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June 16, 2021

***Project #***
60624189

Dear Ms. Paetkau:

**Subject: NEWPCC Interim Phosphorus Removal Max Month Test Results Tech Memo**

AECOM is pleased to submit this technical memorandum as an addendum to the original report (NEWPCC Interim Phosphorus Removal Detail Review and Benchscale Testing, 2020) submitted on December 17, 2020.

This memorandum provides a summary of the Maximum Month benchscale test results conducted at the University of Manitoba in March 2021. As well, the report includes a summary section providing general conclusions based on the annual average and maximum month BioWin modeling and benchscale test results.

If you have any questions or comments regarding this technical memorandum, please do not hesitate to call me at 204.928.8335.

Sincerely,
**AECOM Canada Ltd.**

[redacted]

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To: Michelle Paetkau, P.Eng.
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cc: Keith Sears, AECOM

Date: June 16, 2021
Project #: 60624189
From: Mona Lashkarizadeh, P. Eng.
Matt Kowalski, EIT

# Memorandum

Subject: **NEWPCC Interim Phosphorus Removal Max Month Test Results Tech Memo**

## 1. Background

Due to Covid-19 and the University of Manitoba laboratory shutdown, maximum month (MM) conditions were not able to be tested in March 2020 and therefore, the original report (NEWPCC Interim Phosphorus Removal Detail Review and Benchscale Testing, 2020) did not include the MM benchscale testing results.

With a recent relaxation of the Covid-19 restrictions, MM testing was initiated in March 2021. This technical memorandum provides a summary of the MM benchscale test results conducted in March 2021 and will be submitted as an addendum to the 2020 report.

A series of benchscale phosphorus removal tests were conducted at the University of Manitoba's Environmental Engineering Laboratory. Three different interim phosphorus removal scenarios were tested on samples collected during the MM conditions at the NEWPCC and WEWPCC between March 11 to 18, 2021. The timing for MM sampling and testing was selected based on the historical occurrence of MM conditions at the NEWPCC. The impact of each scenario on various parameters including alkalinity consumption (pH), sludge production, and anaerobic digestion was investigated.

Scenario 1 simulated the full scale side stream phosphorus removal process at NEWPCC where soluble phosphorus is precipitated in two steps: during and after anaerobic digestion. Scenario 2 simulated chemically enhanced primary treatment (CEPT) where soluble phosphorus is precipitated during the primary clarification process. Finally, Scenario 3 simulated phosphorus removal in the high purity oxygen (HPO) reactors where soluble phosphorus is removed during the biological carbon removal process.

This Technical Memorandum presents a summary of the results obtained during the MM benchscale testing. The benchscale testing results will help to assess the possibility of implementing interim phosphorus removal during MM conditions at full scale, and to determine if the annual average (AA) chemical dosing rates can be used for MM conditions and their effect on process performance.

## 2. Scenario 1: Side-Stream Chemical Phosphorus Removal

In this option, ferric chloride was dosed to a blend of NEWPCC and WEWPCC sludges prior to digestion and subsequently after bio-methanation potential (BMP) tests to achieve less than 20 mg $PO_4$-P/L in the centrate. The primary objective of this scenario was to maintain the current effluent soluble phosphorus concentration with the projected increased phosphorus load from SEWPCC.

Benchscale tests investigated the required ferric chloride doses, the impact of the ferric chloride doses on alkalinity and pH, and the overall effects on digestion.

## 2.1 Results

Samples from the NEWPCC and WEWPCC sludges were collected and analyzed, **Table 1** summarizes the raw sludge sample characteristics.

**Table 1: Scenario 1 Raw Sludge Sample Characteristics**

| Parameter | Unit | NEWPCC Primary Sludge | NEWPCC Digested Sludge | WEWPCC Sludge |
|---|---|---|---|---|
| pH | | 6.38 | 7.23 | 5.60 |
| Alkalinity | mg $CaCO_3$/L | 4040* | 2940 | 740 |
| Total Solids (TS) | mg/L | 23,878 | 15,384 | 44,008 |
| Volatile Solids (VS) | mg/L | 15,512 | 8,552 | 35,464 |
| Ortho-P | mg/L | 34.2 | 37.2 | 383.5 |

* The alkalinity of NEWPCC primary sludge is higher than expected which may be due to a measurement error.

NEWPCC primary sludge and WEWPCC holding tank sludge were combined at a ratio of 3:1 to replicate MM conditions once SEWPCC BNR upgrades are complete. The mixed sludge characteristics are summarized in **Table 2**.

**Table 2: NEWPCC Primary Sludge and WEWPCC Holding Tank Sludge Mixture Characteristics**

| Parameter | Unit | NEWPCC PS + WEWPCC Sludge |
|---|---|---|
| pH | | 5.88 |
| Alkalinity | mg $CaCO_3$/L | 2180 |
| Total Solids | mg/L | 47,626* |
| Volatile Solids | mg/L | 32,462 |
| Ortho-P | mg/L | 174 |

* Mixed sludge TS results are higher than expected which may be due to a sampling error.

### 2.1.1 Ferric Chloride Dose Upstream of Anaerobic Digestion

Jar testing was completed on the sludge mixture for four different ferric chloride doses. The four ferric chloride doses prior to digestion were 0, 135, 250, and 500 mg Fe/L which correspond to the control dose, the current dose for hydrogen sulfide control, half the BioWin predicted dose, and the BioWin predicted dose, respectively. The selected doses were the same as the AA doses used in the previous benchscale study. A total of four sets of jar tests were completed with the following conditions: no pH adjustment, a duplicate of no pH adjustment, pH adjusted to 6 during jar tests, and pH adjusted to 7 during jar tests.

During tests with no pH adjustment, the pH dropped to 5.5 which affected the efficiency of orthophosphate removal at doses of 135 and 250 mg Fe/L. Orthophosphate removal was more effective in tests with pH adjustment but there was no significant difference between pH adjustment to 6 or 7 (**Figure 1**). The pH drop did not have any effect on Orthophosphate removal at a dose of 500 mg Fe/L. At the high ferric chloride dose of 500 mg Fe/L, the pH drop did not indicate a reduced efficiency in orthophosphate removal; however, pH adjustments will be required to prevent negative impacts on anaerobic digestion.

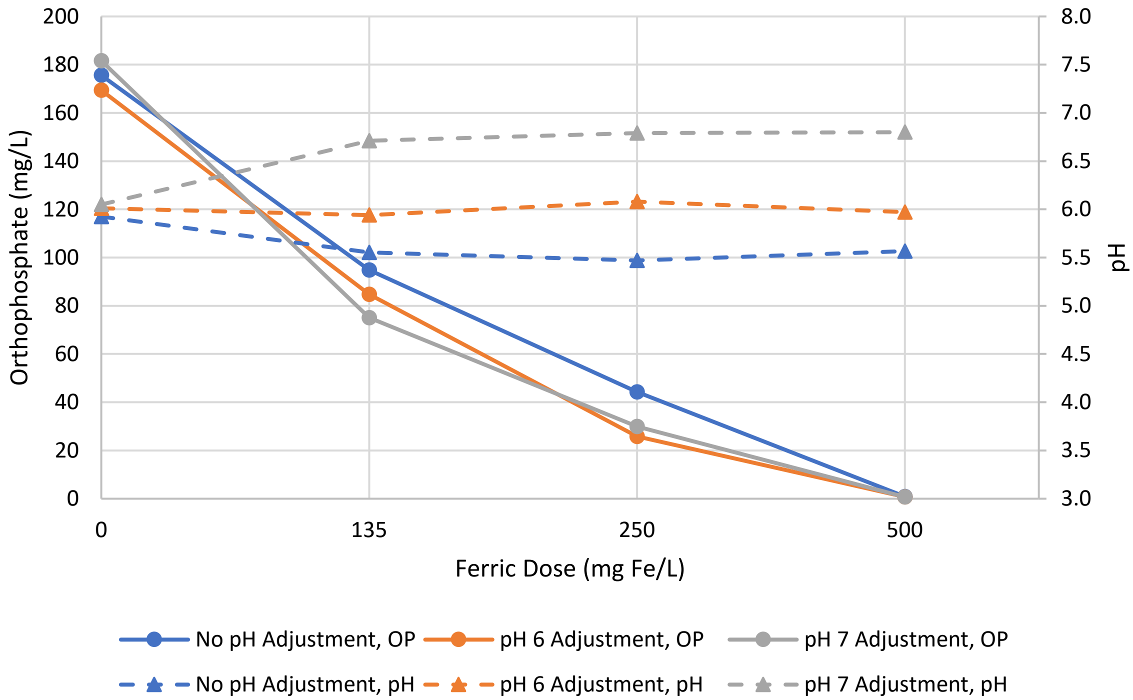


**Figure 1: Soluble Orthophosphate and pH for Scenario 1 Jar Tests**

### 2.1.2 Impacts on Anaerobic Digestion

After 20 minutes of reaction time, 50 mL of the sludge from the jar test was added to 450 mL of NEWPCC digested sludge to replicate the digester volumetric loading of 0.10 $m^3/m^3/d$ based on historical data during MM conditions. The 500 mL bottles were placed in a 36°C water bath and mixed with magnetic mixers for 15 days to simulate the conditions in a mesophilic anaerobic digester with a solids retention time (SRT) of 15 days.

Cumulative biogas production and biogas composition were monitored during the BMP test to assess the impact of ferric chloride addition on digestion during the BMP tests, as shown in **Figure 2, Figure 3,** and **Figure 4**. Biogas was sampled and analyzed for gas composition throughout the 15 days. Based on the results, there was no significant effect of the sludge pH on the methane production. This may be due to the low chemical sludge to digester inoculum ratio (50:450).

No data was recorded for a few hours during day 2 of the BMP test due to a power outage. The sample dosed with 250 mg Fe/L of sludge and adjusted to pH 7 prior to digestion did not correctly record biogas production for almost two days, but otherwise closely followed the curve of the other doses. The samples dosed with 135 mg Fe/L of sludge and adjusted to pH 7 appears to be an outlier as the sample with no pH adjustment and with pH adjusted to 6 do not show any inhibition due to the high ferric dose.

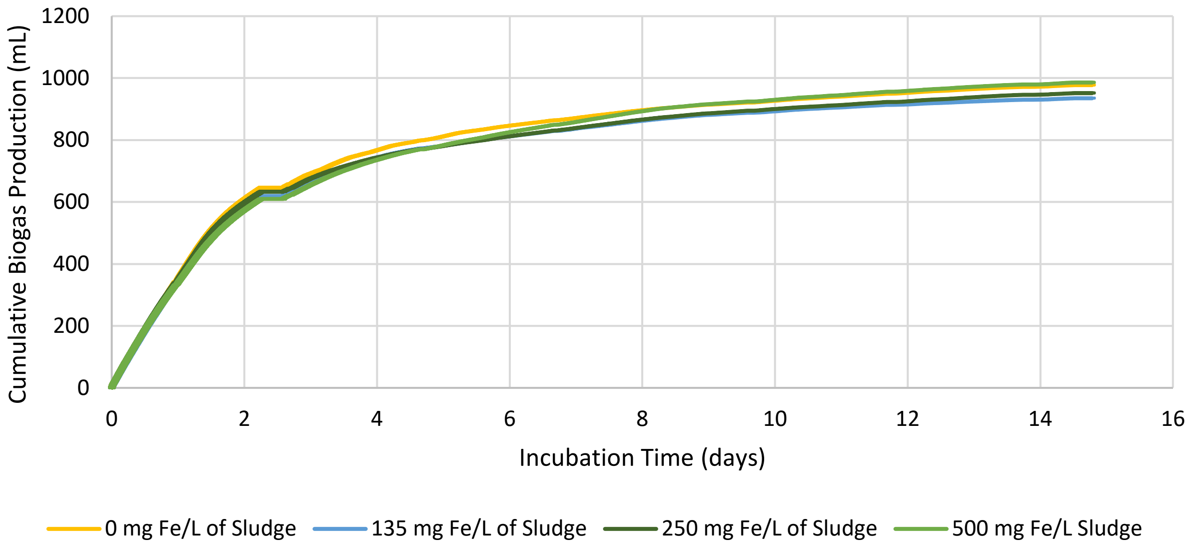


**Figure 2: Scenario 1 Cumulative Biogas Production – No pH Adjustment**

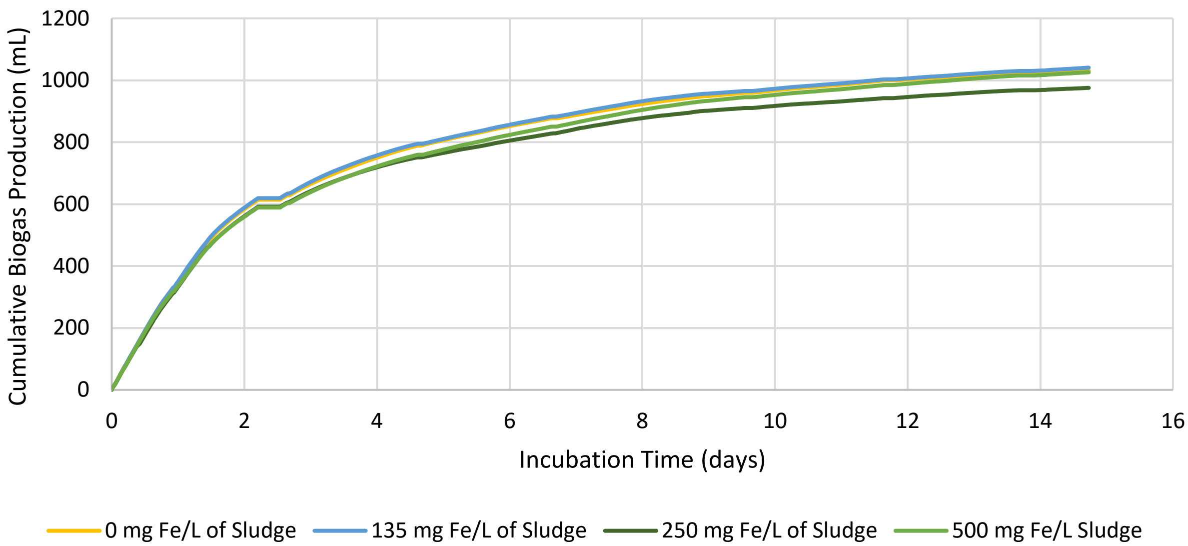


**Figure 3: Scenario 1 Cumulative Biogas Production – pH 6 Adjustment**

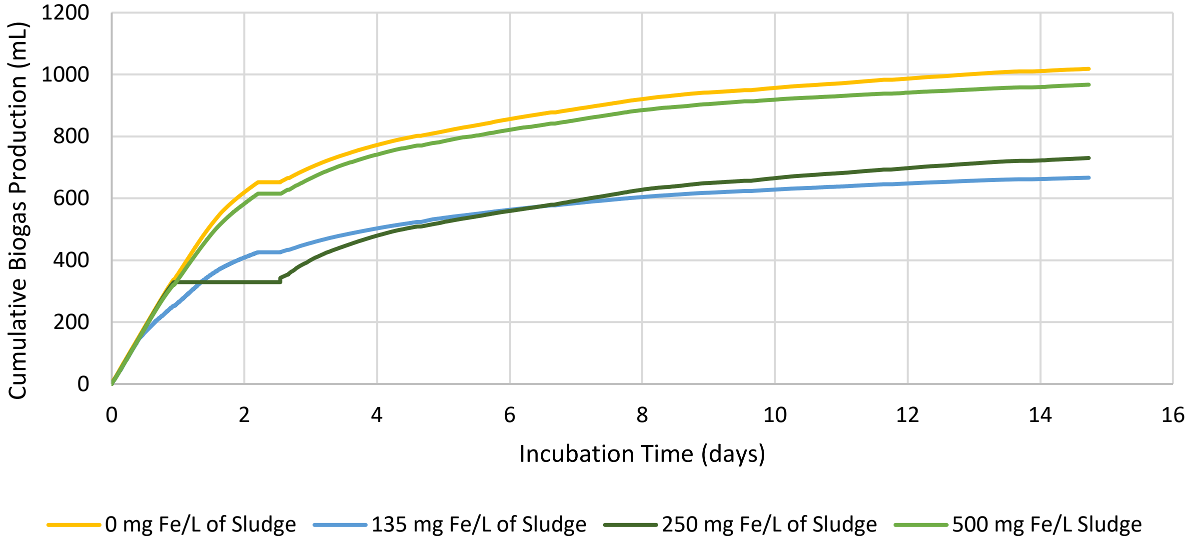


**Figure 4: Scenario 1 Cumulative Biogas Production – pH 7 Adjustment**

**Figure 5**, **Figure 6,** and **Figure 7** show the biogas composition throughout the BMP tests. The average methane content for each sample was between 60% to 70%, which is a typical biogas composition in anaerobic digesters.

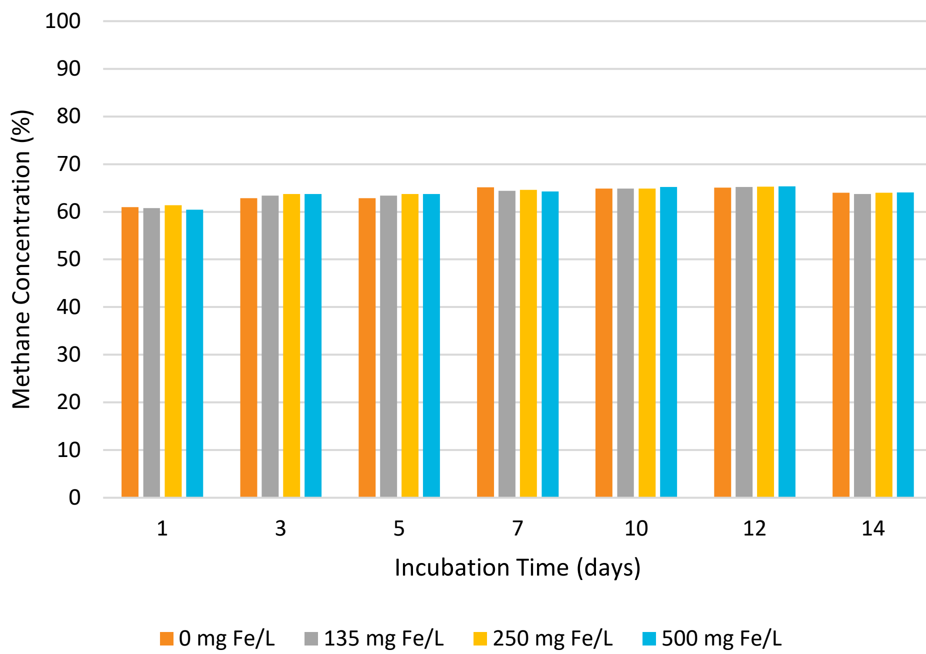


**Figure 5: Scenario 1 Biogas Composition – No pH Adjustment**

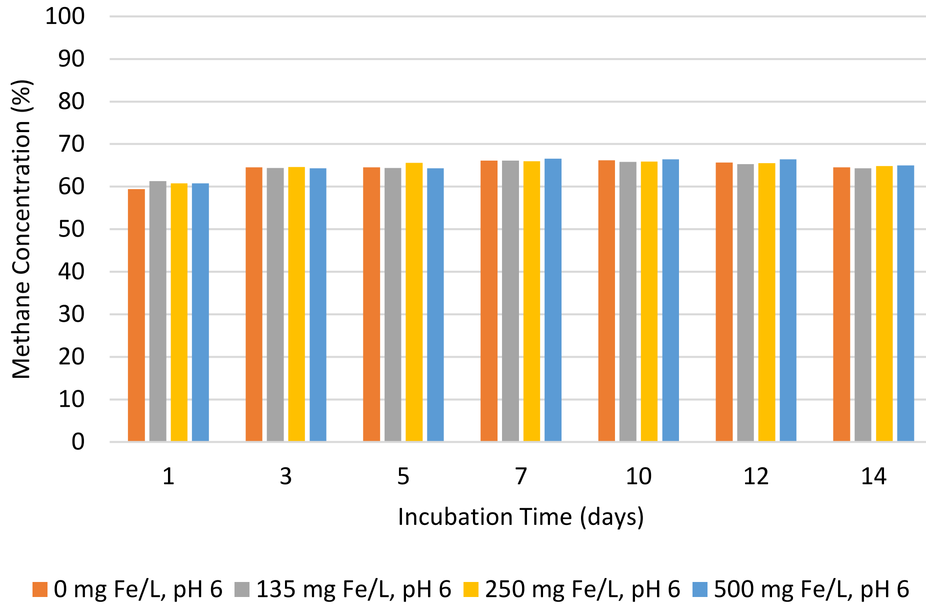


**Figure 6: Scenario 1 Biogas Composition – pH 6 Adjustment**

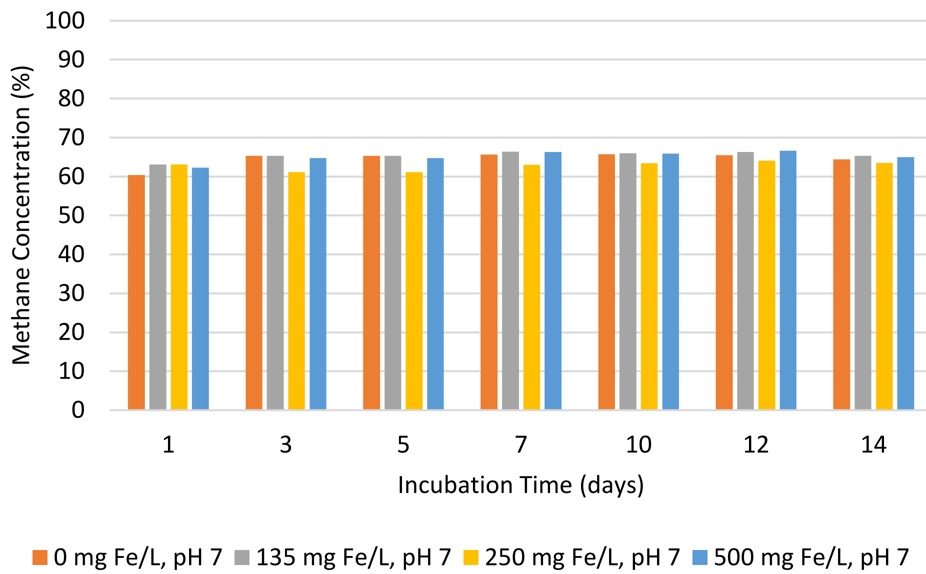


**Figure 7: Scenario 1 Biogas Composition – pH 7 Adjustment**

The average methane content in biogas from each test is summarized in **Table 3.** There was no significant difference between the different ferric chloride doses and pH adjustments.

**Table 3: Scenario 1 Biogas Composition**

| Ferric Dose to Sludge | Unit | Methane | Carbon Dioxide | Other |
|---|---|---|---|---|
| **No pH Adjustment** | | | | |
| 0 mg Fe/L | % | 63.7 | 33.4 | 2.9 |
| 135 mg Fe/L | % | 63.7 | 33.5 | 2.8 |
| 250 mg Fe/L | % | 64.0 | 33.5 | 2.6 |
| 500 mg Fe/L | % | 63.8 | 33.5 | 2.7 |
| **Adjustment to pH 6** | | | | |
| 0 mg Fe/L | % | 64.4 | 32.8 | 2.8 |
| 135 mg Fe/L | % | 64.5 | 33.2 | 2.3 |
| 250 mg Fe/L | % | 64.6 | 33.0 | 2.4 |
| 500 mg Fe/L | % | 64.8 | 32.7 | 2.4 |
| **Adjustment to pH 7** | | | | |
| 0 mg Fe/L | % | 64.6 | 33.4 | 2.0 |
| 135 mg Fe/L | % | 65.4 | 32.6 | 2.0 |
| 250 mg Fe/L | % | 62.8 | 35.1 | 2.1 |
| 500 mg Fe/L | % | 65.1 | 32.6 | 2.4 |

Total solids and volatile solids destruction after the 15-day BMP test were found to be between 13 and 17% and 21 and 29%, respectively, as shown in **Figure 8**. Neither ferric doses nor pH had any significant effect on solids destruction.

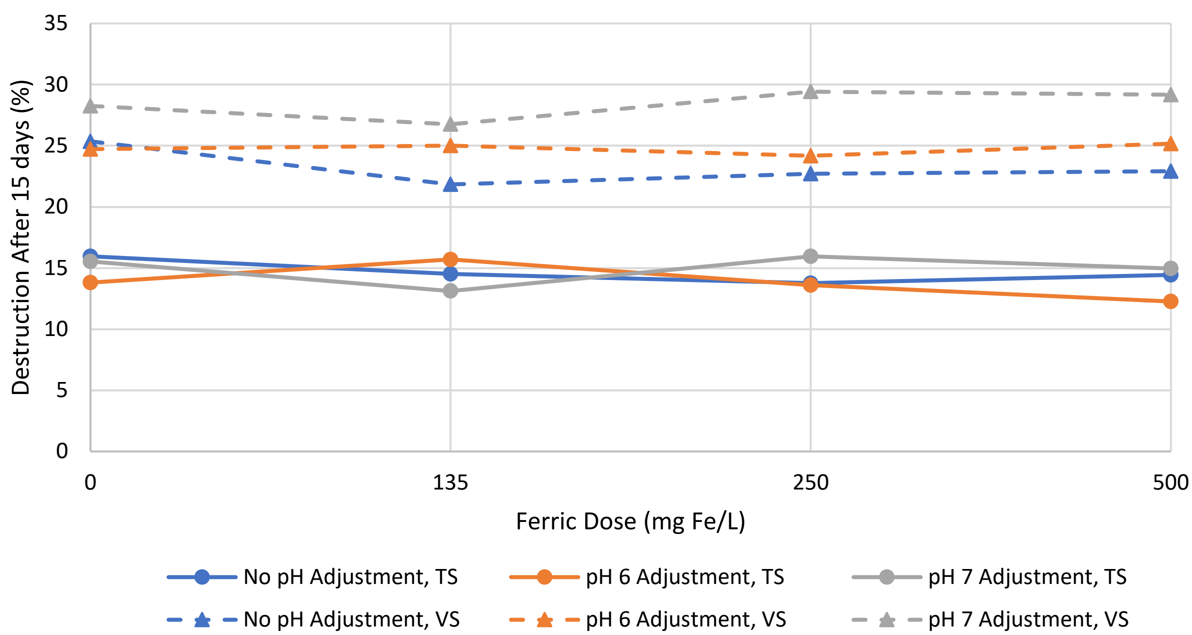


**Figure 8: Scenario 1 Total Solids and Volatile Solids Destruction**

Soluble orthophosphate in the digested samples was found to be between 42 and 67 mg P/L with pH ranging from 7.1 and 7.2 as shown in **Figure 9**.

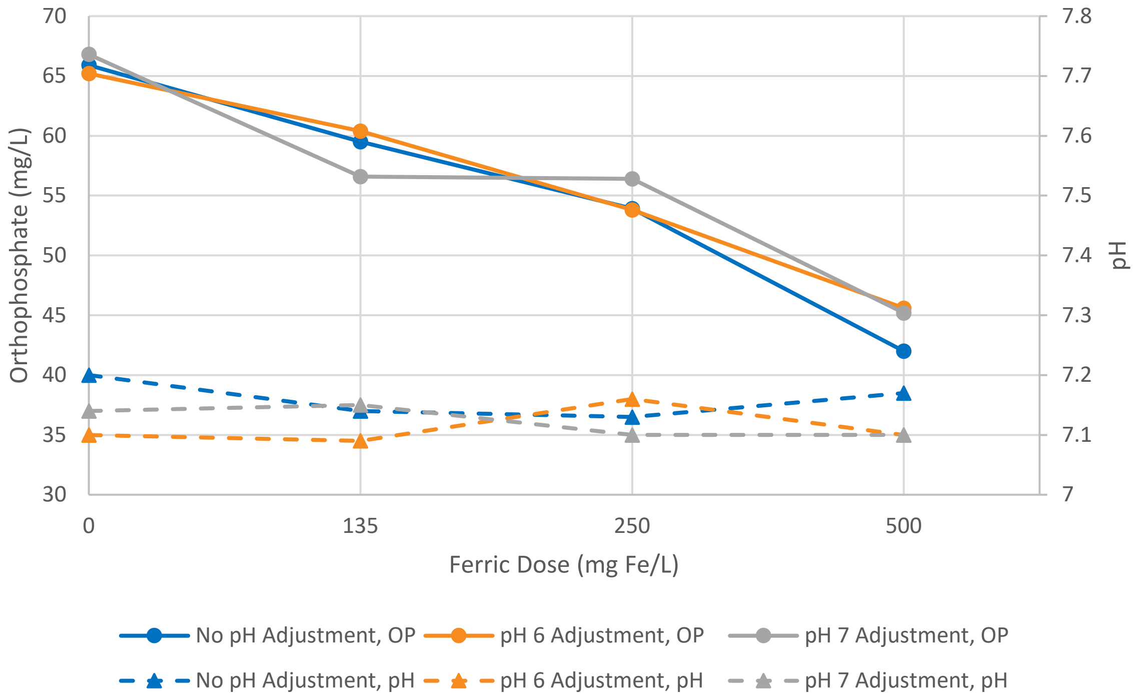


**Figure 9: Soluble Orthophosphate and pH for Scenario 1 Post-Digestion**

### 2.1.3 Ferric Chloride Dose Downstream of Anaerobic Digestion

As the objective for Scenario 1 dosing was to reach a soluble orthophosphate concentration of around 20 mg/L in the centrate, a second ferric chloride dose after digestion was necessary. A dose of 100, 80, 65, and 45 mg Fe/L of digested sludge were added to the digested sludge with prior doses of 0, 135, 250, and 500 mg Fe/L, respectively. For example, the sludge sample that was given a dose of 135 mg Fe/L (**Figure 9**), it was then subsequently given a second dose of 80 mg Fe/L (**Figure 10**) post digestion. **Figure 10** shows the soluble orthophosphate and pH of the samples after the second ferric chloride dose. According to the pH values shown in **Figure 9** and **Figure 10**, the second ferric chloride dose resulted in a slight pH drop which does not require further pH adjustments.

Results show that a minimum secondary dose of 100 mg Fe/L was necessary to lower the concentration of orthophosphate below 20 mg/L.

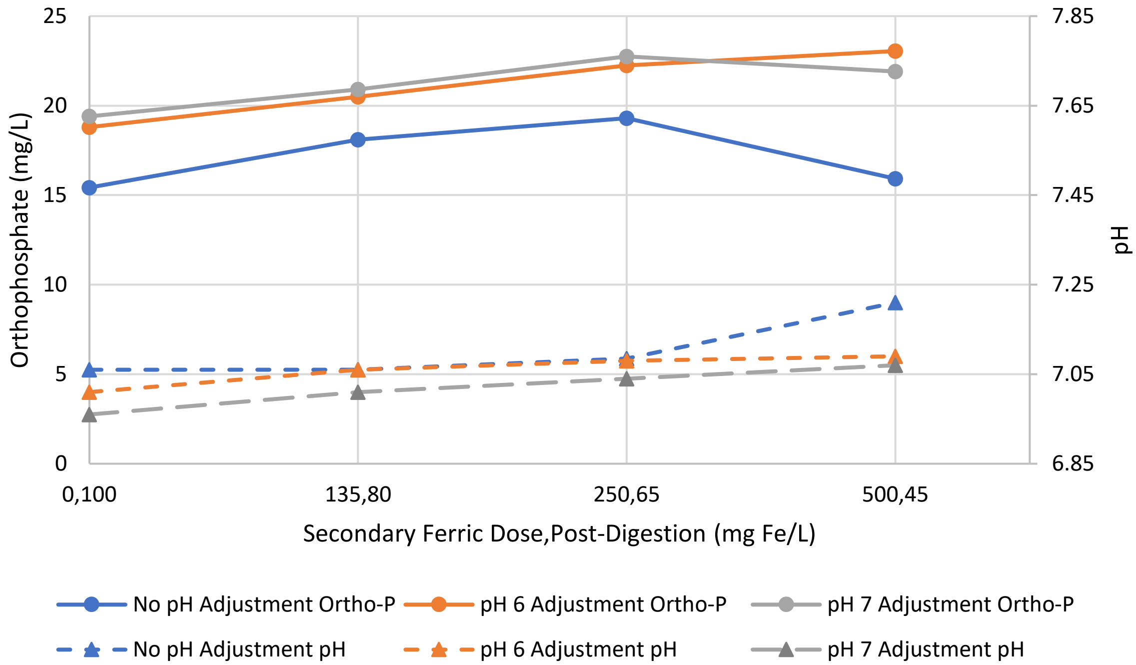


**Figure 10: Soluble Orthophosphate and pH for Scenario 1 After Second Ferric Dose**

# 3. Scenario 2: Chemically Enhanced Primary Treatment

In the jar tests for Scenario 2, ferric chloride was dosed to Primary Influent (PI) samples.

## 3.1 Results

Samples from NEWPCC and WEWPCC were collected and analyzed on March 11, 2021. **Table 4** summarizes the raw sample characteristics. During the benchscale testing, the orthophosphate concentration in the primary influent was higher than the historical data for MM conditions. Historically, the influent orthophosphate concentration during MM conditions is only around 1 mg/L. Similarly, the BioWin model assumed 1.7 mg OP/L in the primary influent. At the time of sampling the plant might not have been experiencing MM conditions. The orthophosphate concentration in the primary influent was very close to AA conditions, so one of the ferric chloride doses selected for MM testing was based on the ferric to orthophosphate (Fe:P) ratio results from AA conditions.

**Table 4: Scenario 2 Raw Sample Characteristics**

| Parameter | Unit | NEWPCC Primary Influent | NEWPCC Digested Sludge | WEWPCC Sludge |
|---|---|---|---|---|
| pH | | 7.06 | 7.23 | 5.6 |
| Alkalinity | mg $CaCO_3$/L | 300 | 2,940 | 740 |
| TS | mg/L | 1,480 | 15,384 | 44,008 |
| VS | mg/L | 680 | 8,552 | 35,464 |
| Ortho-P | mg/L | 4.31 | 37.2 | 383.5 |

Jar testing was completed on primary influent for three different ferric chloride doses based on AA testing removal rates and BioWin modeling. The three ferric doses used for testing were 0, 10, and 20 mg Fe/L of primary influent which represent the control dose, the dose calculated based on AA removal rates, and the BioWin dose, respectively. All jar tests were completed with 7.5 minutes of slow mixing. After 60 minutes of settling, the volume of settled sludge was recorded and sampled for further testing and analysis. Supernatant was sampled immediately following the 60 minutes of settling for further analysis, results shown in **Table 5**.

**Table 5: Scenario 2 Supernatant Characteristics**

| Parameter | Unit | 0 mg Fe/L | 10 mg Fe/L | 20 mg Fe/L |
|---|---|---|---|---|
| pH | | 7.22 | 7.19 | 7.19 |
| Alkalinity | mg $CaCO_3$/L | 300 | 260 | 235 |
| Ortho-P | mg/L | 4.92 | 1.62 | 0.22 |

Soluble orthophosphate concentration in the supernatant was as expected based on the results observed during the AA testing. The ferric doses of 10 mg Fe/L of primary influent and 20 mg Fe/L of primary influent had orthophosphate concentrations of 1.62 mg/L and 0.22 mg/L, respectively, as shown in **Figure 11**.

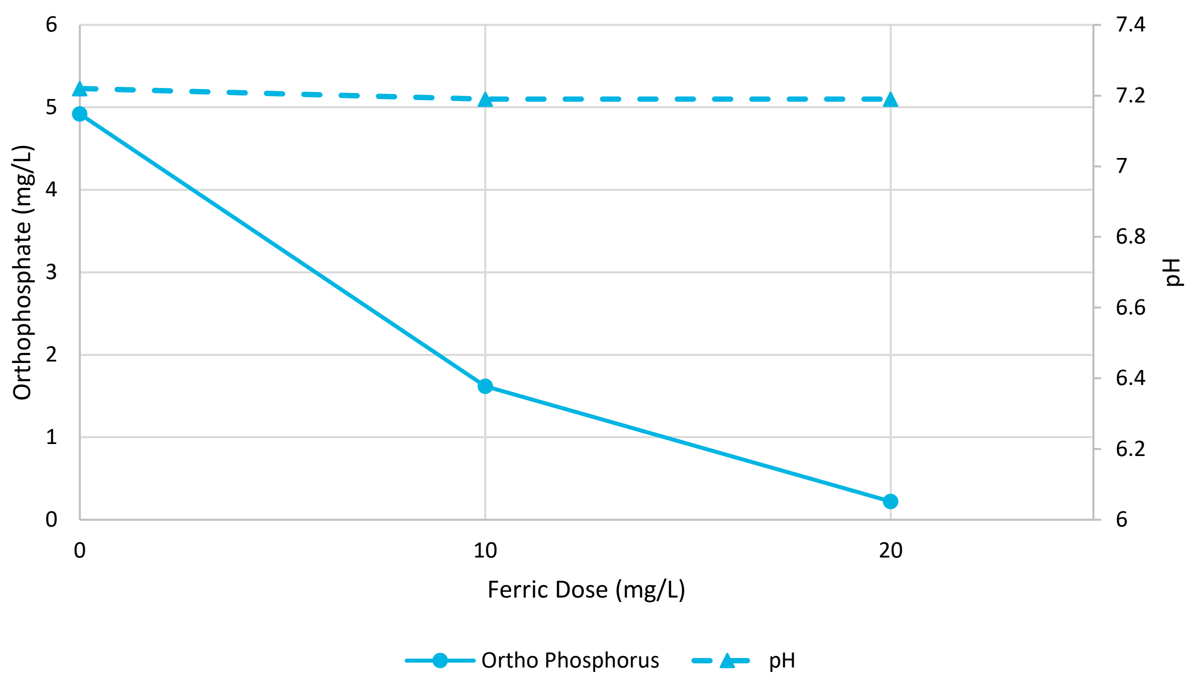


**Figure 11: Soluble Orthophosphate for Scenario 2 Jar Tests**

### 3.1.1 Sludge Production

The volume of settled sludge as well as the total sludge produced increased as the ferric chloride dose increased, as shown in **Figure 12**.

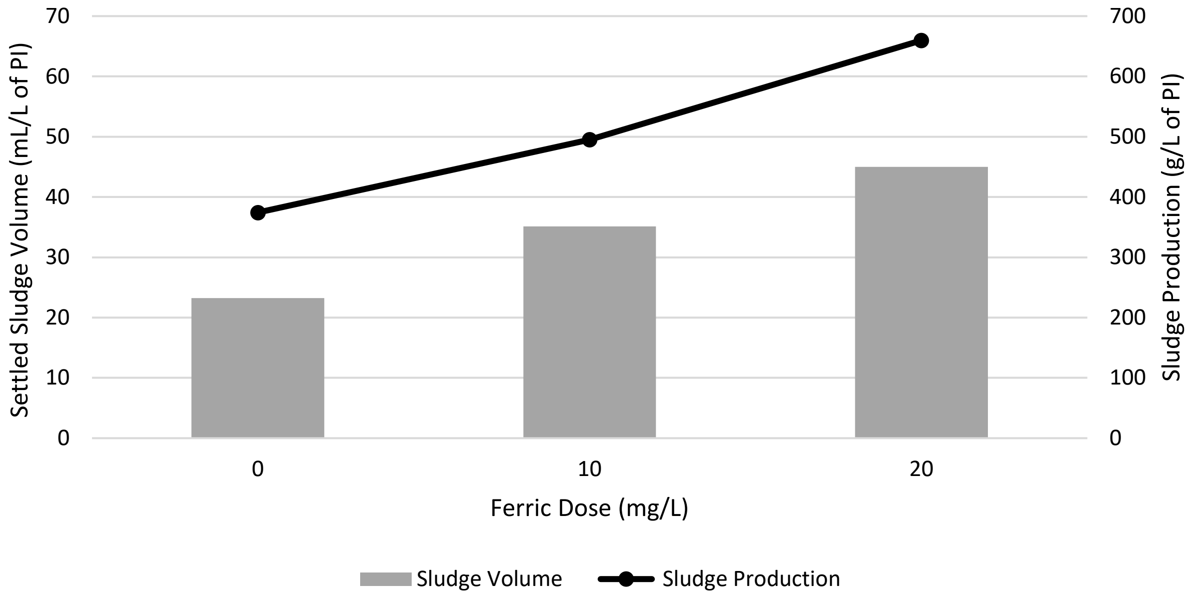


**Figure 12: Scenario 2 Sludge Volume and Mass Production**

### 3.1.2 Impacts on Anaerobic Digestion

Sludge produced from each jar test was mixed in a 3:1 ratio with WEWCC sludge sampled from the holding tank. The mixed sludge was then added to digester inoculum at a volumetric loading rate of 0.10 $m^3/m^3/d$ and a 15-day BMP was started to record biogas production. **Figure 13** shows the gas production for the two sets of three ferric doses over the 15 days. Each bottle contains 500 mL of sludge made up of 37.5 mL of sludge from the jar test, 12.5 mL of WE sludge, and 450 mL of digester inoculum.

Based on the results, the ferric chloride doses used in this experiment had no effect on the biogas production.

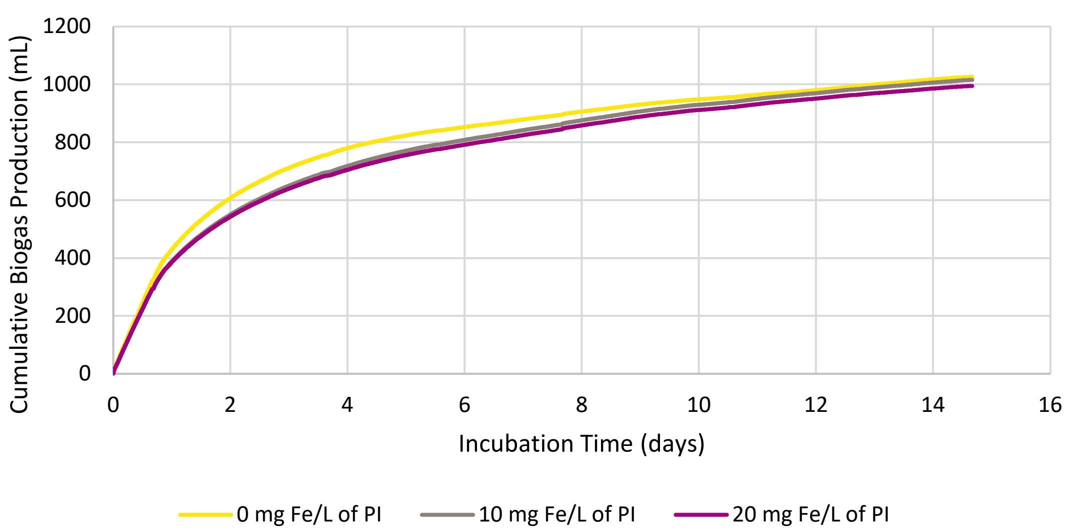


**Figure 13: Scenario 2 Cumulative Biogas Production**

Biogas was sampled and analyzed for gas composition throughout the 15 days. **Figure 14** shows the biogas composition throughout the BMP tests. Comparing methane content of the control dose (0 mg Fe/L) with those of the highest dose (20 mg Fe/L) does not indicate significant impacts on anaerobic digestion.

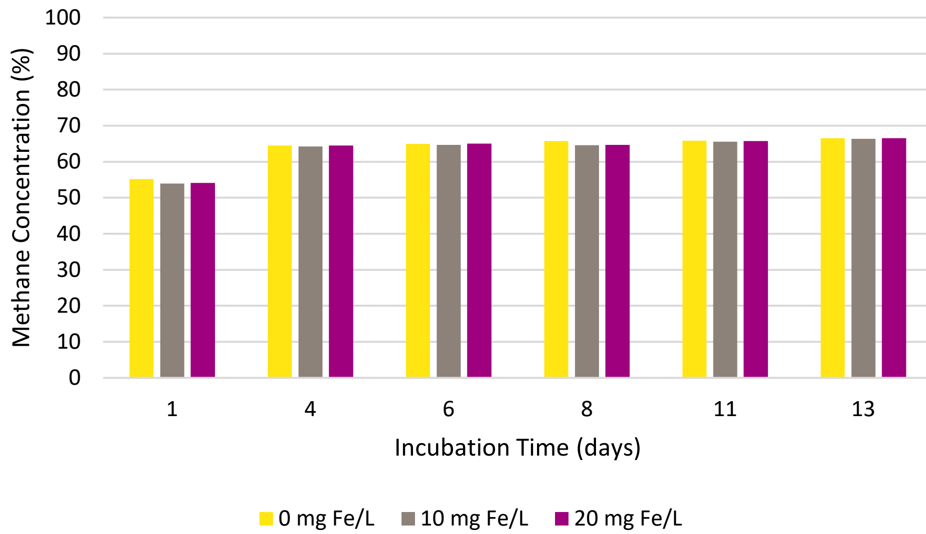


**Figure 14: Scenario 2 Biogas Composition**

The average methane content in biogas from each test is summarized in **Table 6**. There was no significant difference between the different ferric doses.

**Table 6: Scenario 2 Biogas Composition**

| Ferric Dose to Primary Influent | Unit | Methane | Carbon Dioxide | Other |
|---|---|---|---|---|
| 0 mg Fe/L | % | 63.8 | 31.4 | 4.8 |
| 10 mg Fe/L | % | 63.2 | 31.2 | 5.6 |
| 20 mg Fe/L | % | 63.4 | 30.9 | 5.7 |

Total solids and volatile solids destruction after the 15-day BMP test were found to be 10-13% and 19-22%, respectively, as shown in **Figure 15**. Ferric doses did not have any significant effect on solids destruction.

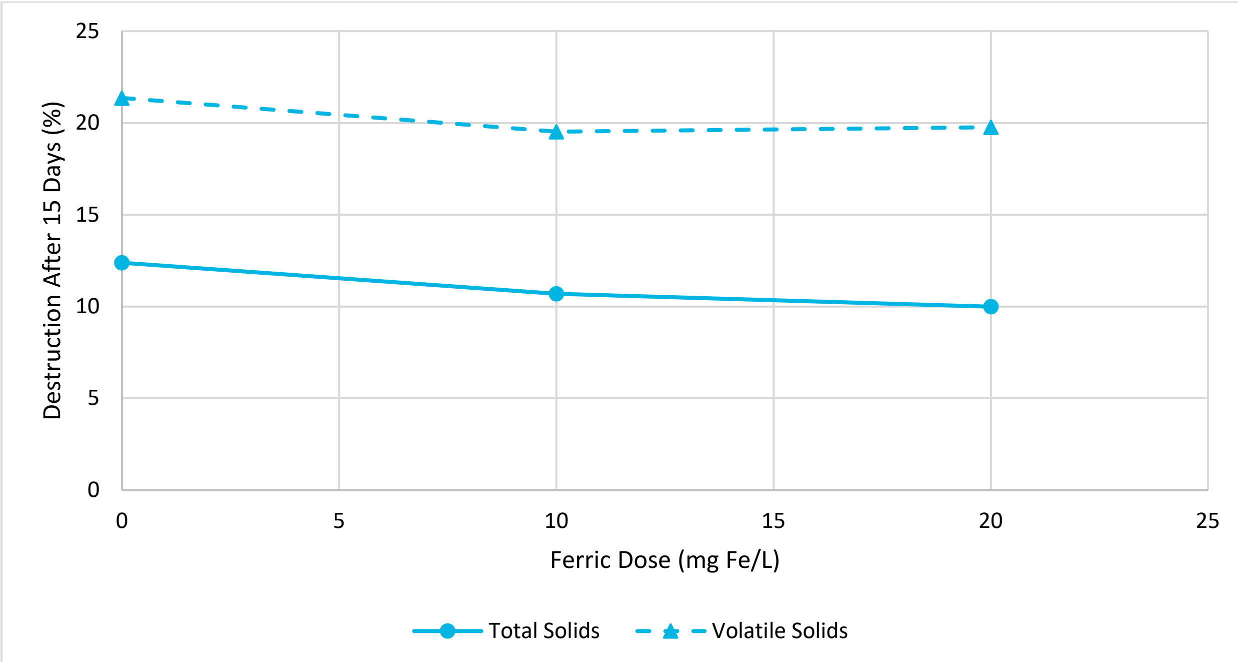


**Figure 15: Scenario 2 Total Solids and Volatile Solids Destruction**

Soluble orthophosphate was found to be between 52 and 60 mg/L in the digested samples, all with a pH around 7.2, as shown in **Figure 16**, which is similar to the results obtained in Scenario 1.

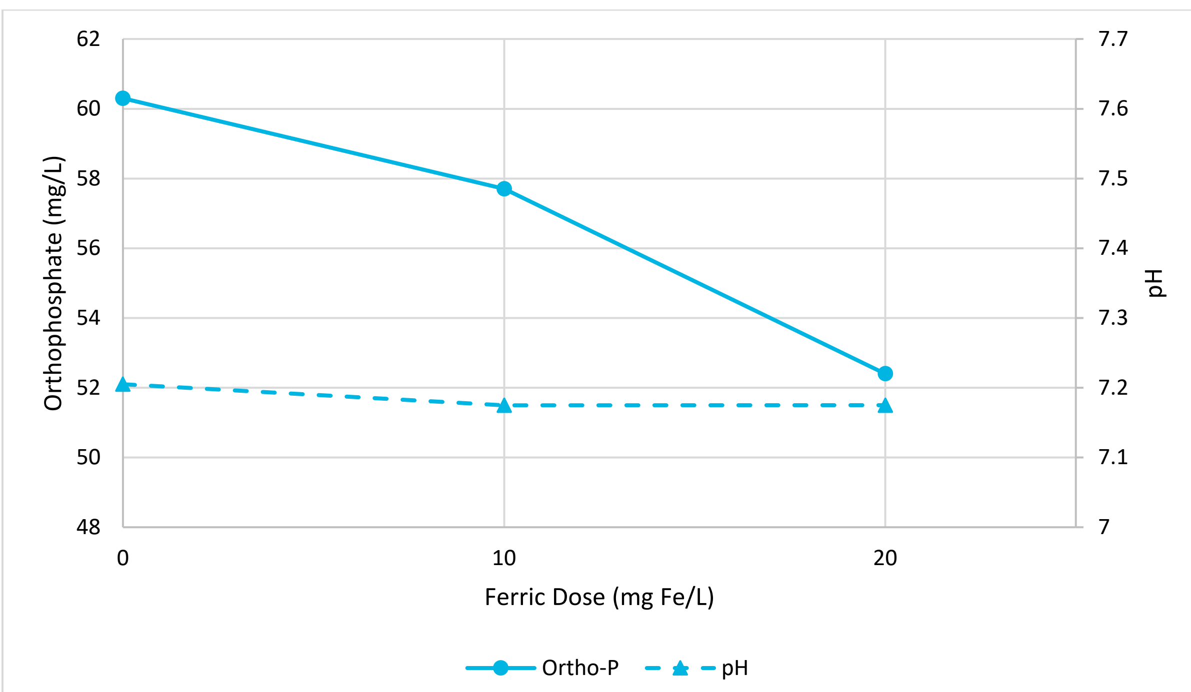


**Figure 16: Soluble Orthophosphate and pH for Scenario 2 Post-Digestion**

# 4. Scenario 3: Phosphorus Removal in HPO Reactors

In Scenario 3, ferric chloride was dosed to the mixed liquor (ML) from HPO reactors.

## 4.1 Results

Samples from NEWPCC and WEWPCC were collected and analyzed on March 18, 2021. **Table 7** summarizes the raw sample characteristics. It is important to note that the orthophosphate concentration in mixed liquor was 1.7 – 1.9 mg/L. This range is higher than the historical orthophosphate concentration during MM conditions, which is closer to 1 mg/L and lower than the orthophosphate concentration measured during AA testing.

**Table 7: Scenario 3 Phase 2 Raw Sample Characteristics**

| Parameter | Unit | NEWPCC Mixed Liquor | NEWPCC Primary Sludge | NEWPCC Digested Sludge | WEWPCC Sludge |
|---|---|---|---|---|---|
| pH | | 6.58 | - | - | - |
| Alkalinity | mg CaCO3/L | 290 | - | - | - |
| TS | mg/L | 3,272 | 31,066 | 13,964 | 43,425 |
| VS | mg/L | 2,276 | 23,266 | 7,524 | 36,339 |
| Ortho-P | mg/L | 1.70 | 77.6 | 55.3 | 388 |

Jar testing was completed on mixed liquor for three different ferric chloride doses of 0, 4, and 5 mg Fe/L of mixed liquor. All jar tests were completed with 7.5 minutes of slow mixing. After 60 minutes of settling, the volume of settled sludge was recorded and sampled for further testing. Supernatant was sampled immediately following the 60 minutes of settling for further testing, with results outlined in **Table 8**.

**Table 8: Scenario 3 Supernatant Characteristics**

| Parameter | Unit | 0 mg Fe/L | 4 mg Fe/L | 5 mg Fe/L |
|---|---|---|---|---|
| pH | | 6.66 | 6.68 | 6.67 |
| Alkalinity | mg CaCO3/L | 299 | 301 | 297 |
| Ortho-P | mg/L | 1.94 | 0.983 | 0.827 |

Soluble orthophosphate concentration in the blank sample was lower than during AA conditions and therefore the mg Fe/L of mixed liquor dose was lower in this Scenario. The relative dose of Fe to P; however, was similar to the one during AA conditions. The ferric chloride doses of 4 mg Fe/L of mixed liquor and 5 mg Fe/L of mixed liquor resulted in an orthophosphate concentrations of 0.98 mg P/L and 0.83 mg P/L, respectively, as shown in **Figure 17**.

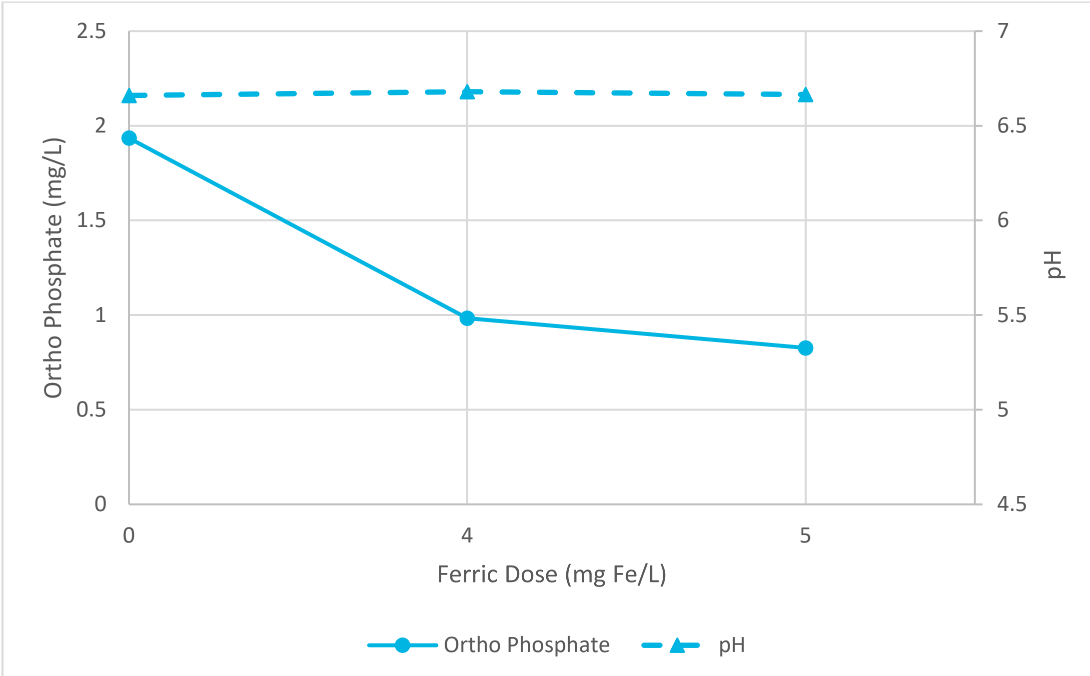


**Figure 17: Soluble Orthophosphate for Scenario 3 Jar Tests**

### 4.1.1 Sludge Production

The volume of settled sludge as well as the total sludge produced per liter of mixed liquor did not significantly increase as the ferric chloride dose increased, as shown in **Figure 18**. This is can be attributed to the relatively lower dose of ferric chloride compared to AA testing.

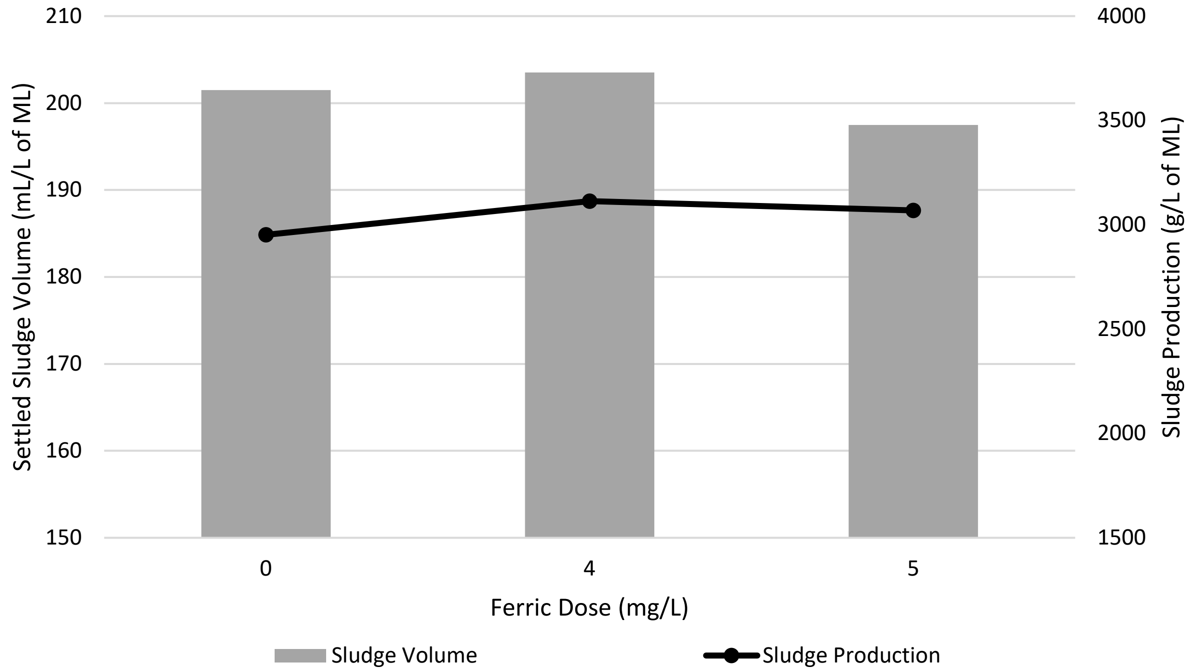


**Figure 18: Scenario 3 Phase 2 Sludge Production**

### 4.1.2 Impacts on UV Disinfection

Ultraviolet transmittance (UVT) was measured on all supernatant samples to determine if UV treatment would be hindered. As the ferric chloride dose to the mixed liquor increased, UVT increased which means the ferric chloride doses tested in this experiment did not have negative impacts on UV transmittance, as shown in **Figure 19.**

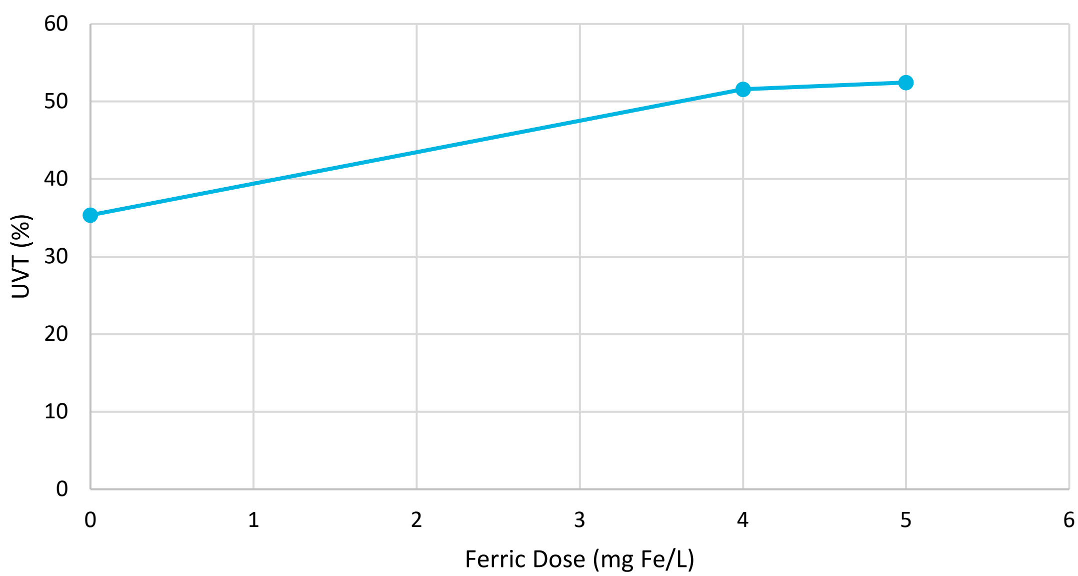


**Figure 19: UVT for Scenario 3 Supernatant**

### 4.1.3 Impacts on Anaerobic Digestion

Sludge produced in the jar tests was then mixed with primary sludge at a ratio of 36:64. Three parts of the mixed sludge were mixed with one part of WE sludge sampled from the holding tank. The mixed sludge was then added to digester inoculum at a volumetric loading rate of 0.10 $m^3/m^3/d$ and a 15-day BMP test was started to record biogas production. Each bottle contained 500 mL of sludge made up of 14 mL of sludge from the jar test, 24 mL of primary sludge, 12 mL of WE sludge, and 450 mL of digester inoculum.

Cumulative biogas production during the BMP test is shown in **Figure 20**. Based on the results, the ferric chloride doses used in this experiment had no effect on the biogas production.

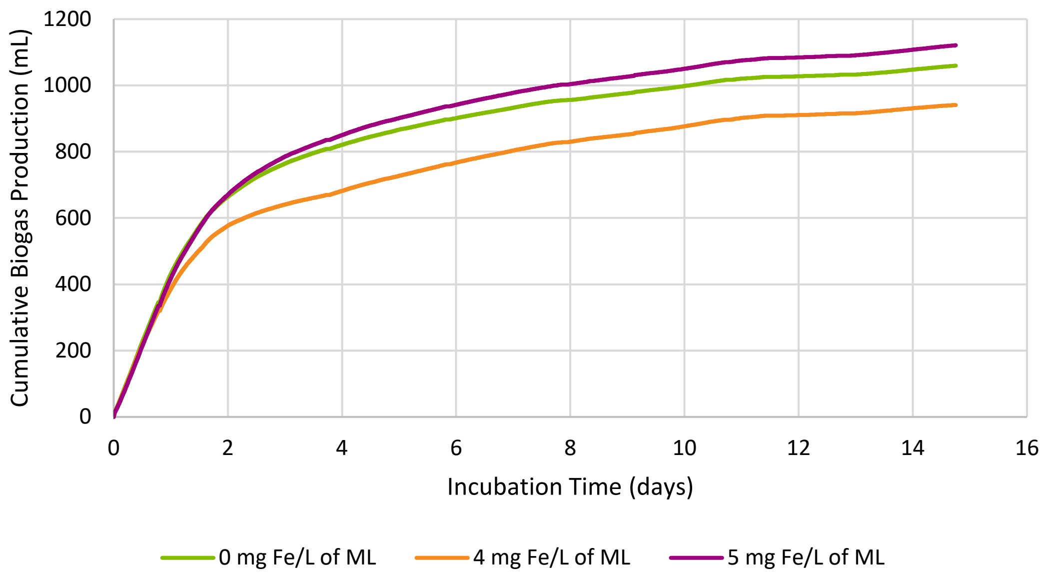


**Figure 20: Scenario 3 Cumulative Biogas Production**

Biogas was sampled and analyzed for gas composition throughout the 15 days. **Figure 21** shows the biogas composition throughout the BMP tests. Methane concentrations were considered in the normal range of 60% to 70%.

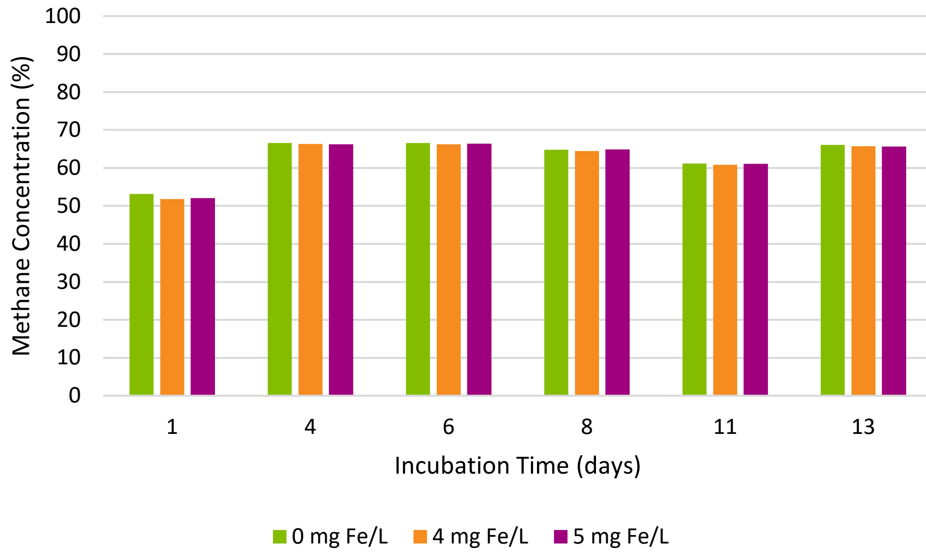


**Figure 21: Scenario 3 Biogas Composition**

The average methane content in the biogas from each test is summarized in **Table 9**. There was no significant difference between the different ferric doses.

**Table 9: Scenario 3 Biogas Composition**

| Ferric Dose to Primary Influent | Unit | Methane | Carbon Dioxide | Other |
|---|---|---|---|---|
| 0 mg Fe/L | % | 63.1 | 33.2 | 3.7 |
| 4 mg Fe/L | % | 62.6 | 33.2 | 4.2 |
| 5 mg Fe/L | % | 62.7 | 33.0 | 4.3 |

Soluble orthophosphate in the digested samples was found to be between 93 and 94 mg/L, all with a pH around 7.0, as shown in **Figure 22**. There was no significant difference in orthophosphate concentration between tests.

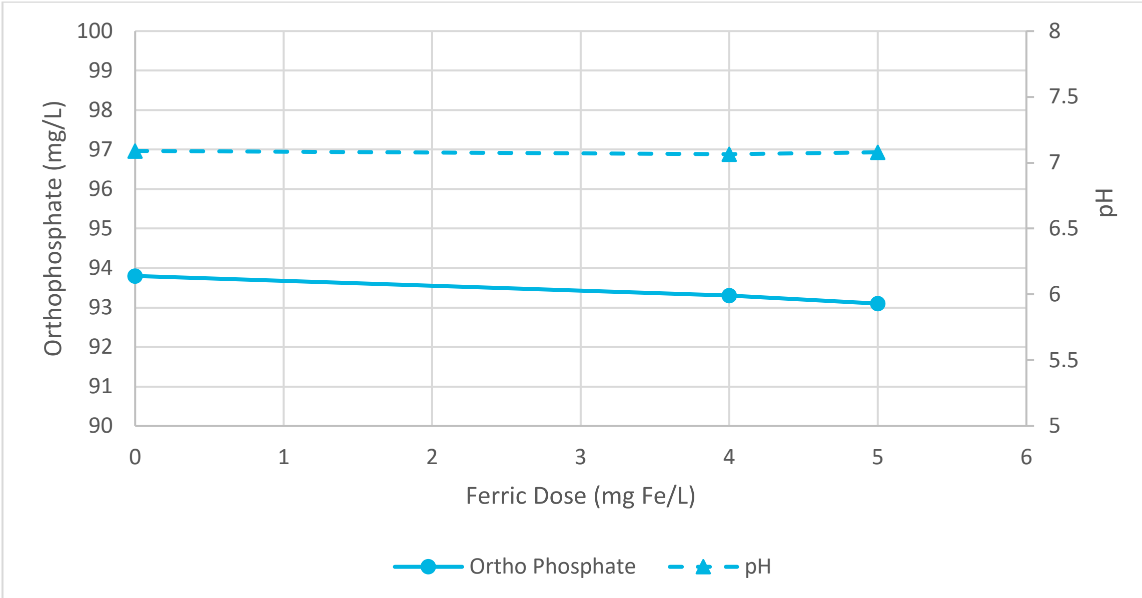


**Figure 22: Soluble Orthophosphate and pH for Scenario 3 Post-Digestion**

Total solids and volatile solids destructions after the 15-day BMP test were found to be between 16% to 19% and 28% to 31%, respectively, as shown in **Figure 23**. There was no significant difference in solids destruction between the tests.

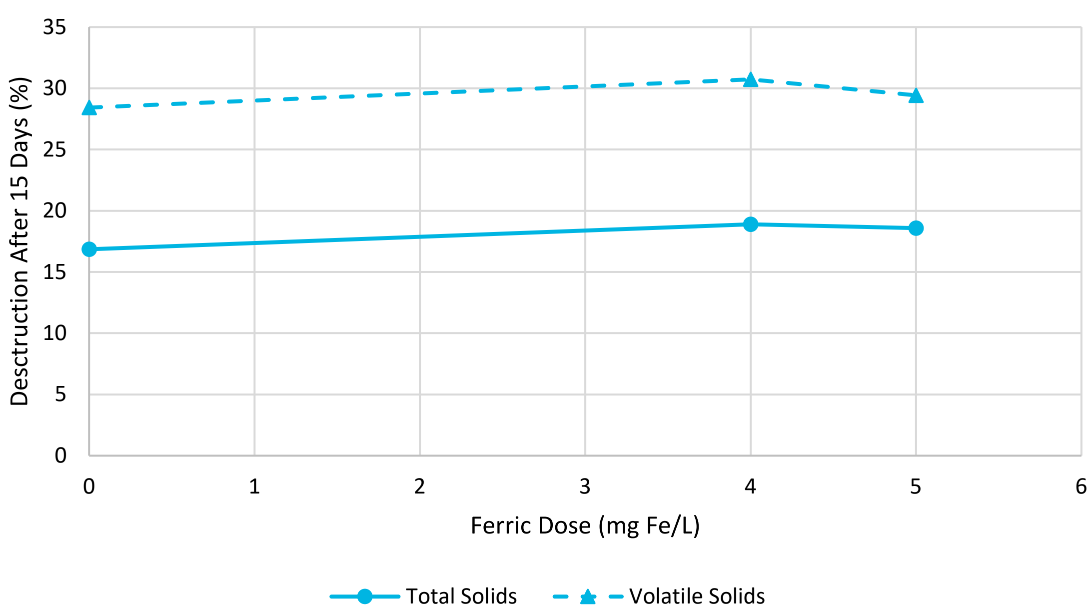


**Figure 23: Scenario 3 Total Solids and Volatile Solids Destruction**

# 5. Benchscale Testing Findings Summary

In Scenario 1, it was possible to achieve a soluble orthophosphate concentration of 20 mg P/L or less in the supernatant by dosing ferric chloride before and after digestion. Dosing ferric chloride in the range of 0-500 mg Fe/L prior to digestion did not show any negative effects on biogas and methane production during anaerobic digestion. A pH drop was observed in mixed sludge after the first dose of ferric chloride prior to digestion, which indicates the requirement for pH adjustment. Methane content in biogas was not affected by pH adjustment. Total and volatile solids destruction during the digestion process were not found to be affected by the higher ferric chloride doses or the pH adjustment, suggesting that the digestion was not affected. These conclusions, however, are based on a set of benchscale batch digesters which will be different from the continuous addition of chemical sludge to the digesters in full scale application.

In Scenario 2, a ferric dose of approximately 10 mg Fe/L lowered the orthophosphate concentration to less than 2.0 mg/L without significantly affecting pH given the initial orthophosphate concentration of approximately 5 mg/L, which is comparable to average conditions. Sludge production (mg/L of primary influent) was shown to increase by 35% from the control dose for ferric dose of 10 mg Fe/L. Dosing ferric chloride to the primary influent did not show a negative effect on biogas and methane production during digestion. Total and volatile destruction during the digestion process was also not found to be affected by dosing ferric chloride to the primary clarifiers.

In Scenario 3, a ferric dose between 4 and 5 mg Fe/L lowered the final effluent orthophosphate concentration to less than 1 mg/L, without significantly affecting the pH. It was found that the UVT of the final effluent increased as the ferric chloride dose increased, indicating UV treatment effectiveness would increase when dosing ferric chloride to the HPO reactors. At higher doses of ferric chloride, however, high concentration of unreacted iron in the liquid may cause fouling of the UV lamps which requires intensive maintenance and cleaning.

Sludge production (mg/L of mixed liquor) was not significantly affected by the ferric chloride addition, mainly because the ferric dose was relatively small. Dosing ferric chloride to the HPO reactors did not show a negative effect on biogas and methane production during digestion. Total solids and volatile solids destruction during the digestion process were not found to be affected by dosing ferric chloride to the HPO reactors.

# 6. BioWin Modeling and Benchscale Testing Comparison

## 6.1 Ferric Chloride Demand

The total amount of ferric chloride required to achieve the desired orthophosphate concentration depends on the initial orthophosphate concentration in the wastewater. The initial orthophosphate concentration in the BioWin model and samples used for benchscale testing are different so the mass ratio of the ferric chloride added to orthophosphate removed are compared to provide a standardized method for analysis.

The BioWin modeling and benchscale testing results for ferric to orthophosphate removed ratio (Fe:P) for each of the dosing points for Scenario 1 are compared in **Table 10.** Since BioWin did not predict a pH drop, only one ratio (neutral pH) is provided. However, jar testing was completed under different conditions and the ratio for each of these conditions is provided in **Table 10**.

**Table 10: Scenario 1 Fe to Orthophosphate Ratio- MM Conditions**

| Source | mg Fe /mg Ortho-P (1st Dosing Point) | | | mg Fe /mg Ortho-P (2nd Dosing Point) | | |
|---|---|---|---|---|---|---|
| BioWin Modeling | 2.4 | | | 5.5 | | |
| Benchscale testing | No pH Adj | pH 6 | pH7 | No pH Adj | pH 6 | pH7 |
| | 2.2 | 2.0 | 2.0 | 1.8 | 2.0 | 2.0 |

The BioWin modeling and benchscale testing results for Fe:P ratio for Scenario 2 are compared in **Table 11.**

**Table 11: Scenario 2 Fe to Orthophosphate Ratio- MM Conditions**

| Source | mg Fe /mg Ortho-P |
|---|---|
| BioWin Modeling | 7.0 |
| Benchscale testing | 3.0 |

The BioWin modeling and benchscale testing results for Fe:P ratio for Scenario 3 are compared in **Table 12**.

**Table 12: Scenario 3 Fe to Orthophosphate Ratio- MM Conditions**

| Source | mg Fe /mg Ortho-P |
|---|---|
| BioWin Modeling | 3.8 |
| Benchscale testing | 4.4 |

## 6.2 Sludge Production

In Scenario 1, ferric chloride is added to the sludge stream, which does not have considerable impacts on sludge volume and digesters SRT.

The results of the BioWin modeling and benchscale testing for the impact of dosing ferric chloride to primary clarifiers on primary sludge production in Scenario 2 are compared in **Table 13**.

The settling time in primary clarifiers is longer than the settling time allowed during the benchscale testing. The amount of settled sludge increases with longer settling time. The impact of settling time becomes more important when coagulant is not added (control dose). Therefore, the increase in sludge production based on the benchscale testing results may not be a true representation of the real conditions at the NEWPCC.

**Table 13: Scenario 2 Sludge Production**

| Source | % increase in Sludge Production |
|---|---|
| BioWin Modeling | 2% |
| Benchscale testing | 32% |

The results of the BioWin modeling and benchscale testing for the impact of dosing ferric chloride to HPO reactors on waste activated sludge production on Scenario 3 are compared in **Table 14.**

Due to the shorter settling time in benchscale testing, the same as Scenario 2, the increase in sludge production based on the benchscale testing results may not be a true representation of the real conditions at the NEWPCC.

**Table 14: Scenario 3 Sludge Production**

| Source | % increase in Sludge Production |
|---|---|
| BioWin Modeling | 2% |
| Benchscale testing | 5% |

# 7. Summary

A series of benchscale chemical phosphorus removal tests were conducted at the University of Manitoba's Environmental Engineering Laboratory. Three different interim phosphorus removal scenarios were tested for average and maximum month conditions. The purpose of the work was to verify some of the key parameters such as alkalinity consumption (pH), sludge production, and anaerobic digestion toxicity.

General conclusions from the overall benchscale work are summarized as follows:

- Benchscale results indicated a pH drop following the first dose of ferric chloride in Scenario 1; therefore, pH adjustment is required to prevent low pH conditions in the digesters and provide efficient chemical phosphorus removal.
- Benchscale results indicated a higher amount of sludge production for Scenarios 2 and 3 compared to the modeling work. When these results are applied to the full scale facility it will result in higher solids loading rates to the digesters and subsequently reduce the digesters' solids retention time (SRT). Since during certain periods of the year, the digesters are already operating close to their minimum SRT, it is recommended to limit Scenario 2 and Scenario 3 dosing to those periods of the year when the digesters can accommodate the higher sludge production.
- Benchscale results indicated a lower ferric to orthophosphate ratio (Fe:P) for Scenario 1 and Scenario 2 compared to the modelling work. However, for Scenario 3, the benchscale work showed a higher Fe:P ratio than the modeling work. Higher Fe:P ratio indicates lower phosphorus removal efficiency and higher chemical demand. To address these differences, the proposed chemical dosing system (NEWPCC Interim Phosphorus Removal Detail Review and Benchscale Testing, 2020), has been sized to provide the flexibility to accommodate a wide range of dosing rates.
- Benchscale results did not indicate any negative effects of chemical dosing on digesters biogas production or its composition from adding chemical sludge. These results are based on a one-time chemical sludge addition, which will be different from the continuous addition of chemical sludge experience at full scale. To address the difference in benchscale versus full scale operation, it is recommended that any full scale plan include a gradual increase in the ferric chloride dose in conjunction with a monitoring plan so that toxicity impacts can be identified.

Overall, based on the results of the University of Manitoba benchscale testing work and BioWin model work, sufficient information was available to use as the basis for the conceptual design and cost estimate development.

Sincerely
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