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Green Solutions For Achieving Your Limits

2018

Biological Nitrogen Removal Workshop

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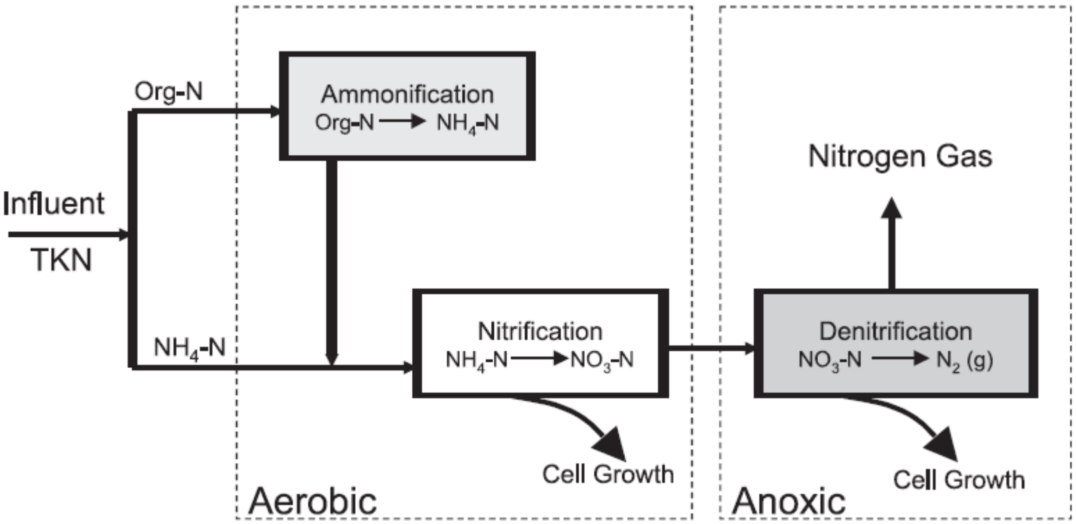
Nitrogen

- Forms of Nitrogen in Domestic Sewage
  - Primary Effluent
    - TKN: 25-50 mgN/L
  - Side-stream or Sludge Handling
    - TKN: 100-1,000 mgN/L



Florida Water Resources Journal 2005

- Process
  - Nitrification
  - Denitrification

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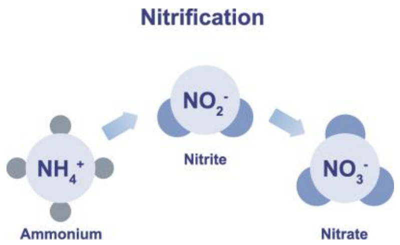
Nitrification



- Autotrophic Bacteria
  - Nitrification is a two step biochemical process performed by specific bacteria known as nitrifiers that convert ammonia to nitrate
  - use carbon dioxide as the carbon source
  - use ammonia and oxygen as an energy source

$$NH_3 + 2\,O_2 \rightarrow NO_3^- + H^+ + H_2O$$

  - $NH_3 + 1.5\,O_2 \rightarrow NO_2^- + H^+ + H_2O$ *by Ammonia Oxidizing Bacteria (AOB)*
  - $NO_2^- + 0.5\,O_2 \rightarrow NO_3^-$ *by Nitrite Oxidizing Bacteria (NOB)*

- To Oxidize 1 g NH_3-N:
  - 4.57 g O_2 is needed (3.43 g O_2 for Nitrite and 1.14 g O_2 for Nitrate)
  - 7.14 g of Alkalinity as $CaCO_3$ is needed ($\frac{2\times 50 g - CaCO_3/eq}{14\ g-N}$)
    - $NH_4^+ + 2HCO_3^- + 2O_2 \rightarrow NO_3^- + 2CO_2 + 3H_2O$
  - Considering the whole biological process including the assimilation for nitrification of 1 g Ammonia:
    - 4.25 g of O_2 are utilized
    - 0.16 g of new cells are formed
    - 7.07 g of alkalinity as $CaCO_3$ are removed
    - 0.08 g of inorganic Carbon are utilized in the formation of new cell

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Process Parameter - Nitrification

- **Oxygen:**
  - DO is normally maintained at 2 mg O_2/L to have the optimal nitrification rate.
- **Temperature:**
  - Higher temperature increases the growth rate. Every 10 °C increase in Temp doubles the growth rate of Nitrifiers and cuts the required MLSS in half
- **pH:**
  - Nitrification is pH sensitive and rates decline significantly below pH 6.8
  - At pH 6 and below the rates may be 10% of the rate at pH 7
  - Optimal Nitrification rate occurs at pH values in the 7.5-8 range
  - A pH 7.2 is normally used to maintain the reasonable nitrification rate
- **Toxicity:**
  - Nitrifying organisms are sensitive to a wide range of organic and inorganic compounds (organic solvents, amines, proteins, phenolic compounds, alcohols, benzene and etc.)
  - Metals: complete inhibition of growth occurs at 0.1 mg/L copper and 0.25 mg/L nickel.
  - Un-Ionized Ammonia: at 20 °C and pH 7, NH_4-N concentration at 100 mgN/L and 20 mgN/L may initiate inhibition of AOB and NOB respectively.
- **Alkalinity:**
  - Added depending the initial alkalinity and ammonia in the influent (7.15 Ib alkalinity as $CaCO_3$ per Ib of Ammonia)
- **SRT:**
  - Typical design SRT values may range from 10-20 days at 50 °F to 4-7 days at 68 °F

Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

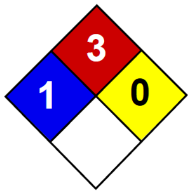
- Heterotrophic Bacteria
  - Denitrification is a biochemical process performed by specific bacteria known as heterotrophs that convert nitrate to nitrogen gas
  - use organic carbon as the carbon source

    $NO_3 + BOD \rightarrow N_2 + OH^- + H_2O + CO_2$

    - *Anoxic Condition*
    - Mixing and Nitrogen Recycle

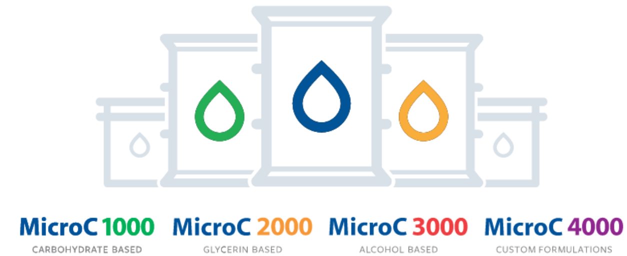
- Important Process parameter :
  - Carbon: Denitrification rate depends upon the availability of carbon. Theoretically 2.86 g BOD is needed to reduce Nitrate to Nitrogen gas (**Practically <u>6 g BOD</u>**)
    - $\frac{BOD}{NO3-N} = \frac{2.86}{1-1.42Y_n}$; $\quad$ *where* Y_n *is net biomass yield* $\frac{g-VSS}{g-BOD}$
  - 3.57 g of Alkalinity as CaCO3 is formed (~Recovering the 50% of consumed alkalinity in nitrification)
  - 0.45 g of New Cells will be formed
  - O_2: Anoxic condition, DO should be less than 0.2 mg O_2/L
  - pH: Denitrifiers are less sensitive to pH than Nitrifiers. pH recommended range is 7.2
  - SRT: 3-6 days

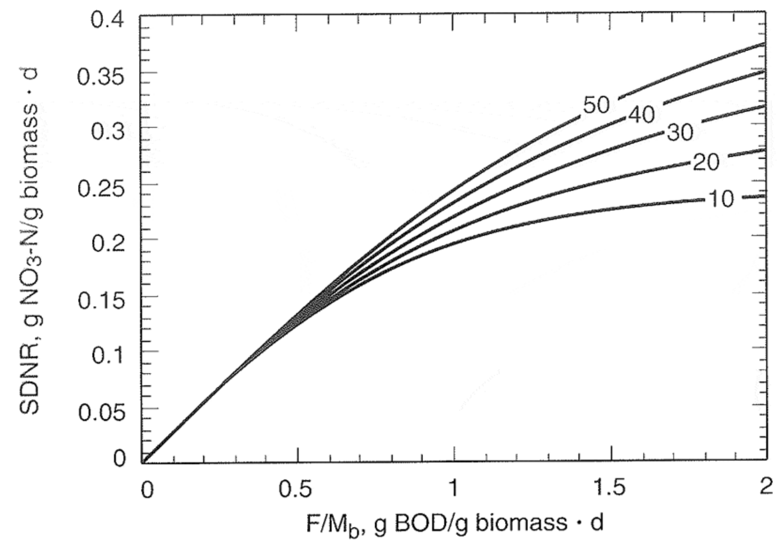
Typical WW Supplemental Carbon Sources:



- Alcohol base: Methanol
  - –Safety: Several incidents and explosion has been reported
    - Bethune Point Wastewater Plant Explosion, 2006
      - Two municipal workers died and another was seriously injured while attempting to remove a steel canopy above a methanol storage tank at the Bethune Point wastewater plant operated by the City of Daytona Beach.

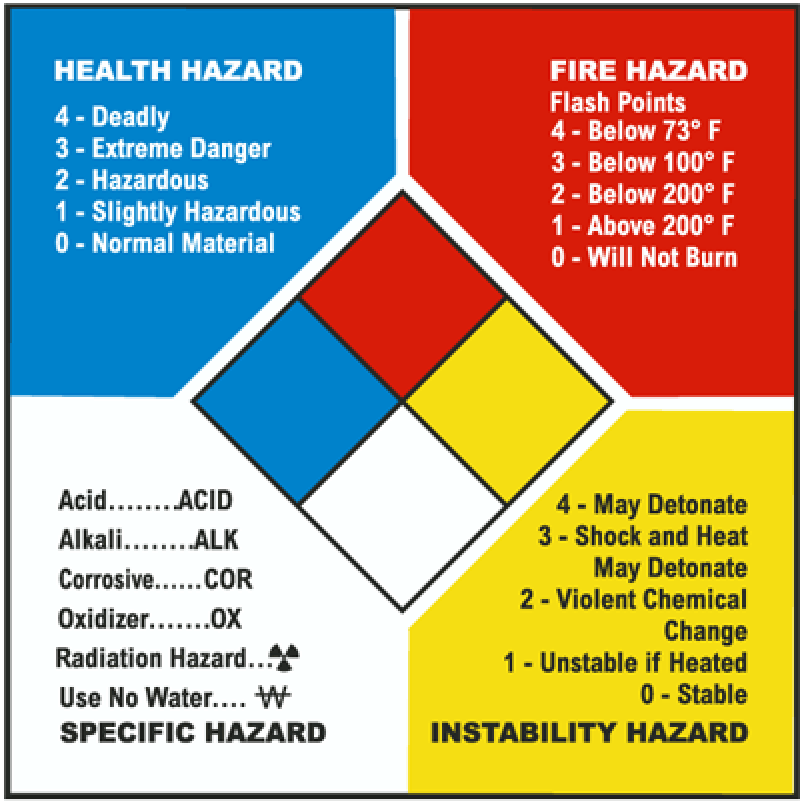
- Glycerol base: MicroC® 2000
  - –Safety: No incident has been reported





Specific denitrification rate as function of F/M ratio and the ratio of readily biodegradable BOD to total BOD (Metcalf & Eddy, 2003).

The National Fire Protection Association (NFPA)



COD Calculation

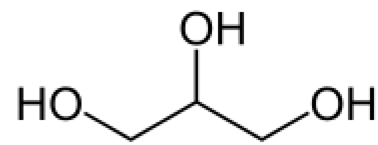
- Chemical Oxygen Demand

$$COD = \frac{Sum\ of\ \ Y \times 8}{MW_{Compound}} \times Density_{Compound}$$

Element	Degree of Reduction (Y)
C: Carbon	+4
O: Oxygen	-2
H: Hydrogen	+1
N: Nitrogen	-3

Calculate the COD of Glycerol (Glycerin)

- Glycerol:
  - Glycerol: $C_3H_8O_3$
  - $Glycerol\ Density$: $1{,}261\ \frac{g}{L}$
  - $Molecular\ Weight$: $92.1\ \frac{g}{mol}$



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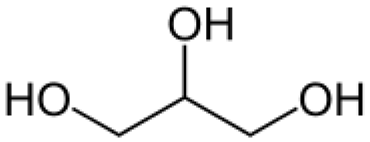

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$$COD = \frac{Sum\ of\ \ Y \times 8}{MW_{Compound}} \times Density_{Compound}$$

$$COD_{C_3H_8O_3} = \frac{[3 \times (+4) + 8 \times (+1) + 3 \times (-2)] \times 8}{92.1\,\frac{g}{mol}} \times 1{,}261\,\frac{g - Glycerol}{L}$$

$$COD_{C_3H_8O_3} = \frac{[12 + 8 - 6] \times 8}{92.1\,\frac{g}{mol}} \times 1{,}261\,\frac{g - Glycerol}{L} = 1{,}533\,\frac{g - COD}{L - Glycerol}$$

Case Study:

A chemical manufacturing company claims they have a product that is 75% glycerin with a chemical oxygen demand (COD) concentration of 1,400 g/L. They claim the higher COD value will allow you to reduce your dosing rate and save your plant money. Do you think their claim is valid based on your knowledge as a wastewater engineer?

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$$100\%\ Glycerol\ COD = 1{,}533\,\frac{g - COD}{L - Glycerol}$$

$$75\%\ Glycerol\ COD \sim 0.75 \times 1{,}533\,\frac{g - COD}{L - Glycerol} = 1{,}150\,\frac{g - COD}{L - Glycerol}$$

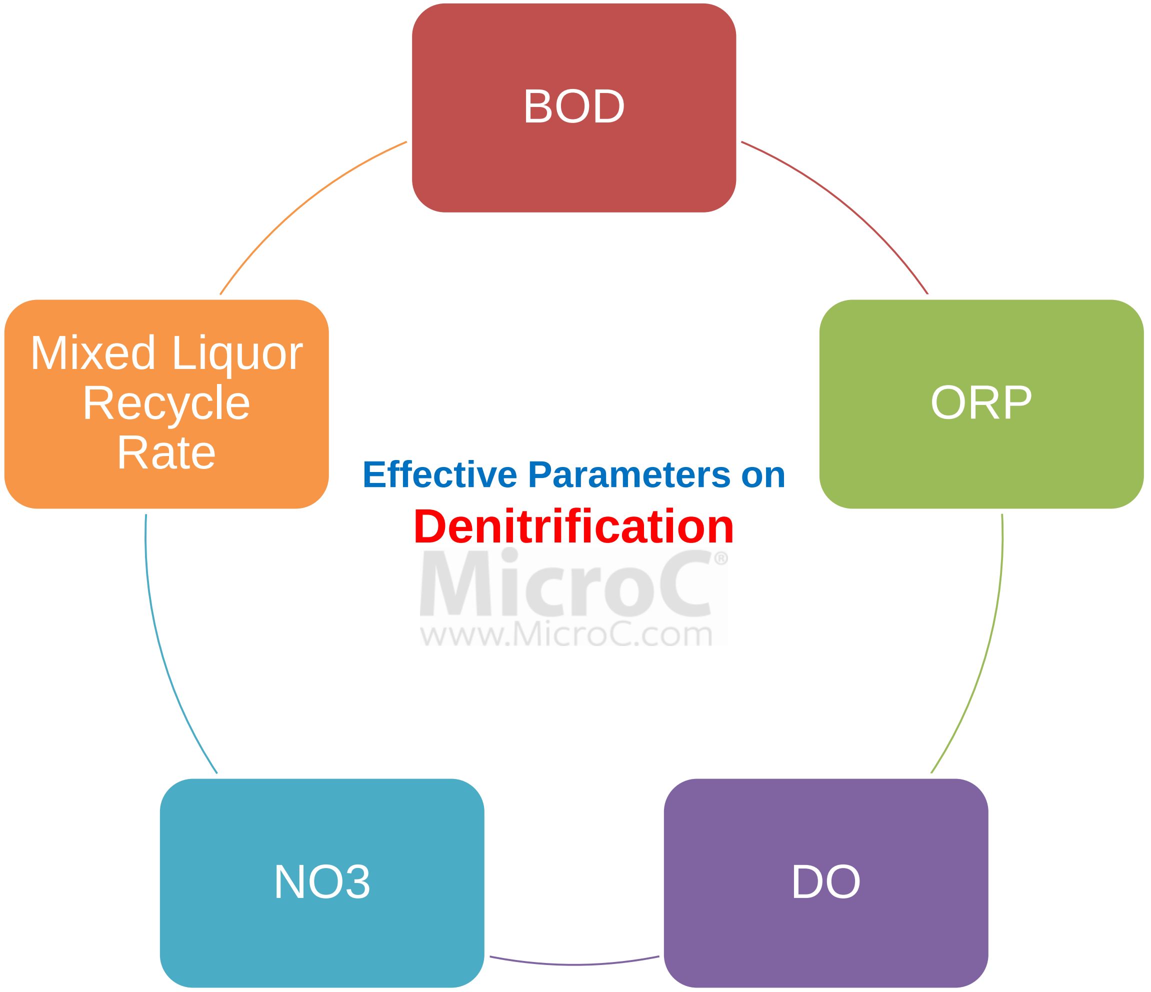
$$\mathbf{75\%\ Glycerol\ COD = 1{,}150\,\frac{g - COD}{L - Glycerol}}\ !!!$$

Case Study

I. Troubleshooting Denitrification: High Nitrate Effluent

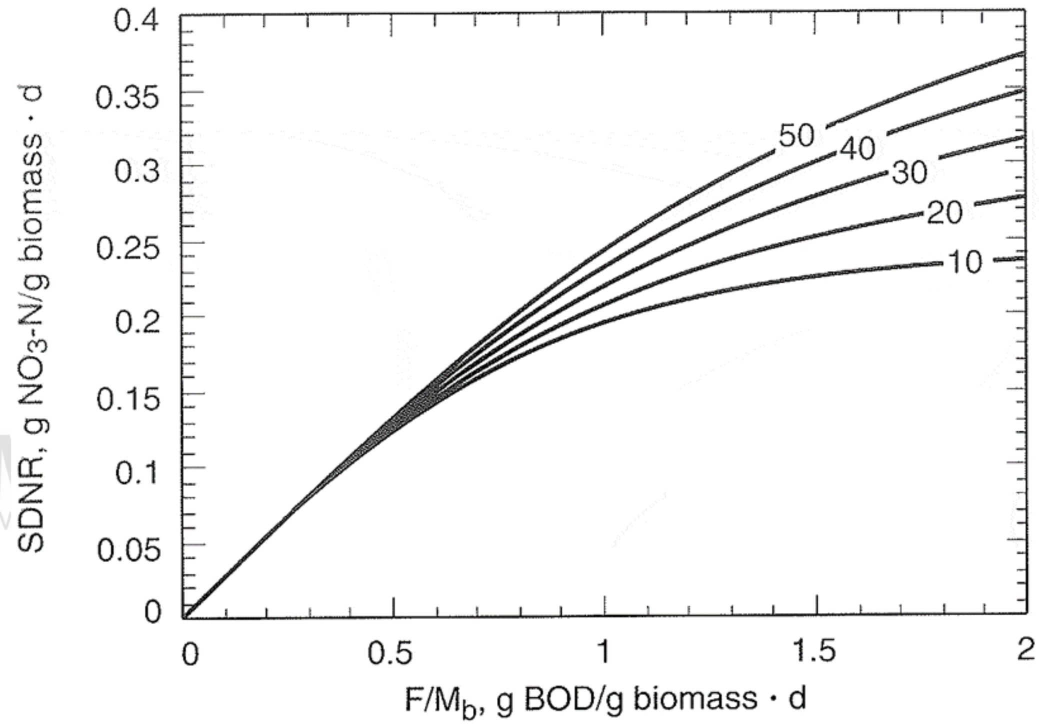
II. Feeding Strategy

Troubleshooting Denitrification: High Nitrate Effluent



Low BOD

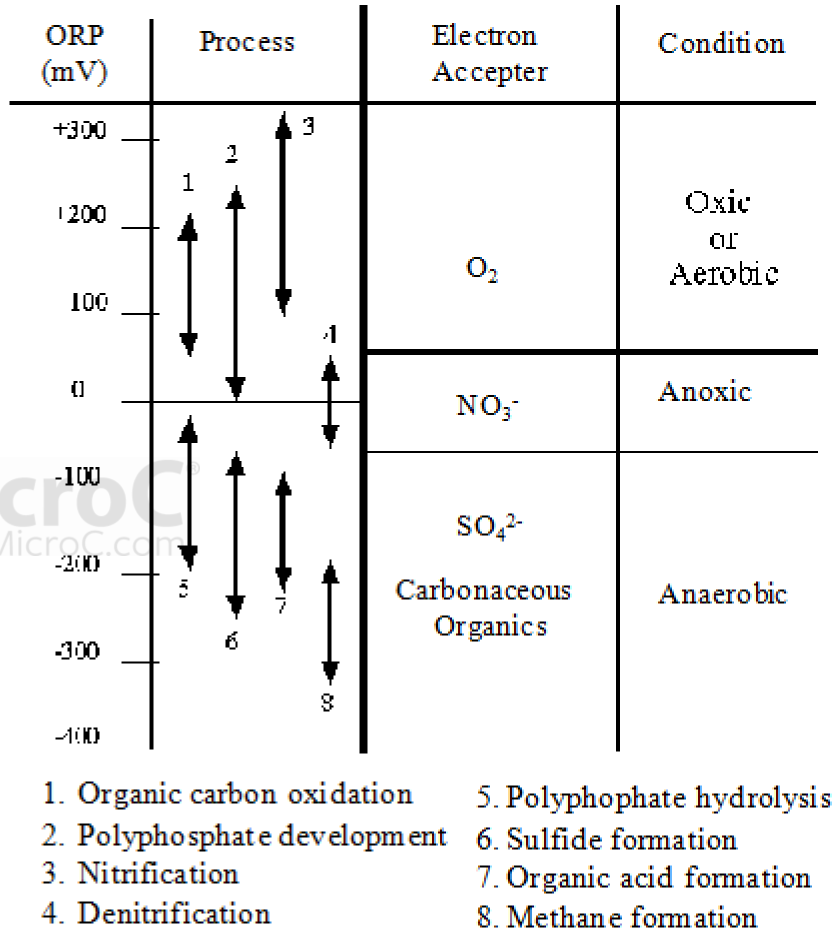
- Theoretically 2.86 Ib of BOD is required to denitrify one Ib-N of NO_3. Practically this number is above 5 mg/L.
- If BOD is not soluble, extra retention time would be required in order to convert particulate BOD to the soluble form.
- Since solubilization is the slowest part of process, it's recommended either to use soluble supplemental carbon or increasing the size of anoxic tank and reducing the MLRcy



Specific denitrification rate as function of F/M ratio and the ratio of readily biodegradable BOD to total BOD (Metcalf & Eddy, 2003)

High ORP and High Recycle O2

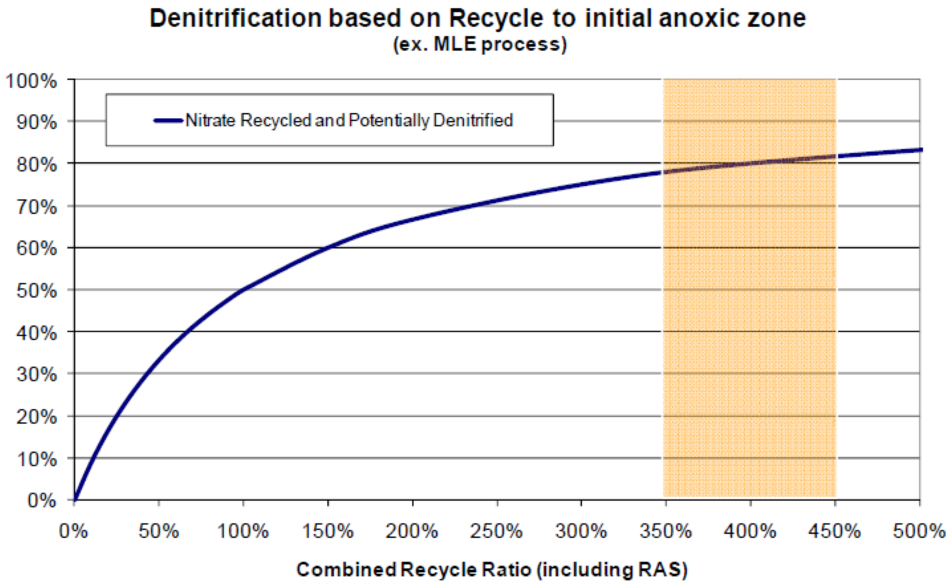
- O_2 can be carried to the anoxic reactor from the aeration basin
- ORP can be used as an indictor.
- Denitrification could occurring in an ORP of -100 to +100 mV. However to achieve better results, it's recommended to keep ORP below 50 mV
- On/Off Aeration: Changing the Regime



Relation between ORP and metabolic processes (Goronsky, 992)

Low Mixed Liquor Recycle Rate

- MLR recycles the nitrate produced in the aeration tank to the anoxic basin.
- To achieve denitrification a significant MLR is required
- Denitrification efficiency may be enhanced by increasing the MLR. However a higher MLR may return excess oxygen to the anoxic tank and the hinder the process.



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Question:

What are the consequences of high

Nitrate/Nitrite in a process?

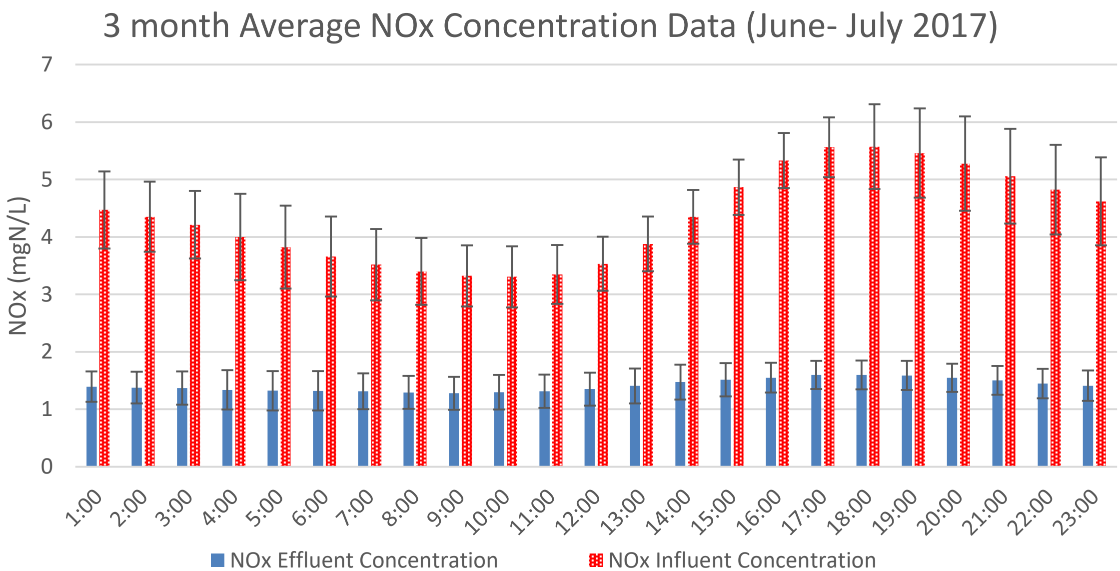
High Nitrite/Nitrate Consequences

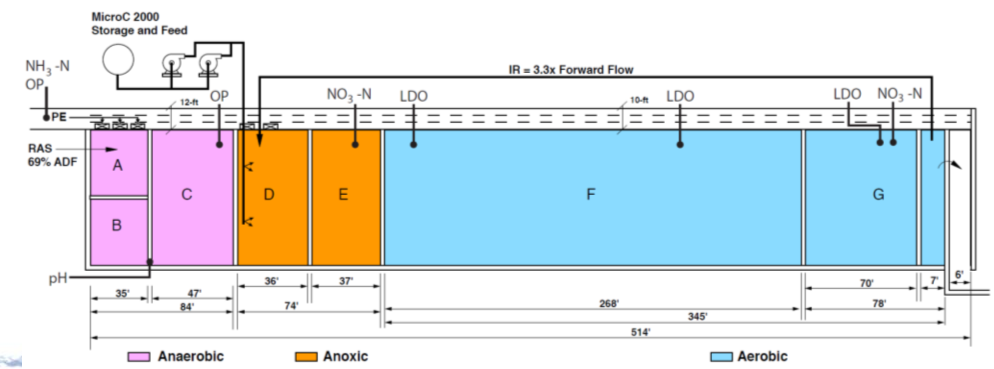
- Alkalinity:
  - High Nitrate corresponds to lower alkalinity recovery and a rise in chemical costs
- Clarifiers
  - Denitrification may occur in the final clarifier. The Nitrogen gas produced may disturb the clarifier and increase the effluent turbidity
- Disinfection
  - Chlorine may be used for denitrification (~5 $\frac{Ib-Cl_2}{Ib-N}$).

$$Cl_2 + H_20 \rightarrow H^+ + OCl^-$$

$$OCl^- + NO_2^- \rightarrow NO_3^- + Cl^-$$

Feeding Strategy
Automation vs Constant Feeding





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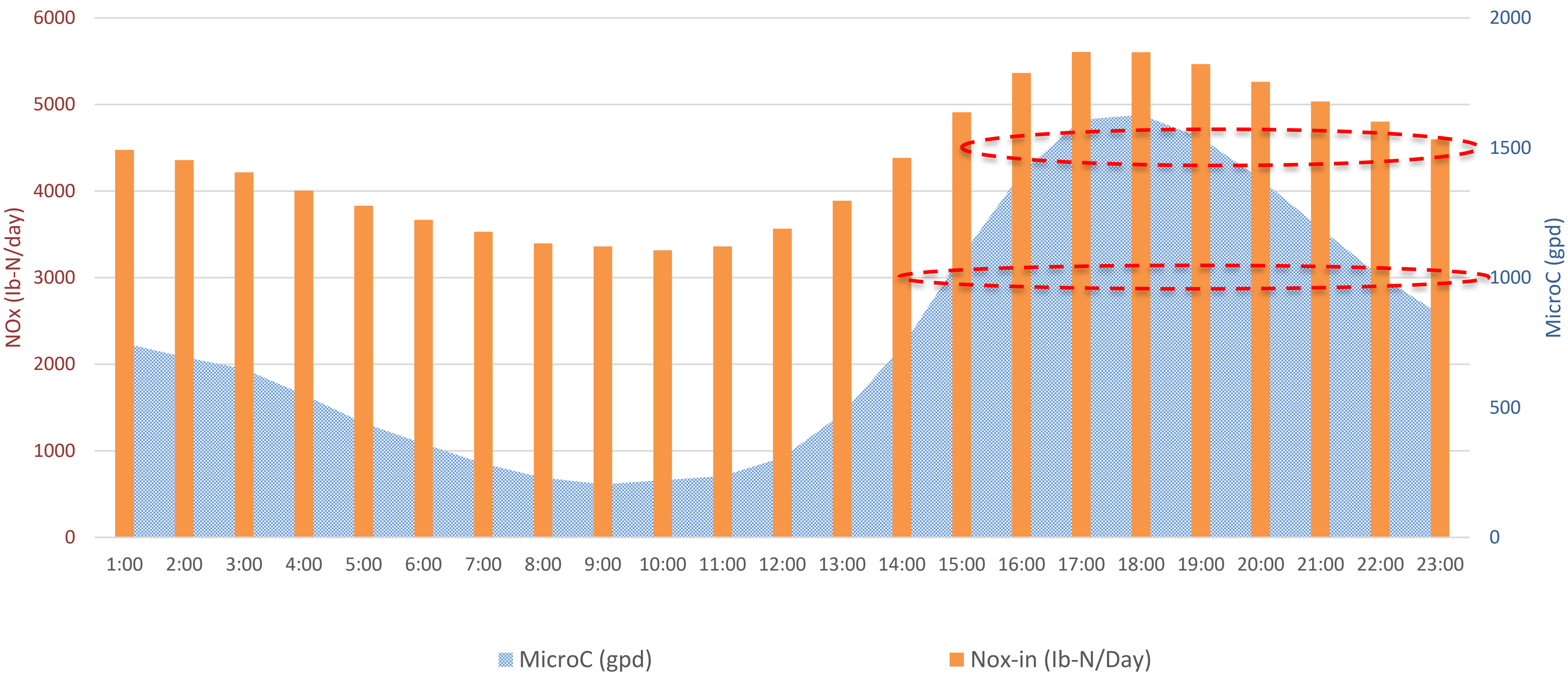
Automation



6000
5000
4000
3000
2000
1000
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2000
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0
NOx (lb-N/day)
MicroC (gpd)
1:00
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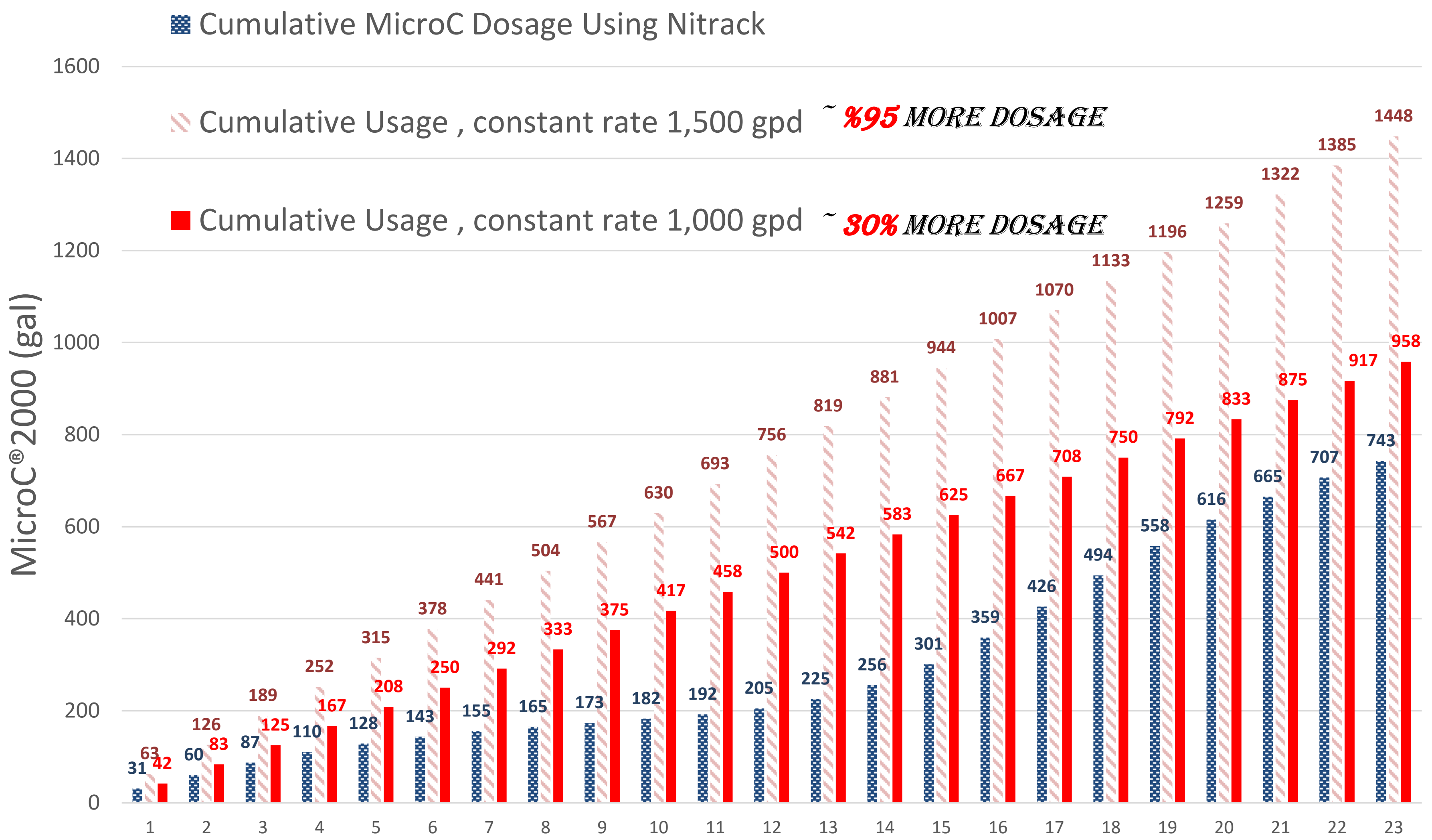
MicroC (gpd)
Nox-in (lb-N/Day)


Cumulative MicroC Dosage Using Nitrack
Cumulative Usage , constant rate 1,500 gpd
~ %95 MORE DOSAGE
Cumulative Usage , constant rate 1,000 gpd
~ 30% MORE DOSAGE
MicroC®2000 (gal)

Environmental Operating Solutions, Inc.

.....*Empowering Clean Water™*

EOSi

Headquartered in Bourne, MA, EOSi is a leading solutions provider for the biological treatment of water and wastewater in North America

Suite of Premium Carbon Sources & Complementary Services

MicroC® 1000
MicroC® 2000
MicroC® 3000
MicroC® 4000

Nitrack®

Process Solutions & Programs

... Enabling Biological Contaminant Removal ...

- Nitrogen
- Phosphorus
- Selenium
- Perchlorate
- BOD Addition

EOSI's Process Solutions & Programs (PS&P) group designs objective based services in alignment with customers' goals

- Sensors & Instrumentation Audit (S&IA):
  - EOSi evaluates monitoring and sampling needs
  - Recommends proper equipment and deployment
  - Trains operators on maintenance and calibration
- Diagnostic Process Analysis (DPA):
  - Establishes a baseline of process performance
  - Analyzes overall plant process and identifies operational risks and excessive costs
- Process Troubleshooting (PT):
  - Employs field equipment, nutrient profiling and available data, including, modeling tools to evaluate process
  - Recommends cost effective solutions with performance guarantees
- MicroC® Evaluation & Application Support (ME&AS):
  - In addition to supplying MicroC® and engineering support, EOSi also provides, instrumentation, storage and feed equipment, as well as inventory management services to accurately and effectively evaluate MicroC®.
- Performance Monitoring & Data Management (PM&DM):
  - Once MicroC is determined to be the long term solution, EOSi provides ongoing engineering support with the objective to continuously optimize the program.
- Process Optimization (PO) :
  - Employs modeling and simulation services along with field calibration to assist customers to optimize biological treatment processes to lower costs and improve compliance

Service Capabilities

- Bench-scale performance evaluations
- Modeling and simulation services
- Nutrient profiling
- Sludge evaluations
- Equipment audits, selection and rental
- Remote monitoring and data analysis

Nitrack® Program

Nitrack® enables MicroC® automation with remote access, creating a conduit for delivering value to our customers

Nitrack® — Think outside the NOx

- Fully automated solution for optimizing customer MicroC® usage while consistently achieving customer objectives:
  - Cost Reduction
  - Consistent Regulatory Compliance
  - Risk Mitigation, eliminate operator error and establish a "second set of eyes" on your operation
- Real time visibility, allows EOSi to provide on-going support establishing strong partnerships with customer.

Nitrack® is custom designed to fit customer's process and operational needs