixed liquor suspended solids – Sample collected from the end of aeration tank prior to clarification. Collect this sample from end of aeration basin just prior to secondary clarifier
  - MLSS along with 30 minute settling can be used to calculate SVI – Sludge Volume Index, SVI indicates how much volume is occupied by 1 gram of settled sludge.
  - Ideally 100 – 1 gram of settled sludge occupies 100 ml, the lower the number the more dense the sludge…granular
- RASSS – return activated sludge suspended solids – sample of concentration settled sludge from clarifier
  - MLSS, RASSS, Flow are used to determine MCRT – Mean Cell Residence Time or Solids Residence Time
  - RASSS along with sludge judging can help determine return flow adjustments

Process Control Monitoring

- MCRT – Mean Cell Residence Time is calculated by dividing solids in the system divided by solids leaving the system (waste and effluent)
- Depending on the type of activated sludge MCRT's range from 5 – 20 days.
- Often smaller plants rely on older sludges, due to low loadings and high ammonia loadings.
- With small systems, it's easy to waste too much

Process Control Monitoring

- pH and dissolved oxygen of aeration tank – critical to know routinely in small or large plants
- pH – critical due to effluent limits
  - Also, can be an indicator of many things, dumps, presence of good nitrification or a quick indicator that pH adjustment is needed
  - Most limiting factor to biological activity, aerobic, anaerobic and attached growth systems are pH dependent (6.5-9.0). Personal Preference 7.5-8.0 SU. 7.0 is on the lower end of the pH scale.

Process Control Monitoring

- pH / alkalinity relationship
- Often the terms are interchanged
- They are related, but not exactly the same
- pH is a measurement of Hydrogen H^+ and Hydroxyl OH^- ion activity in solution. $H^+ = OH^-$ pH = 7.0 SU
- Alkalinity is a water's acid neutralizing capacity (the higher the alkalinity, the more anions it can take before pH drops)
- Since many wastewater processes produce acidic byproducts, these 2 terms are often used interchangably
- This is the importance of understanding alkalinity

Process Monitoring

- Dissolved Oxygen – critical to aeration tanks. Typical consistent values during aerated cycles 2-3 mg/l.
  - Consistently higher than this you may be overaerating. Operator needs to also weigh the value of adequate mixing. Mixing with air is very inefficient, but it's probably the right choice for most treatment systems
  - 30 scfm / 1000 cubic feet of aeration basin
  - May contribute to settling problems and possibly denitrification in the clarifier

Process Control, Large vs. Small

- Large Systems – solids inventory can be managed more efficiently with MCRT
- Small Systems – solids inventory tend to be controlled more by MLSS, RASSS, SVI
  - Tend to be much higher SRT's in small plants vs. large plants
  - Often controlling small plant by MCRT tends to wasting too much
  - Due to low daily loadings w/ often high NH3 leads to the need for longer MCRT

Process Control Large Plant

- May have to take into account
- Primary removal efficiency
- Sand Filter Loading Rates (hydraulic and solids)
- Trickling Filter – Organic loading rate (lbs BOD5 / 1000 cubic foot / day)
- SBR’s – basically have 2-3 different plants based on the # of SBR’s onsite

Process Control, Small Plant

- On top of the standard 30 min, MLSS, RASSS, Sludge Judging, small plants
- Often need additional monitoring of pH, alkalinity
- Due to the type of system being serviced by extended aeration
- Truck Stops, Rest Areas need extra attention or more than you would expect

Process Control

- Truck stops and rest areas
- Heavy concentrations of NH3
- Fluctuations in traffic and people, seasonal / holiday weekends impact these systems
- Often require supplementation of additional alkalinity
  - Sodium Bicarbonate (baking soda), NaOH, Lime
  - pH of aeration basins can easily drop to 4 SU during high loads of ammonia (urine)

Process Control, Small Plant

- Often package plant expansion… install another package plant
- Flow Equalization / diversion is critical
- Even loadings to each plant to keep them consistent with one another

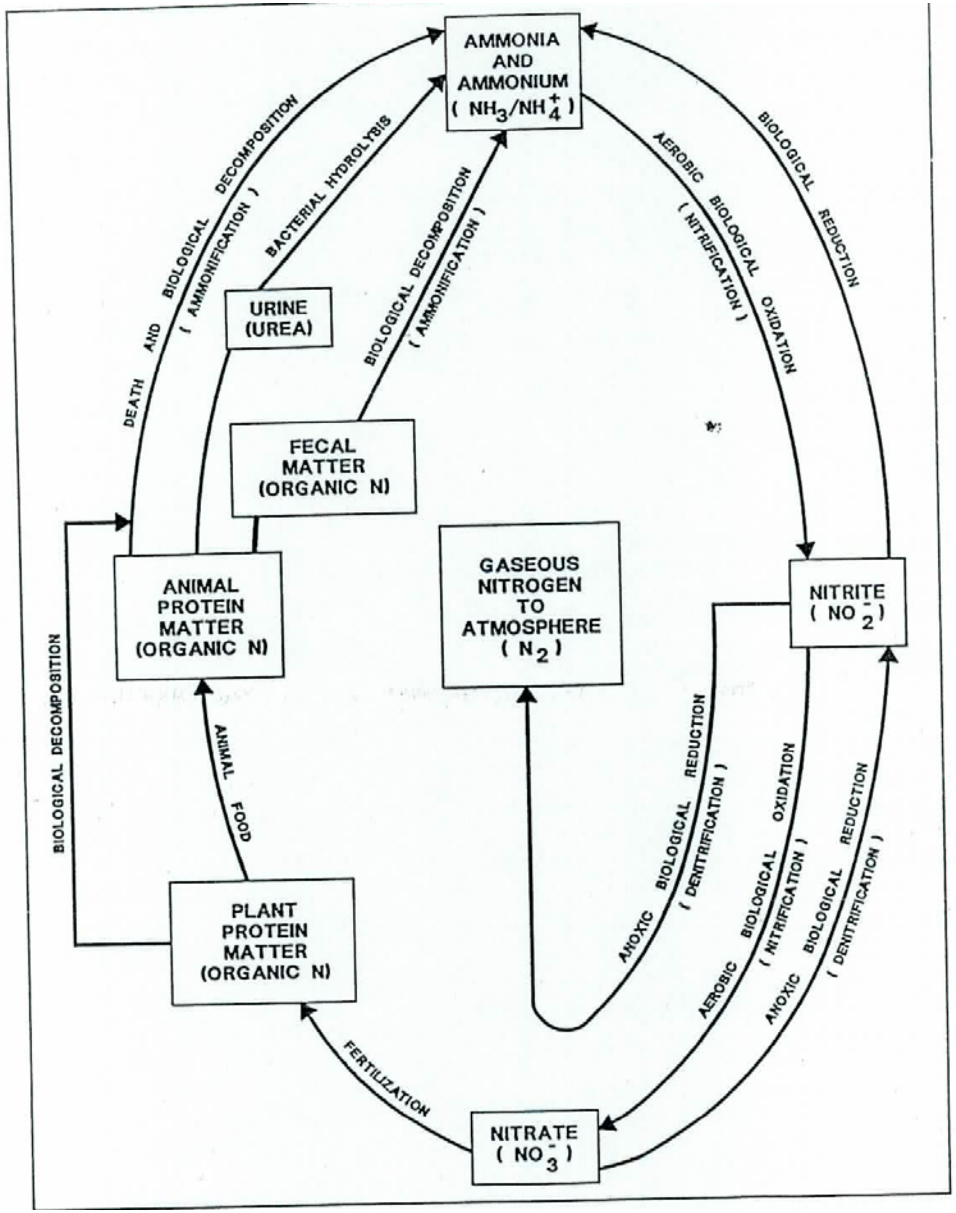
Alkaline Addition

- Sodium Bicarbonate – Baking Soda $NaHCO_3$ – for small plants, probably the method of choice
  - Just dump it in
  - High alkalinity addition
  - Tends not to overshoot the pH
  - Lime – caking issues
  - NaOH – can easily overadd and have too high of pH, issues with gelling below 55 F

Process Monitoring (on the road)
Package WWTP Aeration Basin

Process Control, Nitrification Process

- Nitrification requires ample alkalinity and dissolved oxygen
- Nitrification is a nitrogen conversion process vs. a consumption process (BOD5) by nitrifying bacteria (nitrosomonas and nitrobacter)
- Highly aerobic, requires 4 mg/ l d.o. for every mg/l ammonia, so if you have d.o. issues, check raw ammonia's
- NH3 is converted to nitrite by nitrosomonas. Nitrite is converted to nitrate by nitrobacter.


AMMONIA AND AMMONIUM (NH_3/NH_4^+)
DEATH AND BIOLOGICAL DECOMPOSITION (AMMONIFICATION)
BACTERIAL HYDROLYSIS
BIOLOGICAL DECOMPOSITION (AMMONIFICATION)
AEROBIC BIOLOGICAL OXIDATION (NITRIFICATION)
BIOLOGICAL REDUCTION
URINE (UREA)
FECAL MATTER (ORGANIC N)
ANIMAL PROTEIN MATTER (ORGANIC N)
GASEOUS NITROGEN TO ATMOSPHERE (N_2)
NITRITE (NO_2^-)
BIOLOGICAL DECOMPOSITION
ANIMAL FOOD
ANOXIC BIOLOGICAL REDUCTION (DENITRIFICATION)
AEROBIC BIOLOGICAL OXIDATION (NITRIFICATION)
ANOXIC BIOLOGICAL REDUCTION (DENITRIFICATION)
PLANT PROTEIN MATTER (ORGANIC N)
FERTILIZATION
NITRATE (NO_3^-)

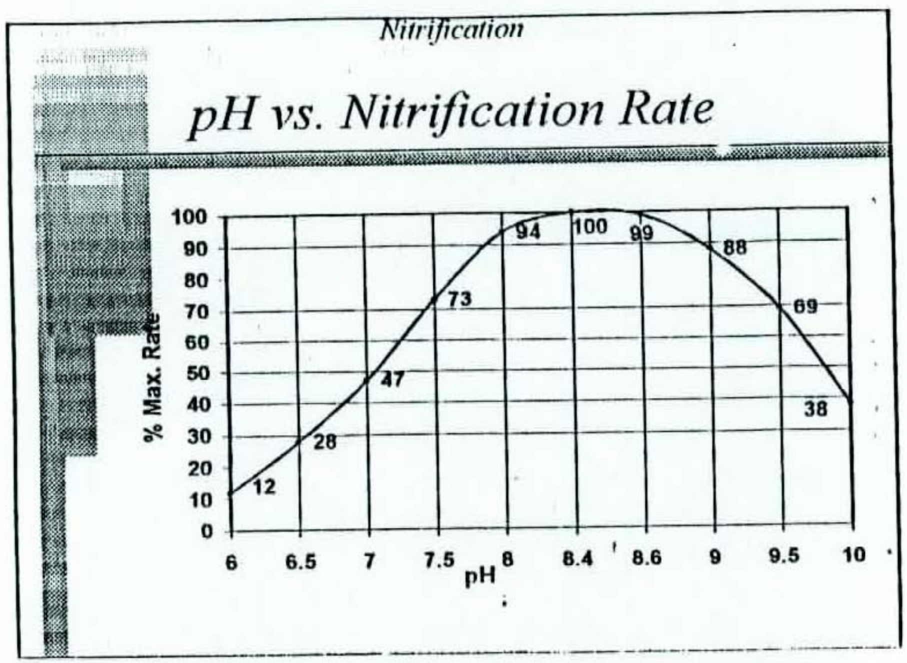
Nitrification

- This process produces acidic ions (anions) (Nitrate) that consume alkalinity, leading to a possible drop in pH
- Nitrification requires 7mg / l alkalinity as $CaCO_3$ for every mg/ l of NH_3 present to buffer the formation of nitrates
- Some of these locations, influent ammonia concentrations can be well over 100 mg/l
- Nitrification of these streams leads to alkalinity deficits and low pH in the aeration basin

Denitrification

- Before you really can denitrify, the effluent needs to be fully nitrified
- Denitrification is process where heterotrophs in periods of reduced dissolved oxygen utilize NO3 as electron acceptor produced during nitrification
- Nitrogen gas is released, 50% of alkalinity lost during nitrification is recovered

Nitrification Ideal pH Operating Range



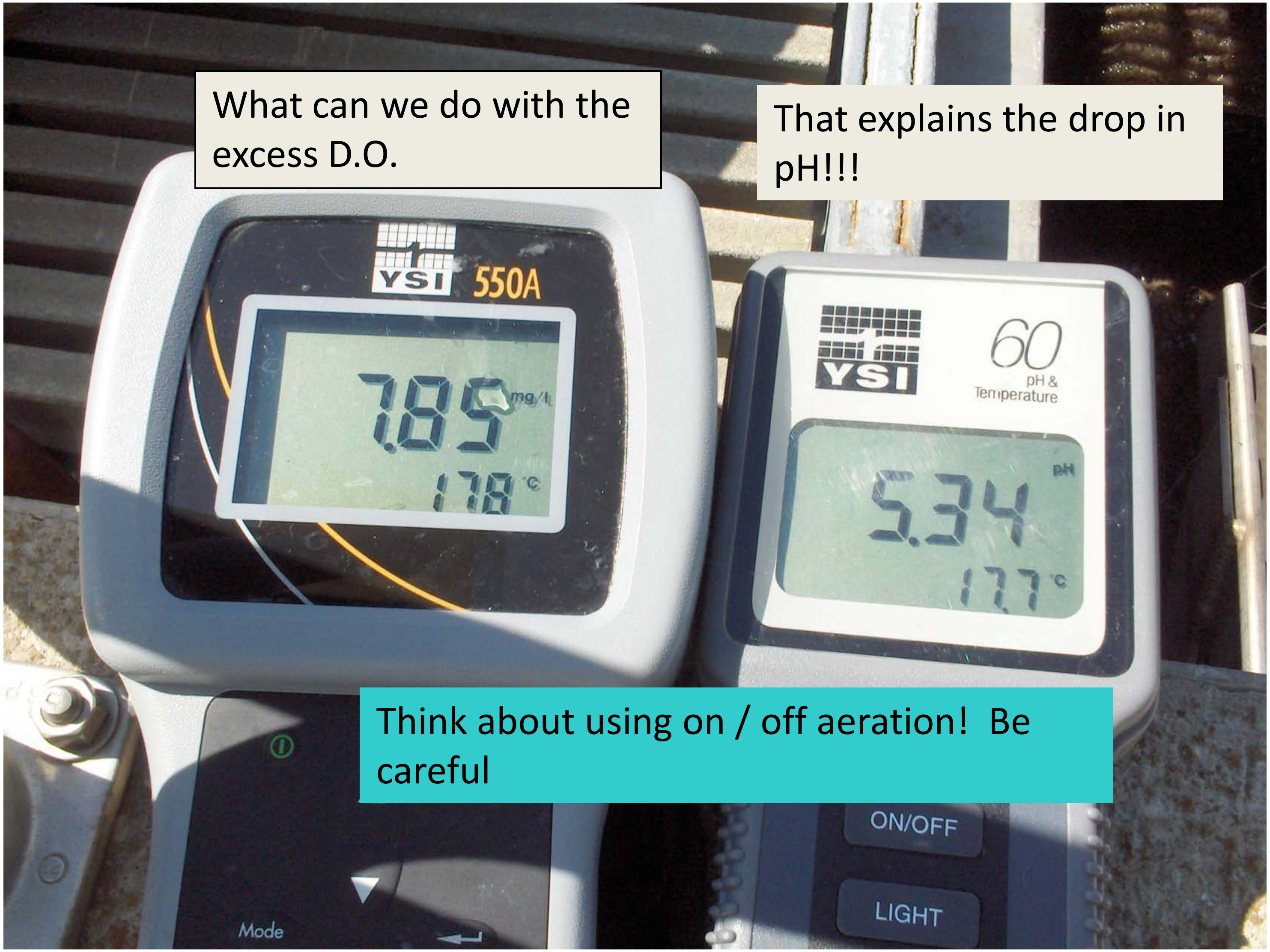
Note the significant decrease in the maximum attainable rate of nitrification between the pH range of 6.9 - 7.2, where most municipal mixed liquors operate, and a pH of 6.5.

A nitrification induced pH drop from 7.0 to 6.5, caused by insufficient alkalinity, could result in process failure.

Nitrification / Alkalinity Relationship

- Influent 100 mg/l NH3 and alkalinity of 400 mg/l
- Need to reach ammonia effluent of 1 mg/ l would require 700 mg/l of alkalinity to buffer nitrate formation and prevent a drop in pH
- Recover approximately 50% of alkalinity consumed through denitrification
- 700 – 400 = -300 mg/l alkalinity deficit + 200 mg/l recovered alkalinity = -100 mg/l, alkalinity deficit
- This type of scenario will lead to low pH in the aeration system and clarifier, which could lead to other treatment issues.
- Goes unattended, nitrification stops and then BOD5 removal can be affected

Nitrification



What can we do with the excess D.O.

That explains the drop in pH!!!

Think about using on / off aeration! Be careful

Nitrification / Denitrification

- In order to denitrify, nitrification must be occurring
- To maintain compliance with ammonia levels, you must stay aerobic, make adjustments slowly in small intervals! Not enough D.O. / MIXING ammonia will increase
- If denitrification is occurring in the clarifiers and you observe low pH in the aeration basin, you may be able to use on /off aeration
  - Make sure it's denitrification and not hydraulic washout of the clarifier(s)
- This will help recover alkalinity by reduction of nitrates in the aeration basin during off cycles, plus reduce the chance for popping sludge in the clarifiers
- By recovering some alkalinity you reduce the demand for alkaline addition
- At capacity systems, you may have to maintain aeration and add alkaline materials consistently

Nitrification / Denitrification Process

- Nitrifiers convert Ammonia ultimately to Nitrate
- Heterotrophic / Facultative bacteria can utilize Nitrate in the presence of BOD5 as a source of oxygen when dissolved oxygen is absent / LOW
- Nitrate is used as electron acceptor, Nitrogen gas is driven off
- During off cycles in the aeration basin, this is more likely to occur
- Prefer a setup with returns @ controlled rate running continuously

PACKAGE PLANT OPERATION

- REMEMBER THE FOLLOWING!!!
- AMMONIA IS THE FIRST INDICATOR OF DEGREE OF TREATMENT
  - INDICATION OF THOROUGH TREATMENT
  - FIRST PARAMETER TO GO OUT OF WHACK DUE TO MECHANICAL ISSUE / PLANT UPSET

PACKAGE PLANT OPERATION

- DUE TO IMPROPER LOADING RATIOS
- NEED TO CARRY HIGH MCRT
- LACK OF PROPER MIXING
  - BLOWER FOR MIXING VERY INEFFICIENT
- WE NEED TO ERROR ON THE SIDE OF OVERAERATING TO MEET AMMONIA LIMITS