Impact of Side Streams on Nutrient Removal

Management and Treatment Options

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Background
Nutrient Removal Mass Balance

**Influent**
- P: 100%
- N: 100%

**Primary Treatment**
- P: 10 - 100%
- N: 10 - 30%

**BNR**
- P: 110% - 200%
- N: 110% - 130%

**Solids Processing**
- P: 99%
- N: 20%

**Effluent**
- P: 1%
- N: 20%

**Cake**
**Level of Treatment**

**N-Removal**
- 70% - 1 Barrier (MLE)
- 85% - 2 Barrier (MLE with Post ANX)
- 95% - 3 Barrier (2 Stage + Filtration)

**P-Removal**
- 60% - 1 Barrier (Bio-P)
- 85% - 2 Barrier (Bio-P with + Chem-P)
- 99% - 3 Barrier (2 Stage + Filtration)

*Side Stream Treatment = 1 Barrier for P Removal*
Recycle Load Compounding

Typical Dewatering Schedule: Day Shift Mo – Fr

Net Recycle Load Increases 4.2 Times
Side Stream Characterization and Impact
<table>
<thead>
<tr>
<th>Parameter</th>
<th>(mg/L)</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>1200 - 1600</td>
<td>2 - 3</td>
</tr>
<tr>
<td>BOD</td>
<td>400 - 500</td>
<td>0.7 – 1.0</td>
</tr>
<tr>
<td>TKN</td>
<td>1100 - 1300</td>
<td>12 - 18</td>
</tr>
<tr>
<td>NH4-N</td>
<td>1000 - 1200</td>
<td>15 - 22</td>
</tr>
<tr>
<td>NOx</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TP</td>
<td>300 - 400</td>
<td>30 - 40</td>
</tr>
<tr>
<td>PO4-P</td>
<td>250 - 350</td>
<td>15 - 30</td>
</tr>
</tbody>
</table>
Process Impact

NDN

Carbon Source
Alkalinity Demand
Peak Nitrogen Load
Peak Oxygen Demand
Ammonia Bleed Through

Lincoln WWTP, Lincoln NE
Process Impact

P Removal

Peak P Load
VFA deficit
Chemical Feed Control
Higher Effluent P

Durham AWWTP, Tigard OR
Process Impact

General

- Reduced Capacity
- Impact Compounded by Dewatering
- Reduced Effluent Quality
  - Solids Transfer from Other plant
  - Storage Lagoon Operation
  - Low Max Day Limits

Bud Inlet WWTP, Olympia WA
Side Stream Management

Diurnal Ammonia Load

- PE Ammonia
- Average Ammonia
- PE + Recycle Ammonia
Side Stream Management

Off Peak Dewatering

Reduces Impact for Nitrification

VFA Balance not addressed

Carbon Balance not addressed

Alkalinity Balance not Addressed

Diurnal Ammonia Load

- PE Ammonia
- Average Ammonia
- PE + Recycle Ammonia

NH4-N [lbs/d]

0:00 4:00 8:00 12:00 16:00 20:00 0:00

0 1000 2000 3000 4000 5000 6000
Side Stream Management

24/7 Dewatering/Equalization

Reduces Impact for Nitrification

Alkalinity Balance Improved

Carbon Balance Improved

VFA Balance Improved

Diurnal Ammonia Load

PE Ammonia
Average Ammonia
PE + Recycle Ammonia
Side Stream Management

Impact of SSM

SSM vs Effluent Phosphate

[Graph showing the impact of SSM on effluent phosphate levels over time, with different load scenarios.]
Side Stream Management

Impact of SSM

SSM vs Effluent Nitrate

[mg/L]

4:00 8:00 12:00 16:00 20:00 0:00

Contineous 6AM - 2 PM 12AM - 8 AM No Recycle

No Recycle Load
Side Stream Management

Impact of SSM

SSM vs Effluent Ammonia

- No Recycle Load

- Contineous
- 6AM - 2 PM
- 12AM - 8 AM
- No Recycle

[mg/L]

[4:00 8:00 12:00 16:00 20:00 0:00]
Side Stream Treatment
Side Stream Treatment

Process - General

- Biological, Chemical or Physical/Thermal
- Compact Process
- Take Advantage of Higher Temperatures
- Tolerate Dewatering Recycle Quality
- Aimed at P and/or N removal
- 80 – 90% Removal Efficiency Sufficient
• Integrated in Secondary Treatment
• Equalization not Required
• Limited by OUR
Side Stream Treatment

Biological – Side Stream CAS

- Separate Biology
- Seeding of Main Process
- Equalization Recommended
- Limited by OUR

**Abbreviations**

- AER = Aerobic Zone
- ANR = Anaerobic Zone
- ANX = Anoxic Zone
- PCL = Primary Clarifier
- RAS = Return Activated Sludge
- REA = Renovation
- RRAS = Restoration RAS
- SCL = Secondary Clarifier
- SSFF = Side Stream Treatment Effluent
- SSWAS = Side Stream WAS
- SCL = Secondary Clarifier
- WAS = Waste Activated Sludge
Side Stream Treatment

Biological – Side Stream MBBR

- Separate Biology
- Seeding of Main Process
- Equalization Recommended
- Attached Growth
- No Clarifier
- Pilot Required
Side Stream Treatment

Biological – Sharon

- Utilizes Nitrite Oxidizing Bacteria
- Requires Temperature > 35°C
- Soluble Carbon Source Required
- pH and DO controlled
- Reduced Oxygen Demand
- Reduced Carbon Demand

\[ \text{NH}_4^+ + 1.5 \text{O}_2 \rightarrow \text{NO}_2^- + \text{H}_2\text{O} + 2\text{H}^+ \]
Side Stream Treatment

Biological – Anammox

\[ \text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2^* \]

- Utilizes Nitrite Anammox Bacteria
- Requires Temperature > 35°C
- No external Carbon Source Required
- pH and DO controlled
- Reduced Oxygen Demand
- Reduced Alkalinity Consumption

\[ \text{NH}_4^+ + 1.32\text{NO}_2^- + 0.066\text{HCO}_3^- + 0.13\text{H}^+ \]
\[ \rightarrow 1.02\text{N}_2 + 0.26\text{NO}_3^- + 0.066\text{CH}_2\text{O}_{0.5}\text{N}_{0.15} + 2.03\text{H}_2\text{O} \]
Side Stream Treatment

Biological - Sharon/Anammox

AER = Aerobic Zone
ANR = Anaerobic Zone
ANX = Anoxic Zone
PCL = Primary Clarifier
RAS = Return Activated Sludge
REA = reaeration
RRAS = Resreration RAS
SIA = Sharon/Anammox
SCL = Secondary Clarifier

Secondary Effluent
WAS to Solids Processing

Dewatering Recycle
(Carbon/Alkalinity)

Anammox

Sharon

Dewatering Recycle

Sharon

Dewatering Recycle

Sharon/Anammox

Dewatering Recycle

SIA WAS

SIA WAS

SIA WAS
Side Stream Treatment

Physical/Thermal – NH₄ Stripping

\[ \text{NH}_4^+ + \text{(Heat and/or OH}^-\text{)} \rightarrow \text{NO}_3^- \]

- Volatize NH₄
- Increase temperature and or pH
- Removal is Function of T and pH
- Air Stripping Produces Foul Air
- Pretreatment Required
- Capture of NH₃ possible
Side Stream Treatment

Physical/Thermal – NH4 Stripping

Closed Loop Air Stripping
Side Stream Treatment

Physical/Thermal – NH4 Stripping

Steam Stripping
Side Stream Treatment

Chemical – PO₄-P Precipitation

• Alum, Ferric, or Lime
• Add Upstream of Dewatering
• Good Chemical Utilization
• Simple Process
• Cost from Chemical Use and Chemical Sludge
Side Stream Treatment

Chemical – P- Recovery

• Capture as Struvite
• Grow extractable crystals
• Potential for Cost Recovery or Profit
• Good fit for Bio-P plants

\[ \text{Mg}^{2+} + \text{NH}_4^+ + \text{PO}_4^{3-} + 6 \text{H}_2\text{O} \rightarrow \text{MgNH}_4\text{PO}_4 \cdot 6(\text{H}_2\text{O})_6 \]
Side Stream Treatment

P- Recovery - PHOSPAQ

Side Stream → (Mg^{2+}) → P Recovery Reactor → Plate Settler → Treated Side Stream

Hydrocyclone → P recovery Product

Pelletizer
Side Stream Treatment

P - Recovery - Ostara
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