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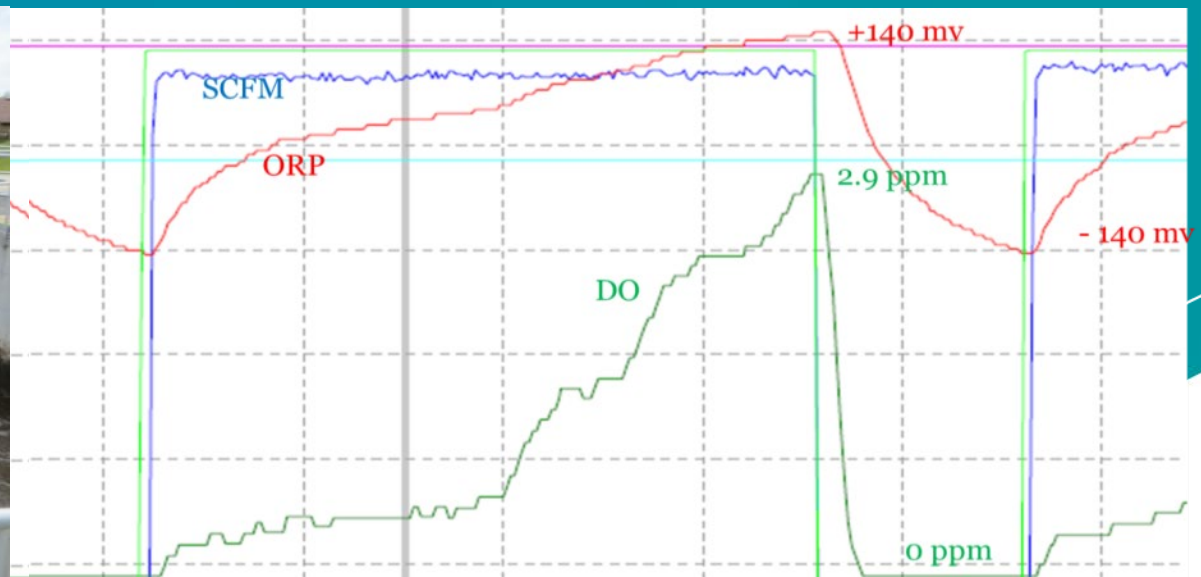
Biological Nutrient Removal

Applications for Monitoring Oxidation Reduction Potential

OWEA ~ June 26th, 2019



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Today's topics

- The Science of ORP
- Applications for ORP monitoring
- Technology for ORP monitoring
- Case Studies
- Sensor Care and Parting Thoughts

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The Science of ORP

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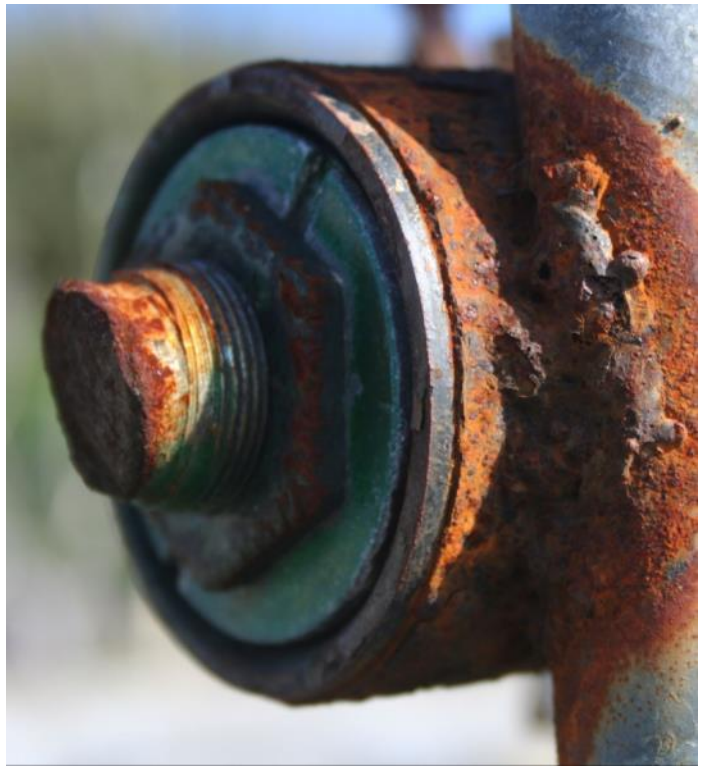
What is Oxidation-Reduction or Redox?

- An **oxidation-reduction** (redox) reaction is a type of chemical reaction that involves a transfer of electrons between two species.
- The **oxidation** number of a molecule, atom, or ion changes by gaining or losing an electron.



What is Oxidation-Reduction or Redox?

LEO goes GER

- Loss of electrons is oxidation
- Gain of electrons is reduction

Why Do We Care?

- Oxidation-reduction potential
- aka: ORP
- aka: Redox

→

Indicates the water's relative state to receive or gain electrons

Growing Bugs Are Happy Bugs!

Bacteria require 4 things for growth:

1. Carbon
2. Nutrients
3. Energy
4. Reducing Power – the ability to transfer electrons

Source: Biological Wastewater Treatment, 2nd ed., Grady, C.P., Daigger, G.T., Lim, H.C., 1999.

Bugs get energy and reducing power from oxidation-reduction (Redox) reactions

Treatment Function	Energy source (e^- donor)	Reducing power (e^- acceptor)
BOD removal	Organic C	O_2
Nitrification	NH_4^+	O_2
Denitrification	Organic C	NO_x
Fermentation	Organic C	Organic C

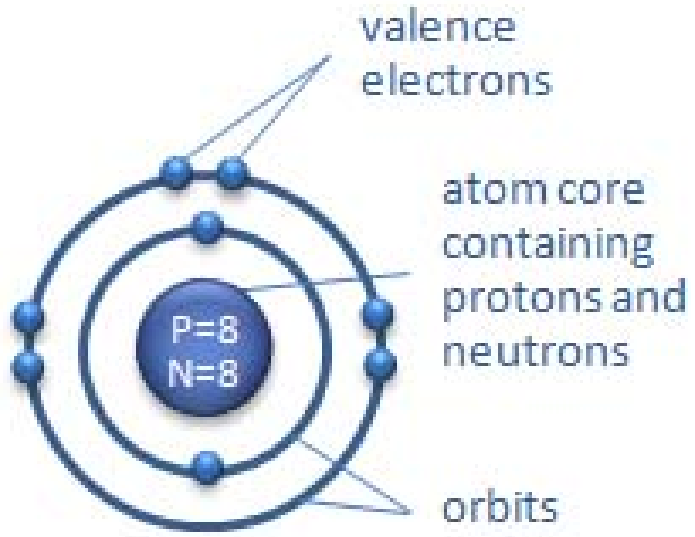
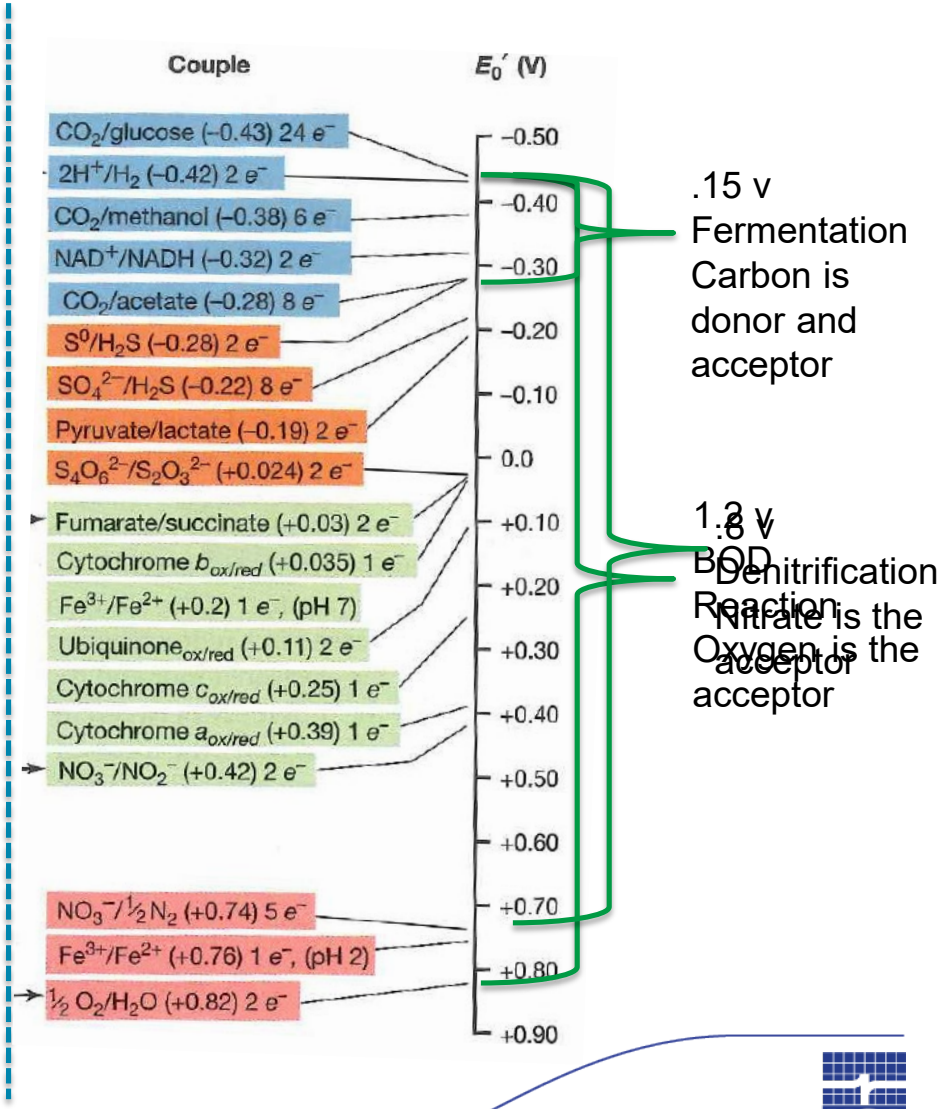


Diagram of an oxygen atom

What has ORP have to do with it?

ORP measures electron donating ability.

- Electron tower: most negative (e^- donors) at top to most positive (e^- acceptors) at bottom.
- Electrons donated from the top of the tower can be “caught” by acceptors at various levels.
- The greater the “fall” the more energy is released



Source: Brock Biology of Microorganisms, 10th Ed., Madigan, M., Martinko, J., Parker, J., 2002

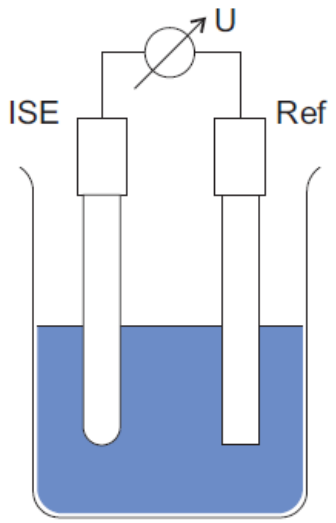
Sounds complicated, huh?

It is, but….

It can be **very** simple if only interested in measuring e^-

ORP Sensor is similar to pH sensor

The measurement is the raw signal, millivolts (mV)



Reference electrode
Reference junction
Electrolyte
Measuring electrode

*YSI SensoLyt PtA electrode (109 125Y)

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Applications for ORP Monitoring

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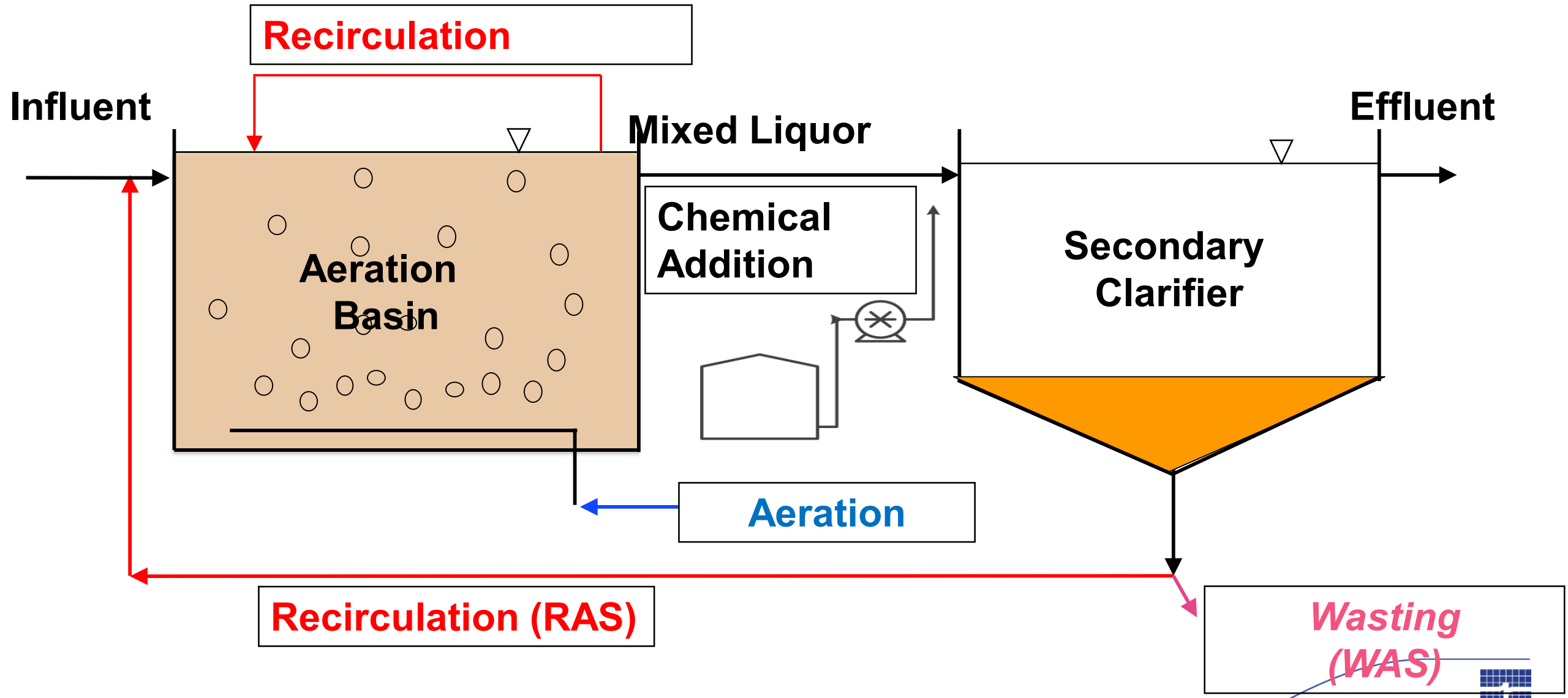
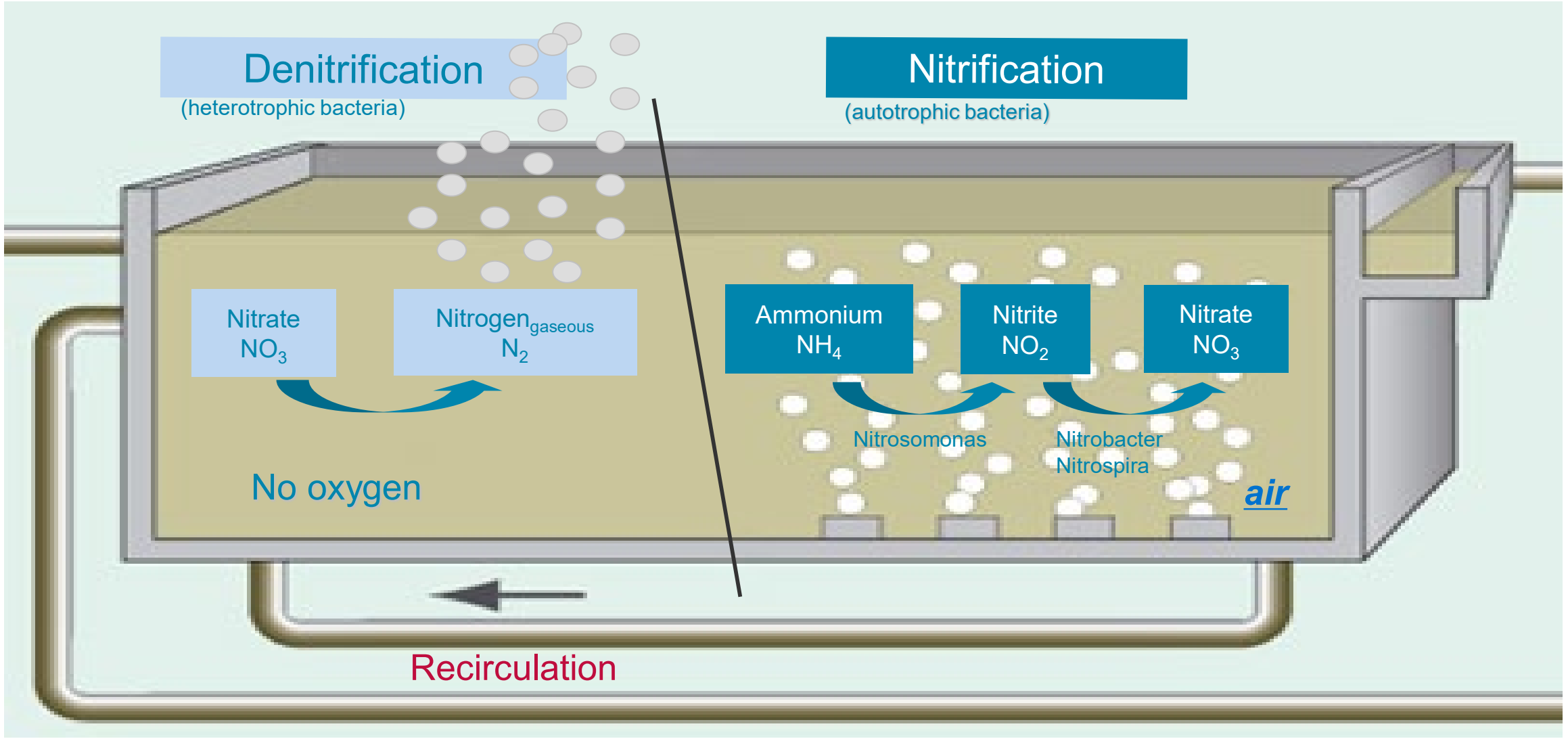
Wastewater Activated Sludge Process




Denitrification
(heterotrophic bacteria)
Nitrification
(autotrophic bacteria)
Nitrate
NO_3
Nitrogen$_{gaseous}$
N_2
Ammonium
NH_4
Nitrite
NO_2
Nitrate
NO_3
Nitrosomonas
Nitrobacter
Nitrospira
No oxygen
air
Recirculation

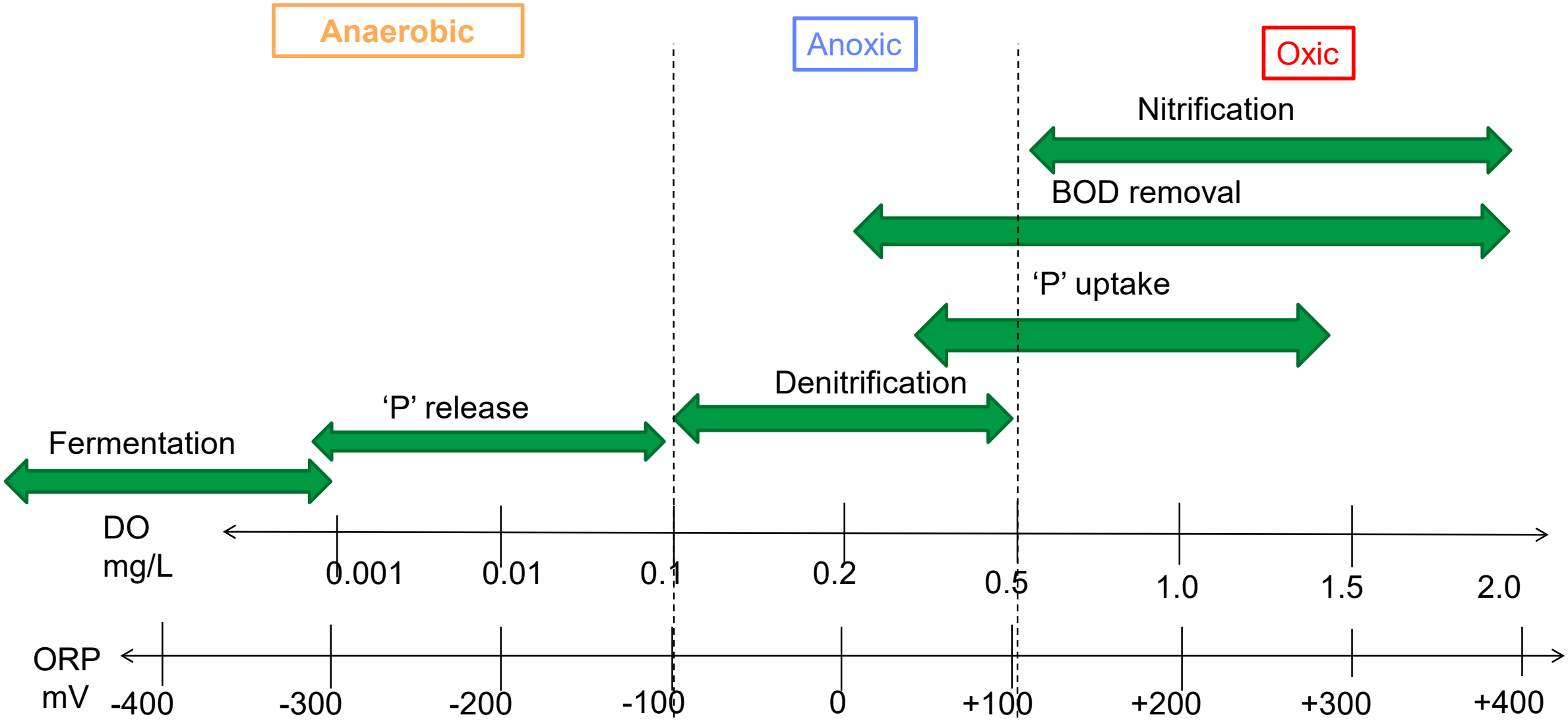
Sludge Activity

Oxic = aerobic = DO is the primary e- accepter

Anoxic = No DO. NO_3 is primary e- accepter

Anaerobic = No DO or NO_3, need something else

Oxidation Reduction Potential (ORP)



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ORP as a DO Sensor

Think of ORP as a DO sensor that measures negative

DO > 1.0 mg/L: primarily O_2

- No direct meaning as to the status of nitrification
- +100 to +400 mV ORP for nitrification pricess

DO < 1.0 mg/L: O_2 + other e^- acceptors

- No direct meaning as to the status of denitrification
- -100 to -100 mV ORP for denitrification process

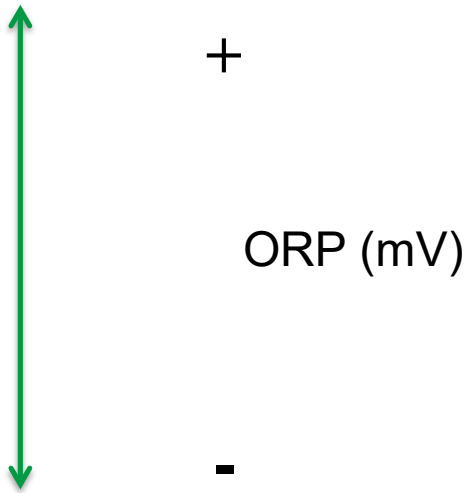
DO < 0.1 mg/L: primarily other e^- acceptors

- No direct meaning as to the status of denitrification
- -100 to -400 mV ORP for denitrification process

ORP as a “N” Sensor

ORP can indicate what forms of N are present

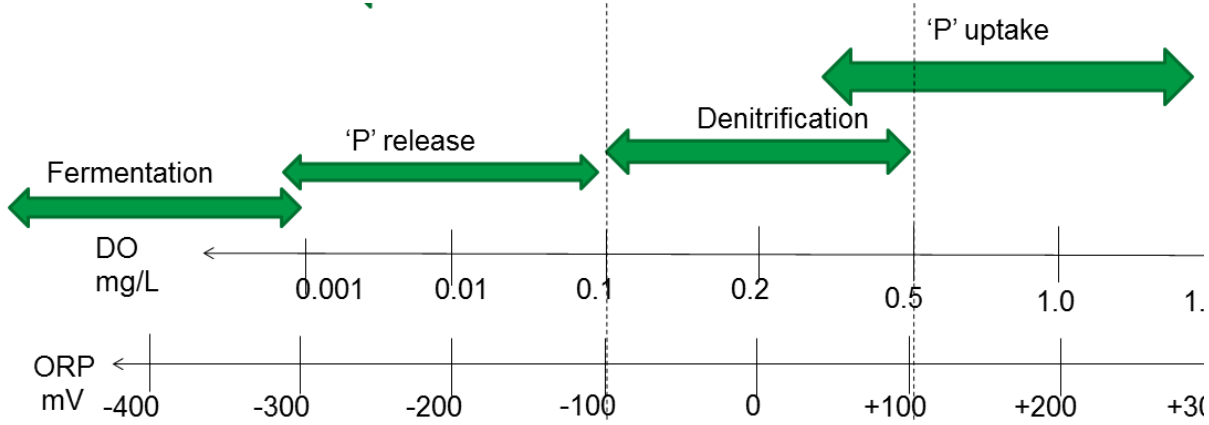
- NO_3 and NO_2
- Ammonium and TKN
- Little to no dissolved ‘N’ (and no DO)



ORP as a “P” Sensor

Well, it can’t really do that

- ‘P’ is neither oxidized or reduced during biological-P removal
- However, it can tell you when conditions are ripe for uptake and release



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Monitoring Methods

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Case Studies

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Englewood, CO

- Switched to ORP control: Cl_2 residual analyzer required continual operator attention.
- DPD test kit was getting interference; Difficult to set the proper dosage.
- Sodium bisulfite overdosed to assure compliance with chlorine residual limit

ORP Monitoring System

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ORP /Ammonium Monitoring System

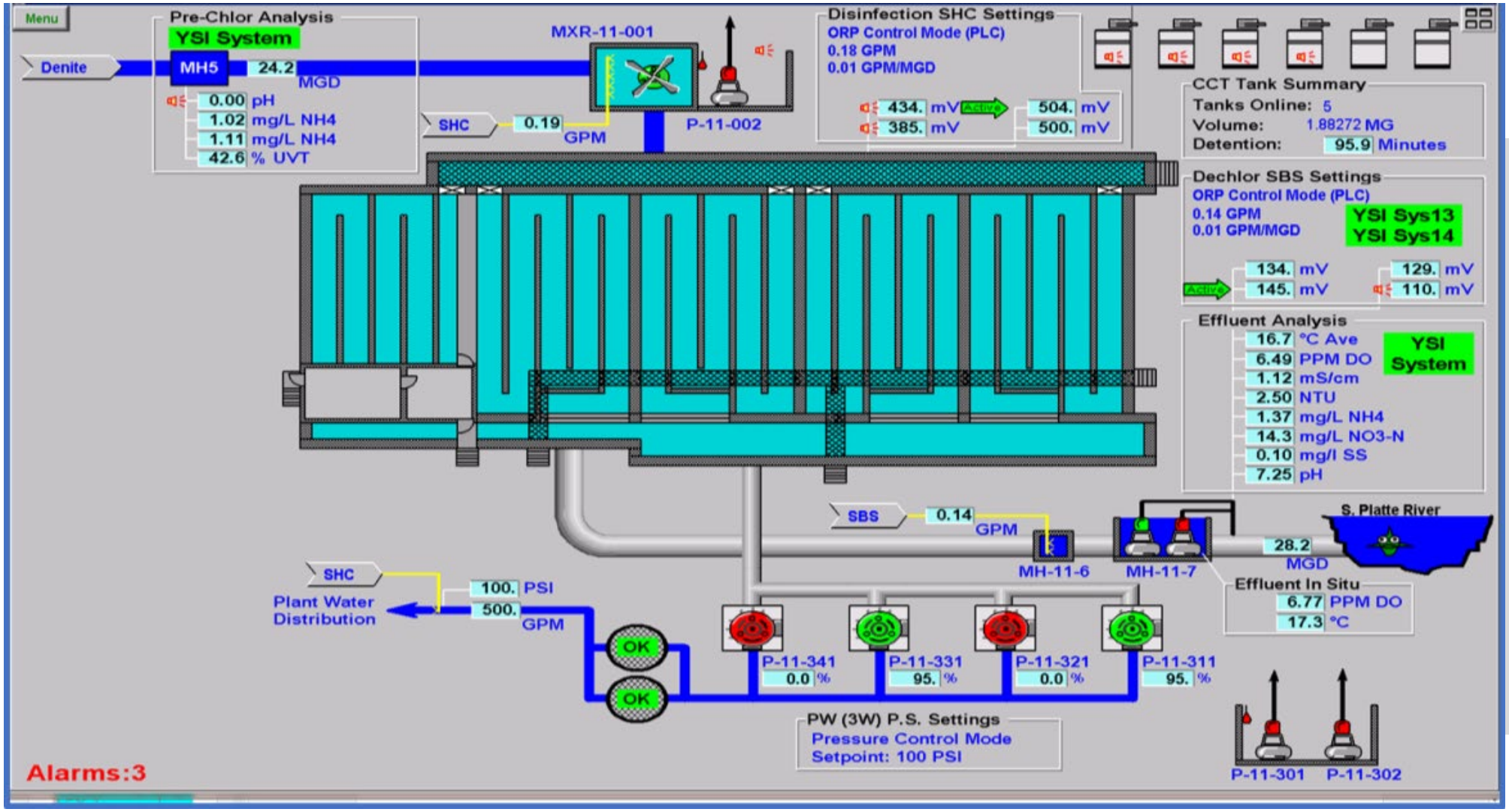
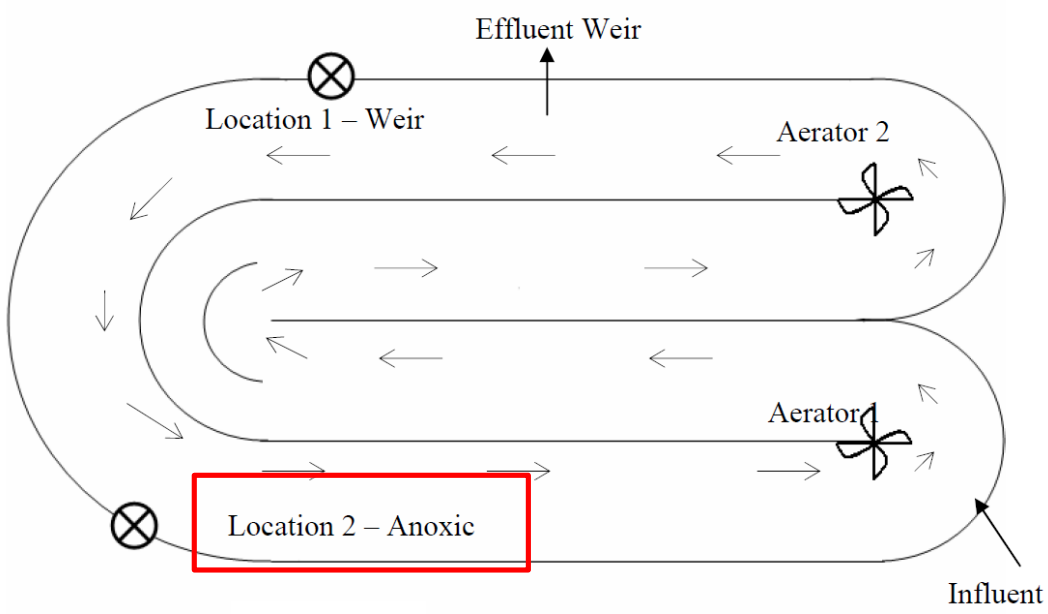


Image courtesy of Greg Farmer

Extended Aeration Process

Goal: minimize aeration & chlorine



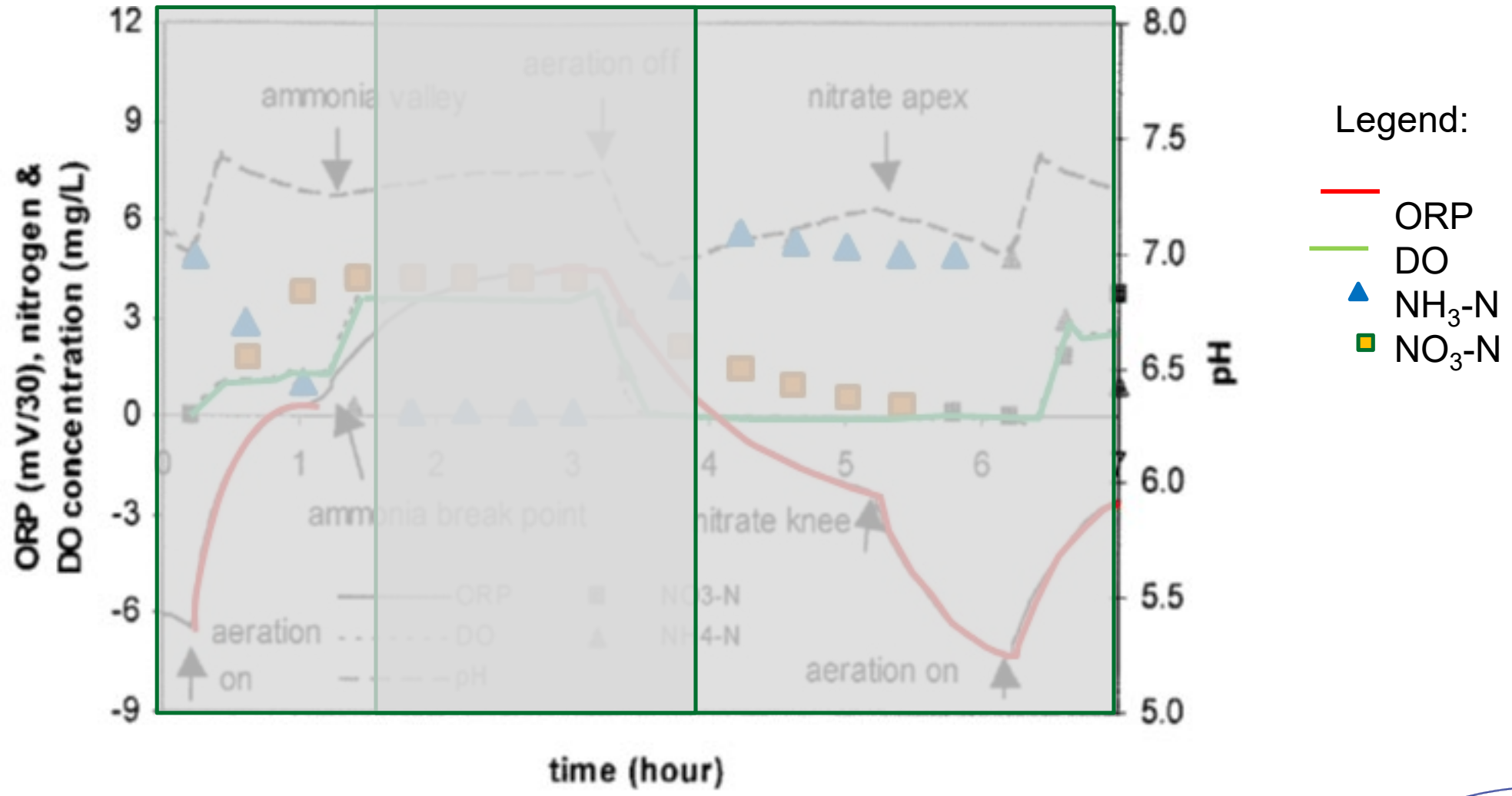
- Measuring ORP in anoxic zone
- NH_3-N target in effluent: 2 – 3 mg/L

- Upper ORP SP: -200 mV
- Lower ORP SP: -270 mV
- NH_3-N maintained between 1 and 3.5 mg/L
- DO near 0 mg/L
- Nitrate also low

Myers, M., Myers, L, Okey, R., "The use of oxidation-reduction potential as a means of controlling effluent ammonia concentration in an extended aeration activated sludge system", WEFTEC 2006

Intermittent Aeration Process

Sequencing Batch Reactor, SBR, cyclic activated sludge



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Sensor Care

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Calibration, Cleaning and Replacement

Calibration: 1-point offset correction

- YSI 3682 Zobell solution: +231 mV @25°C (platinum – Ag/AgCl)

Cleaning:

- In general use the same practices as you would a pH sensor
- Junction: running water / soft brush
- Platinum: Wet and blot dry (avoid rubbing)
- Short-term soak in household dish soap for grease removal

Replacement:

- Electrodes should last many months to years (IQSN electrodes warrantied for 6 months)

Parting Thoughts

- ORP is relative – not comparable between brands, between applications
- ORP accuracy +/- 20 mV
- Response may be slow – up to 24 hours to stabilize in natural waters (but very fast in Zobell)
- ORP measurement is affected by temperature but not corrected for it.

Follow YSI to Get More Information

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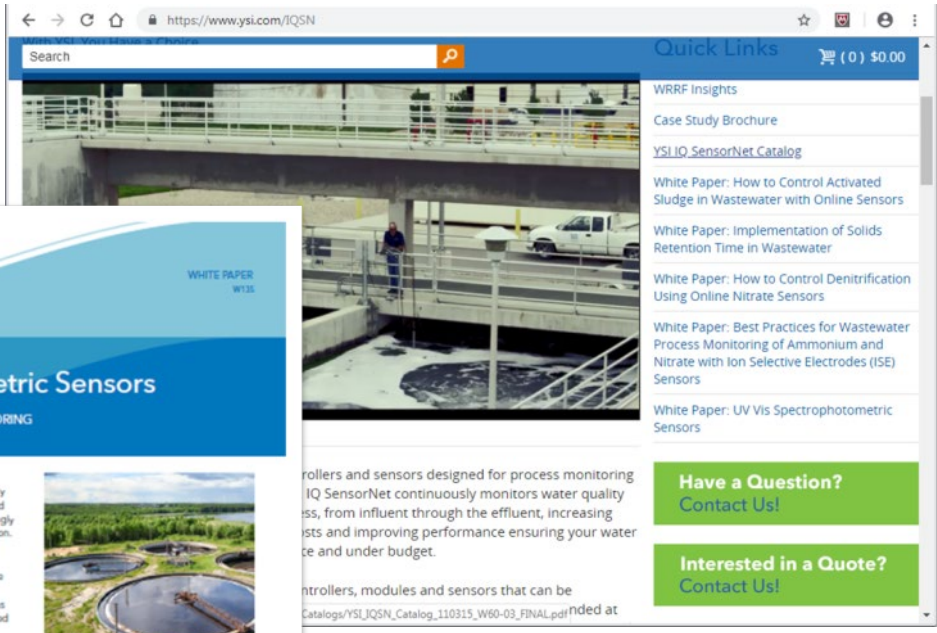

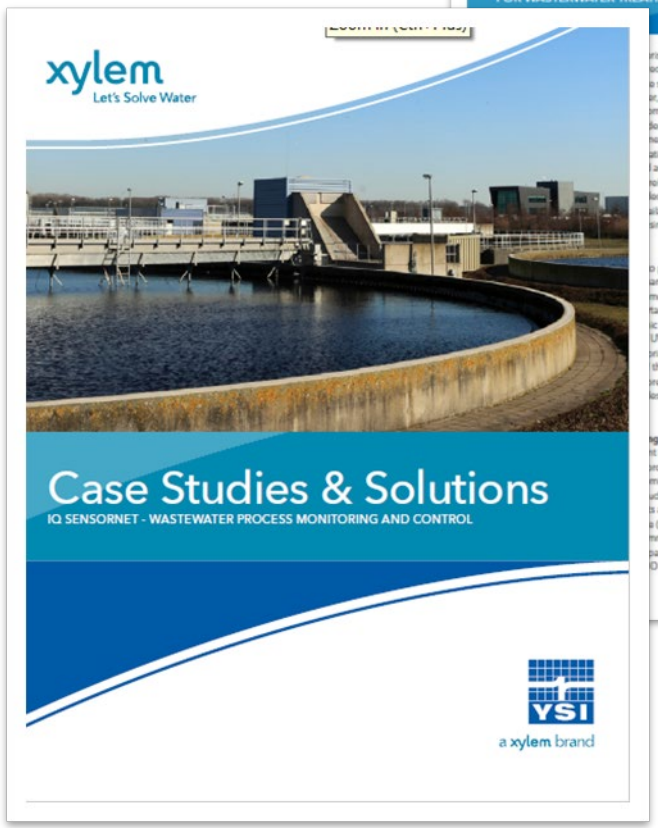

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