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Use of Ammonia and Nitrate Sensors for Activated Sludge Aeration Control

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Overview

Sensors Available

- Optical
  - Nitrate / Nitrite
- Ion Selective Electrodes (ISE)
  - Ammonium / Nitrate

ISE Theory of Operation

- Relationship of Ammonia & Ammonium
- Potassium & Chloride Compensation electrodes

Biological Nitrogen Removal basics

Control Strategy

- Ammonium to control aeration rates
- Nitrate to control recycle rates

Case Studies using Ammonia to control aeration rates

Sensors Available

Optical

Based upon principle that nitrates and nitrates absorb certain wavelengths of light – a miniature spectrophotometer

- Advantages:
  - No electrodes to replace
  - Continuous ultrasonic self cleaning

- Disadvantages
  - Cost 3x of ISE
  - No ammonia measurement

Ion Selective Electrode (ISE)

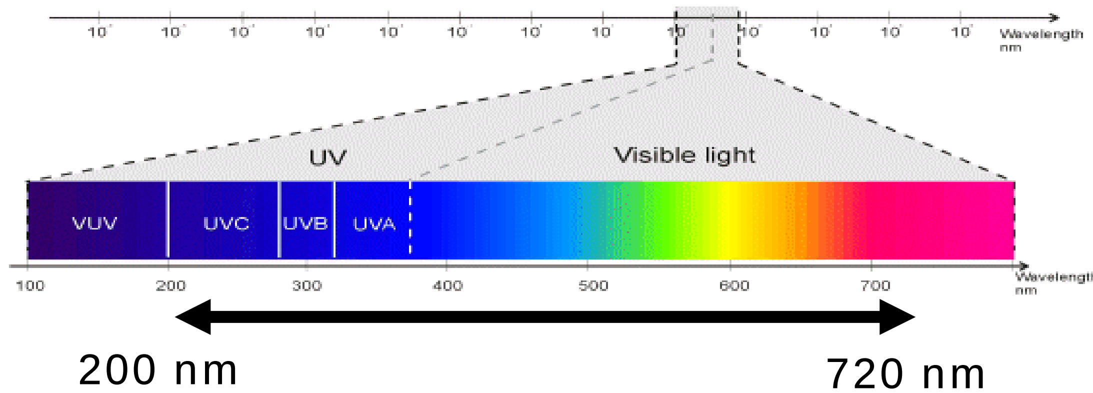
Based upon principle that electrodes generate a mV output proportional to compound of interest

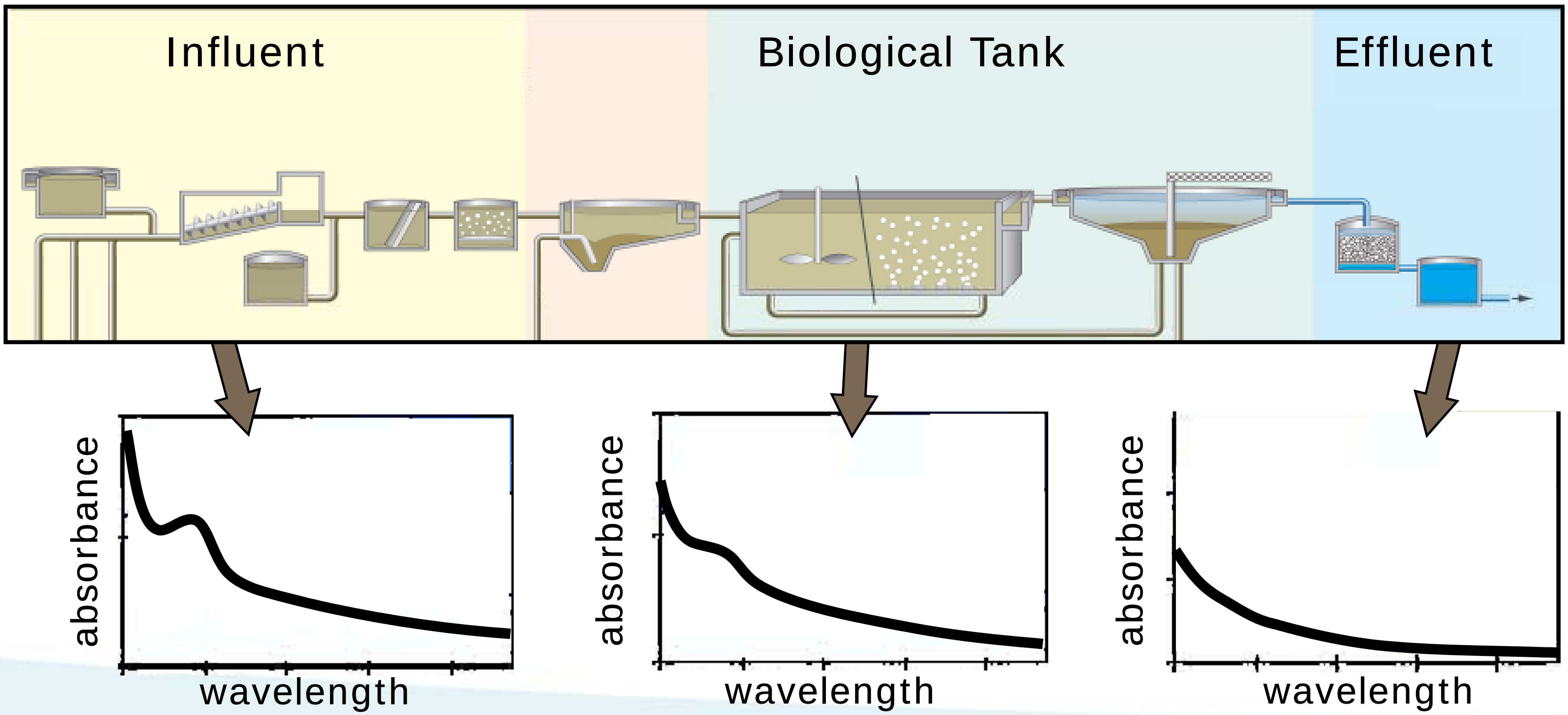
- Advantages:
  - Low cost
  - Measure ammonium and nitrate in one package

- Disadvantages
  - Requires manual or air cleaning
  - Requires replacement electrodes every other year

Theory of Operation

Optical


Wavelength nm
UV
Visible light
VUV
UVC
UVB
UVA
100
200
300
400
500
600
700
Wavelength nm
200 nm
720 nm


Influent
Biological Tank
Effluent
absorbance
wavelength
absorbance
wavelength
absorbance
wavelength

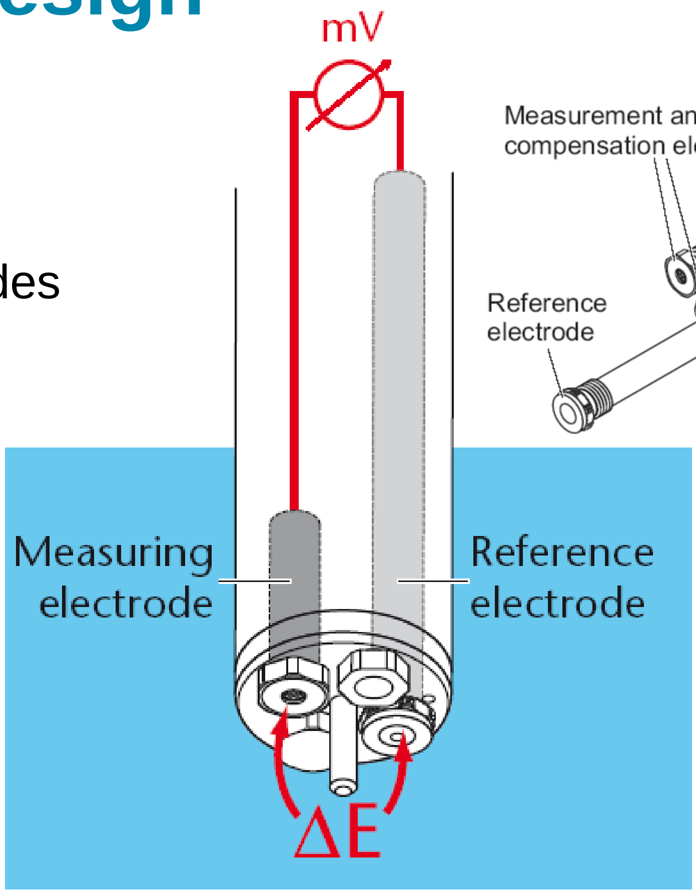
Continuous Ultrasonic Self Cleaning

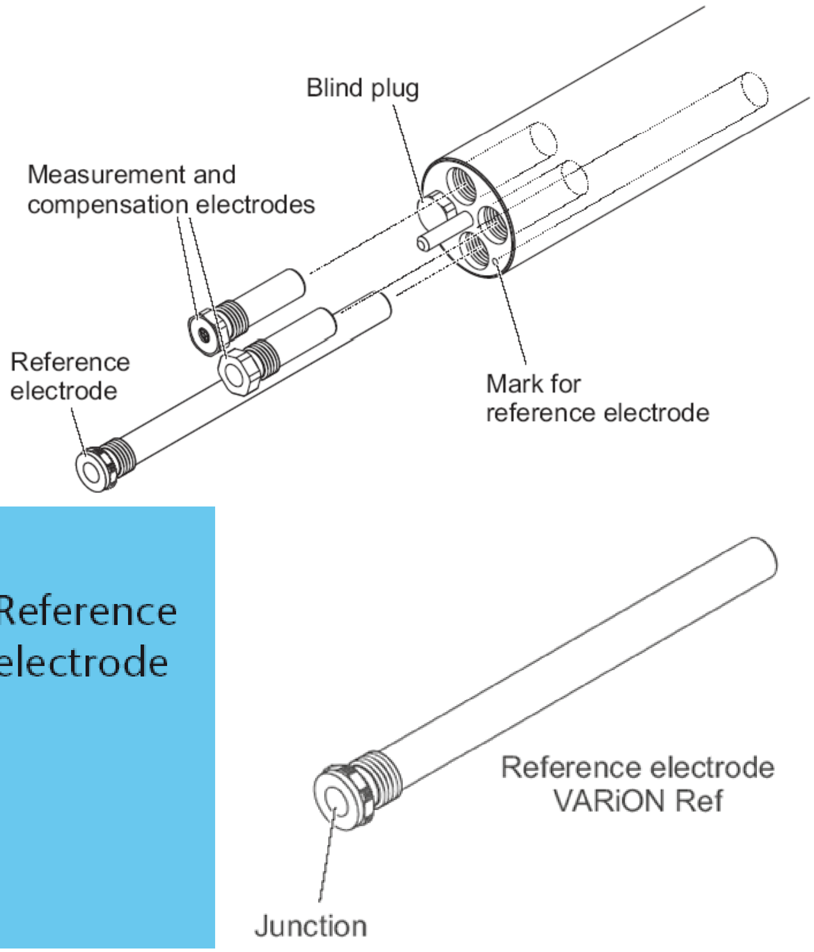
No maintenance
Continuous cleaning
No compressed air requirement

After 1 week of installation,
post trickling filter,
pre aeration contact chamber

ISE Sensor Design

Four Measuring Electrodes
- NH_4-N
- NO_3
- K
- Cl





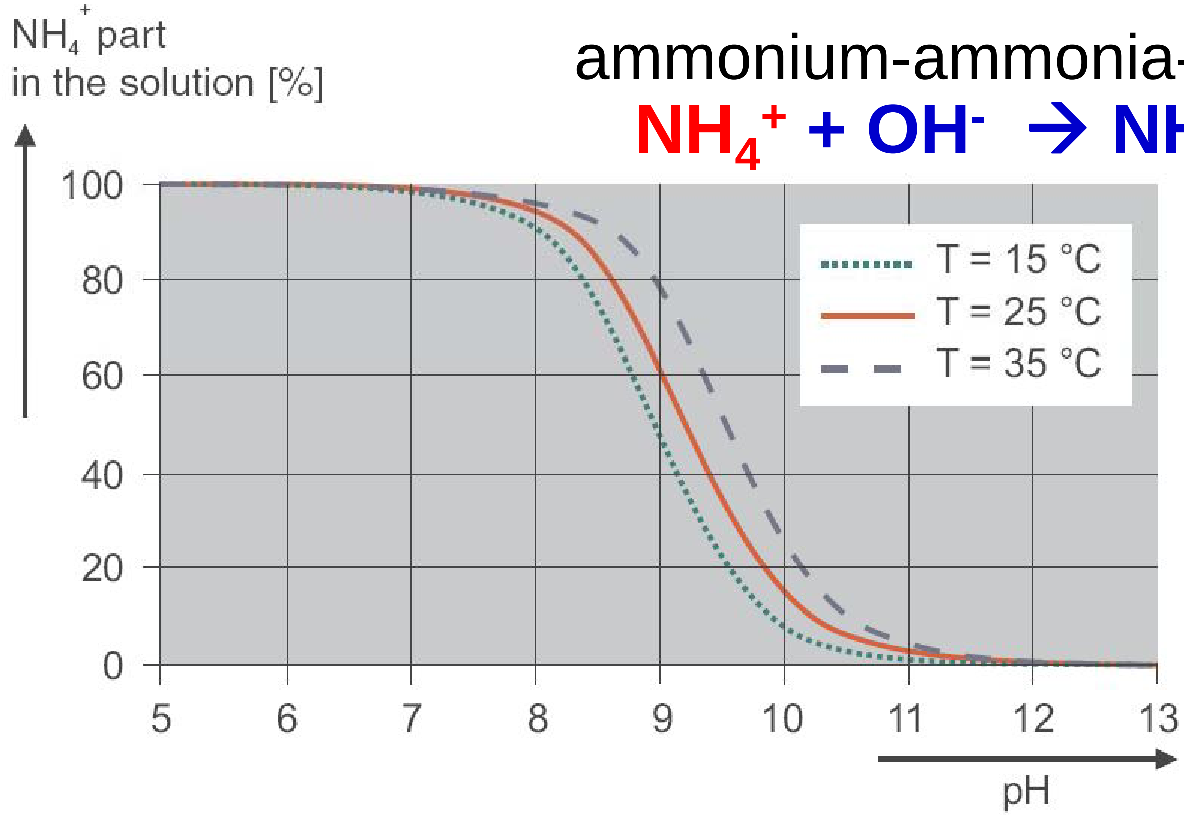
All electrodes can be exchanged individually

New electrodes are automatically recognized

Relationship of Ammonia & Ammonium

ammonium-ammonia-equilibrium

$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$



- **Uncompensated NH_4^+ detection good up to approx. pH 8.5**
- **pH values > 8.5 NH_4^+: detection requires pH compensation**

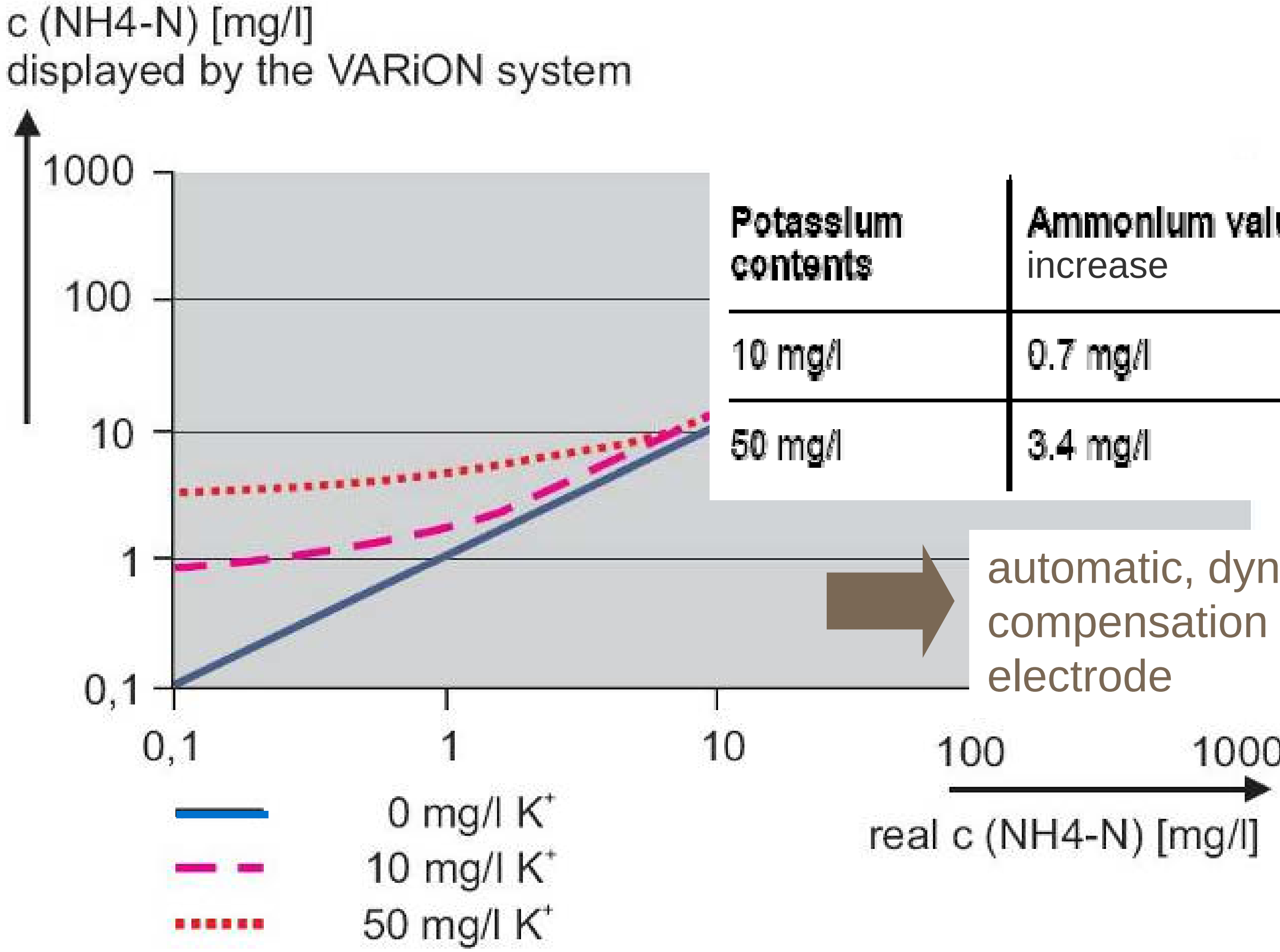
The need for Compensation Electrodes

ISE's have known and predictable interferences:

•Ammonium's primary interference is Potassium

•Nitrate's primary interference is Chloride

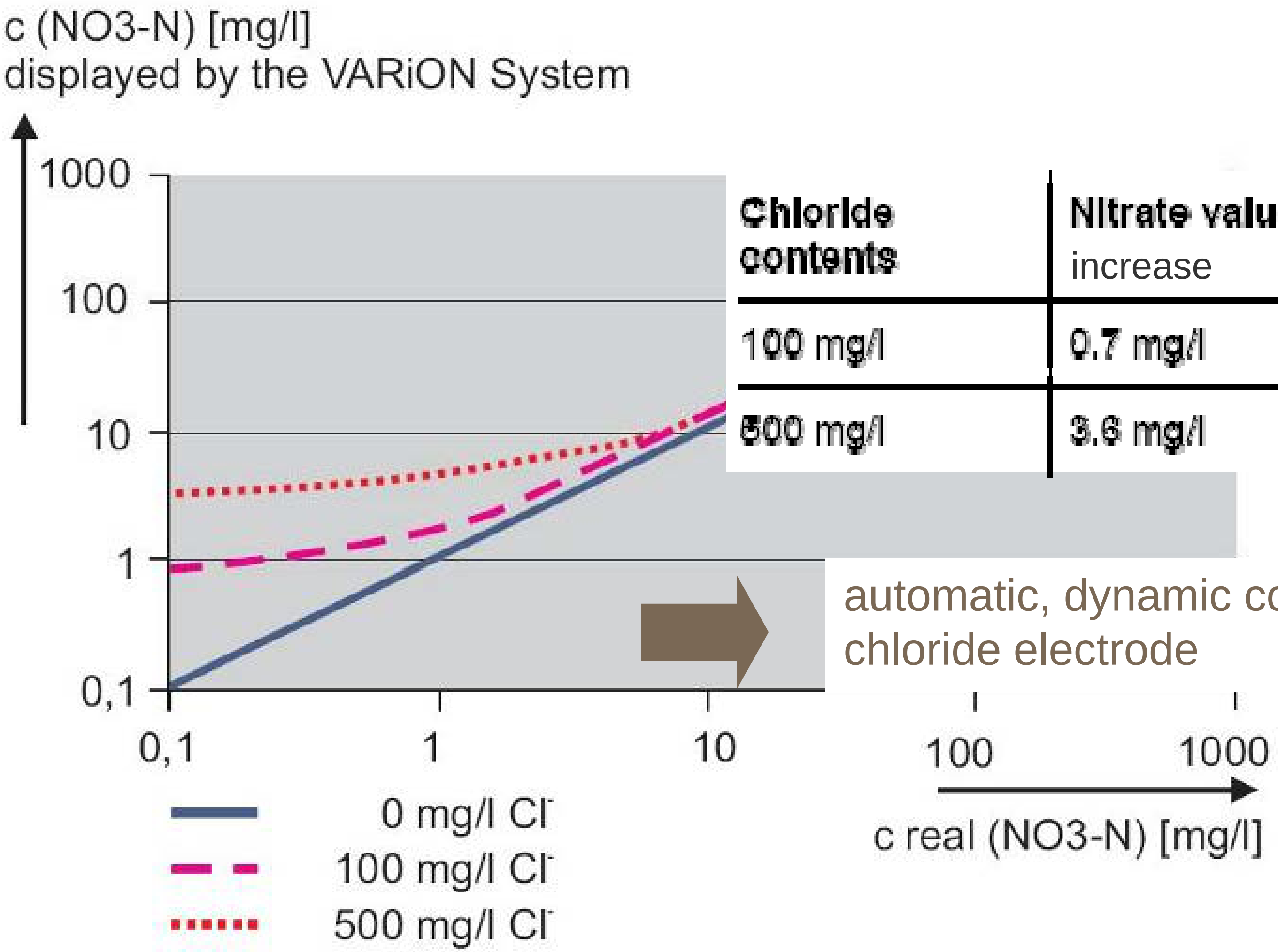
NH_4: Interference mainly by Potassium ions



Potassium contents	Ammonium value increase
10 mg/l	0.7 mg/l
50 mg/l	3.4 mg/l

automatic, dynamic compensation with potassium electrode

NO_3: Interference mainly by Chloride ions



Chloride contents	Nitrate value increase
100 mg/l	0,7 mg/l
500 mg/l	3,6 mg/l

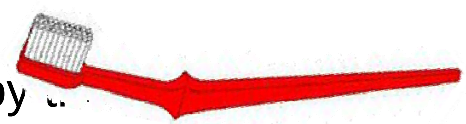
automatic, dynamic compensation with chloride electrode

Robust electrodes

Metal grid effectively protects the sensitive ISE membranes from damage due to physical cleaning

Easily clean electrodes, even with plastic brushes

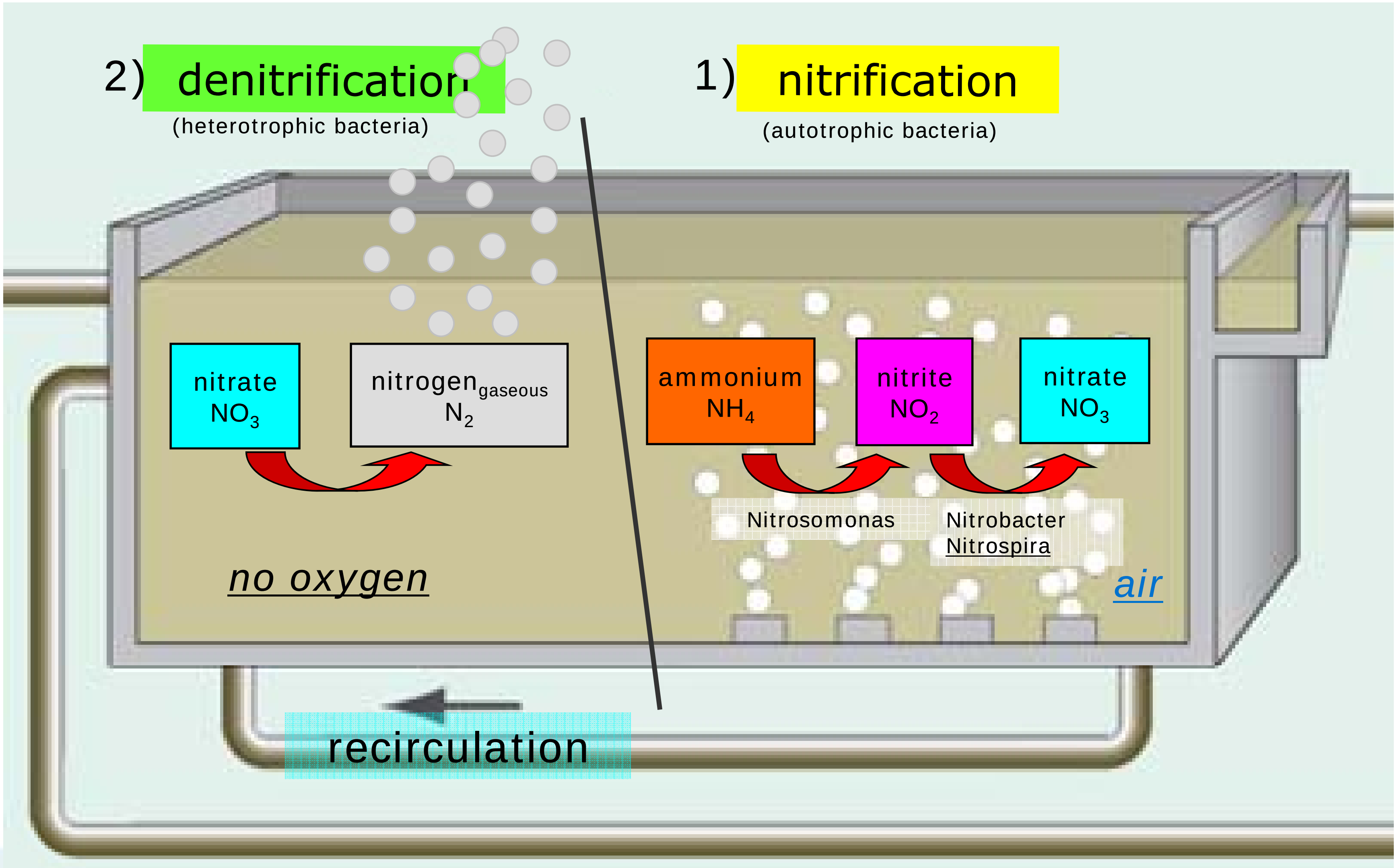
Important:
do not use detergents/soaps for cleaning, as they destroy
membranes



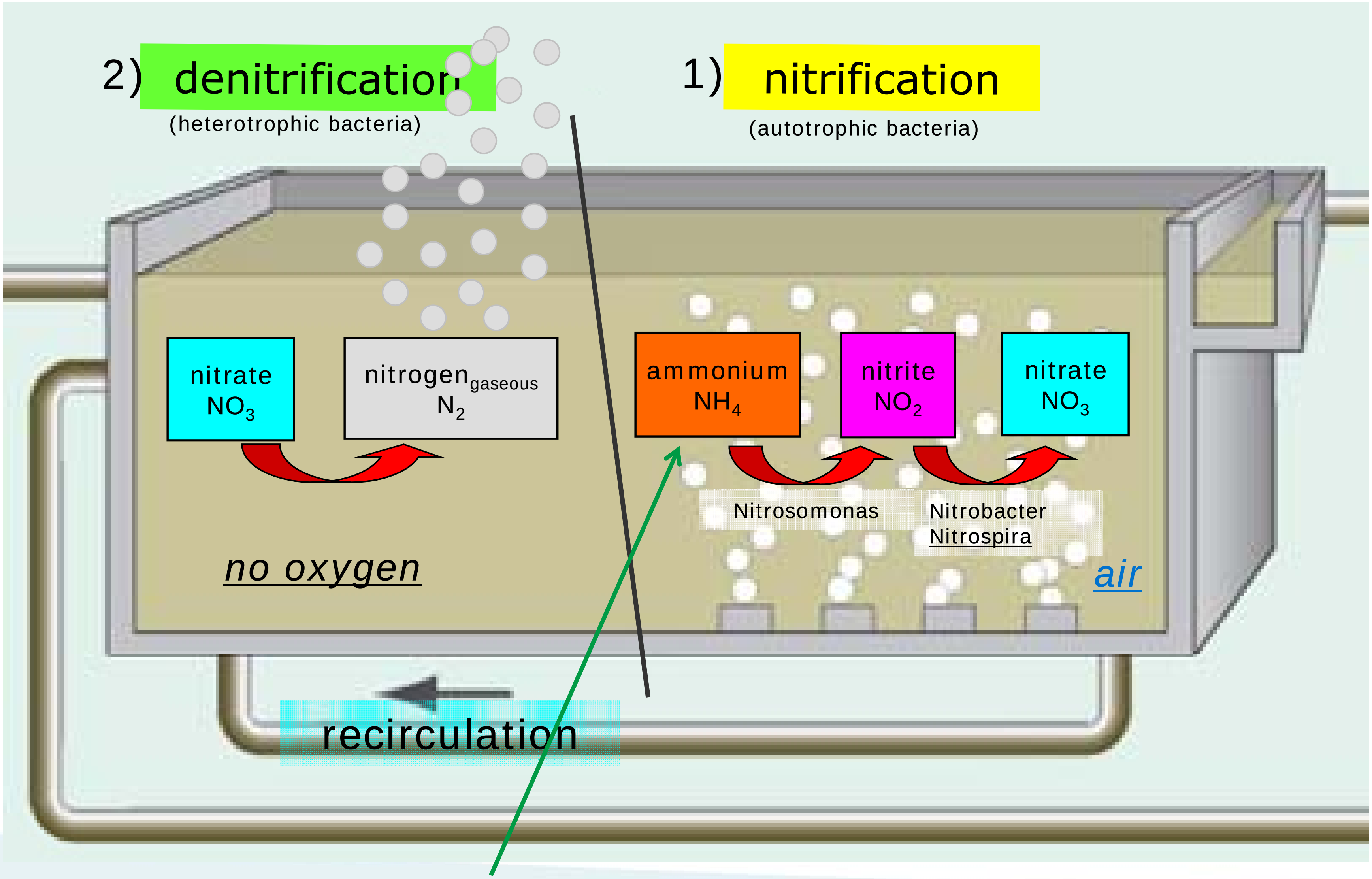
use only warm water and, e.g., a toothbrush

Biological Nitrogen Removal basics

Biological Nitrogen Removal

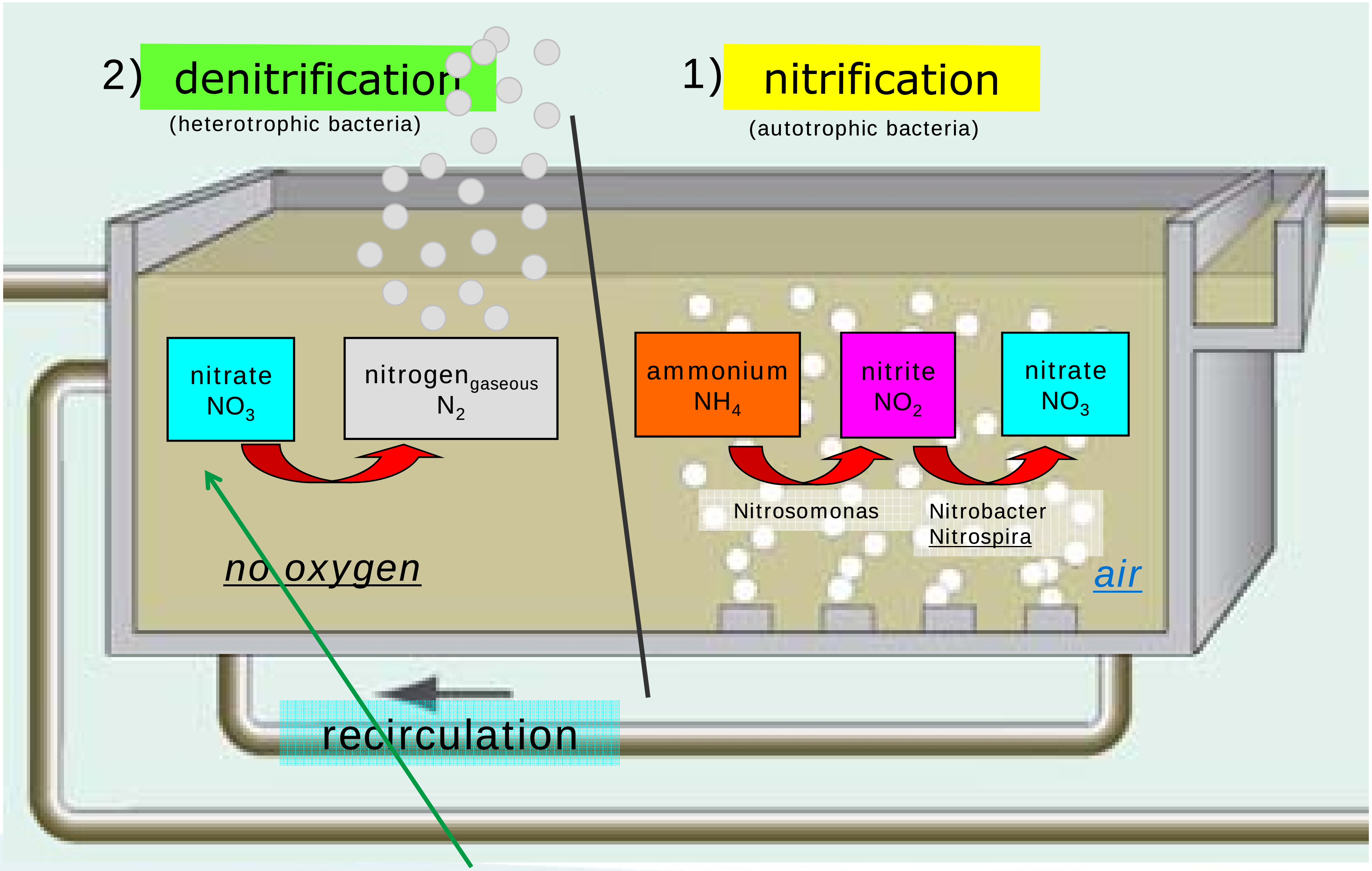


Ammonia control objective



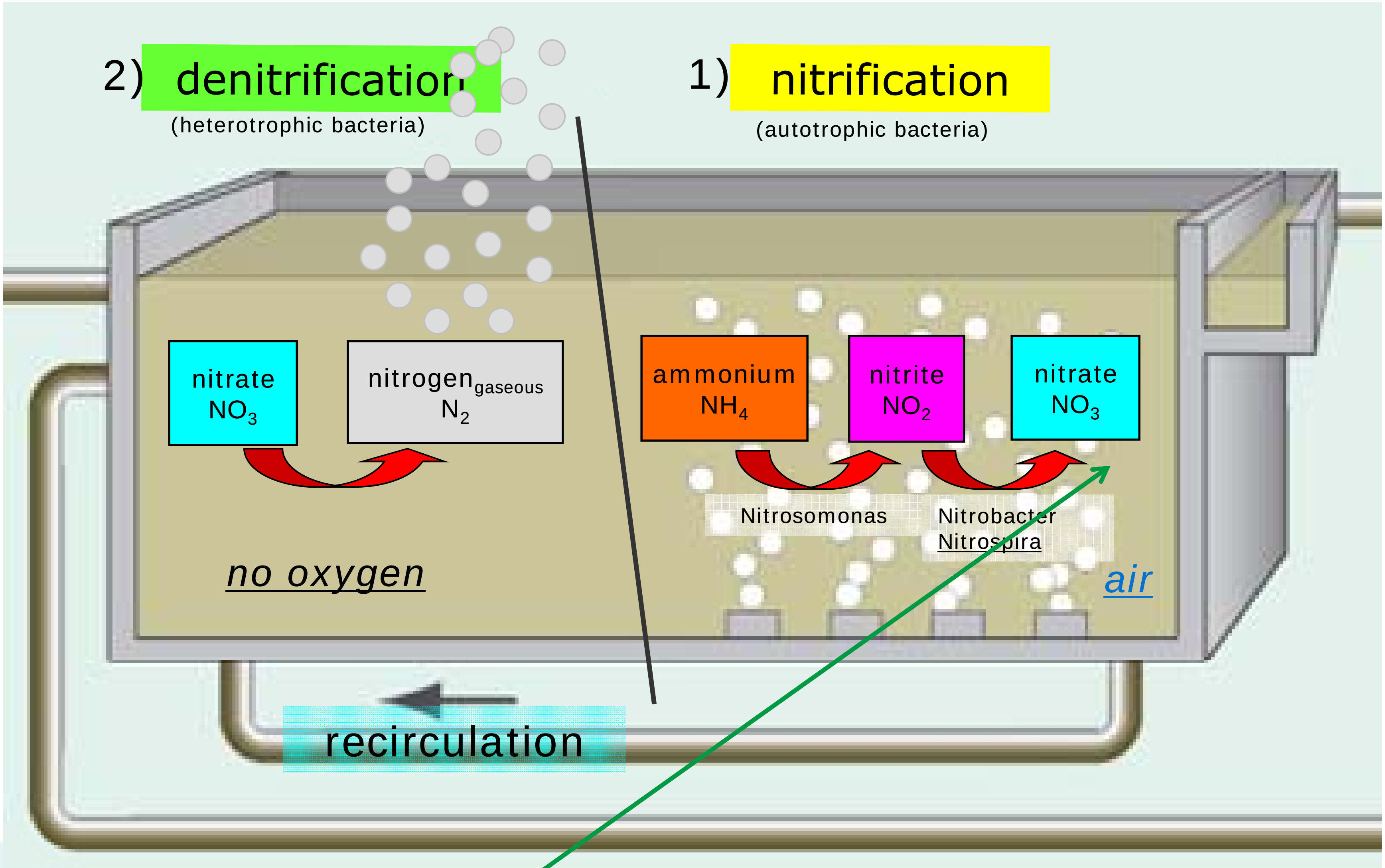
As Ammonia level rises above setpoint, increase air supply rate to further nitrification

Nitrate control objective via aeration



As nitrate level rises above setpoint, decrease air supply rate to further denitrification

Nitrate control objective via recirculation

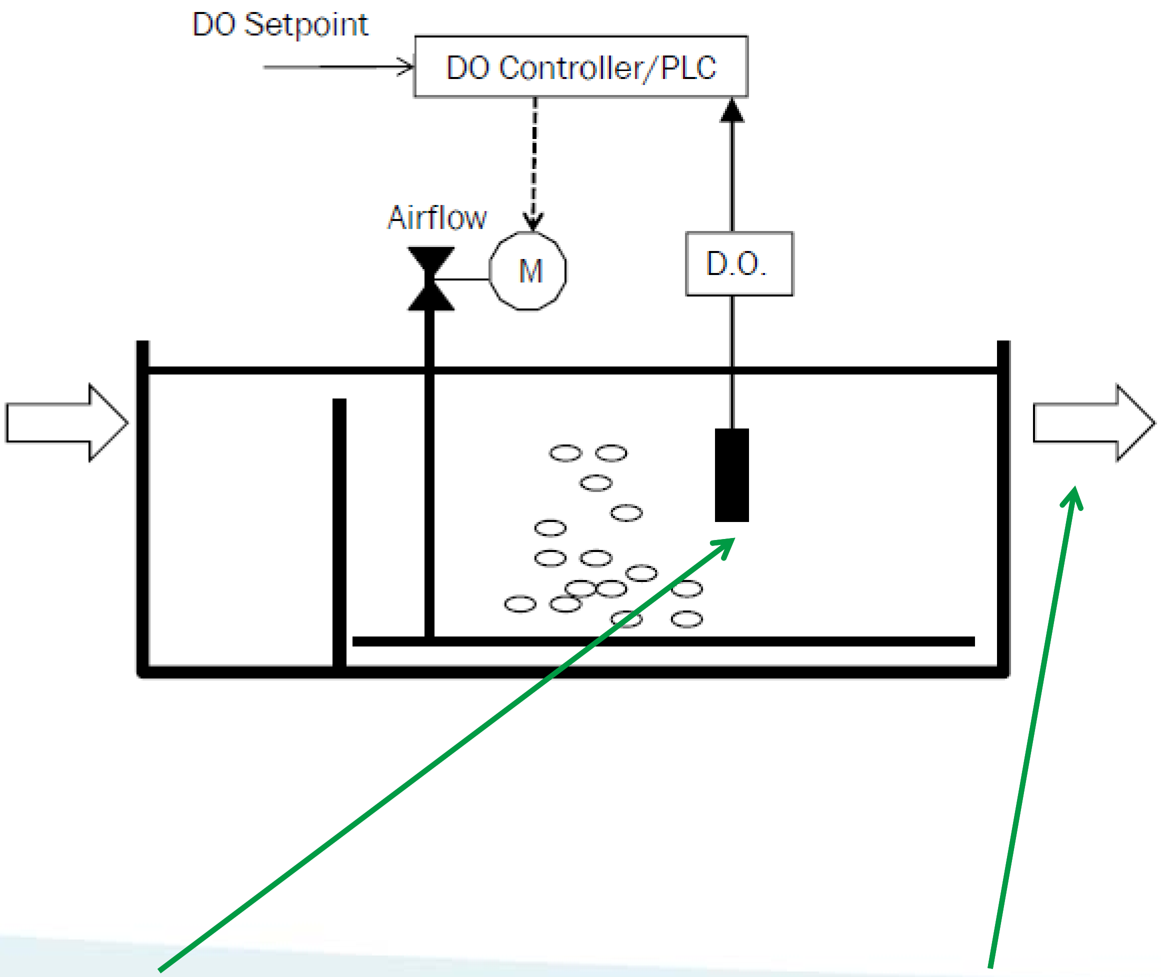


Use of Nitrate to control Internal Mixed Liquor flow rate

Ammonia based Control Strategy

Source: Ammonia Controlled Aeration by Don Esping

Typical Aeration Basin Control Strategy - DO



DO setpoint chosen to minimize historical NH_4 breakthrough.

Objective of Ammonia based Aeration control

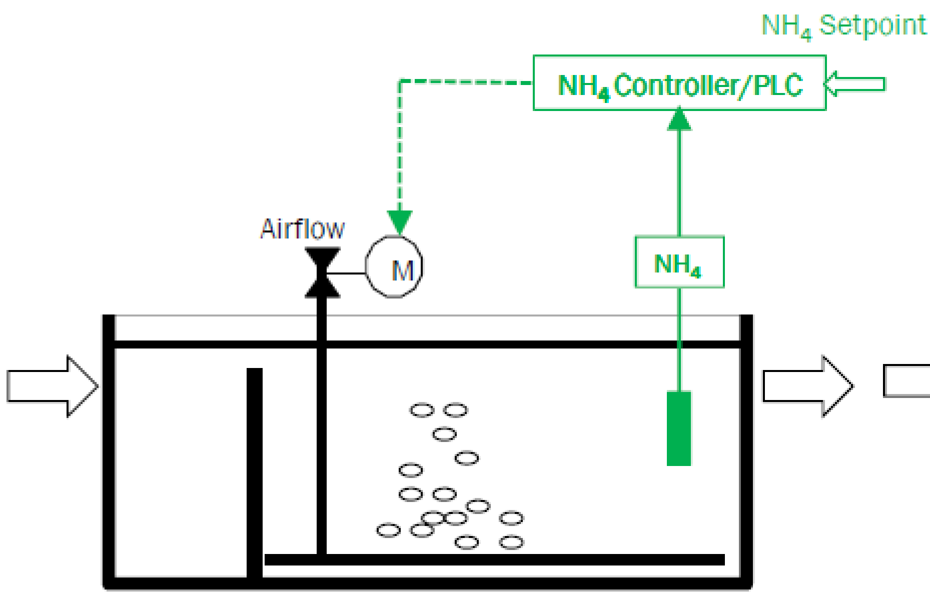
Aeration control based on ammonia measurement essentially is applied for one of two reasons:

- Limiting aeration: Aeration is limited to prevent complete nitrification. The potential benefits include energy savings, increased denitrification, and in some cases improved bio-P performance.

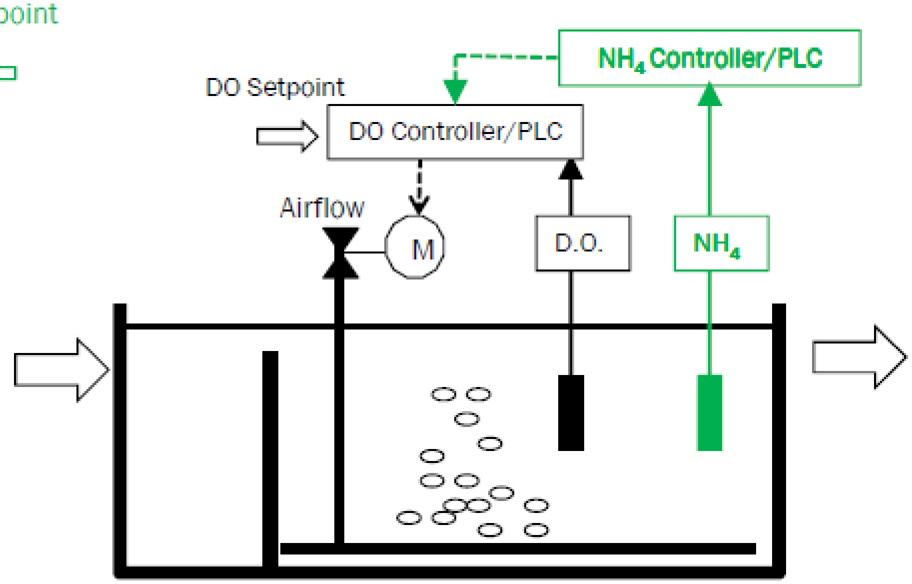
- Reducing effluent ammonia peaks: Aeration is manipulated to reduce the extent of effluent ammonia peaks.

Source: Myths About Ammonia Feedforward Aeration Control

Ammonia/Aeration Basin Control Strategies



Ammonia Feedback Control

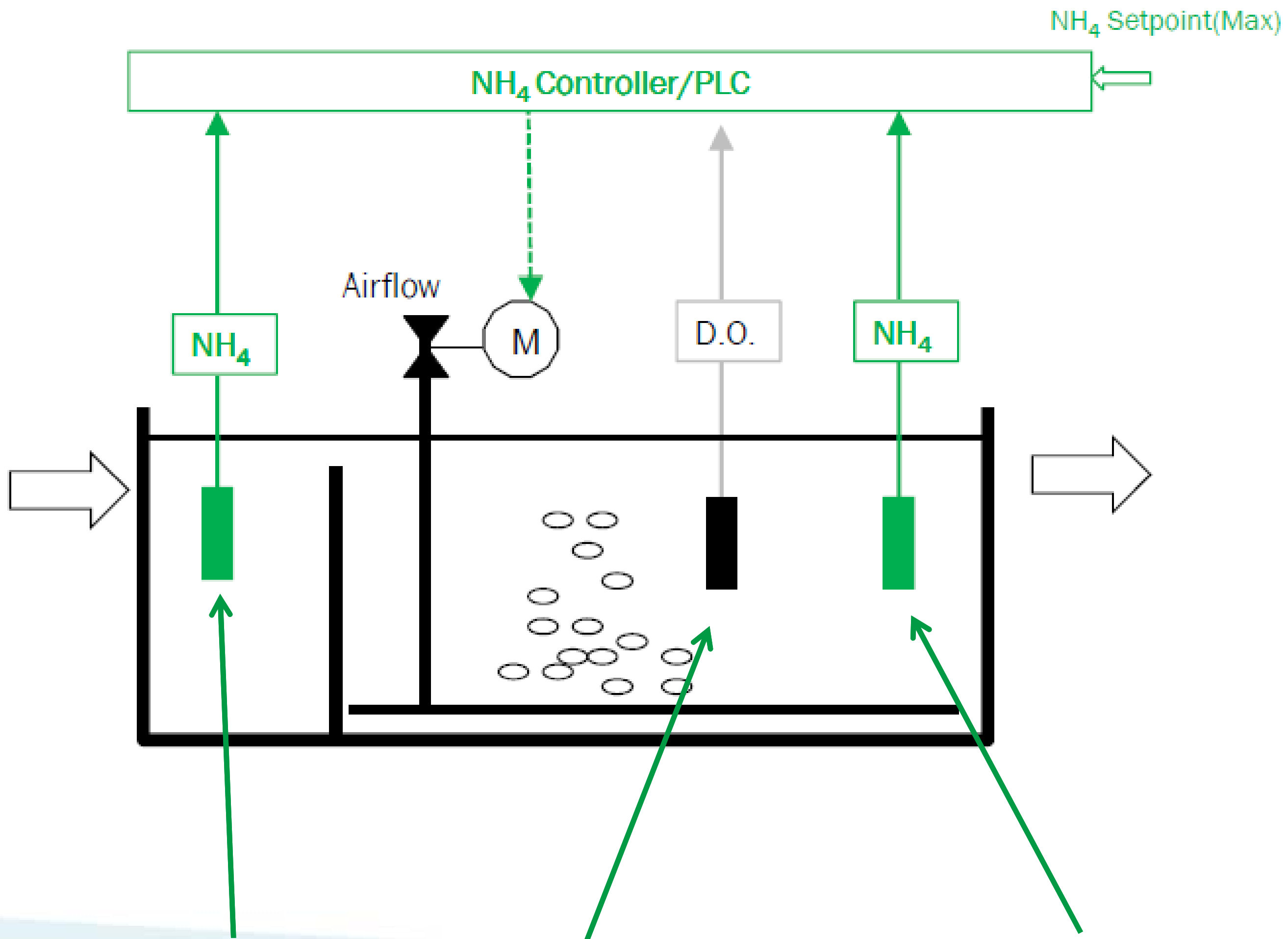


Cascade to DO set point (or visa versa)

Example
NH4 < 1.5 mg/L then DO setpoint = 0.5 mg/L
NH4 >1.6 mg/L then DO setpoint = 2.0 mg/L

Cascade setpoint control slow to adjust DO

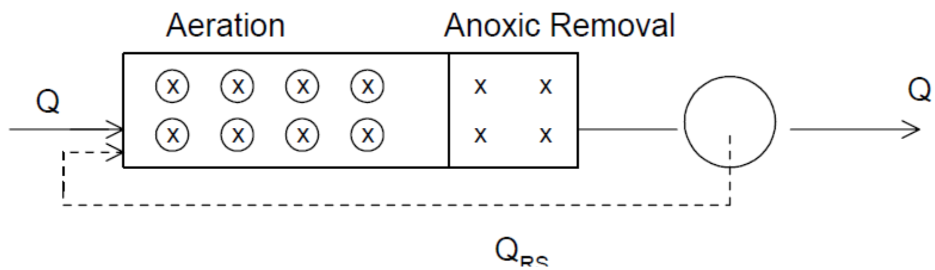
Ammonia Feed Forward – Feedback Control



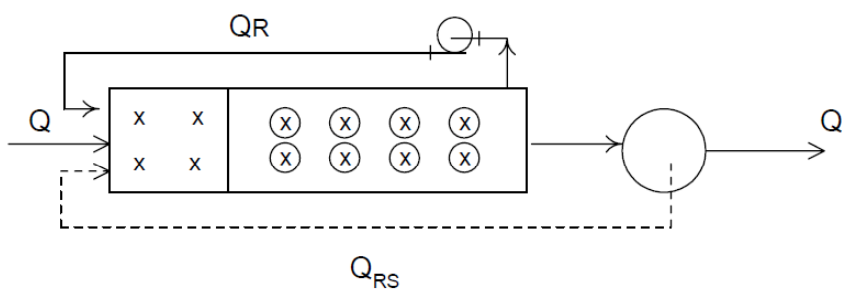
Upstream NH_3. Min & Max limiting DO. Downstream NH_4.

Types of Single Sludge Nitrogen Removal

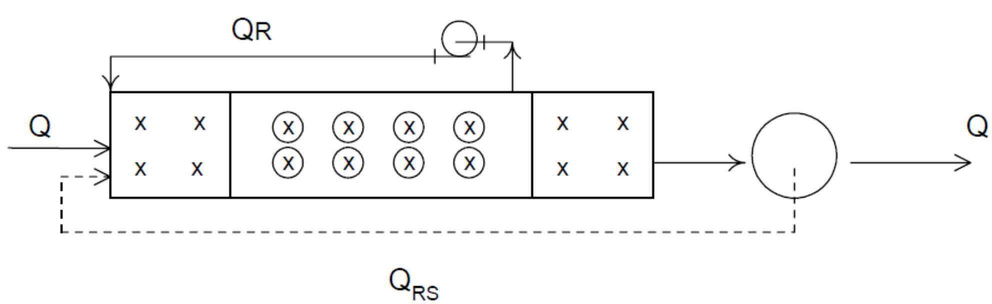
Post-denitrification



Pre-denitrification



Pre and Post-denitrification

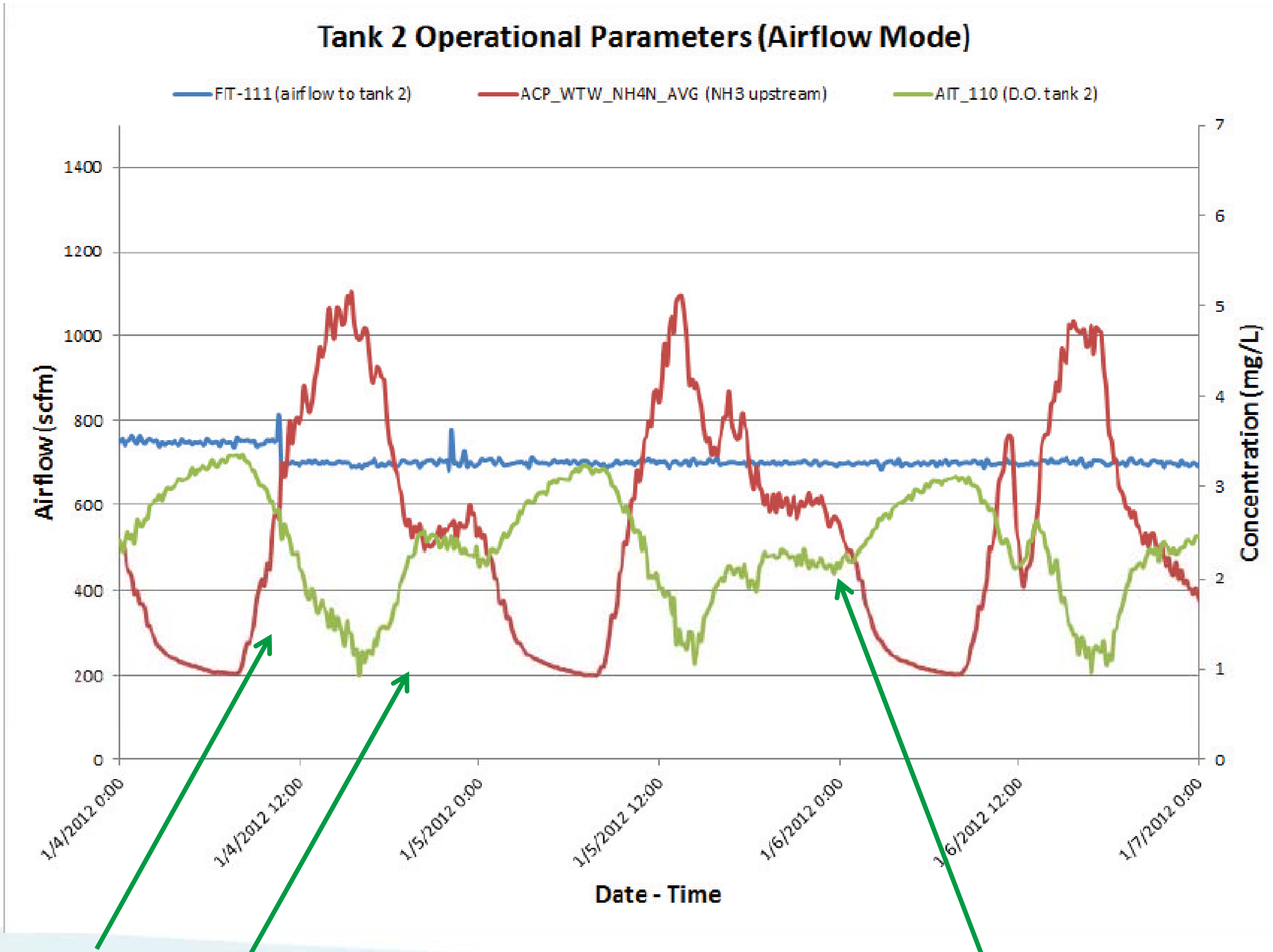


Case Study: Wheaton Sanitary District

Source: Wheaton Case Study NH_4 to control DO

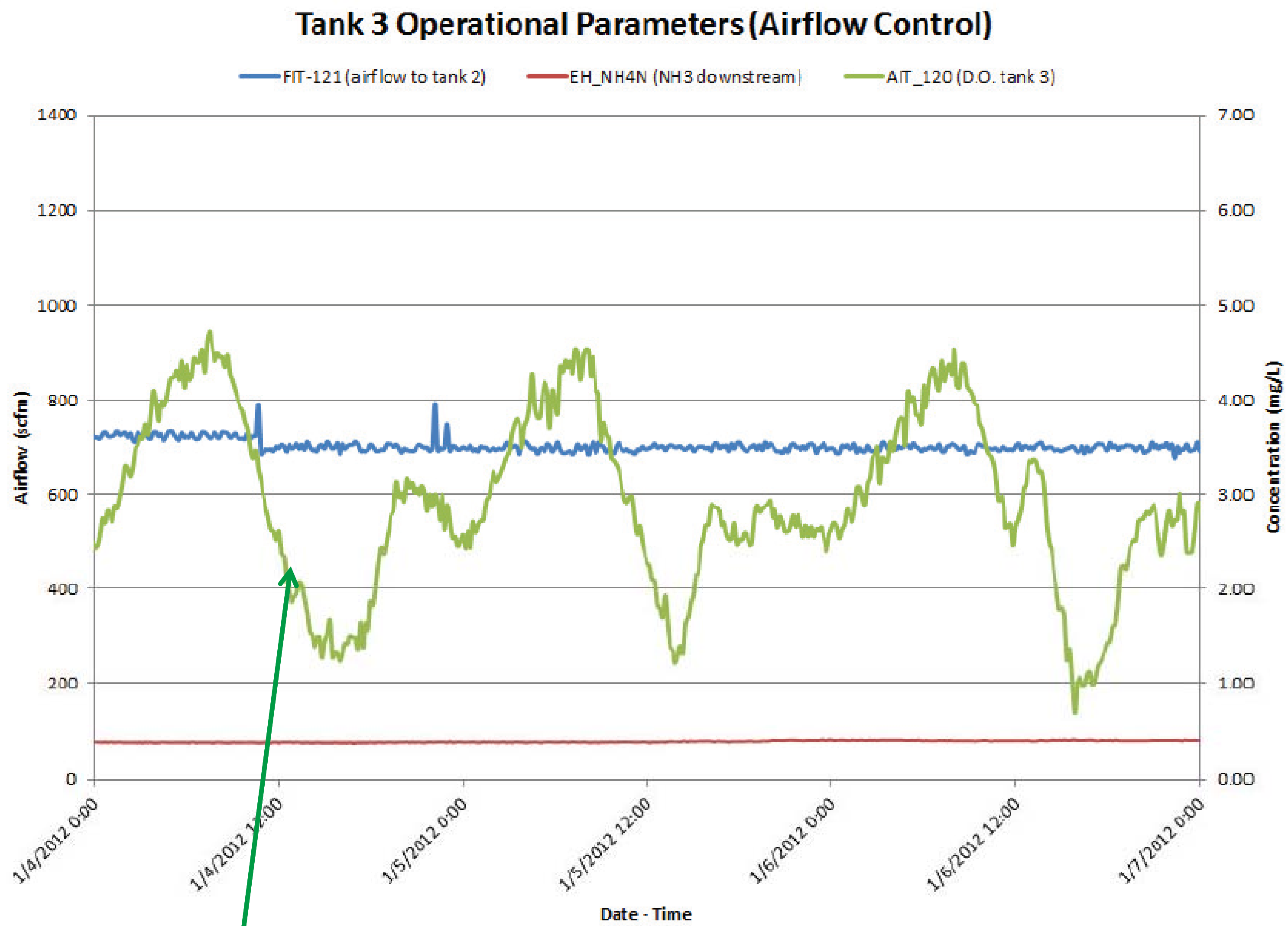
Aeration Basin Instrumentation

Constant Airflow Mode - upstream



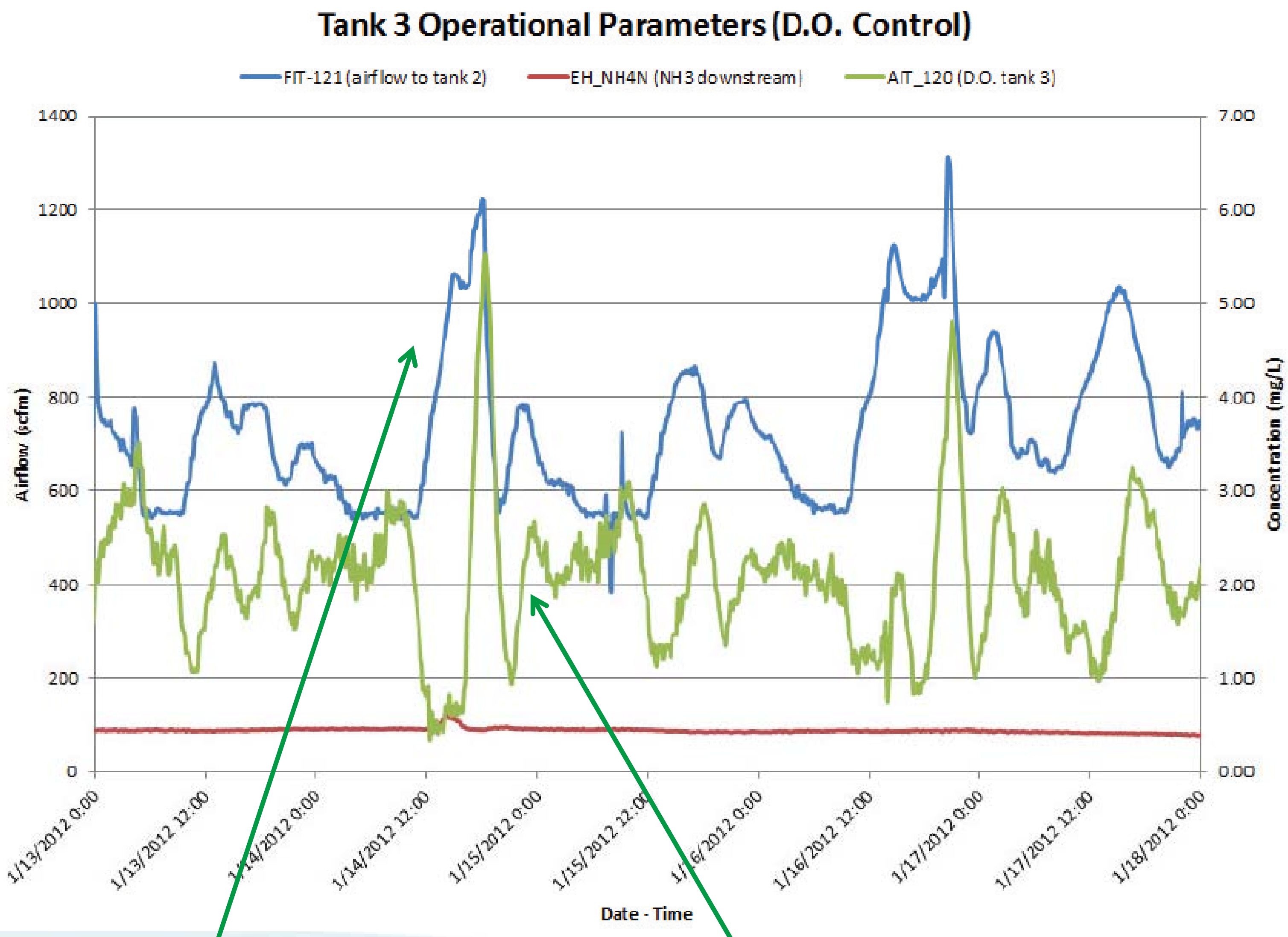
NH_3 and DO are inversely proportional. DO response to NH_3 is fast.

Constant Airflow Mode – downstream



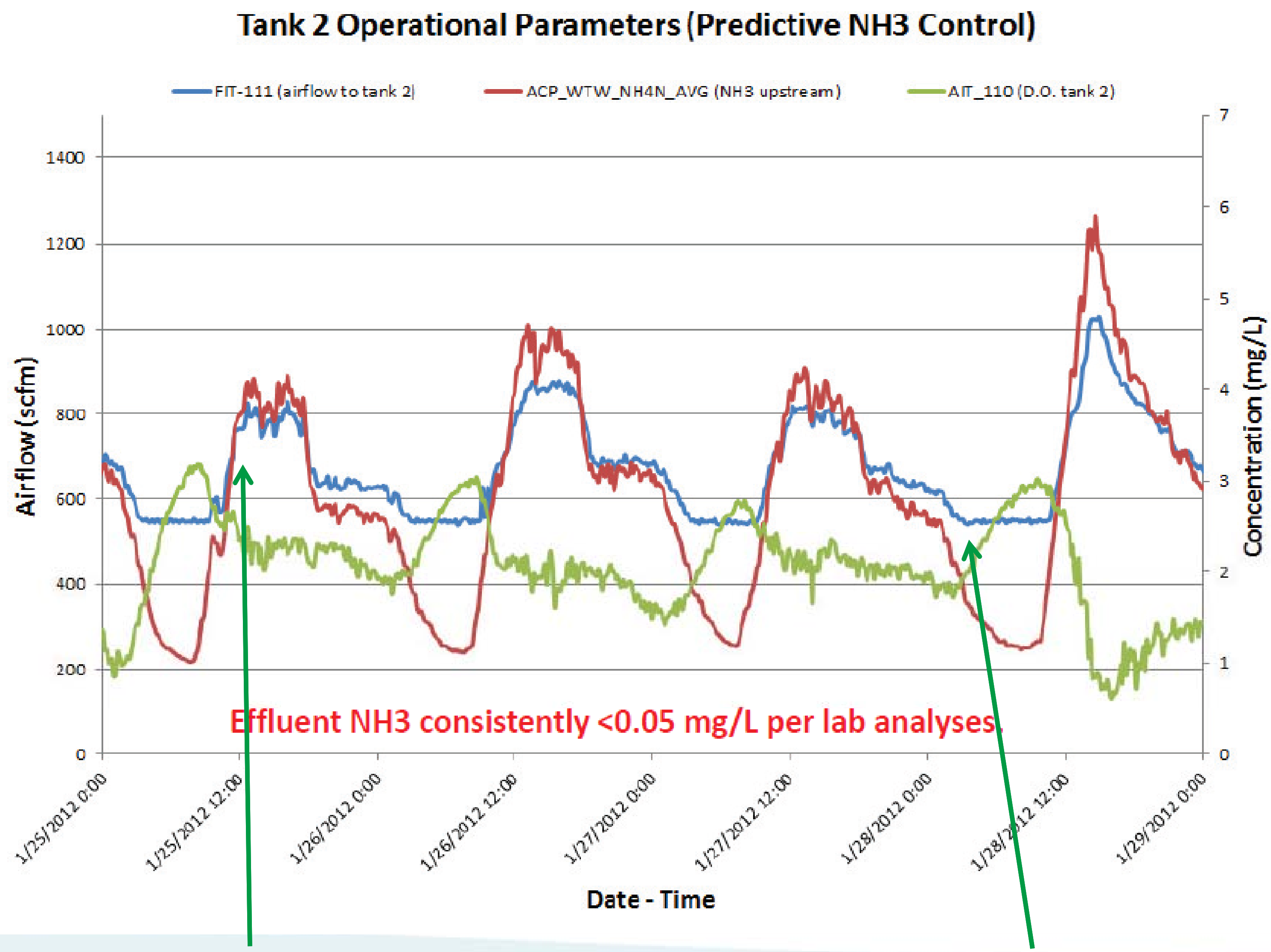
DO swings based upon NH_3 loading at influent

DO control mode – 2ppm setpoint



Airflow inversely proportional to DO. Note NH_3 breakthrough.

NH_3 Predictive Control

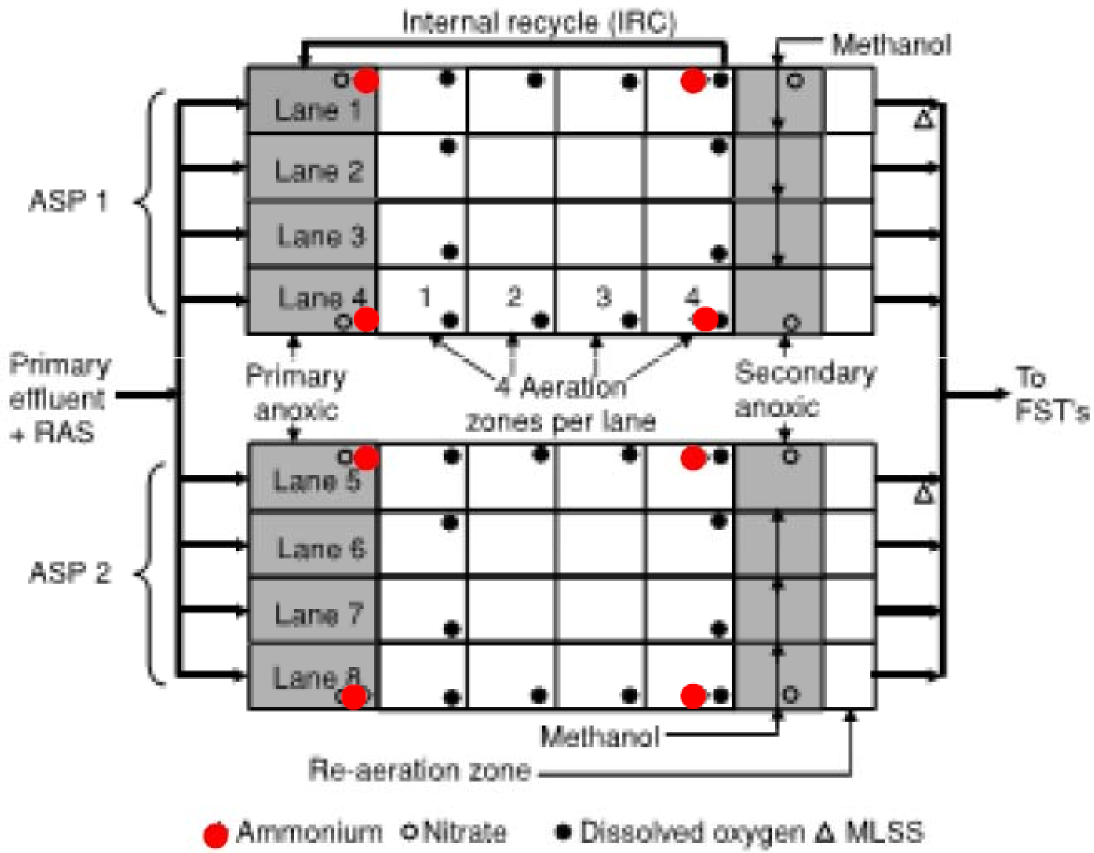


Airflow proportional to NH3 concentration. Note lower limit on airflow for mixing.

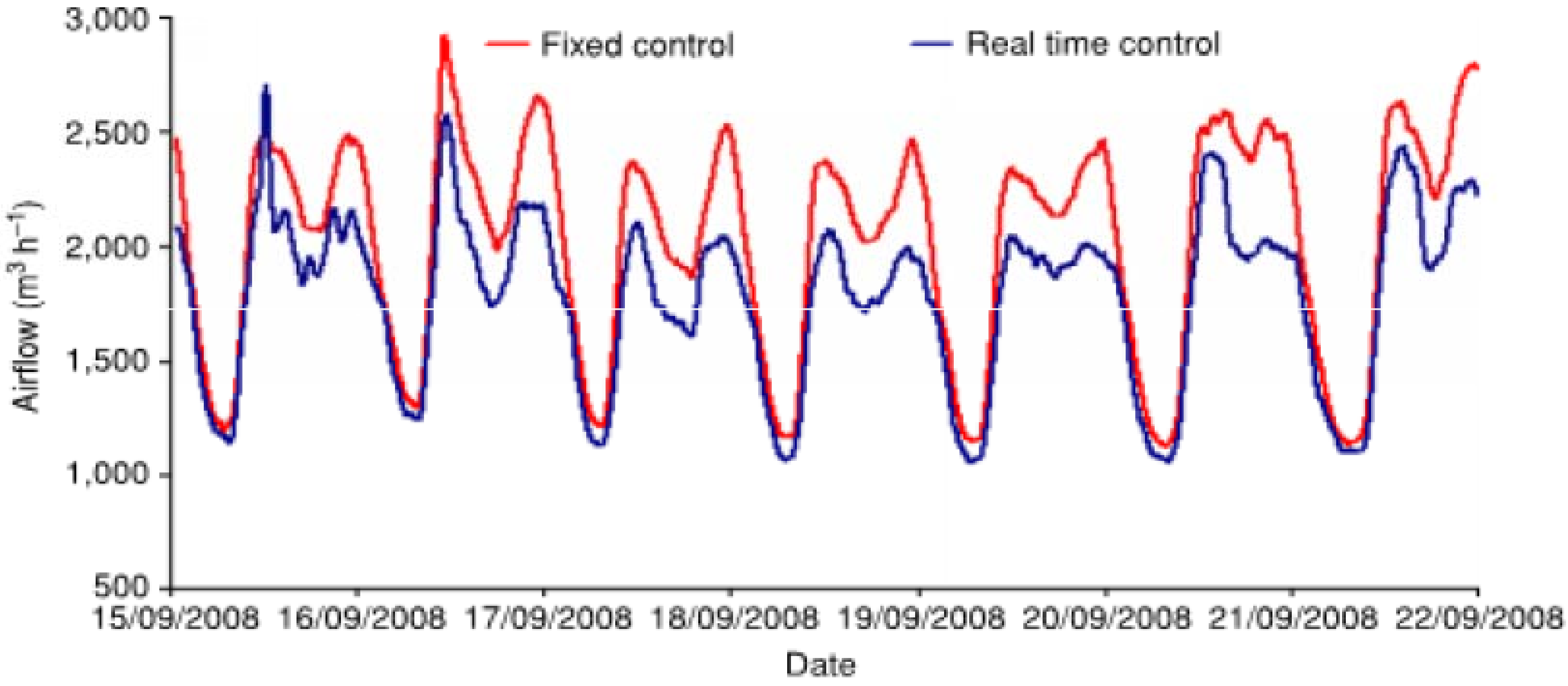
Case Study:
U.K. 4 Stage Bardenpho

Source: Ammonia Controlled Aeration

Plant Layout and Sensor Location

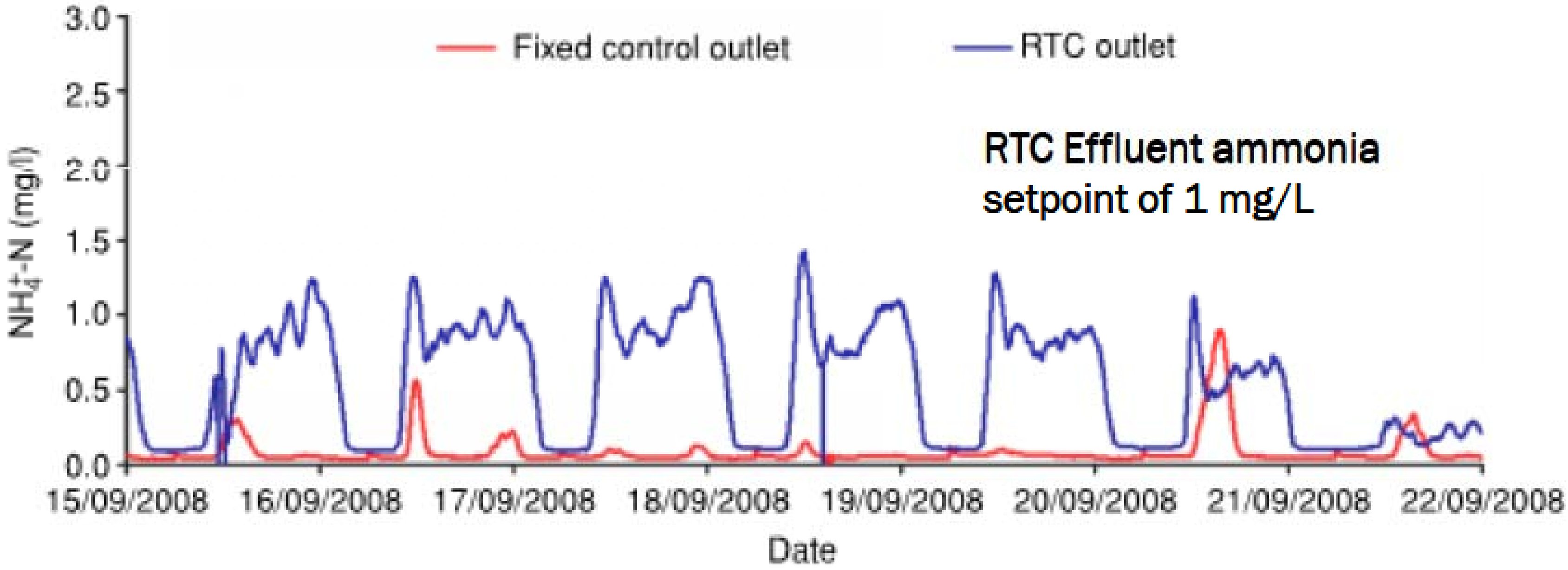


DO setpoint vs Predictive NH4 Control



20% airflow savings overall

Effect of Limiting Aeration preventing Complete Nitrification



Case Study Summaries - Cons

- Need reliable and accurate sensors – test sensors for requirements

- Control can be more complex
  - Sensor outlay and maintenance
  - More monitoring
  - More maintenance (0.5 to 3 hours/week/device)
  - Cascade loops – lag times/fine tuning
  - Historical treatment or process model algorithms

- Blower turndown critical but must maintain minimum airflow for mixing

- Low D.O. bulking a concern–especially if D.O. <2.0 mg/L

Case Study Summaries - Pros

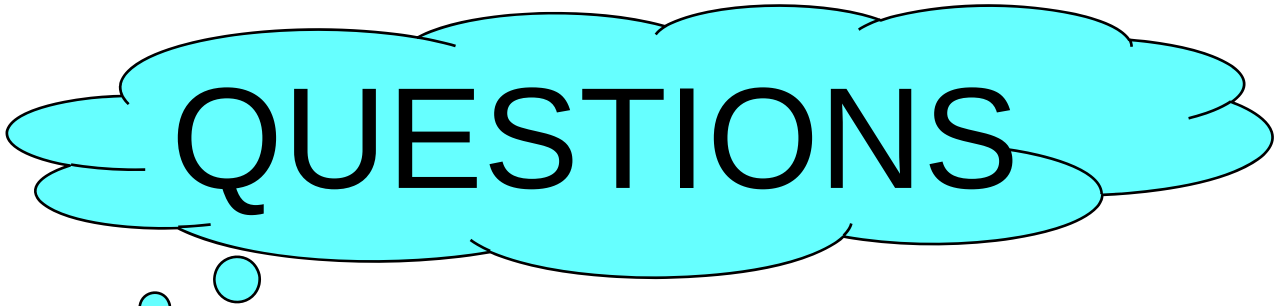
- Switching to NH_3 control can decrease airflow by 20%

- More stable effluent D.O. concentrations

- Allows for Limiting Aeration preventing complete nitrification to further increase savings

- Feed-forward provides greater safety w.r.t. peak loadings
  - More stable effluent ammonia in high flows

- Depending on the starting conditions, even the simplest control (e.g. 1-point D.O. control) can provide significant energy savings
  - Take advantage of the low end of the blower curve
  - Minimal cost of implementation (VFD, in-tank instrumentation, programming)



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