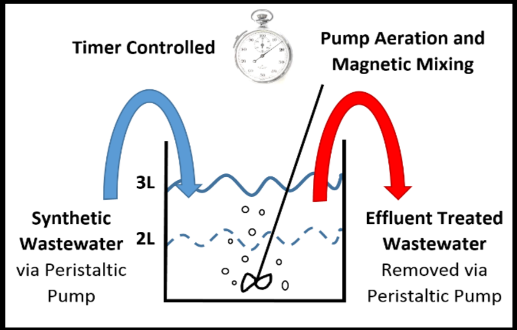
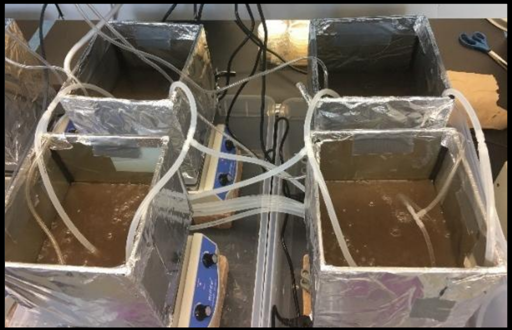
Determining Effects of Class I Landfill Leachate on Biological Nutrient Removal in Wastewater Treatment





Ashley A. Danley-Thomson, Ph.D.

Florida Gulf Coast University

SWANA Florida Summer Conference, Palm Beach Gardens

Ashley Danley-Thomson, Ph.D.

- Assistant Professor in Environmental Engineering at Florida Gulf Coast University
- B.S. in Civil and Environmental Engineering from Florida State University
- Ph.D. in Civil and Environmental Engineering from Duke University
- Research: sustainable water and wastewater treatment design, biotechnology, microbial engineering, community development, and international development. Solid waste engineering, water reuse, nutrient and energy recovery.

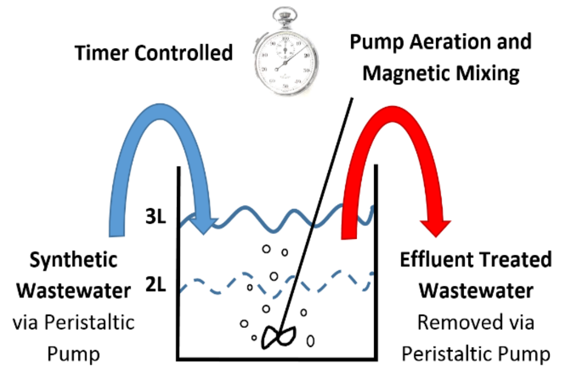
Objectives

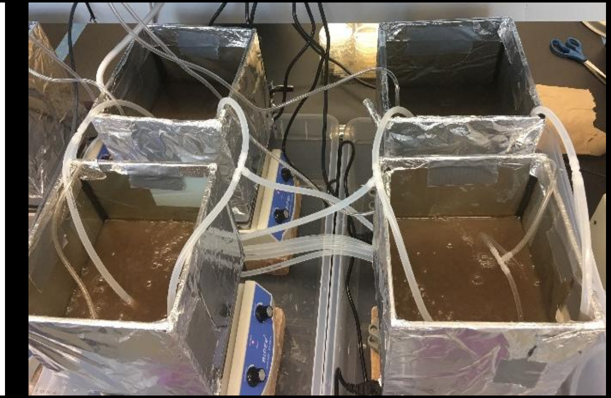
- Objective 1: Evaluate the effect of leachate on the efficacy of biological nutrient removal (BNR) activated sludge processing using lab scale sequencing batch reactors (SBRs). Here, sequencing batch reactors are operated with nitrifying activated sludge and fed distinct ratios of synthetic wastewater and landfill leachate. Controls are also operated (100% loading of leachate as positive control, 100% loading of activated sludge as negative control).

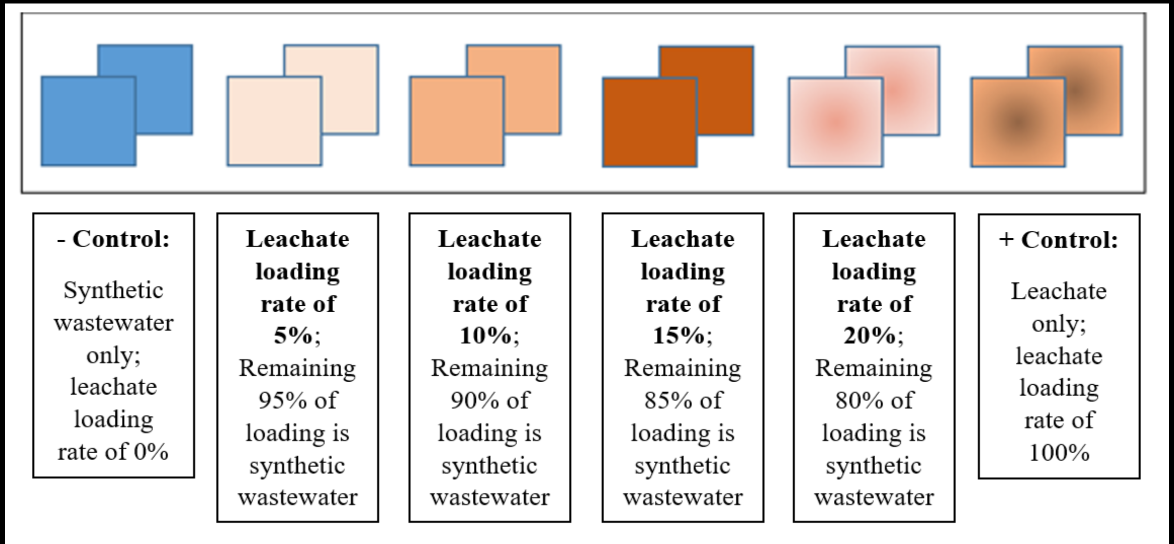
- Objective 2: Determine the extent that BNR activated sludge can be adapted to effectively handle a loading of landfill leachate known to cause overloading using lab scale sequencing batch reactors (SBRs). Here, sequencing batch reactors operated with nitrifying activated sludge adapted to leachate loadings as described in Objective 2 are fed a ratio of 70% synthetic wastewater and 30% landfill leachate for one week.

Research Approach

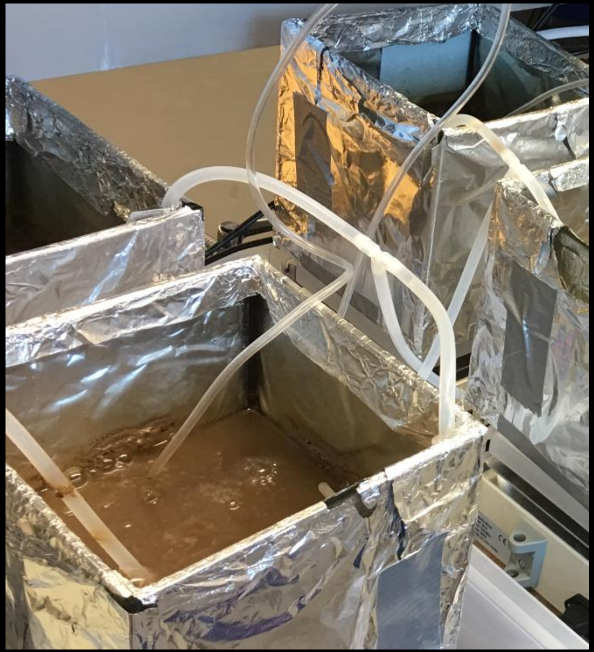
1







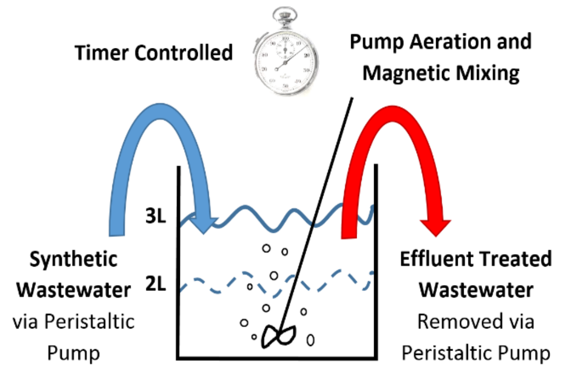
2

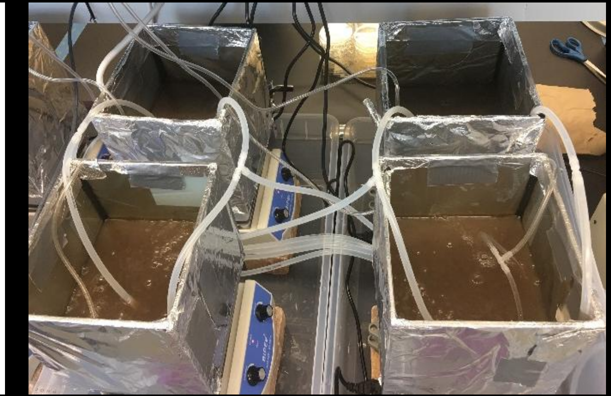


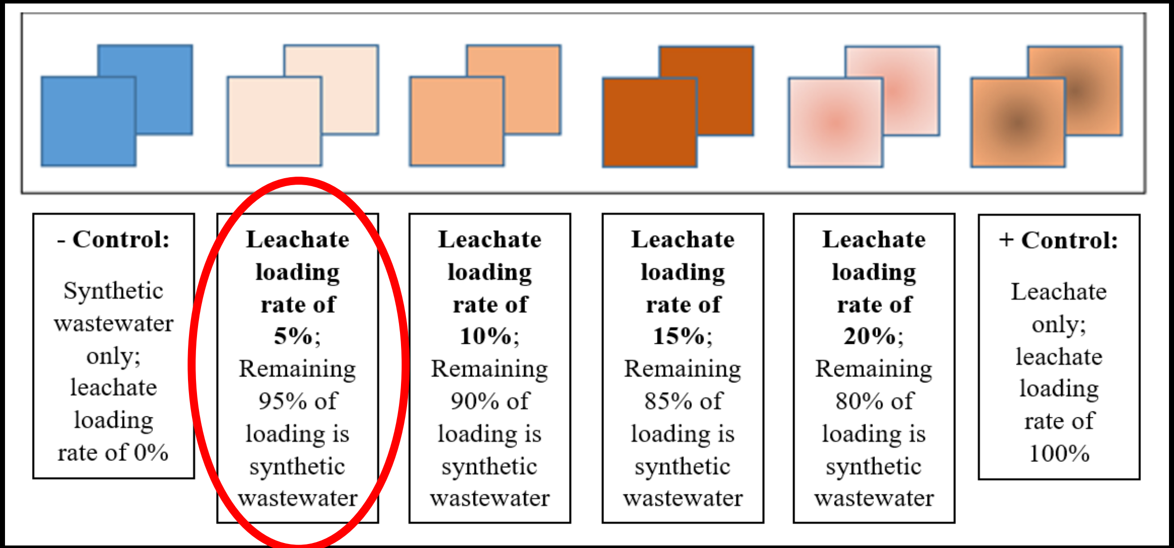
30% leachate loading

Research Approach

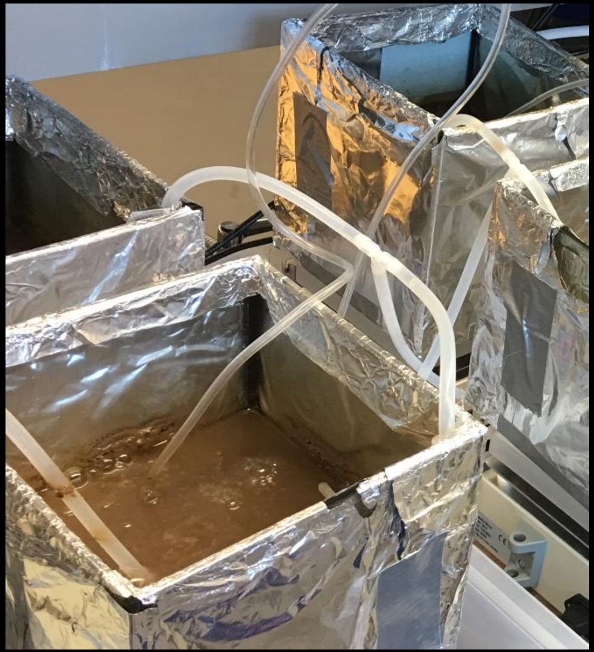
1







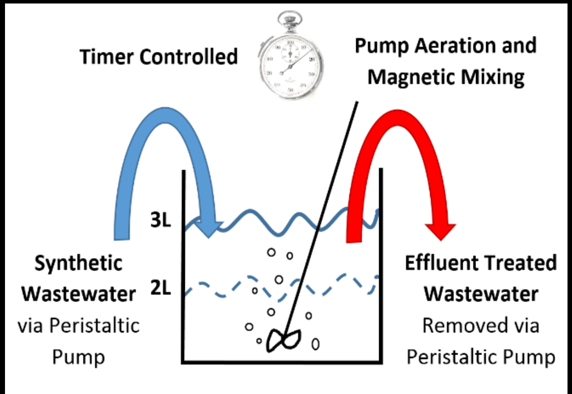
2

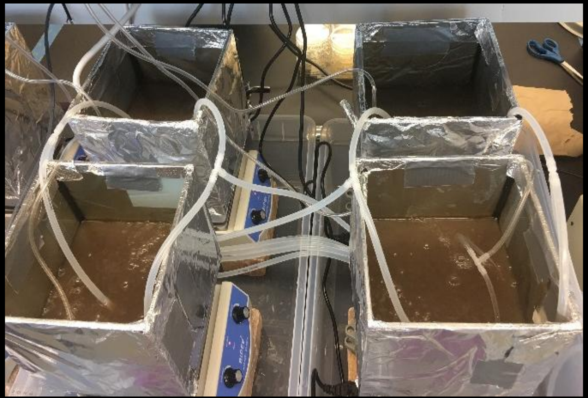


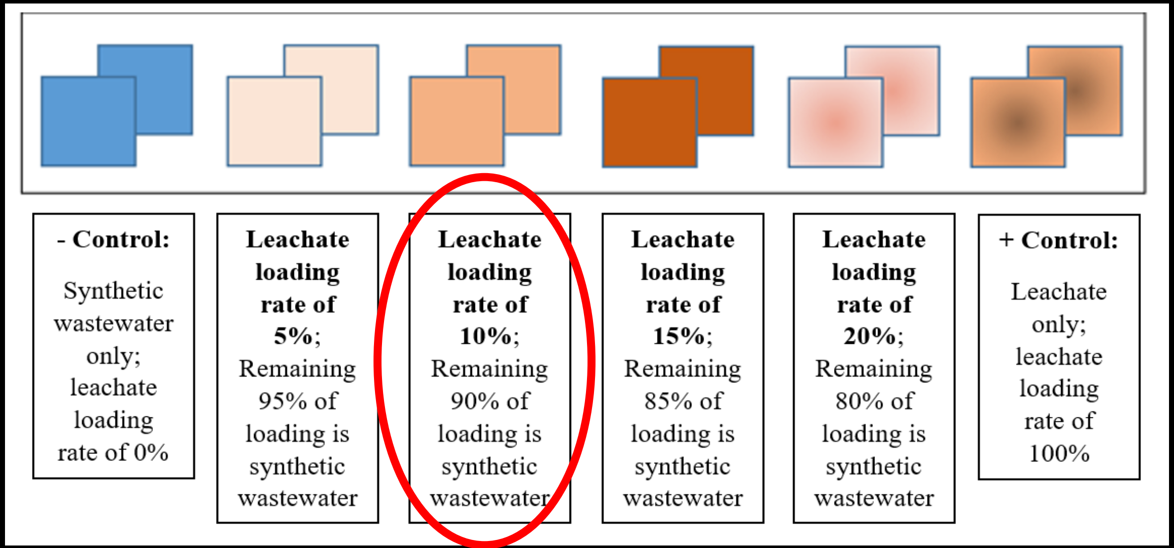
30% leachate loading

Research Approach

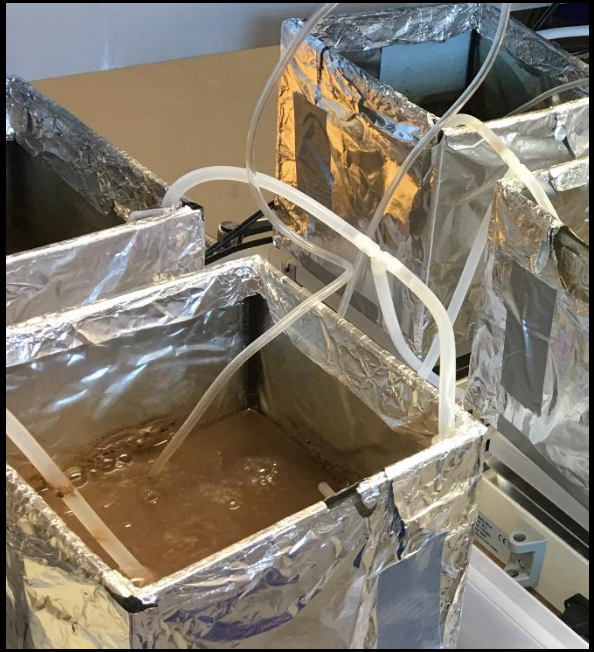
1







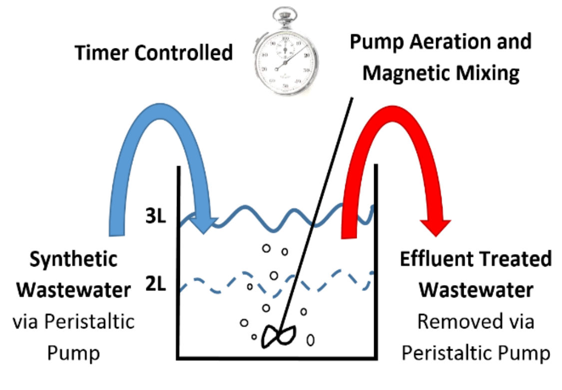
2

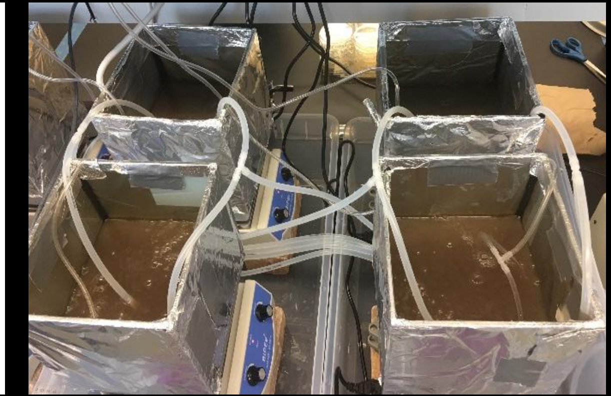


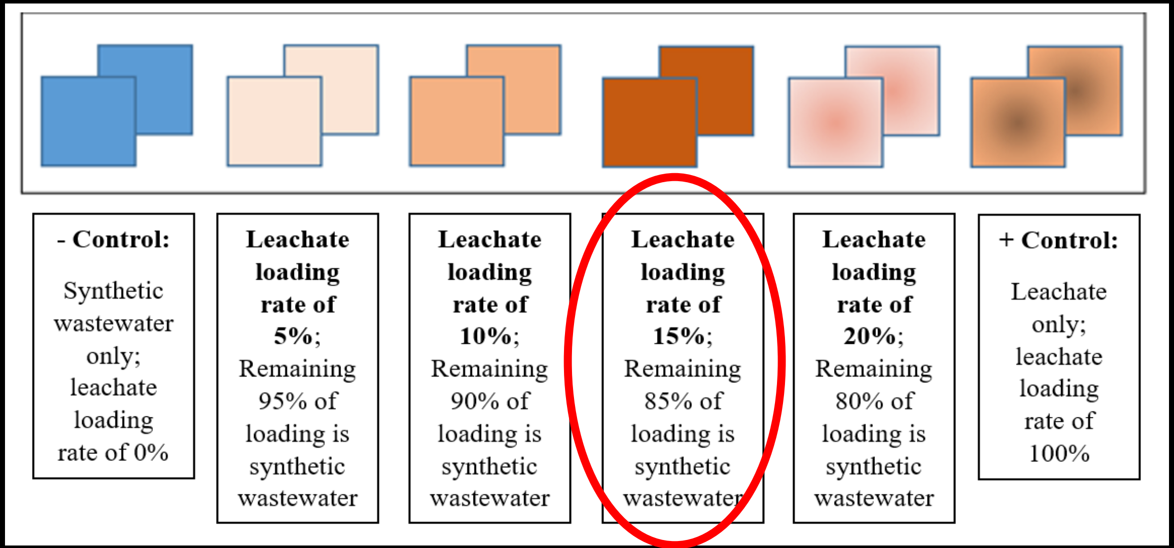
30% leachate loading

Research Approach

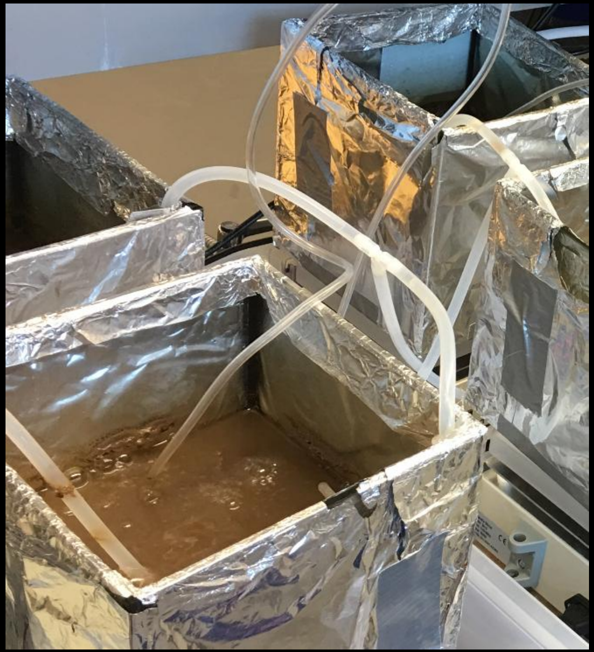
1







2

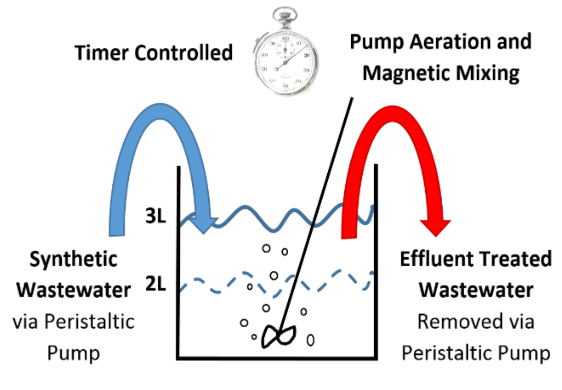


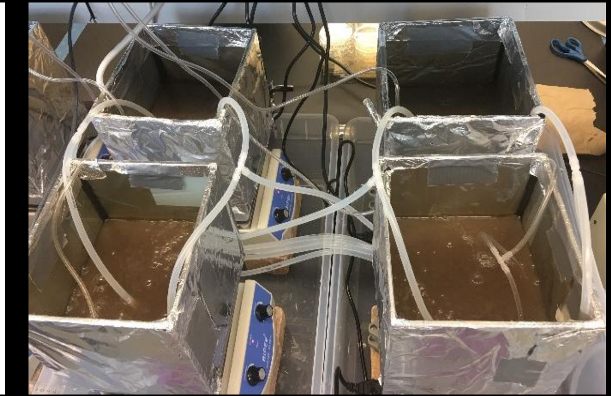
30% leachate loading

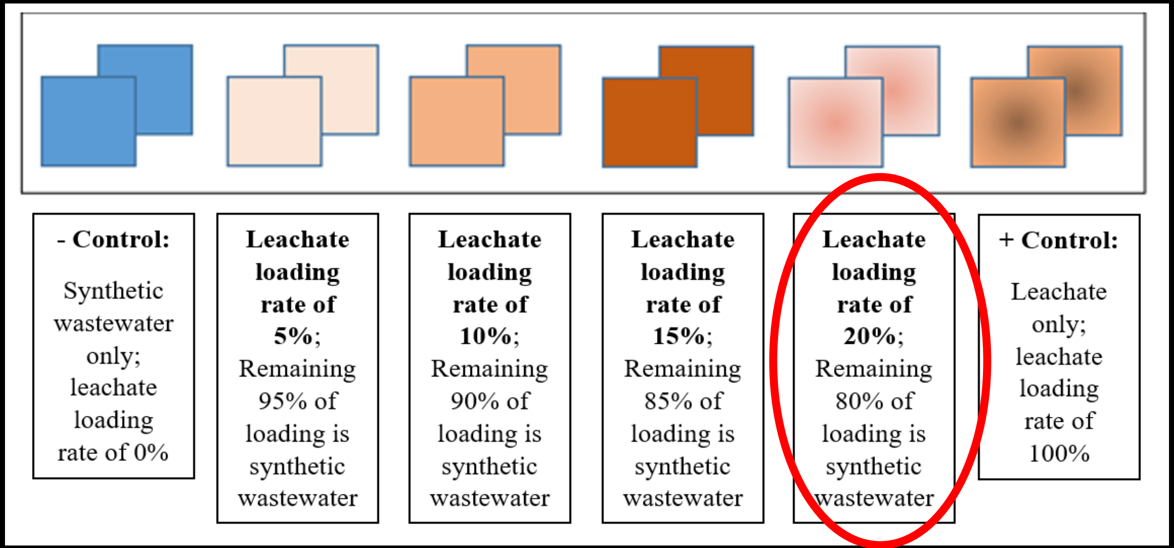
Research Approach

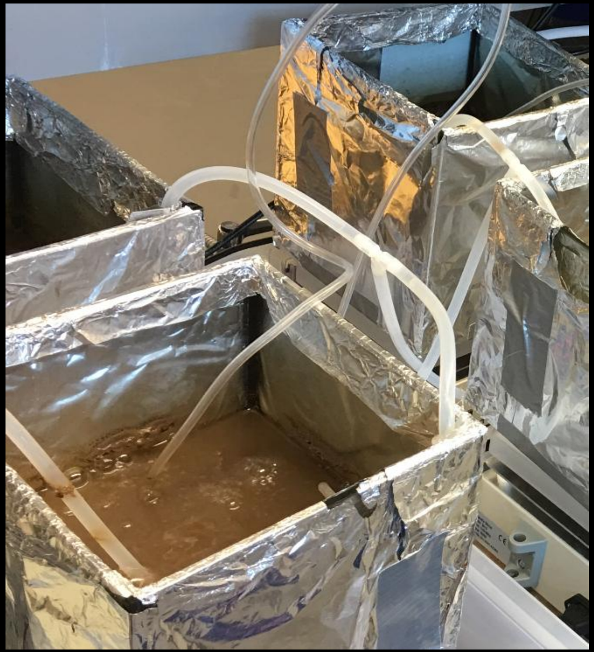
1

2





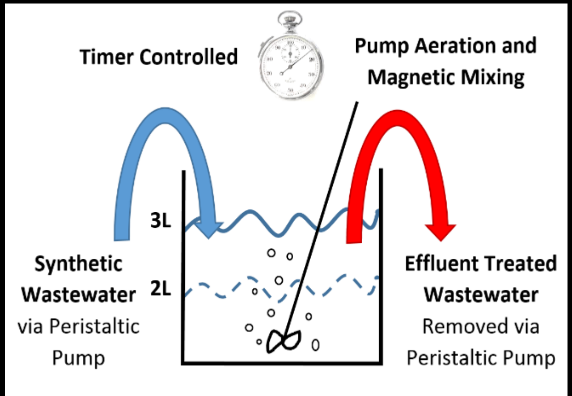


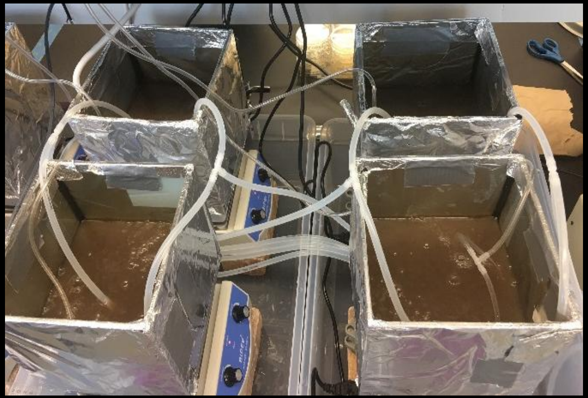


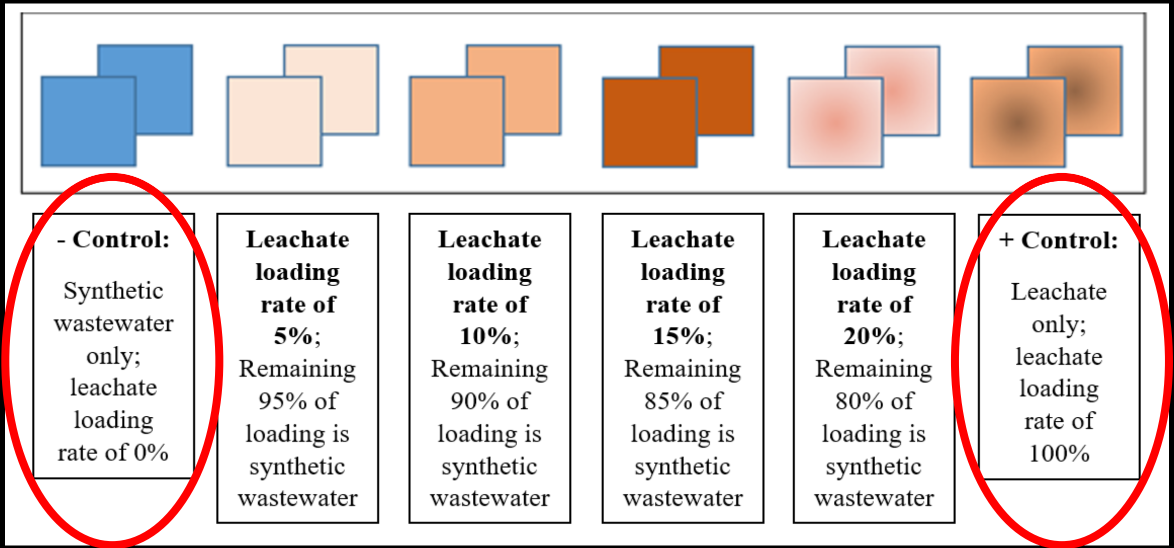
30% leachate loading

Research Approach

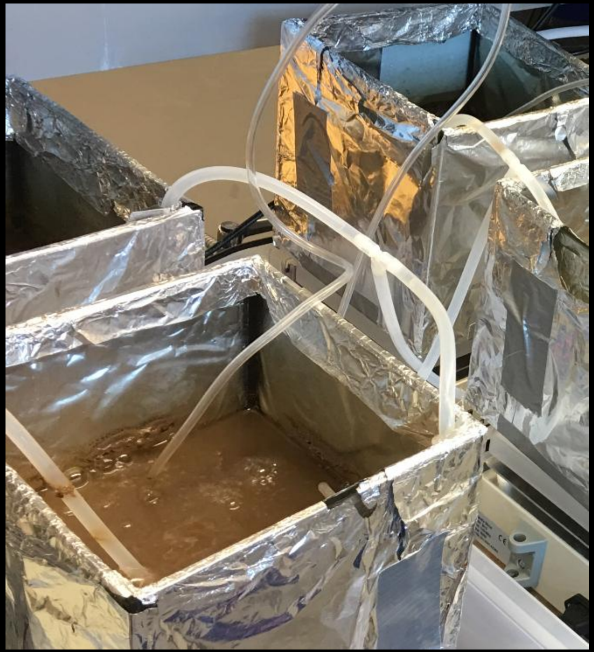
1







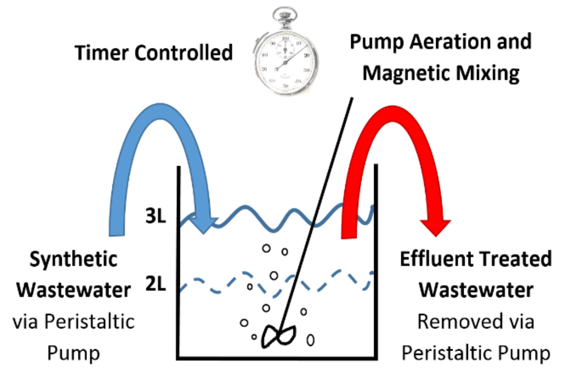
2

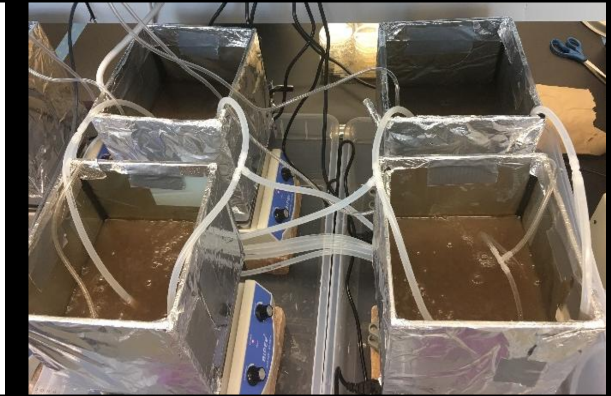


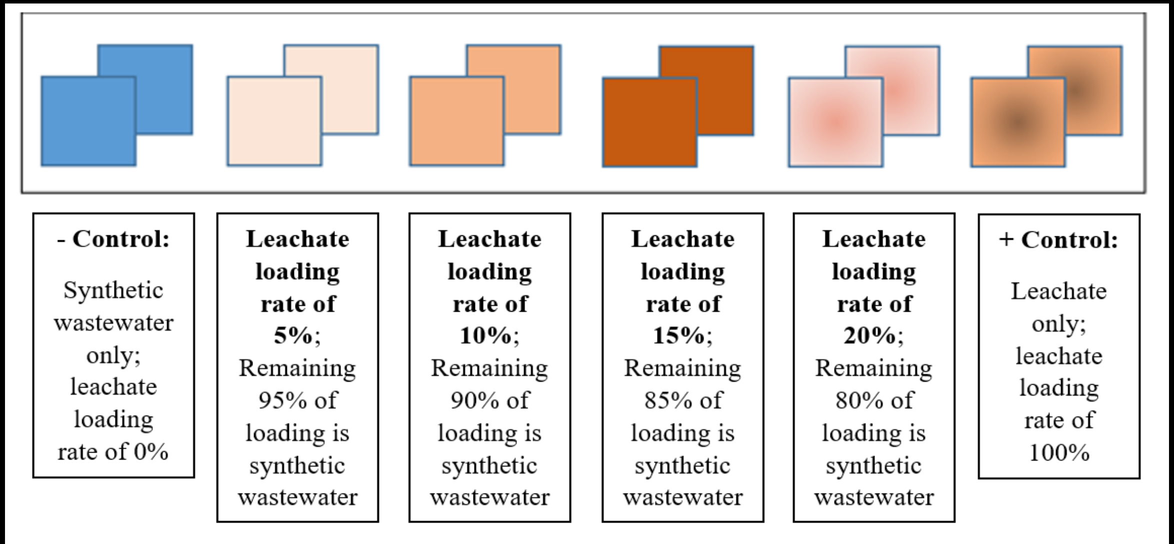
30% leachate loading

Research Approach

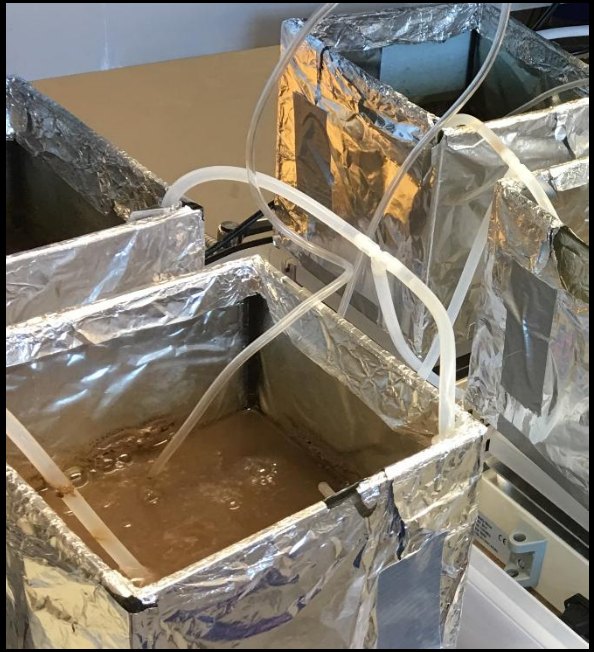
1





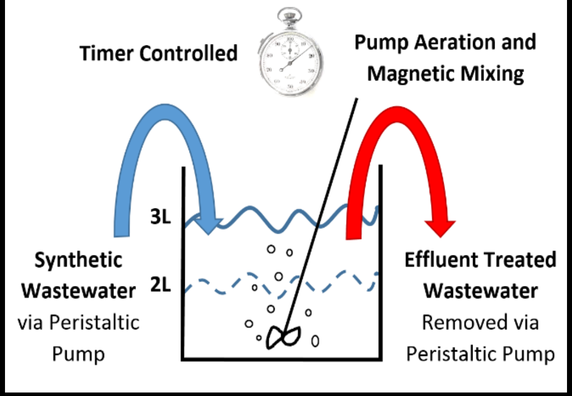


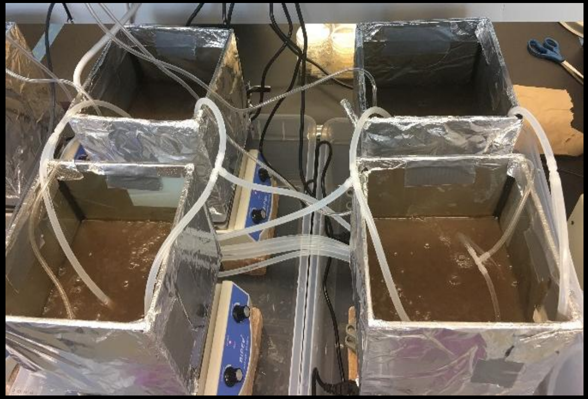
2



30% leachate loading

Phase I





All reactors receive synthetic wastewater.

Average COD, total inorganic nitrogen (TIN), and phosphate loading were 599.3 ± 266.8 mg/L, 65.9 ± 11.4 mg/L, and 5.3 ± 1.1 mg/L, respectively.

Average VSS in all 10 reactors receiving synthetic wastewater was 4,378 ± 411.7 mg/L

<table>
<tr><th>Reactor Leachate Loading (% v/v)</th><th>Influent COD (mg/L)</th><th>Influent TIN-N (mg/L)</th><th>Influent COD/TIN-N ratio (mg/mg)</th><th>Influent Organic Loading Rate

(g COD / (L d))</th><th>g COD in influent / g VSS in SBR</th><th>g TIN-N in influent / g VSS in SBR</th></tr>
<tr><td>0</td><td rowspan="5">599.3 ± 266.8</td><td rowspan="5">69.5 ± 11.4</td><td rowspan="5">8.6</td><td rowspan="5">0.6</td><td rowspan="5">0.14</td><td rowspan="5">0.02</td></tr>
<tr><td>5</td></tr>
<tr><td>10</td></tr>
<tr><td>15</td></tr>
<tr><td>20</td></tr>
<tr><td>100</td><td>6,758.2 ± 528.3</td><td>2,099.5 ± 361.5</td><td>3.2</td><td>6.8</td><td>29.7</td><td>9.2</td></tr>
</table>

Table 2. Average loading for each condition in Phase I.

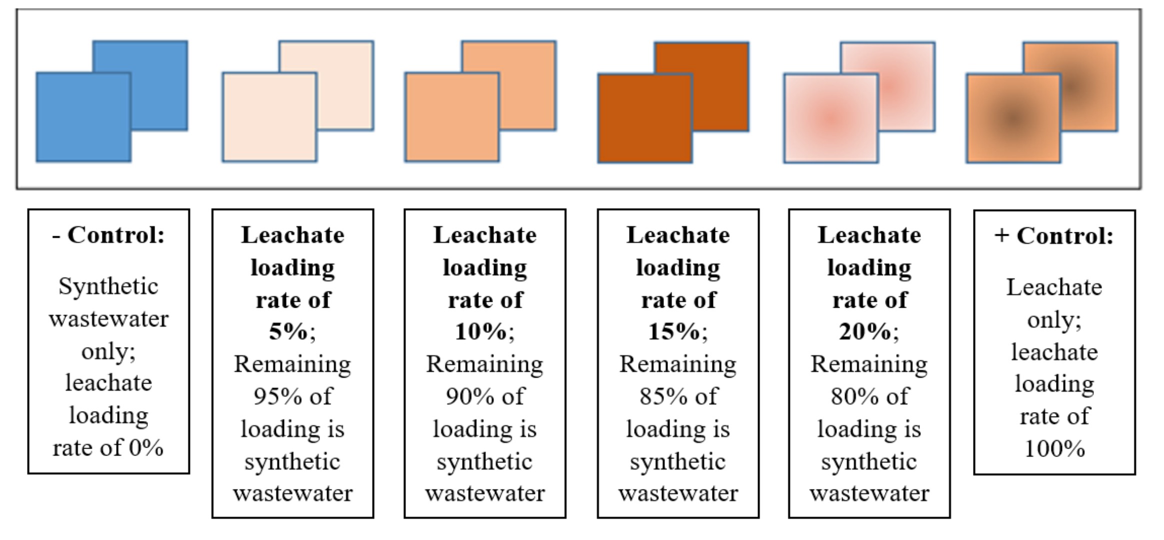
COD, TIN, and TP removals of 91.0%, 69.4%, and 35.8%, respectively

No statistically significant difference in treatment was observed in the SBRs receiving synthetic wastewater ($p>0.05$).

<table>
<tr><th>Reactor Leachate Loading (% v/v)</th><th>Effluent COD (mg/L)</th><th>Effluent TIN-N (mg/L)</th><th>Effluent COD/TIN-N ratio (mg/mg)</th><th>COD Removal (%)</th><th>COD Removal (mg)</th><th>TIN-N Removal (%)</th><th>TIN-N Removal (mg)</th></tr>
<tr><td>0</td><td rowspan="5">54.2 ± 21.7</td><td rowspan="5">21.3 ± 4.1</td><td rowspan="5">2.5</td><td rowspan="5">91.0</td><td rowspan="5">545.1</td><td rowspan="5">69.4</td><td rowspan="5">48.2</td></tr>
<tr><td>5</td></tr>
<tr><td>10</td></tr>
<tr><td>15</td></tr>
<tr><td>20</td></tr>
<tr><td>100</td><td>6,450.4 ± 703.4</td><td>2,050.9 ± 445.8</td><td>3.1</td><td>4.6</td><td>308.0</td><td>2.3</td><td>49.0</td></tr>
</table>

Table 3. Average effluent for each condition at the end of Phase I.

Phase II



Reactors receive defined ratios of synthetic wastewater and landfill leachate until steady state is achieved.

Characteristics of the leachate sample throughout the experiment were COD = 5,935.6 $\pm$ 2,222.8 mg/L, NH_4^+ = 2,047.8 $\pm$ 419.9 mg/L, NO_3^- = 157.4 $\pm$ 69.6 mg/L, NO_2^- = 0.29 $\pm$ 0.16 mg/L, PO_4^- = 1.78 $\pm$ 1.1 mg/L, and pH of 8.3 $\pm$ 0.1

Reactor Leachate Loading (% v/v)	Influent COD (mg/L)	Influent TIN-N (mg/L)	Influent COD/TIN-N ratio (mg/mg)	Influent Organic Loading Rate (g COD / (L d))	g COD in influent / g VSS in SBR	g TIN-N in influent / g VSS in SBR
0	599.3 $\pm$ 266.8	65.2 $\pm$ 12.1	9.2	0.6	0.11	0.01
5	884.3 $\pm$ 227.0	183.0 $\pm$ 48.5	4.8	0.9	0.19	0.04
10	1,144.2 $\pm$ 191.5	268.1 $\pm$ 64.8	4.3	1.1	0.20	0.05
15	1,583.2 $\pm$ 293.3	591.3 $\pm$ 55.6	2.7	1.6	0.38	0.14
20	1,828.9 $\pm$ 410.7	697.3 $\pm$ 38.8	2.6	1.8	0.34	0.13
100	6,419.7 $\pm$ 1,179.1	2,407.7 $\pm$ 147.8	2.7	6.4	16.6	6.3

Table 4. Average loading for each condition in Phase II.

SBRs receiving only synthetic wastewater (0% leachate loading), 5% loading, and 10% loading had ammonium removals of 92.6%, 98.5%, and 84.0%, respectively. Suggest that nitrification was not inhibited at leachate loadings of 5% and 10%.

Reactor Leachate Loading (% v/v)	Effluent COD (mg/L)	Effluent TIN-N (mg/L)	Effluent COD/TIN-N ratio (mg/mg)	COD Removal (%)	COD Removal (mg)	TIN-N Removal (%)	TIN-N Removal (mg)
0	85.6 ± 36.6	15.0 ± 4.2	5.7	85.7	513.4	76.9	50.0
5	242.9 ± 53.0	34.1 ± 4.9	7.1	72.5	641.0	81.4	149.0
10	507.9 ± 53.1	82.2 ± 8.3	6.2	55.6	636.0	69.4	186.0
15	892.0 ± 20.0	379.8 ± 41.2	2.3	43.7	691.0	35.7	211.0
20	1,285.0 ± 169.9	496.7 ± 100.7	2.6	29.7	543.0	28.7	200.0
100	5,361.6 ± 42.3	2,325.3 ± 464.2	2.3	16.5	1058.0	3.4	82.0

Table 5. Average effluent for each condition at the end of Phase II.

Inorganic nitrogen conversion was affected at leachate loadings above 15%, as has been seen in previous studies. For leachate loadings of 15% and 20%, ammonium removal was 50.2% and 52.8%, respectively.

Reactor Leachate Loading (% v/v)	Effluent COD (mg/L)	Effluent TIN-N (mg/L)	Effluent COD/TIN-N ratio (mg/mg)	COD Removal (%)	COD Removal (mg)	TIN-N Removal (%)	TIN-N Removal (mg)
0	85.6 ± 36.6	15.0 ± 4.2	5.7	85.7	513.4	76.9	50.0
5	242.9 ± 53.0	34.1 ± 4.9	7.1	72.5	641.0	81.4	149.0
10	507.9 ± 53.1	82.2 ± 8.3	6.2	55.6	636.0	69.4	186.0
15	892.0 ± 20.0	379.8 ± 41.2	2.3	43.7	691.0	35.7	211.0
20	1,285.0 ± 169.9	496.7 ± 100.7	2.6	29.7	543.0	28.7	200.0
100	5,361.6 ± 42.3	2,325.3 ± 464.2	2.3	16.5	1058.0	3.4	82.0

Table 5. Average effluent for each condition at the end of Phase II.

While TIN-N % removal decreased with increasing leachate loading, mg of TIN-N increased as the loading increased.

Reactor Leachate Loading (% v/v)	Effluent COD (mg/L)	Effluent TIN-N (mg/L)	Effluent COD/TIN-N ratio (mg/mg)	COD Removal (%)	COD Removal (mg)	TIN-N Removal (%)	TIN-N Removal (mg)
0	85.6 ± 36.6	15.0 ± 4.2	5.7	85.7	513.4	76.9	50.0
5	242.9 ± 53.0	34.1 ± 4.9	7.1	72.5	641.0	81.4	149.0
10	507.9 ± 53.1	82.2 ± 8.3	6.2	55.6	636.0	69.4	186.0
15	892.0 ± 20.0	379.8 ± 41.2	2.3	43.7	691.0	35.7	211.0
20	1,285.0 ± 169.9	496.7 ± 100.7	2.6	29.7	543.0	28.7	200.0
100	5,361.6 ± 42.3	2,325.3 ± 464.2	2.3	16.5	1058.0	3.4	82.0

Table 5. Average effluent for each condition at the end of Phase II.

Nitrate concentrations in the effluent of 5% and 10% were higher than the control which may indicate inhibition to the denitrification process, possibly due to the need for a supplementary carbon source as the remaining COD may have been non-biodegradable COD.

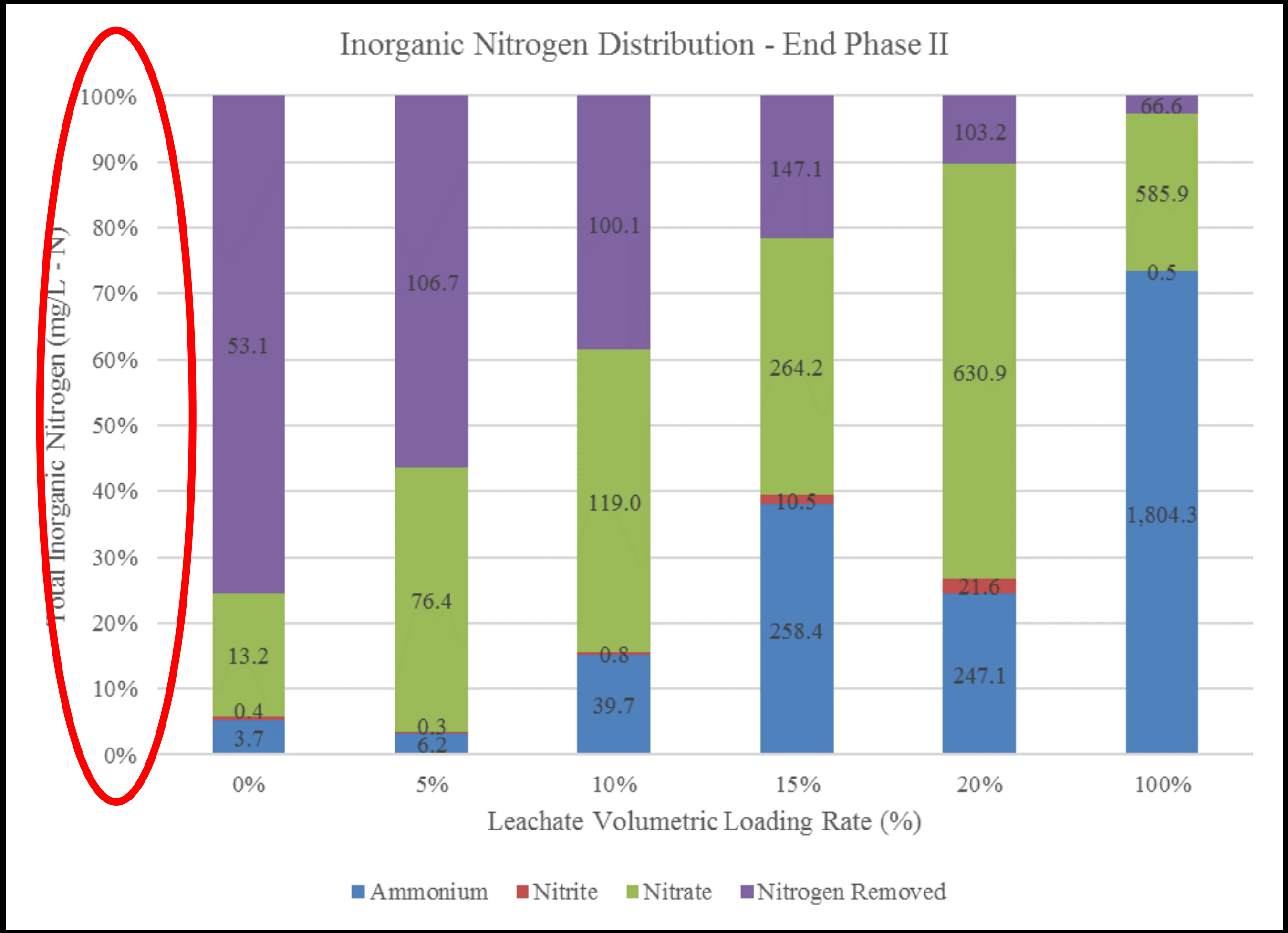


Figure 5. Total inorganic nitrogen distribution in effluent of each SBR leachate loading condition. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

Nitrate concentrations in the effluent of 5% and 10% were higher than the control which may indicate inhibition to the denitrification process, possibly due to the need for a supplementary carbon source as the remaining COD may have been non-biodegradable COD.

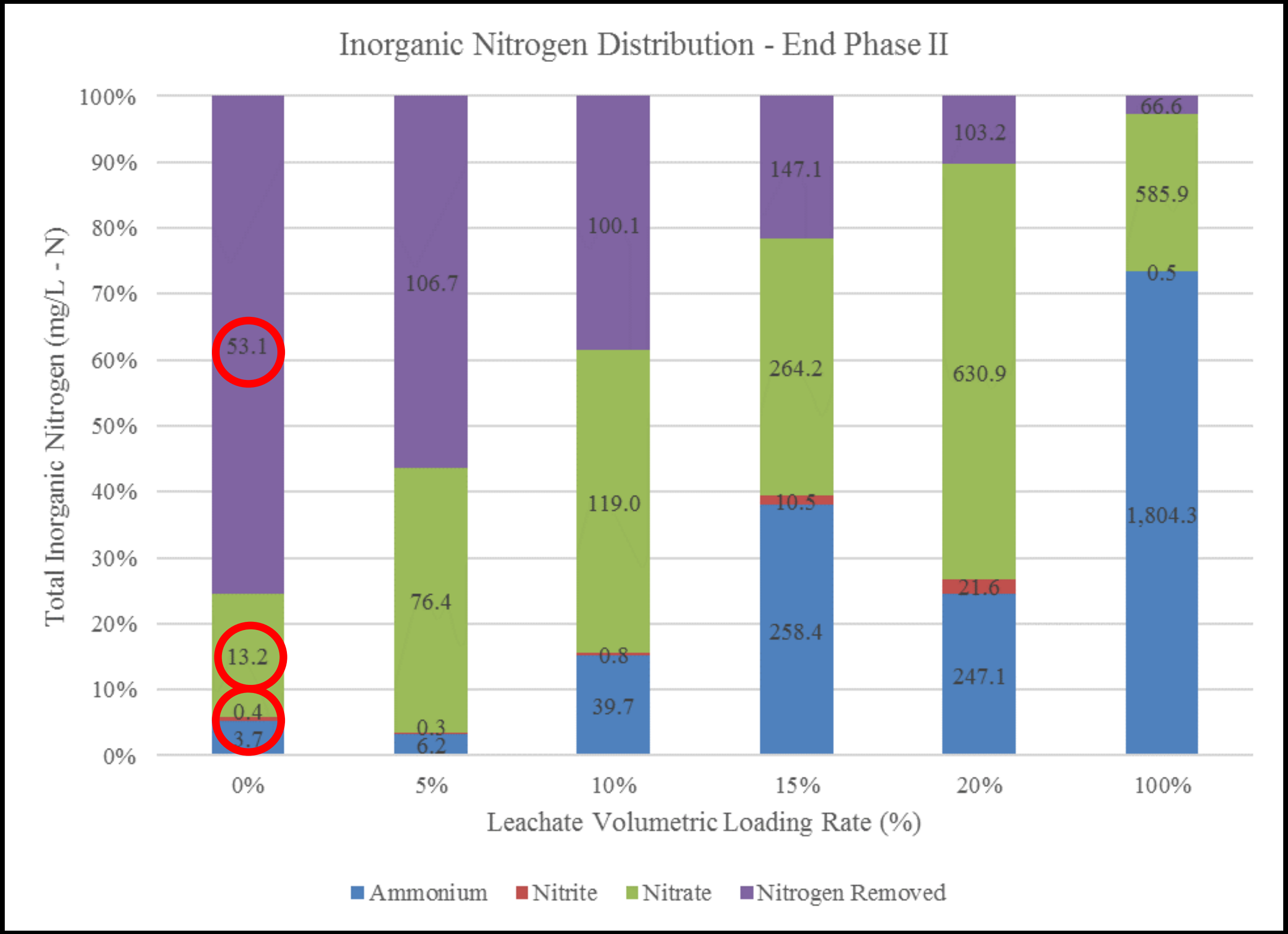


Figure 5. Total inorganic nitrogen distribution in effluent of each SBR leachate loading condition. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

Nitrate concentrations in the effluent of 5% and 10% were higher than the control which may indicate inhibition to the denitrification process, possibly due to the need for a supplementary carbon source as the remaining COD may have been non-biodegradable COD.

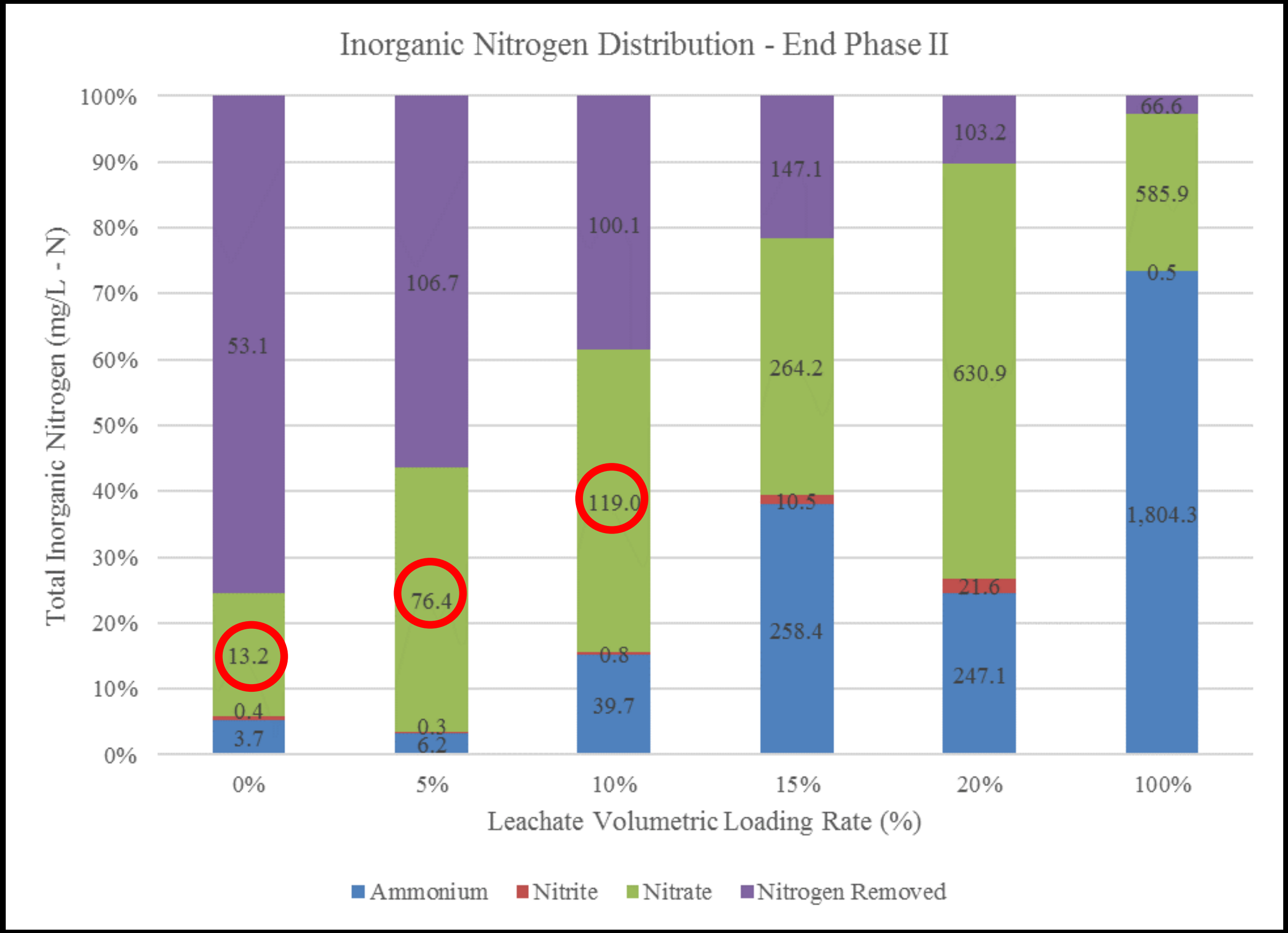


Figure 5. Total inorganic nitrogen distribution in effluent of each SBR leachate loading condition. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

Nitrite build up was observed for leachate volumetric loading rates of 15% and 20%, indicating that nitritation occurred but nitratation was limited. This may be due to NOB inhibition, possibly due to free ammonia levels. Also, it has been observed that the typical inhibition threshold for ammonium is 480 mg/L for nitrifying populations. The 15% and 20% loaded SBRs had influents above this threshold.

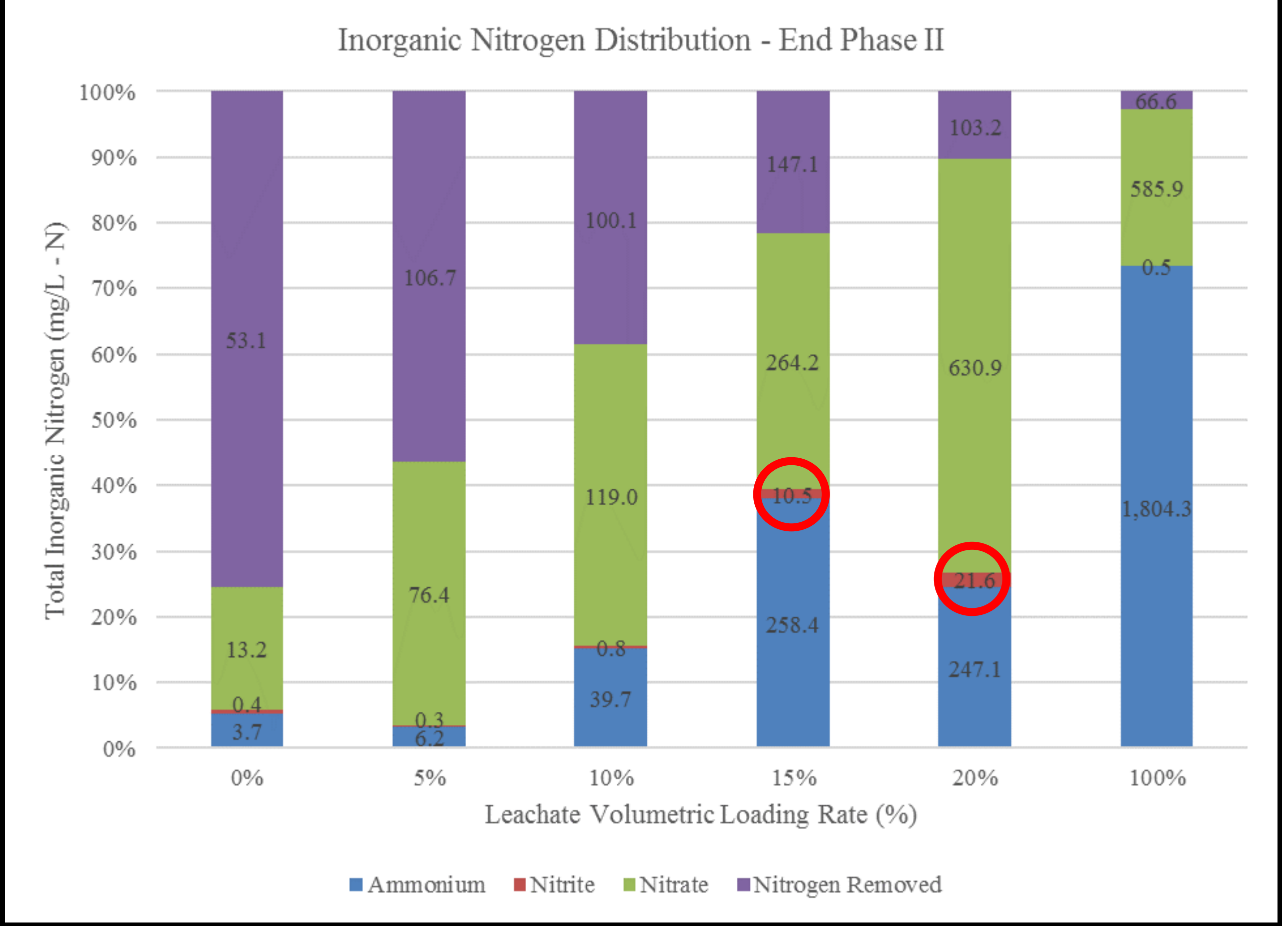


Figure 5. Total inorganic nitrogen distribution in effluent of each SBR leachate loading condition. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

mg of COD removal generally increased as the leachate loading rate increased, but overall COD removal rates (%) decreased, as has been observed in previous studies where effluent COD increases as leachate loading increases, due to the increasing load of COD for each leachate loading condition.

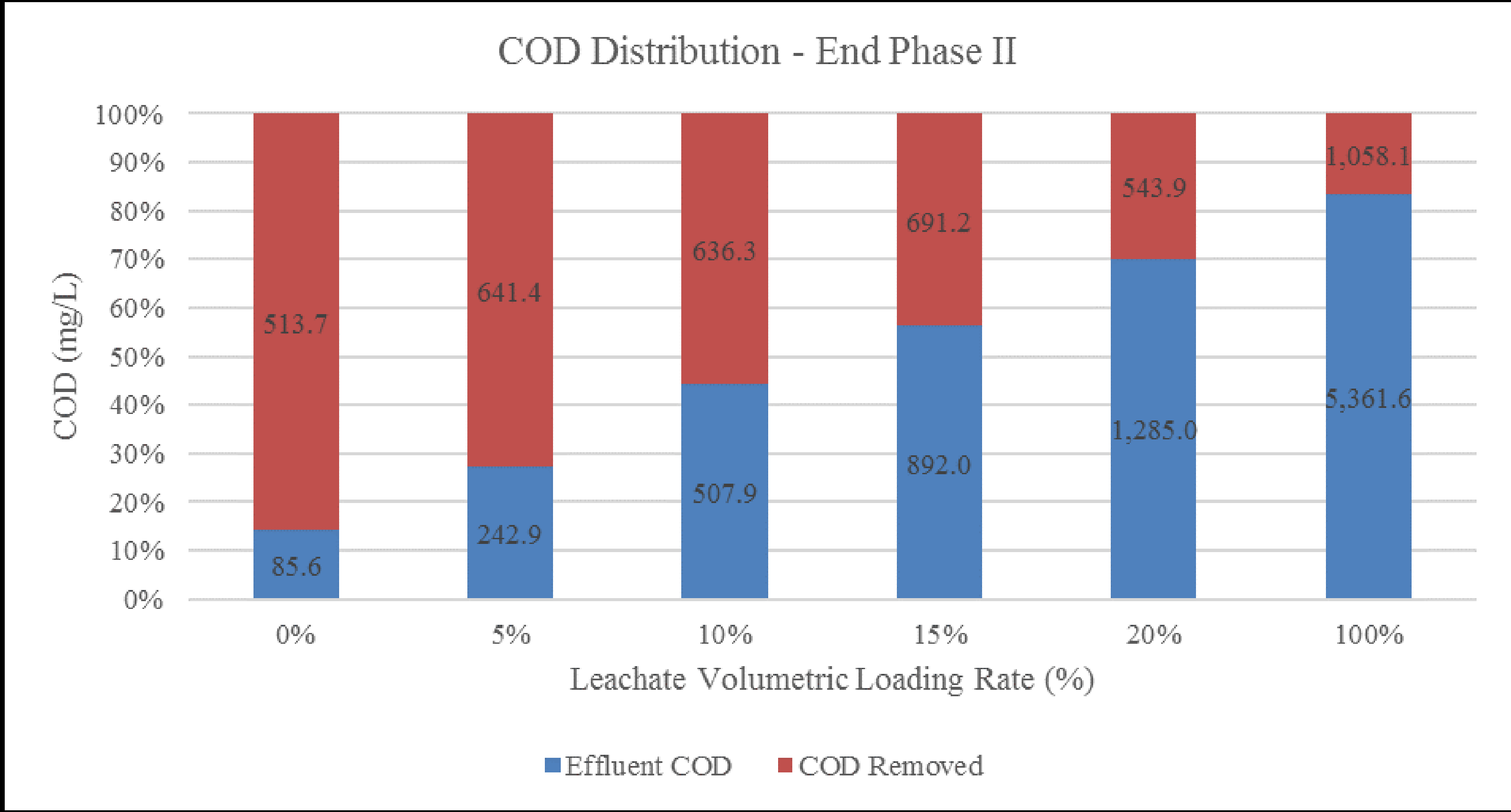


Figure 6. COD in effluent of each SBR leachate loading condition. Bars show relative percentage of COD in the effluent, as well as any COD removal. Each stacked bar is labeled with COD concentration in the effluent and COD removal in mg/L.

Phase III

All reactors receive an organic over-loading of landfill leachate (30% v/v).

Influent organic loading rate was increased to 3.6 g COD / (L d), which was double for the reactors adapted to 20% leachate loading (Phase II organic loading rate of 1.8), and represented a greater than 6X increase for the reactor adapted only to synthetic wastewater and not leachate (Phase II organic loading rate of 0.6)

Reactor Adapted to Leachate Loading (% v/v)	Leachate Loading (% v/v)	Influent COD (mg/L)	Influent TIN-N (mg/L)	Influent COD/TIN-N ratio (mg/mg)	Influent Organic Loading Rate (g COD / (L d))	g COD in influent / g VSS in SBR	g TIN-N in influent / g VSS in SBR
0	30	3,618.9 ± 54.6	905.6 ± 53.5	4.0	3.6	0.61	0.15
5						0.81	0.20
10						0.56	0.14
15						0.90	0.22
20						0.57	0.14
100	100	6,419.4 ± 1,179.2	2,417.3 ± 145.6	2.7	6.4	14.1	5.3

Table 6. Average loading for each adapted sludge SBR condition in Phase III.

SBRs adapted to a leachate loading rate of 5% and 10% experienced increased TIN-N removal than the SBRs adapted to no leachate loading

Reactor Adapted to Leachate Loading (% v/v)	Leachate Loading (% v/v)	Effluent COD (mg/L)	Effluent TIN-N (mg/L)	Effluent COD/TIN-N ratio (mg/mg)	COD Removal (%)	COD Removal (mg)	TIN-N Removal (%)	TIN-N Removal (mg)
0	30	2,477.7 ± 1,057.1	606.1 ± 97.3	4.1	31.6	1142.0	33.1	299.6
5		1,828.0 ± 425.6	518.3 ± 16.3	3.5	49.5	1791.0	42.8	387.6
10		1,855.1 ± 340.3	579.4 ± 85.2	4.4	48.7	1764.0	36.1	326.6
15		2,0107.7 ± 74.5	825.3 ± 68.2	2.4	44.5	1609.0	8.9	80.6
20		1,974.7 ± 331.1	685.8 ± 71.9	2.9	45.5	1645.0	24.4	220.6
100	100	5,704.7 ± 154.8	2,144.7 ± 127.7	2.7	11.1	715.0	11.3	272.0

Table 7. Average effluent for each adapted sludge SBR condition in Phase III.

5% - greater amounts of ammonium removal and overall TIN-N removal
10% - similar ammonium removal rates but had less nitrite accumulation
20% - similar ammonium removal rates and nitrite accumulation but also higher effluent nitrate, decreased denitrification
15% - least amount of TIN-N removal, likely due to the low concentrations of VSS present in the SBRs in this phase

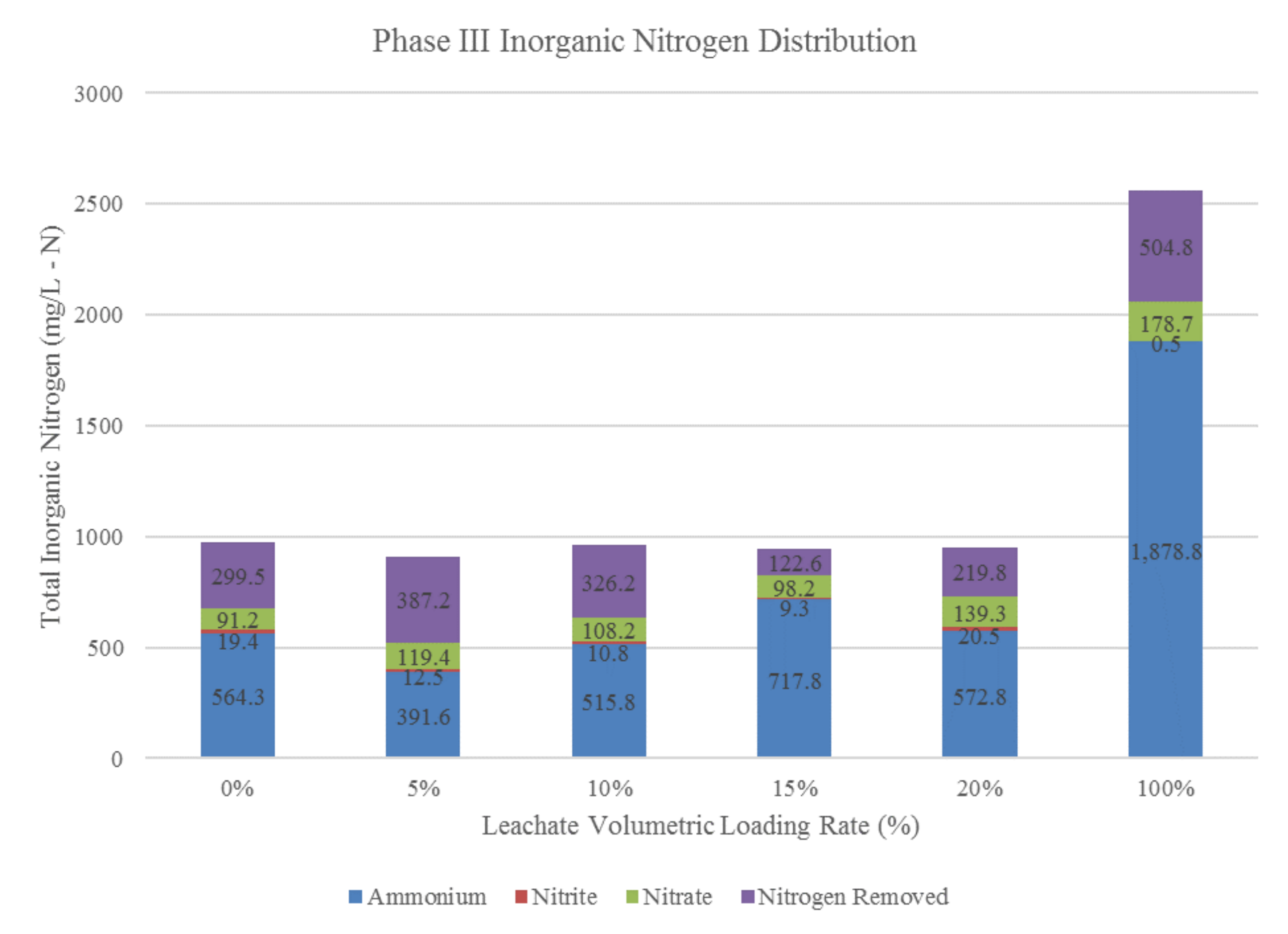


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

5% - greater amounts of ammonium removal and overall TIN-N removal
10% - similar ammonium removal rates but had less nitrite accumulation
20% - similar ammonium removal rates and nitrite accumulation but also higher effluent nitrate, decreased denitrification
15% - least amount of TIN-N removal, likely due to the low concentrations of VSS present in the SBRs in this phase

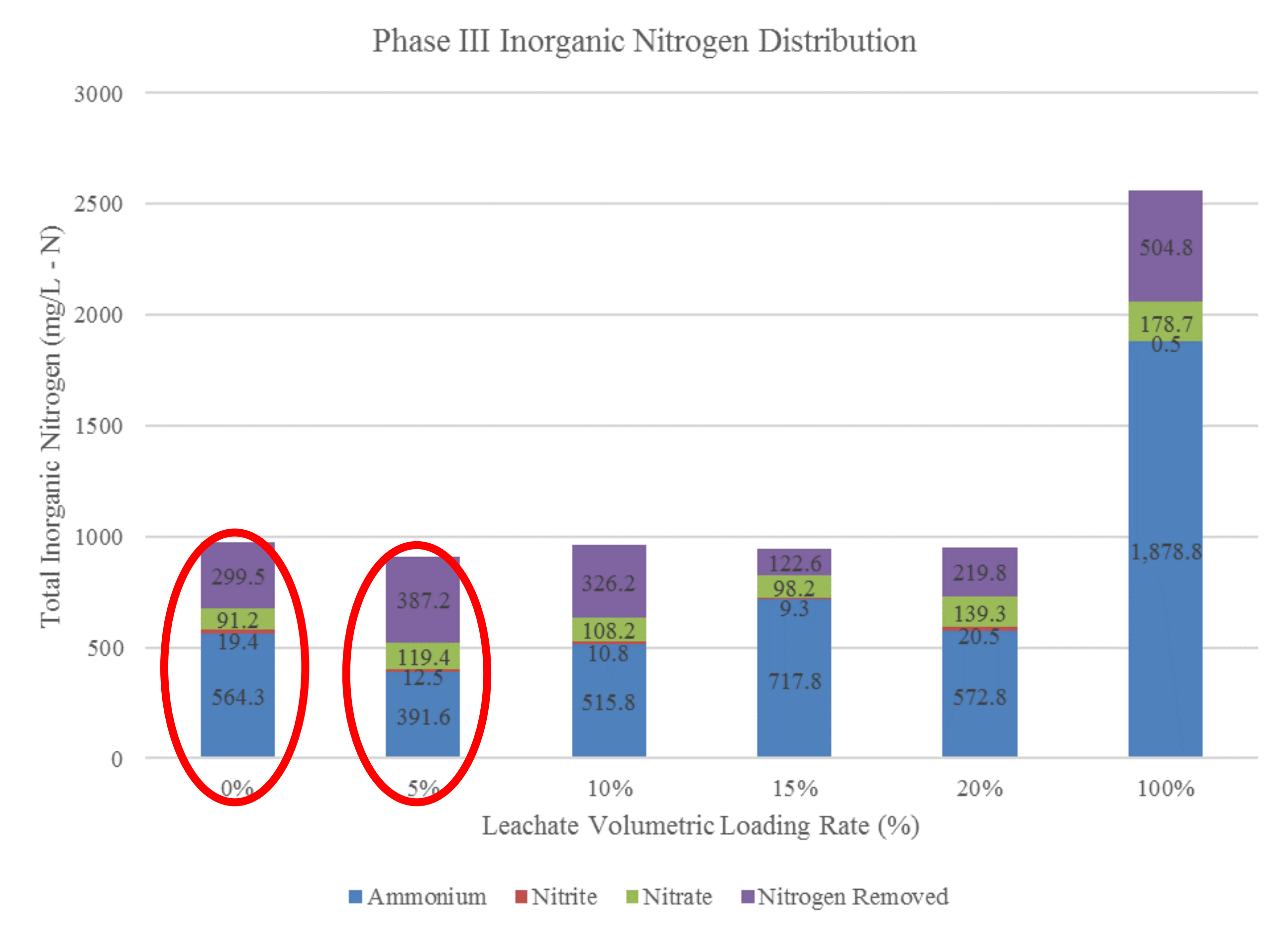


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^--N concentration, NO_3^--N concentration, and TIN removal as N in mg/L.

5% - greater amounts of ammonium removal and overall TIN-N removal
10% - similar ammonium removal rates but had less nitrite accumulation
20% - similar ammonium removal rates and nitrite accumulation but also higher effluent nitrate, decreased denitrification
15% - least amount of TIN-N removal, likely due to the low concentrations of VSS present in the SBRs in this phase

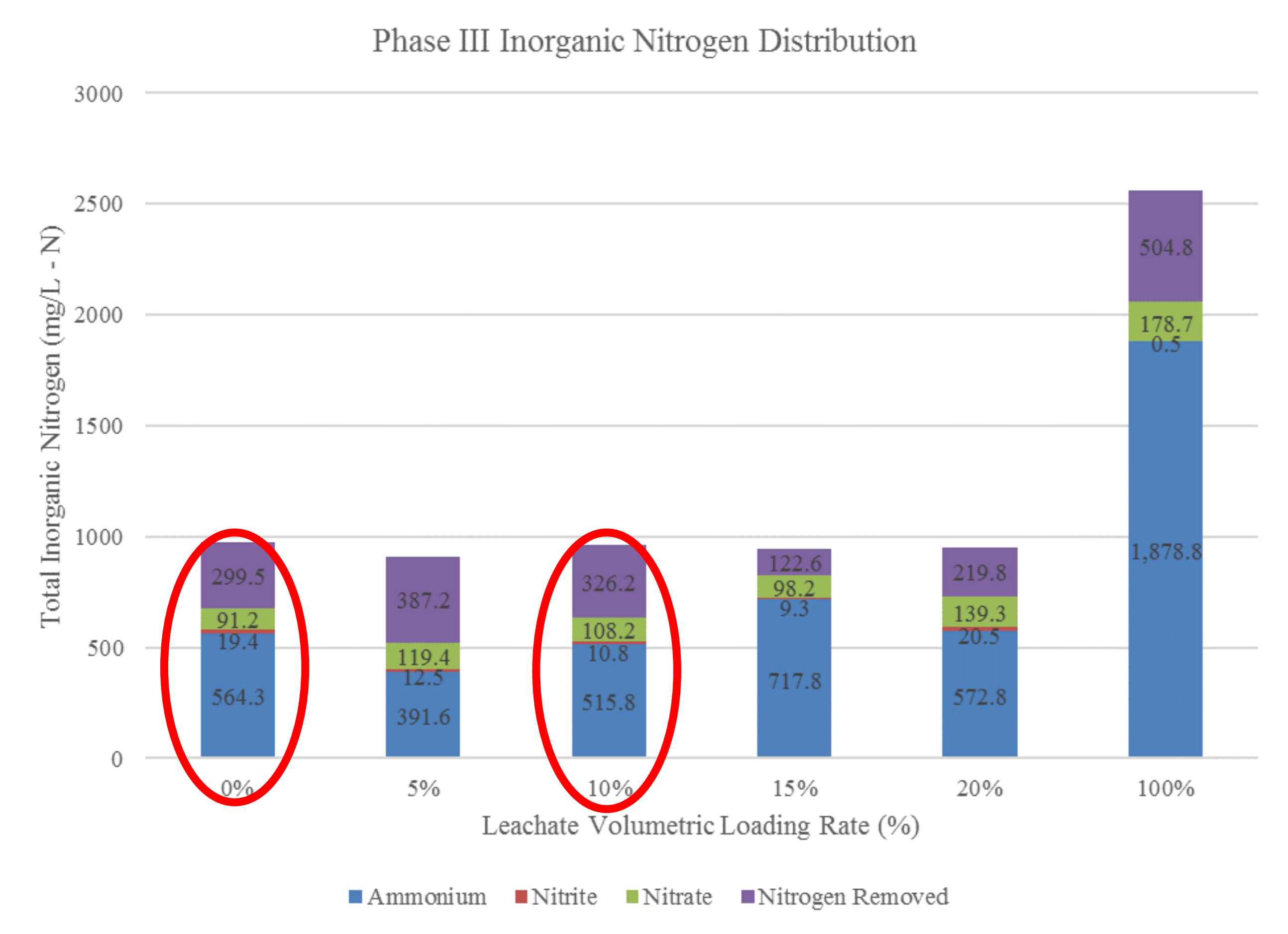


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^--N concentration, NO_3^--N concentration, and TIN removal as N in mg/L.

5% - greater amounts of ammonium removal and overall TIN-N removal
10% - similar ammonium removal rates but had less nitrite accumulation
20% - similar ammonium removal rates and nitrite accumulation but also higher effluent nitrate, decreased denitrification
15% - least amount of TIN-N removal, likely due to the low concentrations of VSS present in the SBRs in this phase

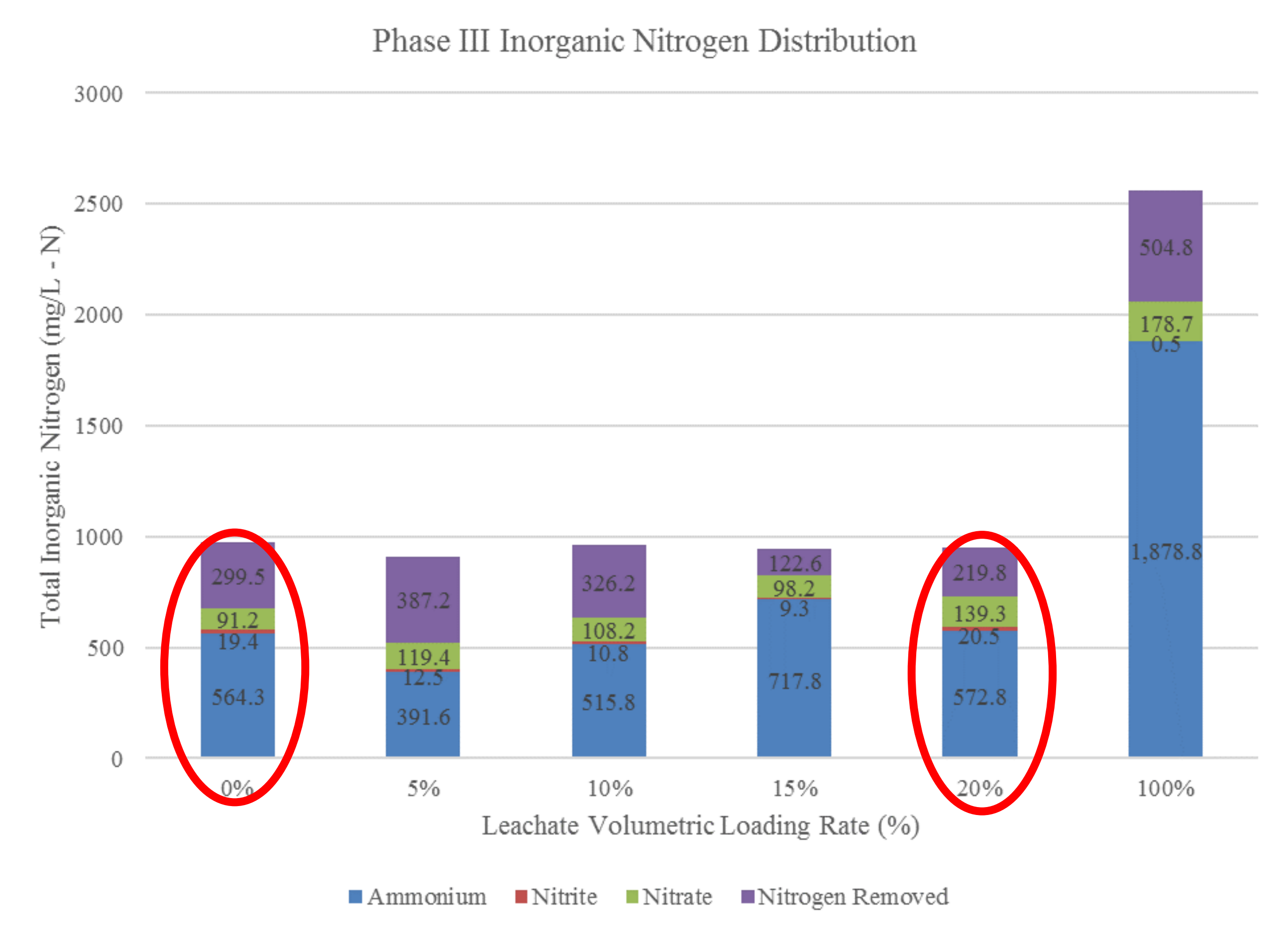


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

5% - greater amounts of ammonium removal and overall TIN-N removal
10% - similar ammonium removal rates but had less nitrite accumulation
20% - similar ammonium removal rates and nitrite accumulation but also higher effluent nitrate, decreased denitrification
15% - least amount of TIN-N removal, likely due to the low concentrations of VSS present in the SBRs in this phase

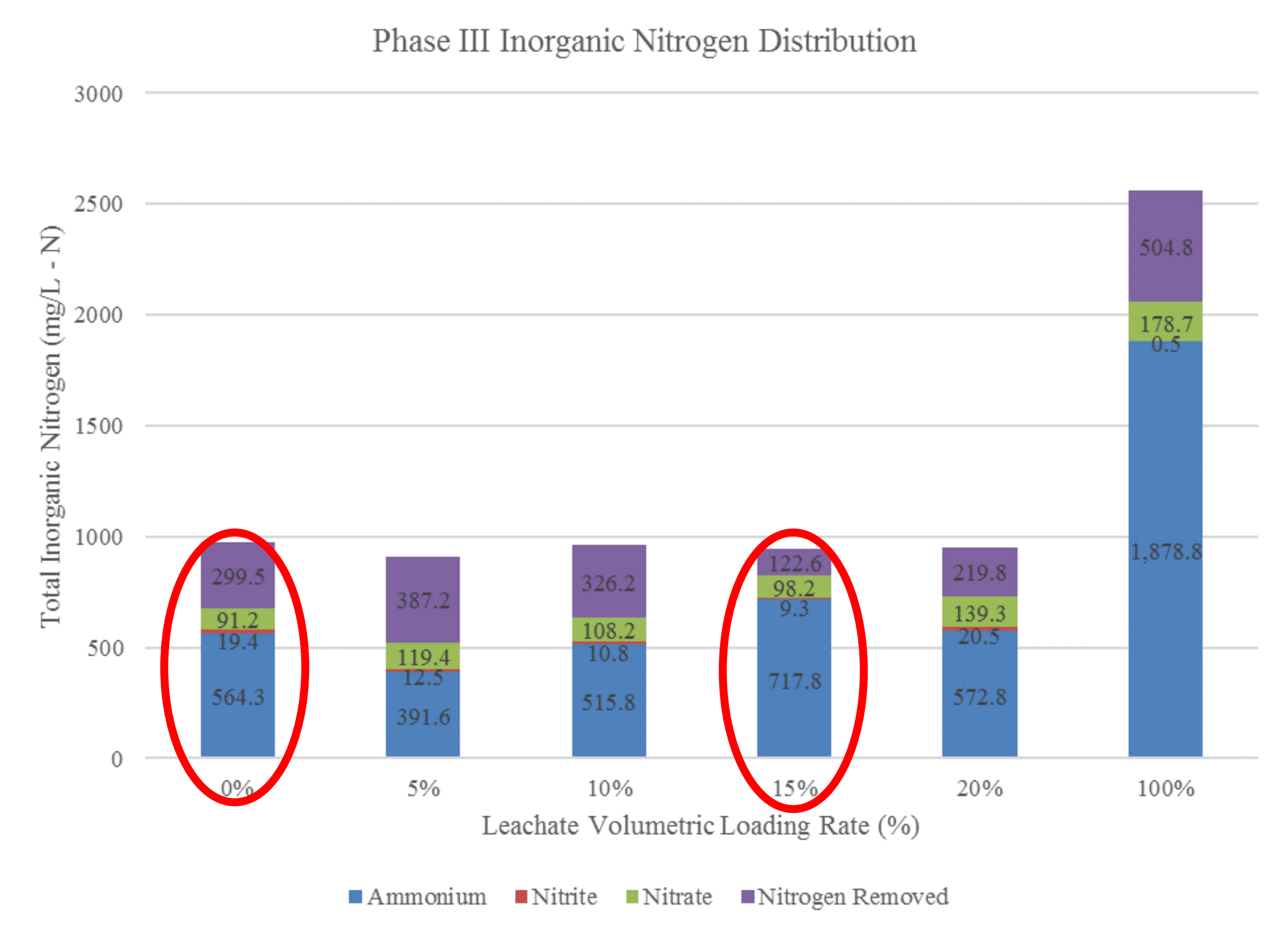


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

Suggest that SBRs adapted to a 5% and 10% leachate loading in Phase II accomplished nitritation (first step of nitrification where ammonium is converted to nitrite) more effectively than the control in Phase III which could suggest previous exposure to leachate allowed the microorganisms to adapt to the components of the leachate that may have otherwise decreased nitritation efficacy as seen in the control.

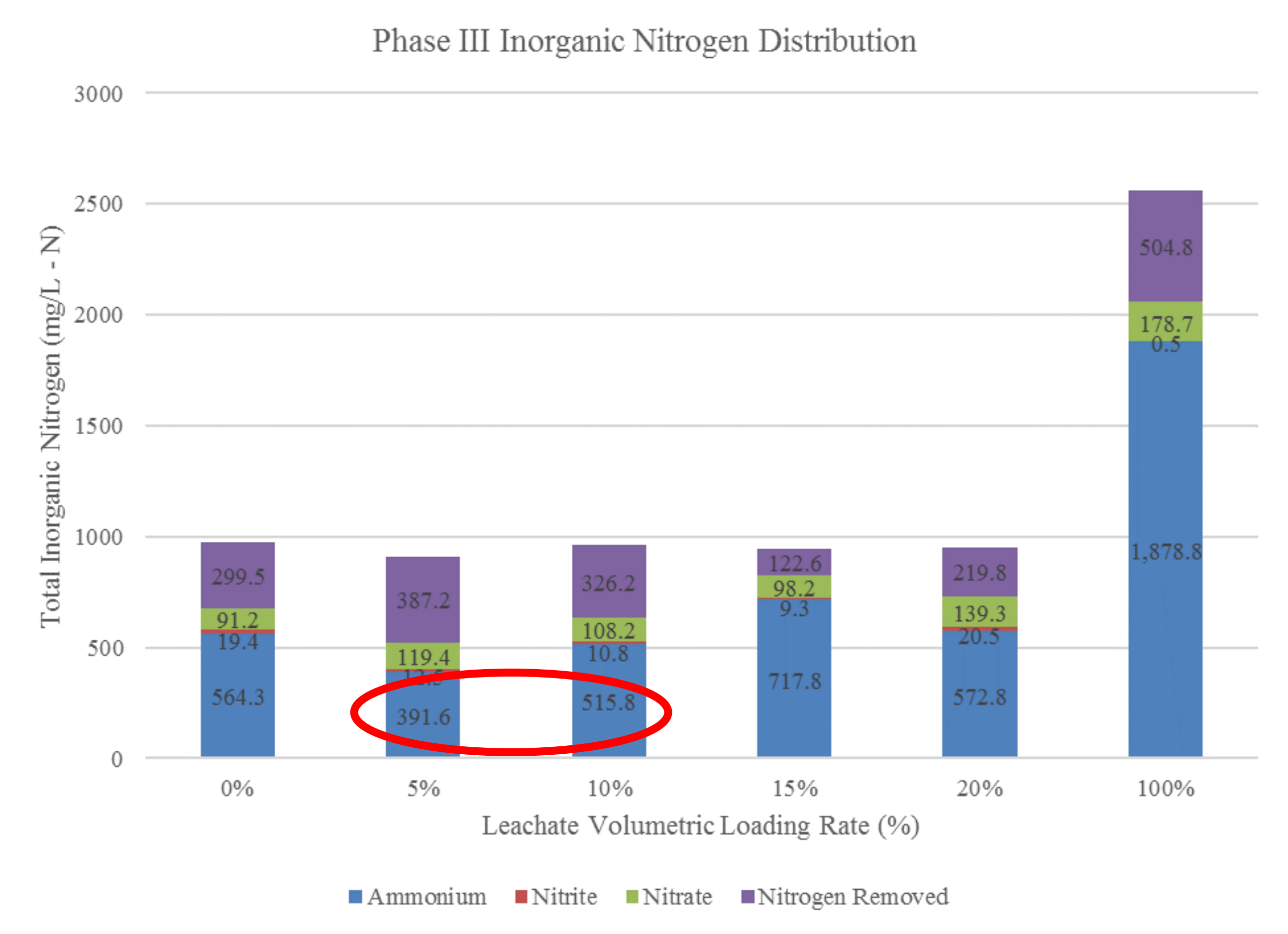


Figure 7. TIN-N in the effluent of each SBR based on leachate loading condition they were adapted to. Bars show relative percentage of each inorganic nitrogen species in the effluent, as well as any TIN removal. Each stacked bar is labeled with NH_4^+-N concentration, NO_2^-—N concentration, NO_3^-—N concentration, and TIN removal as N in mg/L.

SBRs previously exposed to leachate loadings had a higher removal of COD that the SBRs never exposed
5% and 10% - highest amount of COD removal
15% and 20% - slightly lower amounts of COD removal compared to the reactors adapted to 5% and 10% leachate loading.

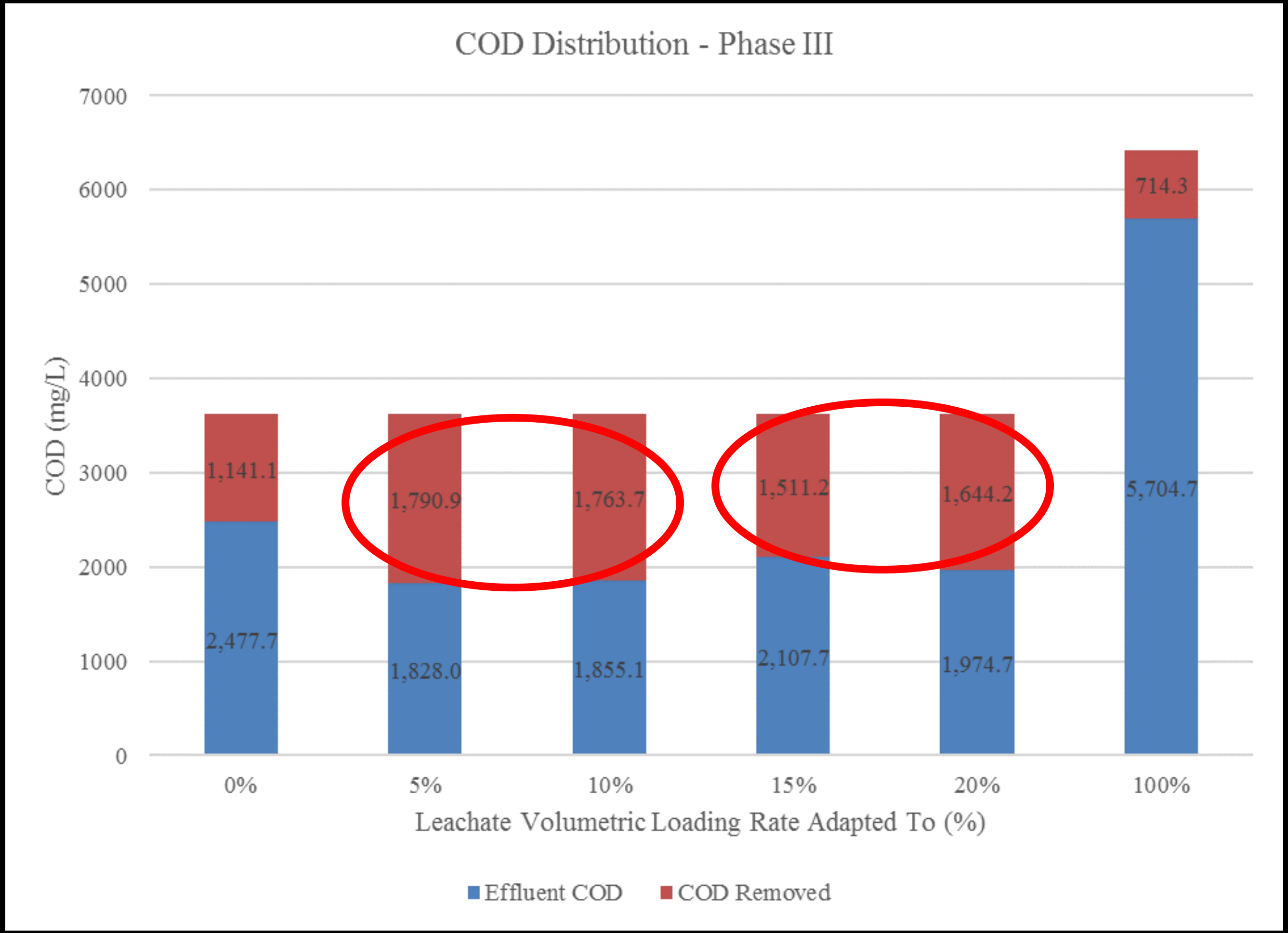


Figure 8. COD in effluent of each SBR with the leachate loading condition that each reactor was adapted to. Bars show relative percentage of COD in the effluent, as well as any COD removal. Each stacked bar is labeled with COD concentration in the effluent and COD removal in mg/L.

SBRs previously exposed to leachate loadings had a higher removal of COD that the SBRs never exposed

5% and 10% - highest amount of COD removal

15% and 20% - slightly lower amounts of COD removal compared to the reactors adapted to 5% and 10% leachate loading.

Reactor Adapted to Leachate Loading (% v/v)	Leachate Loading (% v/v)	Effluent COD (mg/L)	Effluent TIN-N (mg/L)	Effluent COD/TIN-N ratio (mg/mg)	COD Removal (%)	COD Removal (mg)	TIN-N Removal (%)	TIN-N Removal (mg)
0	30	2,477.7 ± 1,057.1	606.1 ± 97.3	4.1	31.6	1142.0	33.1	299.6
5		1,828.0 ± 425.6	518.3 ± 16.3	3.5	49.5	1791.0	42.8	387.6
10		1,855.1 ± 340.3	579.4 ± 85.2	4.4	48.7	1764.0	36.1	326.6
15		2,0107.7 ± 74.5	825.3 ± 68.2	2.4	44.5	1609.0	8.9	80.6
20		1,974.7 ± 331.1	685.8 ± 71.9	2.9	45.5	1645.0	24.4	220.6
100	100	5,704.7 ± 154.8	2,144.7 ± 127.7	2.7	11.1	715.0	11.3	272.0

Table 7. Average effluent for each adapted sludge SBR condition in Phase III.

5% and 10% - higher removals of TIN-N per mg of COD than the control
15% and 20% - did not show a significant difference of removal of TIN-N per mg of COD compared to the control.

Suggest that if BNR activated sludge is adapted to relatively low leachate loadings (5% - 10%), the sludge may be better able to handle shock loadings of leachate or temporary high loadings than if the sludge has never been exposed to leachate.

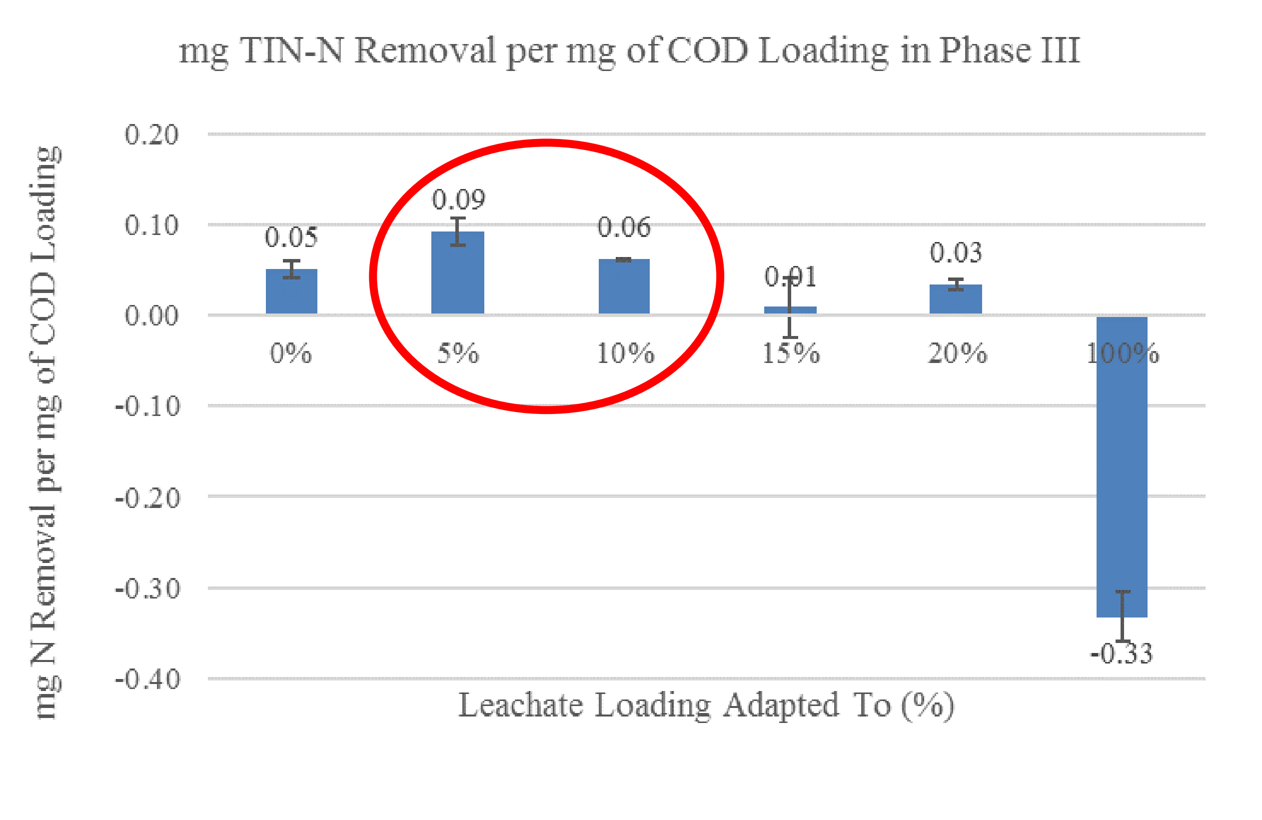


Figure 9. Removal of TIN-N per mg of COD loading in Phase III for each leachate loading condition.

SOUR of SBR MLSS in Phase III

- Used as an indicator for how leachate additions may affect the activity of BNR activated sludge.
- Typically used to understand if a particular sludge is overloaded with COD, is experiencing a toxic response to a particular waste, is underloaded and needs to experience sludge wasting, or to know that the organic loading and VSS are well-balanced
- SOUR index was utilized where the control (0% leachate loading) defined as a SOUR index of one
- SOUR index above one indicate more oxygen uptake rate per g of VSS than the control, which indicates increased activity of the microbes and possible organic overloading
- SOUR index of less than one indicates less oxygen uptake rate per g of VSS than the control, which could indicate organic underloading and a need for sludge wasting, or it could indicate that the microbes are experiencing a toxic response and therefore their activity is decreased.

Two days: SBRs conditioned to 10% and 15% had SOUR index values higher than 1, indicating greater oxygen uptake rate per g of VSS and increased sludge activity as compared to the control. SBRs exposed to 5% and 20% in Phase II had relatively low SOUR index values two days into Phase III, indicating decreased sludge activity as compared to the control, but these SOUR index values raised after additional days of exposure.

Table 7. SOUR Index of each leachate loading condition simulated in Phase II during Phase III when each SBR received a 30% leachate loading.

	SOUR Index				
Days since 30% loading began	**0%**	**5%**	**10%**	**15%**	**20%**
2	1	0.12	1.11	1.54	0.09
4	1	1.54	2.34	4.69	1.39
7	1	2.14	2.01	4.87	1.76

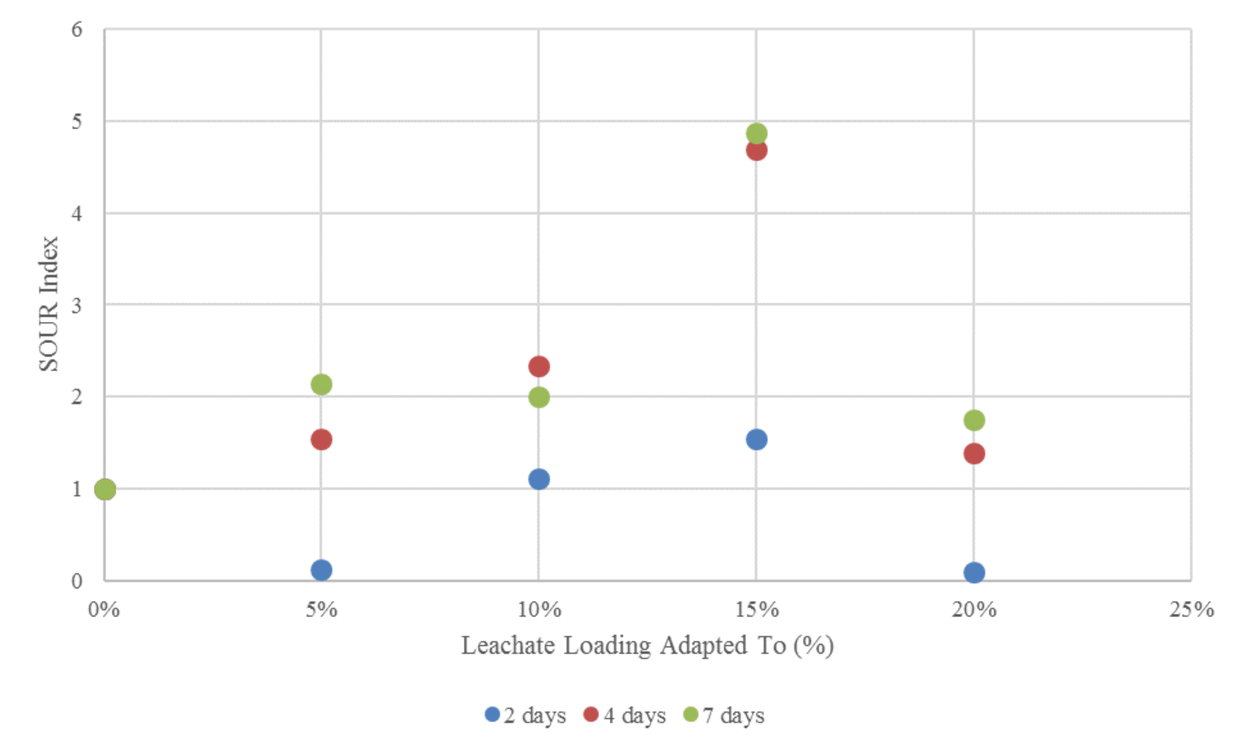


Figure 10. SOUR index and leachate loading each SBR is adapted to over the 7 days of leachate loading at 30%.

Four and seven days: All SBRs had SOUR values greater than 1, indicating greater oxygen uptake rate per g of VSS and increased sludge activity as compared to SBRs never exposed to leachate.

Suggest that previous exposure to leachate may allow the microbial community to continue functioning (indicated by oxygen uptake rate) at a higher rate than the control which had previously not be exposed to leachate. This may suggest that prior exposure to leachate will allow a microbial community to continue to survive and function at better rates when exposed to high concentrations of leachate as compared to microbial communities that have never been exposed to leachate.

Table 7. SOUR Index of each leachate loading condition simulated in Phase II during Phase III when each SBR received a 30% leachate loading.

	SOUR Index				
Days since 30% loading began	0%	5%	10%	15%	20%
2	1	0.12	1.11	1.54	0.09
4	1	1.54	2.34	4.69	1.39
7	1	2.14	2.01	4.87	1.76

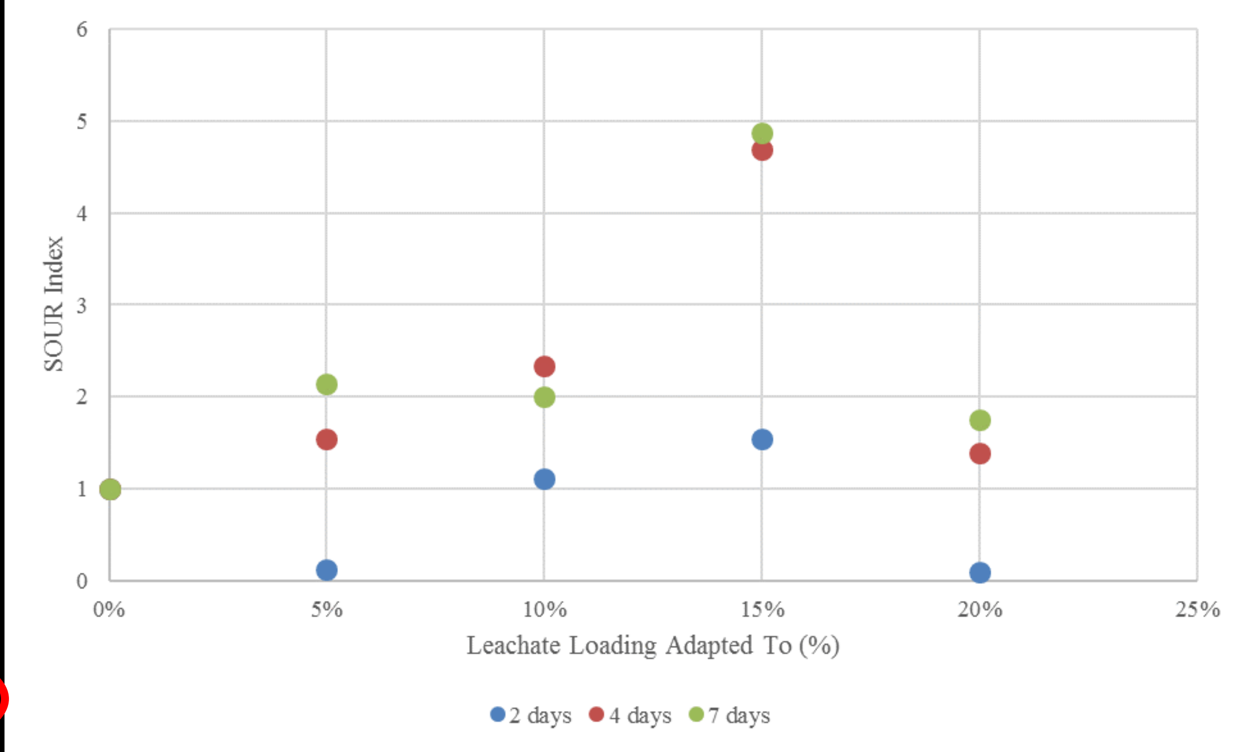


Figure 10. SOUR index and leachate loading each SBR is adapted to over the 7 days of leachate loading at 30%.

Generally, each SBR previously exposed to leachate had increasing SOUR values over the 7 days, indicating increasing tolerance of the microbes to the leachate loading, as compared to the control.

Table 7. SOUR Index of each leachate loading condition simulated in Phase II during Phase III when each SBR received a 30% leachate loading.

	SOUR Index				
Days since 30% loading began	**0%**	**5%**	**10%**	**15%**	**20%**
2	1	0.12	1.11	1.54	0.09
4	1	1.54	2.34	4.69	1.39
7	1	2.14	2.01	4.87	1.76

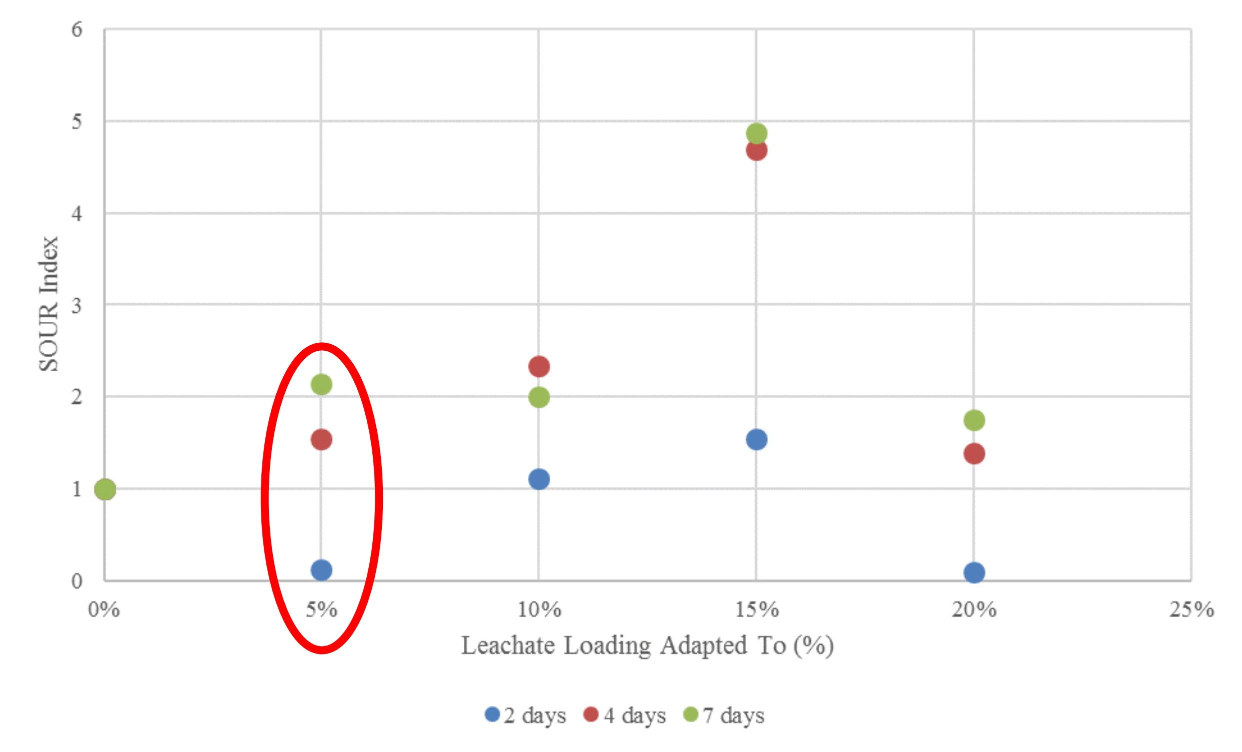


Figure 10. SOUR index and leachate loading each SBR is adapted to over the 7 days of leachate loading at 30%.

Conclusions

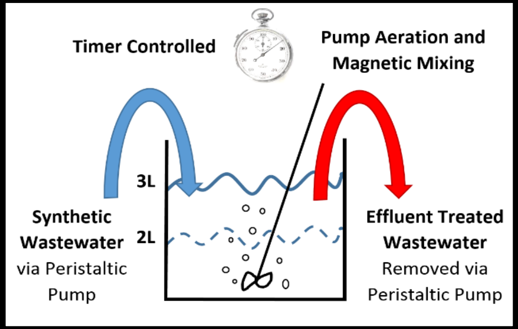
- Leachate loaded at volumetric ratios of up to 10% or 80% of the total WWTP inorganic nitrogen loading did not exhibit nitrification inhibition or decreases in mg of COD removal.
- SBRs previously adapted to leachate loadings of up to 20% v/v had improved COD removal when charged with an organic overloading of 30% v/v when compared to SBRs without previous exposure to leachate.
- The SBRs adapted to a 5% leachate loading exhibited greater amounts of ammonium removal and TIN-N removal than the control when exposed to the 30% v/v loading.
- SBRs exposed to 10% leachate loading exhibited similar ammonium removal rates to the control but had less nitrite accumulation when exposed to the 30% v/v loading.
- Results indicate that BNR activated sludge may be able to be adapted to handle higher loads of landfill leachate in terms of COD removal and TIN removal than BNR activated sludge that has never been exposed to leachate.
- This has implications for wastewater treatment plant operators who may consider accepting leachate. If activated sludge can be exposed to lower concentrations before handling higher loading rates, treatment disruptions may be minimized.

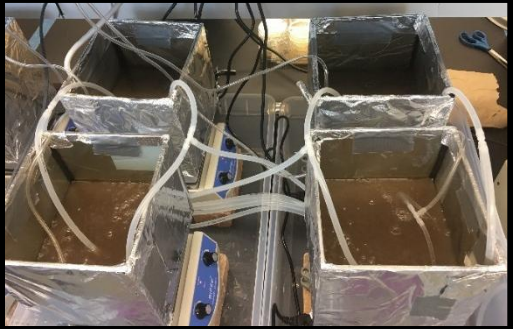
Acknowledgements

Technical Awareness Group

- Rebecca Rodriguez, P.E., Engineering Manager II, Lee County Solid Waste Division, Fort Myers, FL.
- Linda Monroy, P.E., Project Manager Associate, Lee County Solid Waste Division, Fort Myers, FL.
- Wester W. Henderson III, Research Coordinator III, Hinkley Center for Solid and Hazardous Waste Management, Gainesville, FL
- Debra Reinhart, PhD, PE, BCEE, Professor and Assistant Vice President for Research, University of Central Florida, Orlando, FL.
- Kelly Campbell, Landfill Manager, Collier County Solid Waste, Naples, FL.
- Ronald Cavalieri, PE, BCEE, Principal Engineer/Associate Vice President, AECOM, Fort Myers, FL.
- Patty DiPiero, Legislative and Compliance Programs Manager, Lee County Utilities, Fort Myers, FL.
- Isaac Holowell, Engineer II, CDM Smith, Fort Myers, FL.
- Ryan Holzem, PhD, ENV SP, Assistant Professor, University of Wisconsin, Green Bay, WI.
- Thomas Worley-Morse, PhD, PE, Principal Scientist, Hazen and Sawyer, Raleigh, NC.
- Stephanie Bolyard, PhD, Research and Scholarship Program Manager, Environmental Research and Education Foundation (EREF), Raleigh, NC.
- Amir Motlagh, PhD, PhD Candidate, University of Central Florida, Orlando, FL.
- Christina Alito, PhD, PE, ENV SP, Water/Wastewater Engineer, HDR Engineering, Vienna, VA.

Questions?





Ashley Thomson, Ph.D.
Assistant Professor
Environmental and Civil Engineering
Florida Gulf Coast University
athomson@fgcu.edu
https://www2.fgcu.edu/eng/envcivdpt/effectsofleachate/

References

1. APHA, AWWA, and WEF. (2005). Standard Methods for the Examination of Water and Wastewater. 21st edition. American Public Health Association, Washington, D.C.
2. Arnaout, C., and Gunsch, C., 2014. Assessing the Effects of Silver Nanoparticles on Biological Nutrient Removal in Bench-Scale Activated Sludge Sequencing Batch Reactors. Environmental Science and Technology 40: 970 – 976.
3. Anthonisen, A. C., Loehr, R. C., Prakasam, T. B. S., & Srinath, E. G. (1976). Inhibition of nitrification by ammonia and nitrous acid. Journal (Water Pollution Control Federation), 835-852.
4. Bae, J. H., Kim, S. K., & Chang, H. S. (1997). Treatment of landfill leachates: ammonia removal via nitrification and denitrification and further COD reduction via Fenton's treatment followed by activated sludge. Water Science and Technology, 36(12), 341-348.
5. Brennan, R. B., Clifford, E., Devroedt, C., Morrison, L., & Healy, M. G. (2017). Treatment of landfill leachate in municipal wastewater treatment plants and impacts on effluent ammonium concentrations. Journal of environmental management, 188, 64-72.
6. Çeçen, F., & Aktaş, Ö. (2004). Aerobic co-treatment of landfill leachate with domestic wastewater. Environmental Engineering Science, 21(3), 303-312.
7. Çeçen, F., & Çakıroğlu, D. (2001). Impact of landfill leachate on the co-treatment of domestic wastewater. Biotechnology letters, 23(10), 821-826.
8. Danley-Thomson, A. A., Gardner, C. M., Gwin, C. A., & Gunsch, C. K. (2015). Cocopeat for wastewater treatment in the developing world. I: Comparison to traditional packing media in lab scale biofiltration columns. Journal of Environmental Engineering, 142(2), 04015069.
9. Diamadopoulos, E., Samaras, P., Dabou, X., & Sakellaropoulos, G. P. (1997). Combined treatment of landfill leachate and domestic sewage in a sequencing batch reactor. Water Science and Technology, 36(2-3), 61-68.
10. Environmental Protection Agency. (2001). Method 1683: Specific Oxygen Uptake Rate in Biosolids. Accessed online 1.10.2018 at <https://www.epa.gov/sites/production/files/2015-10/documents/method_1683_draft_2001.pdf>.
11. Gerardi, M.H., 2002. Nitrification and denitrification in the activated sludge process. Wiley-Interscience. John Wiley and Sons, Inc., New York.
12. Gutierrez, M., Etxebarria, J., & De las Fuentes, L. (2002). Evaluation of wastewater toxicity: comparative study between Microtox® and activated sludge oxygen uptake inhibition. Water Research, 36(4), 919-924.
13. Henze, M., Harremoes, P., la Cour Jansen, J., Arvin, E., 1997. Wastewater treatment – biological and chemical processes, second ed. Springer.
14. Hongwei, S., Qing, Y., Yongzhen, P., Xiaoning, S. H. I., Shuying, W. A. N. G., & ZHANG, S. (2009). Nitrite accumulation during the denitrification process in SBR for the treatment of pre-treated landfill leachate. Chinese Journal of Chemical Engineering, 17(6), 1027-1031.
15. Hwang, B. H., Hwang, K. Y., Choi, E. S., Choi, D. K., & Jung, J. Y. (2000). Enhanced nitrite build-up in proportion to increasing alklinity/NH4+ ratio of influent in biofilm reactor. Biotechnology letters, 22(16), 1287-1290.
16. Ilies, P., & Mavinic, D. S. (2001). The effect of decreased ambient temperature on the biological nitrification and denitrification of a high ammonia landfill leachate. Water Research, 35(8), 2065-2072.
17. Im, J. H., Woo, H. J., Choi, M. W., Han, K. B., & Kim, C. W. (2001). Simultaneous organic and nitrogen removal from municipal landfill leachate using an anaerobic-aerobic system. Water research, 35(10), 2403-2410.
18. Kim, D. J., Lee, D. I., & Keller, J. (2006). Effect of temperature and free ammonia on nitrification and nitrite accumulation in landfill leachate and analysis of its nitrifying bacterial community by FISH. Bioresource technology, 97(3), 459-468.
19. Liu, Y., & Capdeville, B. (1994). Some observations on free ammonia inhibition to Nitrobacter in nitrifying biofilm reactor. Biotechnology letters, 16(3), 309-314.
20. Neczaj, E., Kacprzak, M., Kamizela, T., Lach, J., & Okoniewska, E. (2008). Sequencing batch reactor system for the co-treatment of landfill leachate and dairy wastewater. Desalination, 222(1-3), 404-409.
21. Surmacz-Gorska, J., Gernaey, K., Demuynck, C., Vanrolleghem, P., & Verstraete, W. (1996). Nitrification monitoring in activated sludge by oxygen uptake rate (OUR) measurements. Water Research, 30(5), 1228-1236.
22. Turk, O., Mavinic, D.S., 1989a. Stability of nitrite build-up in an activated sludge system. J.W.P.C.F. 61, 1440–1448.
23. Welander, U., Henrysson, T., & Welander, T. (1998). Biological nitrogen removal from municipal landfill leachate in a pilot scale suspended carrier biofilm process. Water Research, 32(5), 1564-1570.
24. Wiszniowski, J., Robert, D., Surmacz-Gorska, J., Miksch, K., & Weber, J. V. (2006). Landfill leachate treatment methods: A review. Environmental Chemistry Letters, 4(1), 51-61.
25. Wu, L., Zhang, L., Shi, X., Liu, T., Peng, Y., & Zhang, J. (2015). Analysis of the impact of reflux ratio on coupled partial nitrification–anammox for co-treatment of mature landfill leachate and domestic wastewater. Bioresource technology, 198, 207-214.
26. Zeng, R. J.; Lemaire, R.; Yuan, Z.; Keller, J. Simultaneous nitrification, denitrification, and phosphorus removal in a lab-scale sequencing batch reactor. Biotechnol. Bioeng. 2003, 84 (2), 170−178.

Objectives

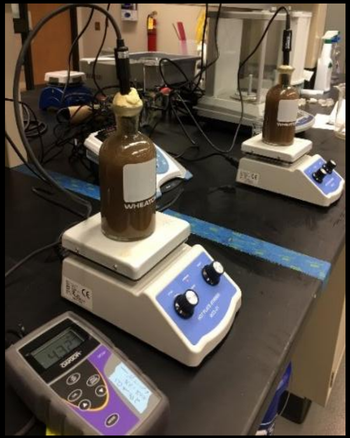
- Objective 1: To quantify the effect of various landfill leachate sources on nitrifying activated sludge utilizing Specific Oxygen Uptake Rate (SOUR). Six landfill leachate samples are tested at discrete ratios to determine how leachate loading may affect sludge activity.

- Objective 2: Evaluate the effect of leachate on the efficacy of biological nutrient removal (BNR) activated sludge processing using lab scale sequencing batch reactors (SBRs). Here, sequencing batch reactors are operated with nitrifying activated sludge and fed distinct ratios of synthetic wastewater and landfill leachate. Controls are also operated (100% loading of leachate as positive control, 100% loading of activated sludge as negative control).

- Objective 3: Determine the extent that BNR activated sludge can be adapted to effectively handle a loading of landfill leachate known to cause overloading using lab scale sequencing batch reactors (SBRs). Here, sequencing batch reactors operated with nitrifying activated sludge adapted to leachate loadings as described in Objective 2 are fed a ratio of 70% synthetic wastewater and 30% landfill leachate for one week.

Research Approach

1

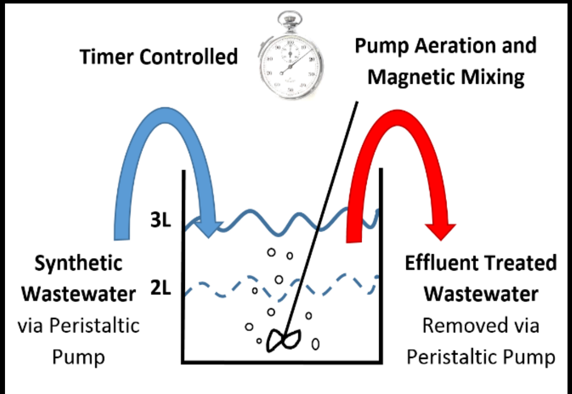


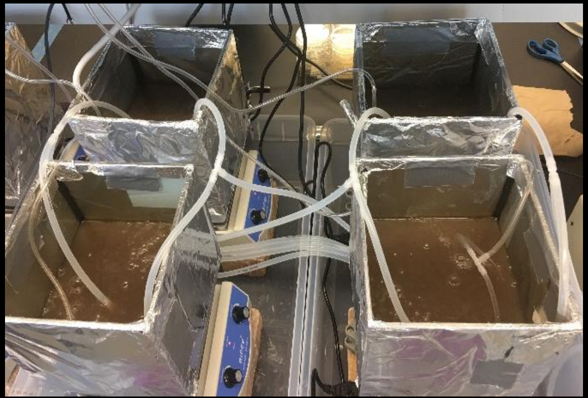
Sample Site	MSW Collected (Ton/year)[a]	Landfill Type
1	NA	Rural
2	229,617	Rural
3	108,227	Regional
4[b]	20,312	Regional
5	244,125	Regional
6	0	Semiurban/ capped

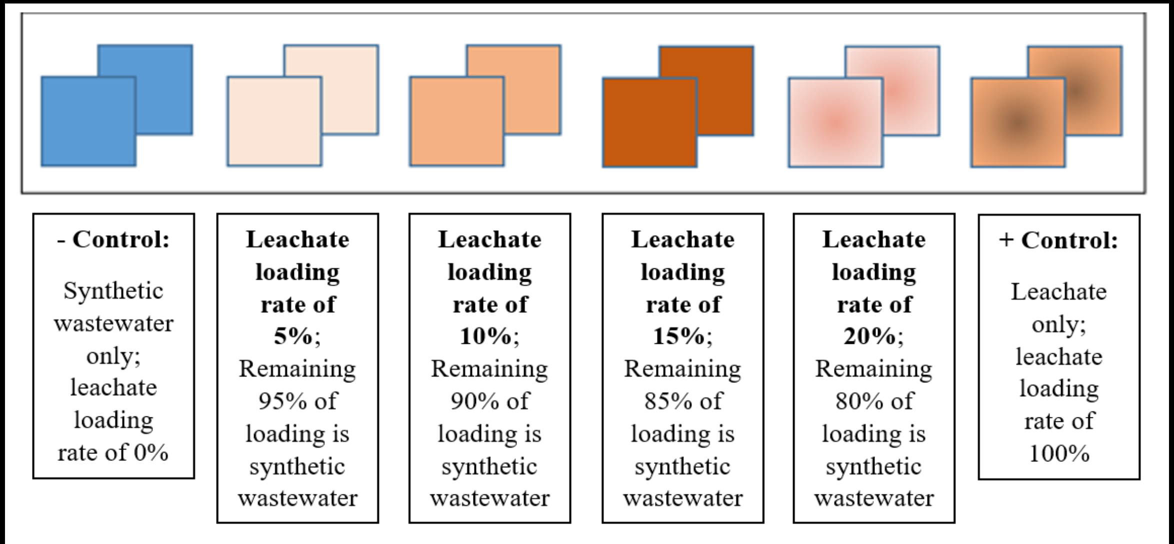
[a] Data from 2017

[b] Leachate utilized in Phase II and III

2







3

30% leachate loading

SOUR of Leachate Samples in Central and SW FL

Leachate sample 3 and 6 both indicate a SOUR index of less than 1 for leachate loadings above 10%

Leachate Sample	Leachate COD (mg/L)	Leachate Ammonium (mg/L)	Leachate Nitrate (mg/L)	Leachate Phosphate (mg/L)	Leachate pH	Leachate VSS (mg/L)	Concentration (% v/v)	SOUR Index
1	2,066.2	549.1	140.2	11.3	7.74	116	0	1.00
							1	-
							5	2.19
							10	2.44
							20	1.62
							50	0.66
							75	-1.16
2	3,421.1	1,553.8	267.6	43.6	8.05	172	0	1.00
							1	-
							5	4.58
							10	2.65
							20	1.90
							50	-
							75	-
3	2,732.9	732.0	186.0	17.5	8.04	354	0	1.00
							1	-
							5	1.49
							10	1.00
							20	0.66
							50	0.66
							75	
4	4,100.0	NA	NA	NA	7.75	NA	0	1.00
							1	1.76
							5	1.59
							10	1.28
							20	-
							50	-
							75	-
5	2,179.7	605.5	108.9	0.7	7.72	283	0	1.00
							1	3.17
							5	3.18
							10	3.28
							20	3.00
							50	1.72
							75	-
6	6,216.6	2,003.0	157.4	1.8	7.2925	545	0	1.00
							1	1.27
							5	1.27
							10	1.09
							20	0.97
							50	-
							75	-

Leachate sample 1 did not exhibit SOUR indices values below 1 until a leachate loading of 50%. However, it can be seen that the COD and ammonium concentrations are lower in leachate sample 1 versus leachate samples 3 and 6.

Leachate Sample	Leachate COD (mg/L)	Leachate Ammonium (mg/L)	Leachate Nitrate (mg/L)	Leachate Phosphate (mg/L)	Leachate pH	Leachate VSS (mg/L)	Concentration (% v/v)	SOUR Index
1	2,066.2	549.1	140.2	11.3	7.74	116	0	1.00
							1	-
							5	2.19
							10	2.44
							20	1.62
							50	0.66
							75	-1.16
2	3,421.1	1,553.8	267.6	43.6	8.05	172	0	1.00
							1	-
							5	4.58
							10	2.65
							20	1.90
							50	-
							75	-
3	2,732.9	732.0	186.0	17.5	8.04	354	0	1.00
							1	-
							5	1.49
							10	1.00
							20	0.66
							50	0.66
							75	-
4	4,100.0	NA	NA	NA	7.75	NA	0	1.00
							1	1.76
							5	1.59
							10	1.28
							20	-
							50	-
							75	-
5	2,179.7	605.5	108.9	0.7	7.72	283	0	1.00
							1	3.17
							5	3.18
							10	3.28
							20	3.00
							50	1.72
							75	-
6	6,216.6	2,003.0	157.4	1.8	7.2925	545	0	1.00
							1	1.27
							5	1.27
							10	1.09
							20	0.97
							50	-
							75	-

- Leachate sample 2 and 5 did not show SOUR indices below 1 even though they both exhibited relatively high COD and ammonium concentrations. This may suggest that inhibition in leachate samples 3 and 6 occurred, not necessarily due to COD and ammonium concentrations, but perhaps to other constituents in the leachate
- Due to the complexity of leachate and the variations of leachate from site to site, there may be usefulness in conducting site-specific SOUR tests for leachate when considering loading leachate into a POTW.

Leachate Sample	Leachate COD (mg/L)	Leachate Ammonium (mg/L)	Leachate Nitrate (mg/L)	Leachate Phosphate (mg/L)	Leachate pH	Leachate VSS (mg/L)	Concentration (% v/v)	SOUR Index
1	2,066.2	549.1	140.2	11.3	7.74	116	0	1.00
							1	-
							5	2.19
							10	2.44
							20	1.62
							50	0.66
							75	-1.16
2	3,421.1	1,553.8	267.6	43.6	8.05	172	0	1.00
							1	-
							5	4.58
							10	2.65
							20	1.90
							50	-
							75	-
3	2,732.9	732.0	186.0	17.5	8.04	354	0	1.00
							1	-
							5	1.49
							10	1.00
							20	0.66
							50	0.66
							75	-
4	4,100.0	NA	NA	NA	7.75	NA	0	1.00
							1	1.76
							5	1.59
							10	1.28
							20	-
							50	-
							75	-
5	2,179.7	605.5	108.9	0.7	7.72	283	0	1.00
							1	3.17
							5	3.18
							10	3.28
							20	3.00
							50	1.72
							75	-
6	6,216.6	2,003.0	157.4	1.8	7.2925	545	0	1.00
							1	1.27
							5	1.27
							10	1.09
							20	0.97
							50	-
							75	-

SOUR of Leachate Samples in Central and SW FL

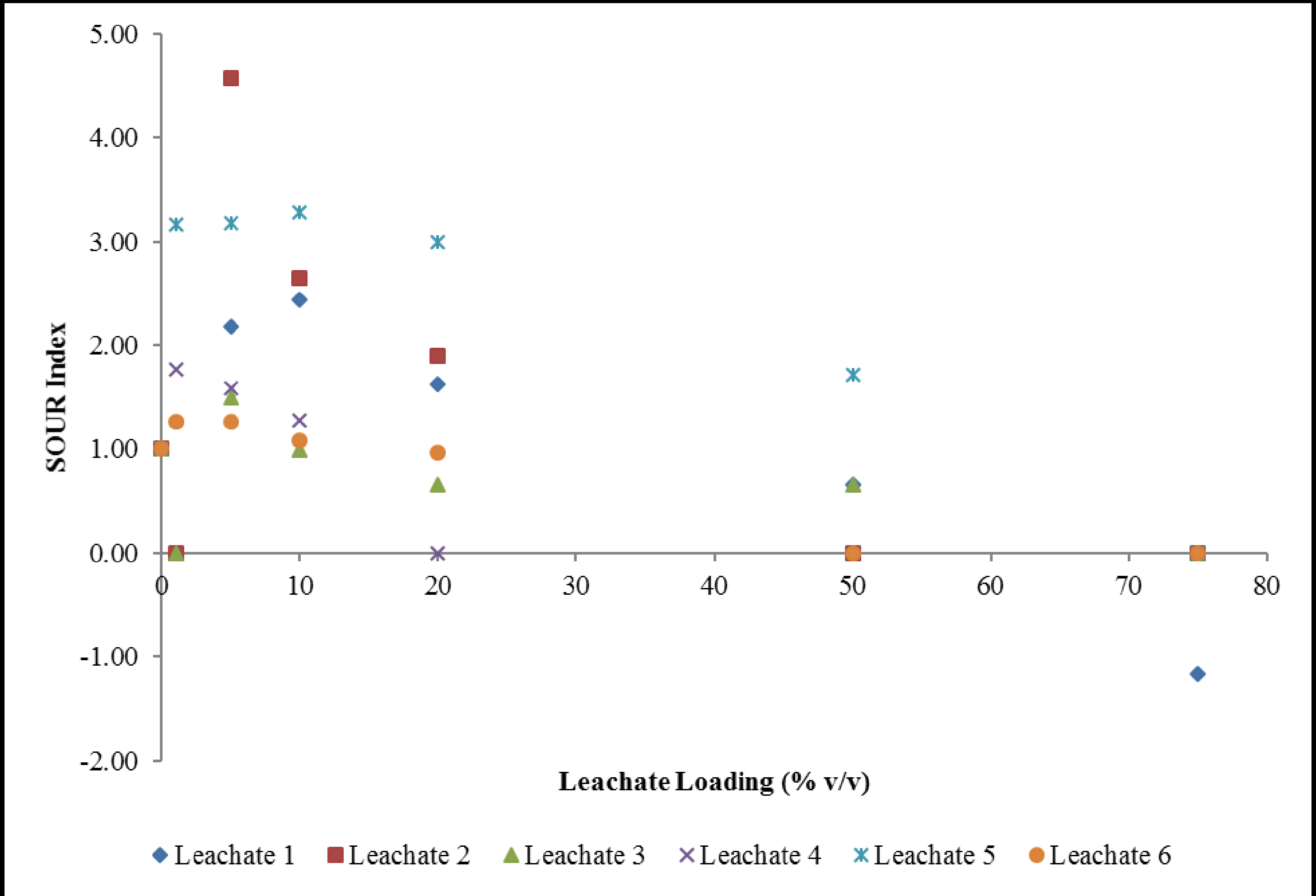


Figure 11. SOUR index of each leachate sample tested for Objective 1.