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Nutrient Recovery and Digestate Treatment

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- Food Waste Digestate
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  - **Nitrosax**
  - *Nitrostep*
  - *Fostrex*
- Nutrient Removal Tech Summary
- Paul's Example

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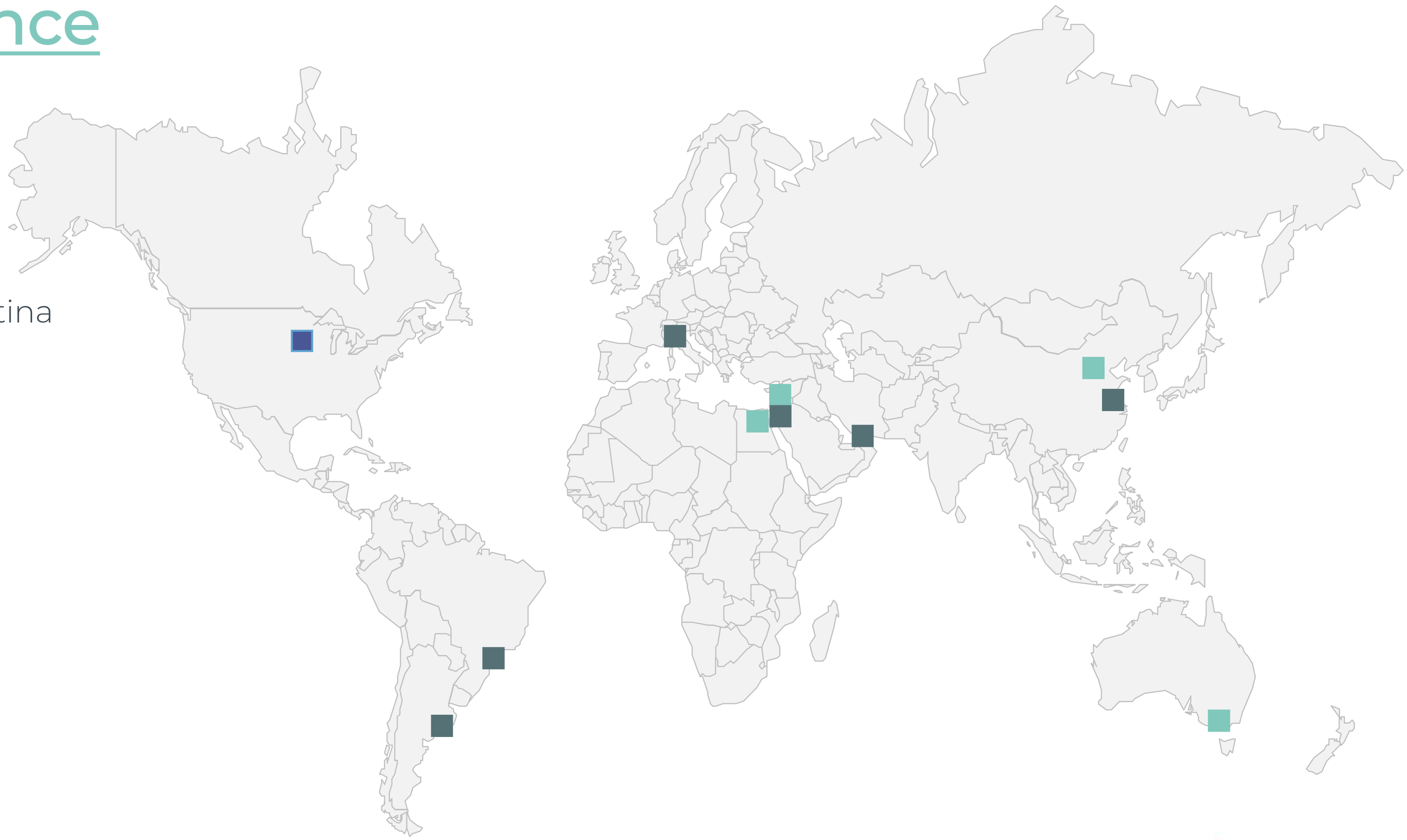
About Fluence

Headquarters
Minneapolis, USA

Operating Entities
Mar del Plata, Argentina
Jundíai, Brazil
Shanghai, China
Caesarea, Israel
Padova, Italy
Minneapolis, USA
Dubai, UAE

Regional Offices
Victoria, Australia
Beijing, China
Karmiel, Israel
El Cairo, Egypt



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About Fluence

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About Fluence – Food waste projects

Annual Energy Generation
+121 GWh

Annual Carbon Savings
+85,730 tons CO_2

About Fluence

Engineering Support

- Consulting and evaluation focused
- Customer and use-oriented research.
- Global operations
- Solutions driven
- Wastewater experts

EPC approach

- Engineering + Design
- Procurement
- Assembly
- Commissioning
- Start up
- Operation

Support

- Remote monitoring
- Maintenance assistance
- Electromechanical support
- Supply of spare parts and consumables
- Sampling and Lab analysis
- Pilot tests

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Understanding W2E

Defining Waste, Energy, and Digestion

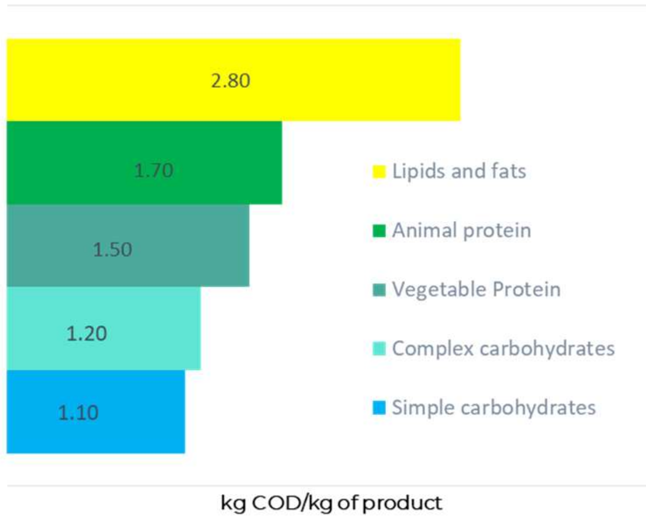
Effluents and organic residues composition

The anaerobic reactor converts the nutrients into energy like our body converts food to energy

- Dissolved → Soluble COD
- Solids suspended → Particulate COD

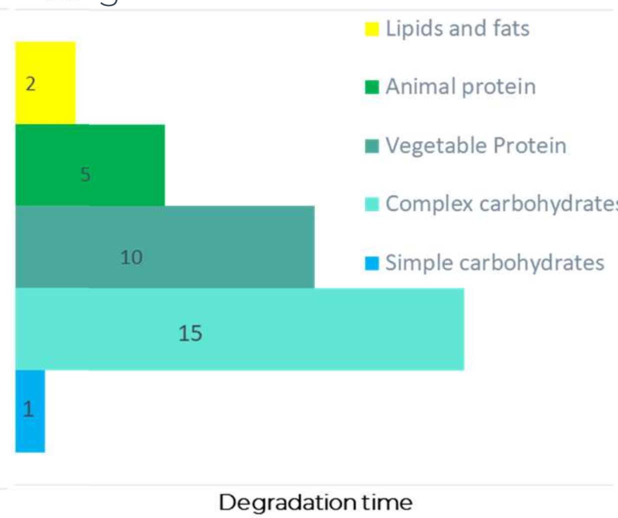
Energy contribution of macronutrients

The relationship between COD and solids measures the amount of energy that each type of waste or effluent can provide.

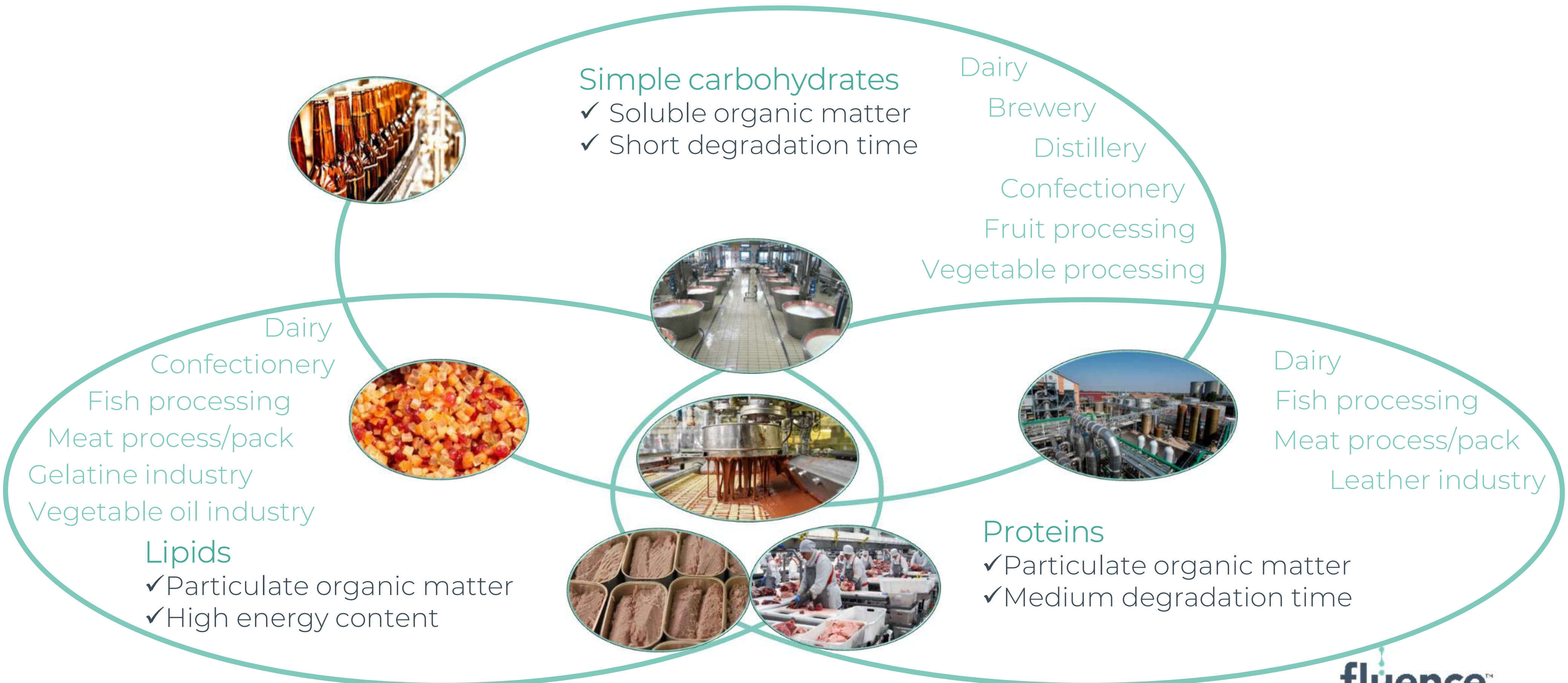


Macronutrients degradability

Each macronutrient has a different degradation time. The fastest products to break down are sugars and fats while compounds with a complex chemical bond take longer.



Defining Waste, Energy, and Digestion



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Defining Waste, Energy, and Digestion

	Fluence CSTR	Fluence AnDAF	Fluence EFC
Designed to operate with:	• Complex carbohydrates • Proteins • Lipids	• Simple carbohydrates • Proteins • Lipids	• Sugar • Starch
Applicable organic loads:	Particulate and soluble COD > 120,000 mg/L	Particulate and soluble 30,000 < COD < 100,000 mg/L	Soluble 2,000 < COD < 30,000 mg/L
Applicable waste types:	• Dairy • Distillery • Confectionary • Leather industry • Gelatine industry • Vegetable processing • Fish and meat processing	• Dairy • Distillery • Confectionary • Vegetable oil industry • Fish and meat processing	• Dairy • Brewery • Confectionary • Pulp and paper • Fruit processing

Defining Waste, Energy, and Digestion

	Fluence CSTR	Fluence AnDAF	Fluence EFC
Suggested pre-treatment	Screening or flotation to concentrate the sludge.	Screening	Filtration and flotation to eliminate the solids
System	Continuous	Continuous + Sludge Recirculation with AnDAF	Granular Sludge Recirculation with Fluence decanter
Feedstock	Sludge > 8% DM	2% DM < Stream < 8% DM	Soluble (TSS_{in} < 250 ppm)
Hydraulic retention time	> 25 days	10 days < HRT < 20 days	Hours
Flow mix	Completely mixed reactor	Completely mixed reactor + recirculation	Up flow reactor + recirculation
Temperature	100°F – 125°F	100°F – 125°F	90°F – 105°F
Typical Digestate Characteristics	Potential for higher effluent TSS, COD, VFA, and TKN; solids ready for dewatering	Reduced TSS and particulate organics; reduced TKN (proteins); solids ready for dewatering	Very low effluent TSS; pre-treatment may reduce TKN (protein)

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Food Waste Digestate

Food Waste Digestate - example

Physical Characteristics	Unit	
Total Solids	%	2.4
VS of TS	%	62.5
COD	mg/L	13,134.4
TSS	mg/L	11,131.0
TDS	mg/L	12,960.0

Nutrients

Short Chain Fatty Acids	Unit	
Formic Acid	ppm	15.8
Acetic Acid	ppm	3,926.7
Propionic Acid	ppm	4,476.2
Isobutyric Acid	ppm	94.1
Butyric Acid	ppm	1,003.4
Isovaleric Acid	ppm	809.2
Valeric Acid	ppm	316.7
Caproic Acid	ppm	ND
Total VFA	ppm	10,642.2

Non-metals	Unit	
Total Nitrogen	ppm	2,575.0
Phosphate	ppm	101.1
Chloride	ppm	1,150.3

Minerals	Unit	
Chromium	ppm	ND
Lead	ppm	0.0
Potassium	ppm	109.0
Selenium	ppm	0.0
Sodium	ppm	39.7
Calcium	ppm	21.3
Nickel	ppm	0.0
Boron	ppm	0.1
Aluminum	ppm	3.0
Arsenic	ppm	ND
Cadmium	ppm	ND
Cobalt	ppm	ND
Copper	ppm	0.0
Iron	ppm	5.0
Manganese	ppm	0.1
Magnesium	ppm	5.1
Barium	ppm	0.1
Molybdenum	ppm	0.0
Zinc	ppm	2.9

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Food Waste Digestate – a perspective

Physical Characteristics	Unit	
Total Solids	%	2.4
VS of TS	%	62.5
COD	mg/L	13,134.4
Total Nitrogen	ppm	2,575.0

- Example
  - Q_{in} = 60,000 gpd = 0.06 MGD
  - NH4 = 80% of TN
  - Ppm = mg/L

COD_{mass} = Q_{in} x COD x 8.34 = 0.06 * 13,134.4 * 8.34 = 6,572.5 ppd

$NH4_{mass}$ = Q_{in} x NH4 x 8.34 = 0.06 * 2,060 * 8.34 = 1,030 ppd

- Compare to municipal
  - COD_{inlet} ~ 800ppm
  - NH4 = 40 ppm

- Correlation – digestate is equivalent to:
  - COD_{mass} = 1 MGD municipal facility (16x)
  - Amm_{mass} = 3 MGD municipal facility (50x)

- Why it matters
  - Significant impact to municipal operations
  - Understand sizing impacts of treating digestate
  - Understanding permitting

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Nutrient Removal Tech

Nutrient Removal Tech - terms

- Acronyms
  - AD – anaerobic digester
  - NOB – nitrite oxidizing bacteria (ie NO_2 > NO_3)
  - AOB – ammonia oxidizing bacteria (ie NH4 > NO_2)
  - HRT – hydraulic retention time…time liquid is held within reactor
  - SRT – solids retention time…time bacterial solids remain in system
  - Passive Aeration – oxygen molecules diffuse through membrane and dissolve directly to aqueous biofilm.
  - Diffused Aeration - submerged device releases air at bottom of tank, creating small bubbles
  - Heterotrophic – General term for bacteria that remove BOD, COD, and or Nitrate. Bacteria require dissolved oxygen (DO) or chemically-bound oxygen (ie Nitrate = NO_3).
  - Autotrophic – General term for bacteria that remove ammonia/ammonium nitrogen. Bacteria require oxygen and generate energy without a carbon source (ie BOD, COD).
  - Ammonia - NH_3 (un-ionized form)…pH dependent
  - Ammonium – NH_4^+ (ionized form)…pH dependent
  - MBR – Membrane Bioreactor – membrane device with micron pore sizes, used to separate liquid + solids
  - MABR – Membrane Aerated Biofilm Reactor – membrane device used to grow biofilm and directly inject oxygen to bacteria
  - Clarifier – process used to gravity settle suspended solids (can be primary or secondary)
  - Swing zone - reactor that can operate either anoxically or aerobically
  - IMLR – internal mixed liquor recycle (ie nitrate recycle)
  - Nitrification – oxidation of Ammonia/Ammonium
  - Denitrification – removal of Nitrate/Nitrite
  - RAS – return activated sludge

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Nutrient Removal Tech – by Fluence

- Membrane Aerated Biofilm Reactor (MABR) + Nitro mode
  - Spiral-wound self-respiring membrane supporting simultaneous nitrification + denitrification
  - Energy-efficient shortcut nitrogen powered by MABR

- Nitrosax – A Modified Sharon process
  - Energy-efficient shortcut nitrogen removal using Nitrosation + Denitrosation

- *Nitrostep*
  - *Modified Ludzack Ettinger (MLE) using conventional nitrification-denitrification*

- *Fostrex*
  - *Preventative struvite and phosphorus removal/recovery*
  - *Magnesium Ammonium Phosphate precipitation*

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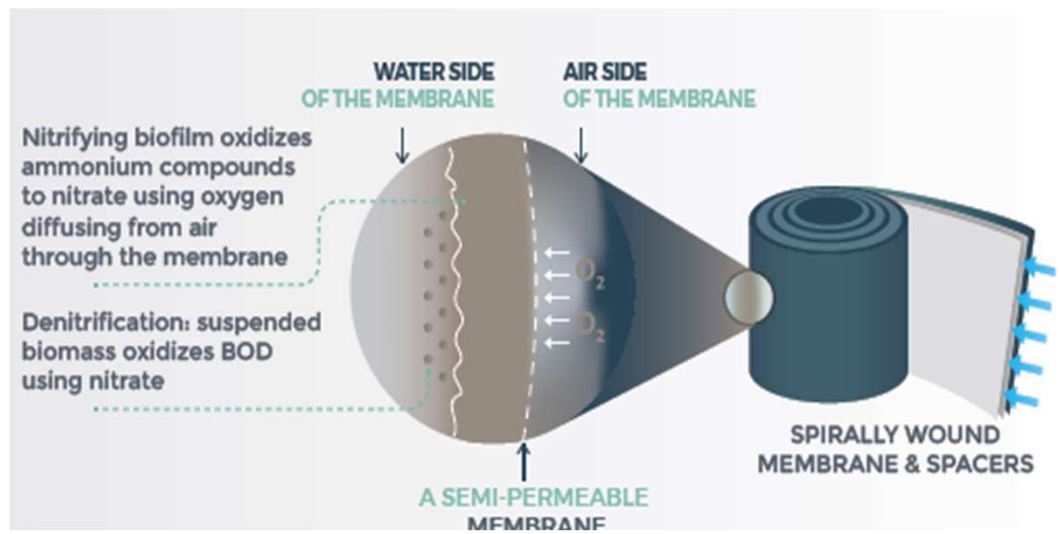
Nutrient Removal Tech – MABR

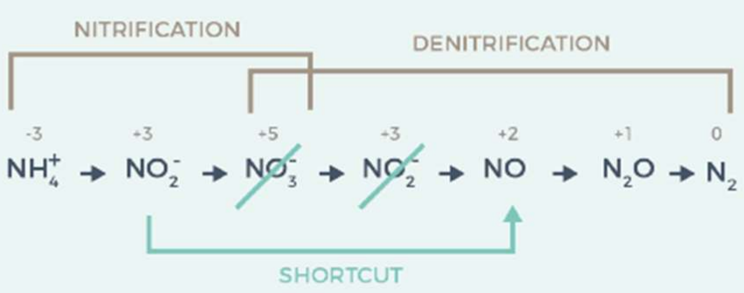
- Self respirating membrane
- Uses passive diffusion (not diffused aeration)
- Creates AEROBIC biofilm growth inside ANOXIC environment
- Total Nitrogen reduction (NH_4, NO_2, NO_3).
- 300+ installations worldwide
- Multiple configurations for new or existing
- Wastewaters with BOD:N ratio < 4:1.
- https://www.youtube.com/watch?v=GNhoWTdre20



Nutrient Removal Tech – Nitro mode

Shortcut Nitrogen Removal

The shortcut nitrogen removal process saves energy by converting ammonia to nitrite, and then directly to nitrogen gas, skipping the conversion to nitrate in between.



- Uses MABR configured at specific pH, DO, and Ammonia
- System converts ammonia directly to nitrogen gas
- Nitrite Oxidizing Bacteria (NOBs) are suppressed
- Ammonia only or TN reduction configurations
- Multiple configurations for new or existing
- Concentrations from 200 ppm to 3,000 ppm NH_4-N
- Typically < 100 ppm NH_4 discharge
- ~0.6 kwh/kg NH_4 removed

Perfect for high nitrogen containing streams like...

Anaerobic digestion and co-digestion

Leachate

Compost

Swine and cow farms

Fertilizer

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Nutrient Removal Tech – Nitrosax (Modified Sharon)

- Suspended growth High activity Ammonia Removal Over Nitrite
- Controlled by ORP, temperature, pH
- Adjusted to prevent $NO_2 \geq NO_3$
- Rapid reduction of Total Nitrogen
- Typically used as primary step for 40-60% reduction
- Often combined with Fluence MABR, MLE, or MBR for lower limits

Nutrient Removal Tech - Summary

Process	Advantages	Disadvantages	HRT	SRT	OPEX	Chemical	Configurations	Target NH4 Removal
MABR	Process Stability Low Energy Total Nitrogen Flexibility Scalability Upgrade for existing Anoxic No Nitrate recirculation	BOD:N ratio (4:1) FOG restrictions TSS restrictions -- -- -- --	Low	High	Low	pH, Alkalinity	MABR + Clarifier MABR + MBR MABR + UF Aer. + MABR + Clarifier -- -- --	High
Nitro	Process Stability Low Energy Total Nitrogen Upgrade for existing Anoxic	Alkalinity dependent BOD:N ratio (2:1)	Low to Medium	High	Low	pH, Alkalinity	MLE + Nitro Nitro + Clarifier Aerobic + Nitro + Clarifier Nitro + Nitrosax + Clarifier	High
Nitrosax	Simple High Rate No chemical Low Energy Total Nitrogen	Alkalinity dependent BOD:N ratio (2:1) May require heat -- --	Low to Medium	Medium	Low	none	Nitrosax + Clarifier Nitrosax + MABR + Clarifier Nitrosax + MBR -- --	Medium
Nitrostep	Simple Proven Low Energy Total Nitrogen	Large reactor Carbon dependent Alkalinity dependent High Recirculation	High	High	Medium	pH, Alkalinity, Carbon	Nitrostep + Clarifier Nitrostep + MBR Nitro + Nitrostep + Clarifier --	High
Fostrex	Preventive Precipitation Phosphorus removal	pH adjustment limited to Mg + NH4	Low	n/a	Medium to High	pH, Alkalinty, micronutrient	Fostrex + N removal	preventive

Paul's Example

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Cadmium	ppm	ND
Cobalt	ppm	ND
Copper	ppm	0.0
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Manganese	ppm	0.1
Magnesium	ppm	5.1
Barium	ppm	0.1
Molybdenum	ppm	0.0
Zinc	ppm	2.9

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Paul's Example

Process Configuration

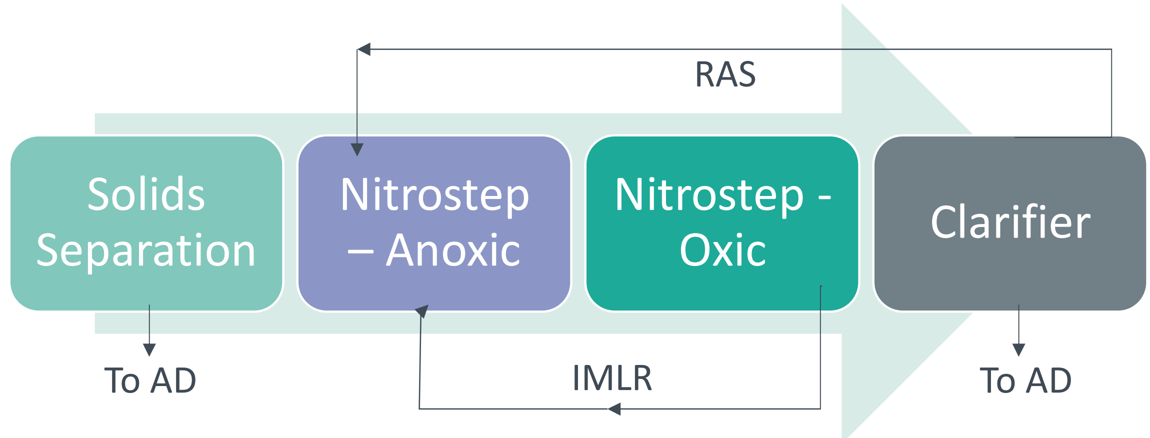
Solids Separation	Swing	Nitrosax	Clarifier	
Solids Separation	Swing	Nitro	Clarifier	
Solids Separation	Swing	Nitrosax	Nitrostep	Clarifier
Solids Separation	Swing	Nitrosax	MABR	Clarifier
Solids Separation	Swing	Nitro	Nitrostep	Clarifier
Solids Separation	Nitrostep	Clarifier		
Solids Separation	Nitrostep	MBR		
Solids Separation	Swing	Nitrosax	MBR	
Solids Separation	Swing	Nitro	MBR	
Solids Separation	Swing	MABR	Clarifier	
Solids Separation	Swing	MABR	MBR	

Nitrogen Removal: Lowest → Highest

Process Volume: Low → High

Paul's Example

- 1st - Reduce TSS + pCOD
  - This will improve biota and energy efficiency downstream
- 2nd – Nitrostep Anoxic
  - 158,000 gallon
  - ~1,000ft^2
- 3rd – Nitrostep Oxic
  - 158,000 gallon
  - ~1,000ft^2
- 4th – Clarifier
  - 20-ft diameter x 12-ft SWD
  - ~200ft^2
- ~50-ft x 50-ft
- < 70 kW
- TN < 40 ppm
- Equipment ~$750k USD
- Construction ~$750k USD
- OPEX ~$40,000.00 USD per year



Thank you for your attention

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