Nutrient Removal in Activated Sludge wastewater treatment plants

US EPA sponsored webinar for Wastewater Treatment Plant Operators
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Optimizing Nutrient Removal & Wastewater Excellence

Optimizing Nutrient Removal in:

- Oxidation Ditches  
  (January)
- Sequencing Batch Reactors  
  (February)
- Other Activated Sludge WWTPs  
  (Today)

Transitioning from Permit Compliance to Wastewater Excellence  
(April 28, 2022)
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PARSONS, KANSAS  Derek Clevenger

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TODAY
Optimizing Nutrient Removal in Activated Sludge wwtps

Nutrient Removal
Nitrogen: Ammonia → Nitrate ... and ... Nitrate → Nitrogen Gas
Phosphorus: Manufacture the food, feed the bacteria, grow the bacteria, prevent re-release

Case Studies
Wastewater treatment plants operating differently than designed to improve N&P removal
  Sunderland, Massachusetts
  Norris, Tennessee
  Conrad, Montana
  Parsons, Kansas
  Kalispell, Montana
  Nashville, Tennessee
  Helena, Montana

Discussion
Ammonia Removal - 1st Step of N Removal
Step 1: Convert Ammonia ($NH_4$) to Nitrate ($NO_3$)

Oxygen-rich Aerobic Process
Don’t need BOD for bacteria to grow
Bacteria are sensitive to pH and temperature
Nitrate Removal - 2\textsuperscript{nd} Step of N removal
Step 1: Convert Ammonia (NH₄) to Nitrate (NO₃)

Oxygen-rich Aerobic Process
Don’t need BOD for bacteria to grow
Bacteria are sensitive to pH and temperature

Step 2: Convert Nitrate (NO₃) to Nitrogen Gas (N₂)

Oxygen-poor Anoxic Process
Do need BOD for bacteria to grow
Bacteria are hardy
THREE steps
Biological Phosphorus Removal

Step 1: prepare “dinner”

VFA (volatile fatty acids) production in septic/fermentive conditions
Biological Phosphorus Removal

Step 1: prepare “dinner”
VFA (volatile fatty acids) production in septic/fermentive conditions

Step 2: “eat”
Bio-P bugs (PAOs, “phosphate accumulating organisms”) eat VFAs in anaerobic/fermentive conditions ... temporarily releasing more P into the water
Biological Phosphorus Removal

Step 1: prepare “dinner”
VFA (volatile fatty acids) production in septic/fermentive conditions

Step 2: “eat”
Bio-P bugs (PAOs, “phosphate accumulating organisms”) eat VFAs in anaerobic/fermentive conditions ... temporarily releasing more P into the water

Step 3: “breathe” and grow
Bio-P bugs (PAOs) take in almost all of the soluble P in aerobic conditions as they grow and reproduce
Questions?
Comments?
What do you think?
SHALL WE BEGIN
Kansas, cont’d
Abilene
Andover
Arkansas City
Baldwin City
Basehor
Beloit
Bonner Springs
Buhlert
Caney
Chanute
Chisholm Creek
Coffeyville
Derby
De Soto
Ellinwood
Eudora
Garden Plain
Gardner
Garnett
Goddard
Great Bend
Halstead
Haysville
Herington
Hiawatha
Holton
Independence
Kansas City #14 & 20
Kingman
Lansing
Lakewood Hills
Lyons
Medicine Lodge
Miami CO - Bucyrus
Miami CO - Walnut Creek
Norton
Osawatomie
Parsons
Phillipsburg
Pratt
Riley CO - University Park
Rose Hill
Shawnee CO - Sherwood
St. Marys
Spring Hill
Tonganoxie
Topeka North
Wamego
Wellington
Wellsville
Wichita Plants 1&2
Winfield
Yates Center

Kentucky
Hopkinsville

Massachusetts
Amherst
Barnstable
Easthampton
Greenfield
Montague
Newburyport
Northfield
Palmer
South Deerfield
South Hadley
Sunderland
Upton
Westfield

Montana
Bigfork
Big Sky
Billings
Boulder
Bozeman
Butte
Chinook
Choteau
Colstrip
Columbia Falls
Conrad
Craig
Dillon
East Helena
Forsyth
Gallatin Gateway
Glendive
Great Falls
Hamilton
Hardin
Havre
Helena
Kalispell
Laurel
Lewistown
Libby
Lolo
Manhattan

Montana, cont’d
Miles City
Missoula
Stevensville
Wolf Creek

New Hampshire
Keene

North Carolina
Asheboro
Eden - Mebane Bridge
Newton
Reidsville

South Carolina
Greeneville

Tennessee
Athens
Baileyton
Bartlett
Chattanooga
Collierville
Cookeville
Cowan
Crossville
Dickson – White Bluff
Harpeth Valley

Tennessee, cont’d
Harriman
Humboldt
Lafayette
La Follette
Livingston
McMinnville
Millington
Nashville Dry Creek
Norris
Oak Ridge
Oneida

Virginia
Strasburg

Washington
Alderwood
Everett
King CO Brightwater
Lake Stevens
Marysville
Mukilteo
Sultan

Wyoming
Laramie
Sunderland, Massachusetts
Population: 3,700
0.5 MGD design flow
Sunderland, Massachusetts

Not designed for nitrogen removal
   Effluent total-nitrogen now 8 mg/L, was 25 mg/L

Not designed for phosphorus removal
   No change

Process changes
   Raised MLSS
   Cycle air/off

Costs
   Portable ORP probe
   Aeration timers

Savings
   Electricity
   Sludge disposal
   Facility upgrade
https://www.tpomag.com/editorial/2017/04/simple_solutions_for_process_improvement
Norris, Tennessee Population: 1,450 0.2 MGD design flow
Norris, Tennessee

Not designed for nitrogen removal
   Effluent total-nitrogen now 6 mg/L, was ??

Not designed for phosphorus removal
   Effluent total-phosphorus now 2-3 mg/L, was 3-4

Process changes
   Raised MLSS
   Cycle air/off
   Created fermentation zone

Costs
   Piping & Fermenters (IBC totes)
   Aeration timers

Savings
   Electricity
   Facility upgrade
Norris, TN: Nitrogen Removal

Nitrogen Removal
Raise MLSS concentration
Cycle aeration:
ON 2-3 hours
OFF 1½-2 hours
Norris, Tennessee
Effluent Nitrogen: 2018-2021

- Monthly Average
- Average of prior 12 months

Effluent total-Nitrogen (mg/L)
Norris, TN: First try at Phosphorus Removal

Phosphorus Removal
Recycle RAS through fermenters
Norris, TN: Second try at Phosphorus Removal

Phosphorus Removal
Create Fermentation Zone in Aeration Tank ...
Air off
70% RAS to aeration
Norris, TN: Third try at Phosphorus Removal

**Phosphorus Removal**
Hold influent in tote fermenters
- and -
Create Fermentation Zone in Aeration Tank
Norris, Tennessee
Effluent Phosphorus: 2018-2021

- Monthly Average
- Average of prior 12 months
Questions?
Comments?
What do you think?
EPA Technical Assistance Webinar Series

Improving CWA–NPDES Permit Compliance

On this page:
- Upcoming Webinars
- Recorded Webinars

This technical assistance webinar series supports the joint EPA and Authorized State Significant Noncompliance (SNC) Rate Reduction National Compliance Initiative (NRCI). The SNC NO is aimed at improving surface water quality and reducing potential impacts on drinking water by assuring that all Clean Water Act (CWA) – National Pollutant Discharge Elimination System (NPDES) permittees are complying with their wastewater discharge permits.

This page includes registration information for upcoming webinars as well as recordings and supplemental materials for past webinars.

Intended Audience: The webinars are intended for plant operators, municipal leaders, technical assistance providers, and compliance inspection staff from federal, state, tribal and local governments. Every plant is unique and plant operators should discuss any major operational changes with their NPDES permitting authority.

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For additional information, contact: Laura Paradisi (lauri.paradisi@epa.gov) or Peter Bahor (peter.peter@epa.gov)

Upcoming Webinars
- Thursday, March 31, 2022 (1:00 – 2:30pm Eastern)
  Optimize Nutrient Removal in Activated Sludge WWTPs
  Presenter: Grant Weaver, PE, President, Grant Tech, Inc

- Thursday, April 28, 2022 (1:00 – 2:30pm Eastern)
  Transitioning from Permit Compliance to Wastewater Excellence
  Presenter: Grant Weaver, PE, President, Grant Tech, Inc

Recorded Webinars
epa.gov/compliance/technical-assistance-webinar-series-improving-cwa-npdes-permit-compliance

- or search –

“EPA Technical Assistance Webinar Series”
Conrad, Montana

Population: 2,500

0.5 MGD design flow
Conrad, Montana

Not designed for nitrogen removal
   Effluent total-nitrogen now 4-8 mg/L, was 30

Not designed for phosphorus removal
   Effluent total-phosphorus now 0.2-0.4 mg/L, was 2.5-3.0

Process changes
   Raised MLSS
   Cycle air/off in both aeration and digester
   Returned fermented MLSS to aeration

Costs
   Lab testing equipment

Savings
   Electricity
   Facility upgrade
Questions?
Comments?
Parsons, Kansas       Population: 9,700       2.5 MGD design flow
Parsons, Kansas

“Continuously Sequencing Reactor” Process

Designed for nitrogen removal
  Air cycles ON for ammonia removal
  Air cycles OFF for nitrate removal
Effluent total-Nitrogen
Parsons, Kansas

Nitrogen concentration (mg/L)

- Monthly average tN
- Rolling AVG tN
Parsons, Kansas

“Continuously Sequencing Reactor” Process

Designed for nitrogen removal
   Air cycles ON for ammonia removal
   Air cycles OFF for nitrate removal

Not designed for phosphorus removal
   NO CHEMICALS
   WAS (waste sludge) sent to digesters
   Digester air is OFF long enough for VFA production and consumption by bio-P bugs
   When sludge is wasted into digesters during air-ON cycles, energized bio-P bugs are sent back
to the aeration basin for Phosphorus removal
Questions?
Comments?
What do you think?
Kalispell, Montana  
Population: 23,200  
5.4 MGD design flow
Kalispell, Kansas

Modified Johannesburg Process with final effluent filtration

Designed for nitrogen removal
- Air-on zones for ammonia removal
- Air-off zones for nitrate removal

Designed for biological phosphorus removal ... no chemicals
- Sidestream fermenter for VFA (volatile fatty acid) production
- Anaerobic zones for energizing bio-P bugs
- Aerobic zones for bio-P bug growth

4-month trial
- Air turned off in large air-on zone
- Primary effluent bypassed treatment units to trial “post-anoxic” zone for nitrate removal
Nashville Dry Creek        Population: 678,000        24 MGD design flow
Dry Creek wwtp
Nashville, Tennessee

Conventional plug-flow aeration with anaerobic selector

Not designed for nitrogen removal
  Nitrate removal during 6-month trial by step-feed flow to air-ON / air-OFF aeration zone

Not designed for phosphorus removal ... but ...
  Anaerobic selector provides habitat for VFA production & “eating” by bio-P bugs
  Phosphorus removal during aeration as bio-P bugs multiply

Benefits
  Potentially significant electrical savings
  Potential money savings design strategy for Metro’s Dry Creek and White Creek wwtps
Helena, Montana       Population: 31,500       5.4 MGD design flow
Helena, Montana

Modified Ludzack-Ettinger (MLE) Biological Nutrient Removal (BNR) Process

Designed for nitrogen removal ... yet 2 mg/L improvement to 4 mg/L total-N

3 aeration zones
2 anoxic zones with internal recycle from 2 aeration zones

Not designed for phosphorus removal ... 25% improvement to 1.5 mg/L

Short-term: “De-tune” primary clarifiers
Long-term: repurpose first anoxic zone by relocating internal recycle outlet

Monetary expenses / savings
Field testing equipment
More staff time spent on process control
Now operating with 3 bio-reactors vs. 2
Potential change to contemplated $50 million+/ - upgrade
Optimizing Nutrient Removal & Wastewater Excellence

Wastewater Excellence
April 28: Transitioning from Permit Compliance to Wastewater Excellence
Comments & Questions

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