Biological Nutrient Removal Challenges at Small WWTPs – Ellsworth, WI

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Presented by: Tim Stockman
Matt Eberhardt
Outline

- Existing Conditions
- Project Goals
- WWTP Upgrades
- Performance and Optimization
- Conclusions
Existing Conditions

- WWTP overview
- Biological treatment process
- Other treatment processes
- Design capacity
- Effluent quality
- Reasons for upgrades
Biological Treatment Process
Existing Conditions

- RBCs (4)
- Trickling filter
- Secondary Clarifiers (2)
- Waste sludge pumps (3)
Other Treatment Processes
Existing Conditions

- Mechanical screens (2)
- Influent pumps (5)
- Effluent re-aeration
- Ferric chloride feed system
- Aerobic digestion
Design Capacity
Existing Conditions

- Design flow: 0.340 MGD
- Peak day flow: 0.905 MGD
- Design BOD$_5$ load: 834 lb/d
- Design TSS load: 834 lb/d
- Capacities based on 2007 re-rating
Effluent Quality
Existing Conditions

- Average annual data from 2007 – 09
  - 5 mg/L cBOD$_5$
  - 12 mg/L TSS
  - 15 mg/L NH$_3$
  - 0.6 mg/L TP
  - 387 mg/L chlorides
Reasons for Upgrades
Existing Conditions

- Existing design was incapable of meeting new permit limits
- Needed to replace equipment and processes reaching the end of their design life
- Projected to exceed design flows and loads in near future
Project Goals

- Meet new permit limits
- Upgrade existing processes
- Increase design capacity
Meet New Permit Limits

Project Goals

- Discharge to Isabelle Creek
  - Disappearing stream (up to 0.223 MGD loss)
  - Classifications vary from Lower Aquatic Life to Cold Water Community
  - Also receives flow from Ellsworth Co-Op Creamery
    - 0.200 MGD process water
    - 0.100 MGD non-contact cooling water
Meet New Permit Limits

Project Goals

- Discharge Option 1 – New Outfall 410th St
  - Surface water limits:
    - 1 mg/L TP
    - Seasonal disinfection to 200 c.f.u.
  - Potential to create sinkhole downstream
    - Public disapproval
  - Future reclassification as Cold Water
    - Would require tertiary filtration
Meet New Permit Limits

Project Goals

- Discharge Option 2 – Existing Outfall
  - Surface water limits:
    - 1 mg/L TP
  - Creek disappears downstream of outfall
  - Groundwater limits:
    - 10 mg/L TN
    - 325 mg/L chlorides
    - Year-round disinfection to 400 c.f.u.
Meet New Permit Limits

Project Goals

- Discharge Option 2 selected
  - Treat for TN and work on chlorides
  - No effluent lift station and force main
  - No tertiary filtration
  - Lower in total present worth
  - No potential for sinkhole creation
- Result: need biological TN and P removal
Meet New Permit Limits

Project Goals

- Effluent Limits (biological)
  - 20 mg/L BOD$_5$ and TSS (monthly avg.)
  - 10 mg/L TN (monthly avg.)
  - Seasonal NH$_3$ limits
    - Daily max. as low as 7.8 mg/L
    - Monthly avg. as low as 3.6 mg/L
  - 1 mg/L TP (monthly avg.)
Meet New Permit Limits

Project Goals

- Effluent Limits (other)
  - 4 mg/L DO (daily min.)
  - 400 c.f.u./100 mL (monthly geo. mean)
  - 325 mg/L chlorides (weekly avg.)
Meet New Permit Limits
Project Goals

- Biological processes evaluated:
  - Activated sludge system
    - Oxidation ditch
    - Anaerobic selector
  - Trickling filter upgrade
    - Add plastic media
    - Additional RBCs
  - RBC expansion
    - Additional RBCs
  - IFAS system
    - Convert sludge tanks
    - Add media
    - Add RAS pumping
Meet New Permit Limits
Project Goals

- Selected activated sludge system
  - Lowest total present worth
  - Highly flexible system
    - Adjust biology (ML concentration)
    - Vary aeration rate
    - Add or remove cells from service
  - Capable of BioP
  - Capable of total nitrogen removal
Upgrade Existing Processes

Project Goals

Processes replaced:

- Mechanical screening
- Influent pumping
- Final clarifiers
- Chemical feed
- Solids handling
Upgrade Existing Processes

Project Goals

- New processes:
  - Biological treatment
    - RBCs to oxidation ditch
  - Disinfection
    - New UV system
  - Re-aeration
    - Weir to diffused air
Increase Design Capacity

Project Goals

- Peak Hour Flow: 2.160 MGD
- Peak Month BOD$_5$ Load: 1,019 lb/d
- Peak Month TSS Load: 1,253 lb/d
- Peak Month TKN Load: 140 lb/d
- Peak Month TP Load: 31 lb/d
- Design Year: 2030
WWTP Upgrades

- WWTP overview
- Biological treatment upgrades
- Biological nutrient removal (BNR) design
- Other upgrades
- Bidding and construction
WWTP Overview

WWTP Upgrades
Biological Treatment Upgrades
WWTP Upgrades

- Type: extended aeration AS with biological nitrogen and phosphorus removal
  - Three cell anaerobic selector
  - Two channel oxidation ditch with simultaneous nitrification/denitrification (SND)
  - Two final clarifiers
  - RAS pumping system
  - Internal mixed liquor recycle
Biological Process Parameters

WWTP Upgrades

- Anaerobic selector volume: 35,000 gal
- Oxidation ditch volume: 280,000 gal
- Maximum MLSS: 5,000 mg/L
- Peak month volumetric BOD$_5$ loading: 24.2 lb/d
- Peak month F:M: 0.103
- Design average SRT: 15 days
- RAS rate: 50 – 200% design average flow
Biological Treatment Schematic
WWTP Upgrades

- RW
- Anaerobic Selector
- Oxidation Ditch
- Clarifiers
- SE
- RAS/WAS

Diagram showing the flow of wastewater through different treatment stages:
1. RW flows to Anaerobic Selector.
2. Flow continues to Oxidation Ditch.
3. Flow proceeds to Clarifiers.
4. Clarifiers lead to SE.
5. RAS/WAS is part of the treatment process downstream of the Oxidation Ditch.
Biological Treatment System
WWTP Upgrades
Anaerobic Selector Basins
WWTP Upgrades
Oxidation Ditch
WWTP Upgrades
Oxidation Ditch
WWTP Upgrades
BNR Design
WWTP Upgrades

- Key biological processes
  - BOD removal
  - Nitrification
  - Denitrification (ML and RAS)
  - BioP
  - Settling
BNR Design
WWTP Upgrades

- Simultaneous Nitrification/Denitrification
  - $\text{NH}_3 \rightarrow \text{NO}_2 \rightarrow \text{N}_2 \uparrow$
  - **Nitrospirea** – Ammonia Oxidizer
  - **Nitrobacter** – Nitrite Oxidizer

- **Nitrospirea**
  - Out competes Nitrosomonas in Aerated Anoxic Reactors
  - Can Go Dormant
BNR Design
WWTP Upgrades

- Anaerobic selector basins
  - RAS denitrification
  - Readily biodegradable chemical oxygen demand (rbCOD) uptake
  - Soluble phosphorus release
  - Fermentation (†)
BNR Design
WWTP Upgrades

- Oxidation ditch (outer channel)
  - BOD removal
  - Simultaneous nitrification/denitrification
  - RAS denitrification

- Oxidation ditch (inner channel)
  - BOD removal
  - Nitrification
  - Soluble phosphorus uptake
Biological Treatment Schematic

WWTP Upgrades

Anaerobic Selector

Oxidation Ditch

Clarifiers

RW

ML

RAS

WAS

SE

Foth
Design Flexibility
WWTP Upgrades

- Multiple process basins
- Multiple RAS addition points
- Multiple basin functions
  - RAS denitrification
  - Detention time
- Flow and load fluctuations
Other Upgrades

**WWTP Upgrades**

- New mechanical fine screen
- Increased RW pumping capacity
- Replaced clarifier mechanisms
- New UV disinfection
- New diffused air re-aeration
- New chemical feed system
- Solids handling system modifications
Bidding and Construction
WWTP Upgrades

- Bid Price: $3.34 million
- Funding: CWF loan and 30% grant
- General Contractor: Rice Lake Construction Group
- Mobilization: April 2011
- Substantial Completion: May 2012
Performance and Optimization

- Initial performance
- Operational and process optimization
- Current performance
Initial Performance
Performance and Optimization

- Influent (July 2012 – April 2013):
  - Flow: 0.269 MGD
  - BOD: 401 lb/day
  - TSS: 399 lb/day
Initial Performance
Performance and Optimization

- MLSS: 2,500–4,000 mg/L
- F:M: 0.067
- SRT: 17 days
- Loading: 10.7 lb/d/kcf
- DO: 2.2 mg/L
- ORP: -150 – -250 mV
- RAS rate: 50%
- Alum rate: 10 gpd
Initial Performance
Performance and Optimization

Effluent quality (July 2012 – April 2013):
- BOD$_5$: 21.6 mg/L
- TSS: 7.6 mg/L
- NH$_3$: 3.5 mg/L
- TN: 12.4 mg/L (some months up to 20 mg/L)
- TP: 0.84 mg/L
System Optimization
Performance and Optimization

- **Operational Changes (April – Nov 2013)**
  - Established consistent nitrification (decreased ORP to -100 mV)
  - Added some WAS to centrate and aerated to promote nitrification
  - Attempted to increase denitrification by raising RAS rate
- **Reduced TN to consistently 9 – 12 mg/L**
Nitrate Recycle
Performance and Optimization

- Nitrate recycle port installed
  - Opening cut in ditch wall between channels
  - Installed November 2013
  - Starting December 2013, NO$_3$ + NO$_2$ improved
  - Winter of 2013-14 cold, NH$_3$ increased
  - Nitrification rebounded in May and system began meeting TN limit
Nitrate Recycle
Performance and Optimization
Nitrate Recycle
Performance and Optimization
Nitrate Recycle
WWTP Upgrades

Anaerobic Selector

Oxidation Ditch

Clarifiers

RW → ML → RW

RAS → WAS

SE
Current Performance
Performance and Optimization

  - Flow: 0.347 MGD
  - BOD: 381 lb/day
  - TSS: 464 lb/day
Current Performance
Performance and Optimization

- MLSS: 2,500–5,500 mg/L
- F:M: 0.052
- SRT: 18 days
- Loading: 10.1 lb/d/kcf
- DO: 3.0 mg/L
- ORP: -100 mV
- RAS rate: 50%
- Alum rate: 10 gpd
Current Performance
Performance and Optimization

  - BOD$_5$: 7.3 mg/L
  - TSS: 3.9 mg/L
  - NH$_3$: 0.4 mg/L
  - TN: 4.5 mg/L
  - TP: 0.43 mg/L
Current Performance
Performance and Optimization
Conclusions

- Biological process start-up is not automatic
- Flexibility in design benefits future operation
- Effective TN and BioP is possible at small WWTPs