Technical Memorandum

701 Pike Street
Suite 1200
Seattle, WA 98101

T: 206.624.0100

Prepared for: City of Bellingham Public Works Department

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Project No.: 154154.320.312

Technical Memorandum No.10

Subject: Biosolids Exceptional Quality Evaluation and Ammonia-to-Total Kjeldahl Nitrogen Ratio

Date: November 16, 2021

To: Steven Bradshaw, Superintendent of Plants

From: Mike Thorstenson, Brown and Caldwell Project Manager

Copy to: Brian Matson, P.E., Carollo Senior Vice President

Prepared by: ______________________
Cameron D. Clark, P.E., Carollo Engineers, Inc.,
Washington License 49936, Exp.: 12/8/2023

Digitally signed by Cameron D. Clark
Contact Info: Carollo Engineers, Inc.
Date: 2021.12.16 16:16:06-08'00'

CAMERON D. CLARK
STATE OF WASHINGTON
49936
REGISTERED
PROFESSIONAL ENGINEER

Reviewed by: ______________________
Susanna Leung, P.E. Carollo Engineers, Inc.,
Washington License 40845, Exp.: 5/8/2023

Prepared by: ______________________
Anne Conklin, Ph.D., P.E., Carollo Engineers, Inc.
Washington License 46350, Exp.: 7/27/2022

Reviewed by: ______________________
Steve Krugel, P.E., Brown and Caldwell,
Washington License 42043, Exp.: 11/12/2022

Reviewed by: ______________________
Rick Kelly, P.E., PhD, Brown and Caldwell,
Washington License 45235, Exp.: 6/3/2023

Limitations:

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List of Abbreviations

%	percent
CFR	Code of Federal Regulation
City	City of Bellingham
Ecology	Washington State Department of Ecology
EQ	exceptional quality
kg	kilogram
L	liter
mg	milligram
mg/kg	milligrams per kilogram
mg/L-N	milligrams per liter as nitrogen
N	nitrogen
NH3-N	ammonia-nitrogen
PC	pollutant concentration
PE	primary effluent
PI	plant influent
Post Point	Post Point Resource Recovery Plant
TKN	total Kjeldahl nitrogen
TM	technical memorandum
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code

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Executive Summary

A biosolids and nutrient sampling campaign was performed at the Post Point Resource Recovery Plant (Post Point) to 1) assess the likelihood that future anaerobically digested biosolids will meet pollutant criteria to achieve exceptional quality limits and 2) evaluate the fate and behavior of nitrogenous species across primary treatment. Characterizing the behavior of nitrogen across primary treatment increases confidence that process modeling will accurately predict the amount of nitrogen sent to solids handling, which can increase ammonia returned to secondary treatment and affect effluent nitrogen loads. Effluent nitrogen loads are a regulatory concern, thus preparing an accurate nitrogen model will be a valuable tool. Sampling also confirms that primary effluent ammonia, which is routinely measured by the facility, is a reasonable proxy for influent ammonia.

Two discrete sampling events were performed – one during winter and one during summer – to bracket the range of expected biosolids pollutant concentrations and nutrient concentrations at the facility. Sampling was performed in late 2019 through mid-2020 by Post Point laboratory personnel. The solids sampling results show that future anaerobically digested biosolids will likely achieve exceptional quality as defined by the United State Environmental Protection Agency (USEPA) Part 503 regulations. Nutrient sampling shows that the raw wastewater is consistent with literature values for medium strength wastewater. The measured ratio of ammonia to total Kjeldahl nitrogen (TKN) was 62 percent, which will be used for subsequent process modeling. Primary effluent ammonia will be a reasonable proxy for influent ammonia.

The recommended sampling campaign protocol and sampling results are included in Attachment A.

Section 1: Biosolids Sampling

The City of Bellingham (City) is planning to achieve USEPA Class A biosolids for land application. Refer to Phase 1 and 2 technical memoranda for a more detailed discussion of biosolids classification considerations. This section summarizes the Post Point cake sampling results and assesses the likelihood that the biosolids will meet regulated pollutant concentration limits. Adhering to pollutant concentration limits dictated by the USEPA and Washington State Department of Ecology (Ecology) will minimize regulatory reporting requirements and maximize beneficial use options.

1.1 Biosolids Regulations

The USEPA promulgated 40 Code of Federal Regulation (CFR) Part 503 to govern beneficial use of biosolids, primarily land application, and to protect human health and the environment. At the state level, the Washington Administrative Code (WAC) 173-308 mirrors the federal guidelines in 40 CFR 503 and enforcement is delegated to Ecology. Broadly, 40 CFR Part 503 and the WAC 173-308 define biosolids quality based on the following three parameters: pollutants, pathogens, and vector attraction.

Depending on the level of pathogen removal, biosolids can be categorized as either Class B or Class A. Class B biosolids are the most common type of biosolids produced in municipal wastewater treatment facilities because they require less stringent treatment techniques and are therefore easier to achieve. Class A biosolids are treated to achieve a near-absence of pathogens, which reduces risk to human health when exposed via direct handling or on land near human receptors.

Although not explicitly defined in the Part 503 regulations, biosolids can also be designated as pollutant concentration (PC) or exceptional quality (EQ) if they do not exceed maximum levels for regulated pollutants.

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The regulated pollutants are arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc (commonly referred to as heavy metals). All biosolids that are land applied must meet ceiling concentration limits, regardless of classification. However, if Class B or Class A biosolids meet stricter pollutant limits averaged over a monthly basis, they can be classified as either PC or EQ biosolids, respectively. Biosolids designated as PC or EQ have minimal restrictions for beneficial use, whether sold in bulk or for personal use. The City is committed to achieving Class A biosolids in the future but may consider producing Class B biosolids for an interim period, depending on the local market demand. This TM focuses on EQ classification of Class A biosolids.

1.2 Methods and Results

Dewatered cake grab samples were collected at the incinerator inlet from November 2019 through January 2020 (winter samples) and from August 2020 through September 2020 (summer samples). The samples were analyzed at a third-party laboratory. Pollutant concentrations for each sampling date are shown in Table 1-1.

All pollutant concentrations quantified in the samples were below concentration limits to meet the EQ biosolids designation. Although copper quantification was excluded from several of the summer samples, historical sampling at the facility starting in 1998 show that copper concentrations are below the regulatory limits. Anaerobic digestion is expected to reduce volatile solids by over 60 percent and total solids by approximately 50 percent. However, pollutants are expected to remain in the solids phase. Therefore, pollutant concentrations could be twice what is currently measured. Predicted maximum pollutant concentrations are shown in the table assuming pollutant concentrations double after digestion. Predicted maximum digested sludge cake pollutant concentrations are 8 to 56 percent of the monthly average concentration limits for EQ biosolids and are therefore well below regulated limits for biosolids. As a result, it is likely that the biosolids will meet the EQ quality standards and will not be subject to annual or cumulative pollutant loading rate recordkeeping requirements.

Should the pollutant concentrations increase in the future, it may be possible to switch the permitting structure to a cumulative or annual pollutant loading rate criteria. Cumulative and annual pollutant loading rate management strategies are more labor-intensive but allow flexibility when biosolids pollutant concentrations exceed the monthly limits.

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Table 1-1. Dewatered Cake Pollutant Concentrations

All Parameters in mg/kg Dry Basis	Arsenic	Cadmium	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Zinc
Winter Samples									
11/19/2019	2.5	1.4	154	16	0.6	2.7	24	4.0	333
11/24/2019	1.8	1.4	159	14	0.1	2.5	17	4.3	363
12/02/2019	1.5	0.9	122	9.4	0.1	2.1	8.1	3.6	254
12/15/2019	5.4(1)	3.1	149	13	0.2	5.4(1)	12	15	315
12/29/2019	1.5	1.1	115	6.7	0.2	1.8	7.8	3.7	269
01/06/2019	1.7	1.2	131	29	0.1	2.4	15	4.4	311
01/26/2019	1.8	1.1	118	13	0.2	1.9	1.0(1)	4.0	280
Summer Samples									
08/03/2020	1.3(1)	1.8	419	12	0.2	2.3	10	1.3(1)	419
08/09/2020	0.8(1)	1.5	-	12	0.2	3.1	7.9	0.8(1)	376
08/11/2020	1.2(1)	1.7	-	12	0.2	3.1	8.2	1.2(1)	399
08/16/2020	1.2(1)	2.2	-	14	0.1	2.6	27	1.2(1)	449
08/23/2020	1.0(1)	1.1	-	8.7	0.1	1.5	4.9	1.0(1)	212
09/08/2020	1.1(1)	1.5	159	14	0.2	2.5	7.1	1.1(1)	379
Cake Sample Minimum	0.8	0.9	115	6.7	0.1	1.5	1.0	0.8	212
Cake Sample Average	1.8	1.5	170	13	0.2	2.6	12	3.5	335
Cake Sample Maximum	5.4	3.1	419	29	0.6	5.4	27	15	449
Cake Sample Maximum – Predicted After Digestion(2)	10.8	6.2	838	58	1.3	11	54	31	898
Ceiling Concentration Limit for all Land-Applied Biosolids	75	85	4,300	840	57	75	420	100	7,500
Concentration Limit for EQ Biosolids, Monthly Avg.	41	39	1,500	300	17	-	420	100	2,800

1. *Data below detection limit. Concentrations taken as detection limit.*
2. *Concentrations predicted after digestion assume that anaerobic digestion will reduce approximately 50 percent of the total solids, resulting in a doubling of currently measured concentrations.*

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Section 2: Ammonia-to-TKN Ratio

Wastewater influent nitrogen is comprised of various speciations which include ammonia-nitrogen (NH_3-N) and total organic nitrogen. The sum of NH_3-N and organic nitrogen is equal to the total Kjeldahl nitrogen (TKN). Post Point has historically measured ammonia concentrations in the primary and secondary effluent. To better understand the impact of the recycle streams on the influent ammonia concentration and to better quantify the total nitrogen entering the plant, two sampling campaigns were performed to provide confirmation of influent nitrogen characteristics to be used in software process modeling of the facility.

Plant influent (PI) and primary effluent (PE) composite samples were collected from November 2019 to January 2020 (winter samples) and from August 2020 to September 2020 (summer samples). Results of that sampling campaign are shown in Table 10-2. In total 27 samples were collected. A quartile-based statistical technique was used to identify potential outliers. The interquartile range of ammonia-to-TKN ratios were determined and multiplied by 1.5 to establish the acceptable range of statistically significant results. This value was subtracted from the 25th percentile and added to the 75th percentile of each data set to determine the range of acceptable results. Ammonia-to-TKN ratios outside of this range were excluded from the analysis. The ammonia-to-TKN ratios of 23 of these samples ranged from approximately 0.5 to 0.75. Two of the samples had ammonia-to-TKN ratios less than 0.3 and two had ammonia-to-TKN ratios greater than 0.9. These four samples (or approximately 15 percent of the total samples collected) were identified as potential outliers and excluded from the analysis. Removing the outliers from the analysis impacted the calculated ammonia-to-TKN ratio by less than 10 percent. The laboratory error of ammonia and TKN analyses can be up to 10 percent, thus the potential error introduced by removing these outliers was considered acceptable for this analysis.

During the winter sampling period, after excluding outliers, the plant influent ammonia-to-TKN ratio ranged from 48% to 74% and averaged 58%. During the summer sampling period, after excluding outliers, the plant influent ammonia-to-TKN ratio ranged from 60% to 71% and averaged 66%. Due to degradation of organic material that can occur in the collection system during warm weather, it is not surprising that the ammonia-to-TKN ratio was higher in the summer than winter. The wider range of ammonia-to-TKN ratios observed in the winter could be due to a wider range in influent flows, possibly the result of storms and flush events.

Since solids loads documented in TM 3 – Biosolids Flow and Load Projections are estimated using a year-long dynamic process model, a site specific annual average ammonia-to-TKN ratio was required as in input to the model. An average value of 62% was calculated by averaging the winter and summer averages. This method was selected so that the higher number of samples collected during the winter sampling period would not bias the overall average. Typical medium strength wastewater has an average free ammonia concentration of 25 milligrams per liter nitrogen (mg/L-N) and an average organic nitrogen concentration of 15 mg/L-N, for an average ammonia-to-TKN ratio of 62.5% (*Wastewater Treatment Engineering and Reuse*, Metcalf & Eddy, 2003). Therefore, the Post Point influent appears to be consistent with published literature values for medium strength wastewater and the calculated average value of 62% was used in the process modeling detailed in TM3 – Biosolids Flow and Load Projections.

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In addition, Post Point has routinely measured ammonia concentrations in the PE. The composite sampling allowed a comparison between PE and PI concentrations to determine if the PE ammonia could be used as a surrogate for PI ammonia in the process modeling as well. As shown in Table 2-1, the average ratio of PI to PE ammonia is 0.95, which indicates that the PE ammonia sample is a reasonably conservative estimate of the PI ammonia concentration.

Table 2-1. Ammonia and TKN Sampling Results

Date	PI NH_3-N (mg/L-N)	PI TKN (mg/L-N)	PE NH_3-N (mg/L-N)	PE TKN (mg/L-N)	PI NH_3-N:TKN	PI NH_3-N: PE NH_3-N
Winter Samples						
Minimum	10.9	21.1	12.8	18.8	48%	81%
Average	19.6	33.7	21.8	30.7	58%	95%
Maximum	31.2	62.4	31.7	50.2	74%	111%
Standard Deviation	7.4	12.7	7.7	11.6	8%	9%
Count(1)	14	14	10	10	14	13
Summer Samples						
Minimum	28.7	40.3	29.0	34.9	60%	81%
Average	30.0	46.0	31.1	40.7	66%	95%
Maximum	32.0	51.6	33.3	43.8	71%	101%
Standard Deviation	1.2	3.8	1.3	3.0	4%	6%
Count(1)	9	9	10	10	9	11

1. Data shown does not include outliers that were excluded, as discussed in the text.

Section 3: Conclusions

The sampling campaigns were performed successfully and yielded the following conclusions:

- Future anaerobically digested biosolids will likely achieve EQ classification as defined by the USEPA Part 503 regulations.
- The influent wastewater nitrogen characterization is consistent with literature values for medium strength wastewater. An influent ammonia-to-TKN ratio of 62% will be used for process modeling.
- Primary effluent ammonia is a reasonable surrogate for the raw wastewater values.

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Attachment A: Sampling Campaign Protocol and Results

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PROJECT MEMORANDUM

POST POINT BIOSOLIDS PLANNING

City of Bellingham

Date:	October 10, 2019
Project No.:	10550A00

Prepared By:	Anne Conklin
Reviewed By:	Susanna Leung
Subject:	Two Week Sampling Plan

Purpose

Phase 2 of the Biosolids Planning project recommended the construction of a Class A biosolids reclamation facility. In order to have the maximum beneficial use of the product, the biosolids will need to be defined as having "exceptional quality". Exceptional quality biosolids are defined in U.S. Environmental Protection Agency (EPA) Regulation 40 CFR 503.13 as containing low metal concentrations. Sampling the dewatered cake currently produced will give a good indication as to whether the plant may likely produce exceptional quality biosolids in the future.

Additionally, due the Washington State Department of Ecology's (Ecology) recent decision to pursue a general permit for the regulation of nutrients, the Biosolids Planning project is scoped to provide potential site impacts of the proposed biosolids project in conjunction with a secondary process designed to remove nitrogen. Sizing the secondary process for nitrogen removal is dictated by gaining a more site specific understanding of the plant influent (raw) total Kjeldahl nitrogen (TKN), sum of ammonia and organic nitrogen.

The purpose of this memorandum is to provide a summary of a two week sampling plan implemented in October that is designed to provide a greater understanding of the potential for the biosolids to meet exceptional quality standards and the influent TKN load.

Two Week Sampling Plan

A two week sampling plan is proposed to assess the metals concentration of the biosolids and the influent TKN concentration. This will provide only a "snap shot" of these concentrations at the time of sampling. Since influent concentrations can change seasonally, it is recommended that the City of Bellingham (City) repeat this sampling during the summer season as well. Additionally, since the plant will likely see nitrogen limits in upcoming permits, Carollo and Brown and Caldwell recommend that the plant begin investigating implementing a regular sampling plant to measure the influent or primary effluent TKN concentration.

Currently the lab analysis analyzes the primary effluent's ammonia concentrations once per month. To exclude the recycle stream impact, we request that the plant use the influent composite sample to take their TKN sample. Additionally, since influent TKN concentrations are expected to fluctuate throughout the year, we'd like the plant to also use the influent composite sample to measure the influent ammonia concentration. This will allow us to calculate an ammonia to TKN ratio which we can apply to the plant's long-term primary effluent ammonia concentrations to estimate future influent TKN loads.

Table 1 summarizes the proposed two week sampling plan.

Table 1 Two Week Sampling Plan

Parameter	Number of Daily Composite Plant Influent Samples	Number of Daily Manually Composited Dewatered Cake Samples	Desired Reporting Limit(1)
Ammonia	14	6 (3 on weekends and 3 on week days)	< 1 mg/L <100 mg/kg (solid)
TKN	14	6 (3 on weekends and 3 on week days)	< 1 mg/L (liquid) <1,000 mg/kg (solid)
Total Phosphorus	NA	6 (3 on weekends and 3 on week days)	<1,000 mg/kg
Total Potassium (K)	NA	6 (3 on weekends and 3 on week days)	<100 mg/kg
Arsenic	NA	6 (3 on weekends and 3 on week days)	<41 mg/kg
Cadmium			<39 mg/kg
Copper			<1,500 mg/kg
Lead			<300 mg/kg
Molybdenum			<75 mg/kg
Nickel			<420 mg/kg
Zinc			<100 mg/kg
Selenium			<100 mg/kg
Mercury			<17 mg/kg

Note:
(1) mg/L – milligrams per liter; mg/kg – milligrams per kilogram

Sample Shipment and Measurement

Since the City will not currently be routinely measuring the metals concentration of the dewatered cake, the collected cake samples can be chilled and shipped to an outside lab. Edge Analytical, a certified lab, estimates that the cost of running the metals sample is around $200/sample.

For the TKN measurements, the collected influent samples can be preserved (by dropping the pH below 2) and shipped to an outside lab. Edge Analytical estimates a TKN analysis would cost approximately $40/sample. Alternatively, the plant may wish to perform doing these measurements in house. Hach offers a simplified TKN method (TNT880) for approximately $160 for 25 vials.

Prepared by:

Anne Conklin

AC:sm

City of Bellingham Post Point Resource Recovery Plant

Sample Date*	Location	Ammonia (mg/L-N)	TKN (mg/L-N)	Ammonia (ug/g-N)	TKN (ug/g-N)	TS (%)	TP (ug/g)	K (ug/g)	As (ug/g)	Cd (ug/g)	Cu (ug/g)	Hg (ug/g)	Pb (ug/g)	Mo (ug/g)	Ni (ug/g)	Se (ug/g)	Zn (ug/g)
11/11/2019	Plant Influent	24.6	38.5														
	Primary Effluent	25.8	35.6														
11/19/2019	Plant Influent	14.7	30.0														
	Primary Effluent	13.3	26.8														
	Incinerator Cake			8,000	50,000	24.0	7,500	5,920	2.50	1.42	154	0.642	15.8	2.71	23.5	3.96	333
11/24/2019	Plant Influent	23.7	43.7														
	Primary Effluent	28.5	43.0														
	Incinerator Cake			10,200	51,000	23.7	16,000	5,820	1.81	1.39	159	0.135	14.1	2.45	16.7	4.26	363
12/2/2019	Plant Influent	30.3	62.4														
	Primary Effluent	31.7	50.2														
	Incinerator Cake			13,200	44,000	27.2	10,000	4,450	1.47	0.919	122	0.092	9.38	2.06	8.12	3.57	254
12/5/2019	Plant Influent	27.8	44.5														
	Duplicate Influent	27.6	44.1														
	Primary Effluent	34.3	38.0														
12/10/2019	Plant Influent	31.2	45.6														
	Primary Effluent	29.0	36.7														
12/15/2019	Plant Influent	15.1	26.5														
	Primary Effluent	16.8	40.5														
	Incinerator Cake			10,200	46,000	23.9	10,000	6,030	<5.4	3.10	149	0.163	13.4	<5.4	12.4	15.4	315
12/22/2019	Plant Influent	12.7	26.0														
	Primary Effluent	12.8	22.9														
12/29/2019	Plant Influent	11.7	54.6														
	Primary Effluent	11.8	50.9														
	Incinerator Cake			11,200	52,000	25.0	12,000	5,200	1.5	1.08	115	0.152	6.72	1.80	7.84	3.68	269
1/1/2020	Plant Influent	12.7	22.1														
	Primary Effluent	13.4	19.5														
1/6/2020	Plant Influent	10.9	22.8														
	Primary Effluent	12.6	27.7														
	Incinerator Cake			19,600	55,000	23.7	11,000	4,940	1.73	1.18	131	0.097	29.1	2.43	15.0	4.39	311
1/15/2020	Plant Influent	16.0	21.7														
	Primary Effluent	16.2	20.7														
Duplicate	Primary Effluent	16.4	20.4														
1/20/2020	Plant Influent	13.7	23.4														
	Duplicate Influent	13.9	21.1														
	Primary Effluent	14.7	18.8														
1/26/2020	Plant Influent	14.4	53.6														
	Primary Effluent	29.9	39.4														
	Incinerator Cake			15,400	61,000	19.6	10,000	5,820	1.84	1.07	118	0.153	12.9	1.94	<1.04	3.98	280

*24-hr flow-weighted composite sample

*Cake reported on a dry weight basis

Value reported by Amtest for 1/26/20 plant influent is 14.4 mg/L-N. Not an error.

City of Bellingham Post Point Resource Recovery Plant   All samples are composites.

Sample Date*	Location	Ammonia (mg/L-N)	TKN (mg/L-N)	Ammonia (ug/g-N)	TKN (ug/g-N)	TS (%)	TP (ug/g)	K (ug/g)	As (ug/g)	Cd (ug/g)	Cu (ug/g)	Hg (ug/g)	Pb (ug/g)	Mo (ug/g)	Ni (ug/g)	Se (ug/g)	Zn (ug/g)
8/3/2020	Plant Influent	29.2	47.9														
	Primary Effluent	32.0	43.6														
	Incinerator Cake			8,860	55,600	22.4	18,600	5,040	<1.3	1.8	419	0.193	12	2.3	9.9	<1.3	419
8/5/2020	Plant Influent	**33.0**	**27.7**														
	Primary Effluent	33.3	43.8														
	Final Effluent	29.9	30.1														
8/9/2020	Plant Influent	32.0	51.6														
	Primary Effluent	32.2	42.6														
	Incinerator Cake			4,300	51,000	24.6	14,900	3,860	<0.8	1.5		0.202	12	3.1	7.9	<0.8	376
8/11/2020	Plant Influent	29.3	44.4														
	Primary Effluent	30.2	40.9														
	Incinerator Cake			4,520	55,800	23.8	16,200	4,240	<1.2	1.7		0.161	12	3.1	8.2	<1.2	399
8/16/2020	Plant Influent	29.4	44.9														
	Primary Effluent	30.2	37.9														
	Incinerator Cake			4,740	59,700	21.4	19,900	5,660	<1.2	2.2		0.091	14	2.6	27	<1.2	449
8/17/2020	Plant Influent	28.7	40.3														
	Primary Effluent	35.3	38.1														
Duplicate	*Primary Effluent*	*30.2*	*37.8*	*DIFF: NH3 = 14.4%, TKN = 0.8%*													
8/19/2020	Plant Influent	31.6	46.3														
	Primary Effluent	31.3	43.6														
8/23/2020	Plant Influent	30.2	43.1														
	Primary Effluent	30.9	40.2														
	Incinerator Cake			9,890	60,300	24.5	8,320	2,210	<1.0	1.1		0.086	8.7	1.5	4.9	<1.0	212
8/26/2020	Plant Influent	29.3	43.6														
	Primary Effluent	29.0	34.9														
	Final Effluent	29.4	26.4														
8/31/2020	Plant Influent	34.1	38.1														
	Primary Influent	39.7	40.7														
	Final Effluent	34.5	38.5														
9/8/2020	Plant Influent	30.7	51.5														
	Primary Effluent	31.9	41.3														
	Final Effluent	33.0	33.3														
	Incinerator Cake			14,300	55,100	23.7	15,700	3,920	<1.1	1.5	159	0.215	14	2.5	7.1	<1.1	379
Duplicate	Incinerator Cake			6240*	53,800		16,000	3,540	<1.2	1.4	153	0.253	14	3.1	7.0	<1.2	386

*Edge Analytical QA/QC for run met accuracy limits of 90 - 110 (105% recovery), precision was 0% RPD and 40% RPD with the 40% qualified INH (non-homogenous sample).

Numbers highlighted in red are likely erroneous since TKN values are lower than measured Ammonia.