



CITY OF DURHAM
Department of Public Works

Water Quality Report # 14-001
September 2016

EVALUATION OF POLLUTANTS IN WASTEWATER PRODUCED FROM AIR CONDITIONING CLEANING OPERATIONS IN DURHAM, NC

EXECUTIVE SUMMARY

In 2014, City of Durham staff identified wastewater discharges produced from air conditioning unit cleaning operations entering the City's municipal separate storm sewer system (MS4). Heating, Ventilation, and Air Conditioning (HVAC) companies clean the metal condenser coils and fins of air conditioning units for maintenance and efficiency purposes. The City of Durham's Stormwater Management and Pollution Control ordinance prohibits discharges from HVAC coil cleaning operations to the City's MS4. In order to comply with the City's ordinance, companies are required to contain, collect and properly dispose of their wastewater into the sanitary sewer system. The purpose of this study was to evaluate wastewater generated from the process of cleaning air conditioning units, and to quantify pollutant loads to the City's MS4 and downstream surface waters. To evaluate the wastewater and quantify pollutant loads, wastewater composite samples were collected at three sites and analyzed for aluminum, cadmium, copper, zinc, ammonia nitrogen, nitrate+nitrite, total Kjeldahl nitrogen (TKN), total nitrogen, total phosphorus, methylene blue active substances (MBAS), biochemical oxygen demand (BOD), and total suspended solids (TSS). Three separate HVAC units were cleaned by Comfort Engineers, Inc., and each event evaluated a different type of cleaning product. Sampling results identified high concentrations of many pollutants of concern in the wastewater composite samples. Since the City of Durham has streams on the state's 303(d) list for copper, zinc, dissolved oxygen, turbidity, and biological impairment; the wastewater composite sample results from this study were compared to the state's surface water quality standards, untreated domestic wastewater data, and data from the City's Mobile Car Wash Study (Water Quality Report #11-001). This study aims to further inform the public, other municipalities, and the HVAC industry about the potential impacts of HVAC coil cleaning wastewater on surface water quality.

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ABBREVIATIONS

- BOD – Biochemical Oxygen Demand
- HVAC – Heating, Ventilation, and Air Conditioning

- MBAS – Methylene Blue Active Substances
- MDL – Method Detection Limit
- MS4 – Municipal Separate Storm Sewer System
- MSDS – Material Safety Data Sheet
- NPDES – National Pollutant Discharge Elimination System
- NCDEQ – North Carolina Department of Environmental Quality
- NTU – Nephelometric Turbidity Unit
- PQL – Practical Quantitation Limit
- PVC – Polyvinyl Chloride
- QAPP – Quality Assurance Project Plan
- TKN – Total Kjeldahl Nitrogen
- TMDL – Total Maximum Daily Load
- TSS – Total Suspended Solids

INTRODUCTION

It is common practice for HVAC companies to clean the metal condenser coils and fins of air conditioning units for maintenance and efficiency purposes. There are various types of cleaning products and cleaning methods available to the HVAC industry. A popular method is to apply a mixture of water and a cleaning product to the HVAC condenser coils and fins using a spray nozzle and hose or power washing equipment. Water and cleaning products are sprayed on the coils to remove microbes, particulates and other debris. Without proper containment and disposal practices in place, wastewater generated from these cleaning operations can flow across impervious surfaces (i.e. rooftops, sidewalks and parking lots) and into the City's MS4.

In March 2014, City of Durham Stormwater Quality staff discovered City staff from another department washing a City-owned air conditioning unit, which resulted in an illicit discharge to the MS4. Field measurements indicated high levels of conductivity and pH in the wastewater. Grab samples were collected downstream of the wastewater runoff and analyzed by North Carolina certified laboratory Environmental Conservation Laboratories, Inc. (ENCO) in Cary, North Carolina. The samples contained high levels of aluminum, copper and zinc. In April 2014, City Water Quality staff observed an illicit discharge of wastewater generated from a private company cleaning multiple air conditioning units. In June 2014, the City worked with Comfort Engineers, Inc. to collect grab samples of wastewater generated from air conditioner cleaning activities on the rooftop of a commercial building in downtown Durham. Laboratory and field results of these samples showed high levels of BOD, TSS, nutrients, metals, pH, and conductivity.

Regulatory Drivers

The City's Phase I Stormwater Program is required under its National Pollutant Discharge Elimination System (NPDES) permit (NCS000249). Also required by the City's

NPDES permit is the adoption of a stormwater ordinance. The City of Durham's primary tool for addressing illicit discharges to the MS4 is the Stormwater Management and Pollution Control Ordinance. This ordinance requires businesses engaged in surface washing activities (such as HVAC coil cleaning companies) to contain, collect, and properly dispose of their wastewater into the sanitary sewer system. Wastewater or "wash water" that enters the City's MS4 can impact local streams and lakes.

The City of Durham has several streams that are on the State's 303(d) list for impaired waters. The parameters of concern related to this study are copper, zinc, dissolved oxygen, turbidity, and biological impairment. Other regulatory drivers include total maximum daily loads (TMDLs) for Jordan Lake, Northeast Creek and Third Fork Creek, as well as, required nutrient management strategies for Falls Lake, Jordan Lake, and the Neuse River Basin.

HVAC Coil Cleaning Guidance

To both prepare for and support this study, the actions and guidance of other municipalities toward HVAC coil cleaning operations were researched. For example, the Colorado Department of Public Health and Environment requires any company who discharges the water from HVAC coil cleaning operations into the environment to secure a permit prior to conducting business. The permit requires companies to use certain BMPs to mitigate the impact of the runoff, but clearly states that wastewater containing soaps or chemicals must be disposed of via the sanitary sewer. Similarly, in the *Knoxville BMP Manual* published in May 2003, the City of Knoxville promotes the capture and proper disposal of all HVAC coil cleaning runoff to significantly reduce the load of toxic materials in the surface waters, while also providing a partial benefit of reducing oxygen-demanding substances.

Other general guidance documents found online encompassed HVAC coil cleaning operations. In an outreach piece entitled *Properly Managing Stormwater for the Hospitality Industry*, Florida's Department of Environmental Protection specifically states runoff from HVAC coil cleaning operations should not be allowed to enter the storm drain. The flyer suggests steam cleaning and wet vacuuming as possible alternatives to traditional coil cleaning. Within the state of North Carolina, the only municipality found to have guidance for this operation was Charlotte-Mecklenberg. This municipality's Stormwater Services department released a guidance document entitled *Storm Water Pollution Prevention: BMP's for Rooftop Work*. In a section called "HVAC and Refrigeration Work," the flyer names several different types of runoff associated with HVAC units and communicates that any runoff that may contain chemicals should be routed to the sanitary sewer.

Purpose and Scope

The purpose of this study was to evaluate wastewater generated from the process of cleaning air conditioning units, and to quantify pollutant loads to the City's MS4 and

downstream surface waters. This study also serves as a validation for the requirements of the City's ordinance. With continued enforcement of the City's ordinance and education efforts, this study may be used to quantify the reduction of pollutant loads to the City's MS4 and receiving surface waters.

MONITORING PLAN

Sample and Field Data Collection

This study was performed in accordance with the *Evaluation of Wastewater Produced from Air Conditioning Cleaning Operations Quality Assurance Project Plan* (QAPP; City of Durham, 2015). For this study, the City partnered with a local HVAC maintenance company, Comfort Engineers, Inc. Personnel from Comfort Engineers selected HVAC units in need of coil cleaning at 3 different locations that were indicative of conditions they regularly encounter. Each site required a different cleaning method to be used. At the first site, a mixture of tap water and Cal-Green coil condenser cleaner (pH = 9 concentrated) was used. At the second, the cleaning mixture consisted of tap water and Nu-Brite coil condenser cleaner (pH = 14 concentrated). At the last site, the unit was cleaned only with pressurized tap water (pH ≈ 7).

Before the cleaning operation began at each site, a new, clean tarp was spread below the HVAC unit to collect wastewater runoff. The tarp was outfitted with berms and other containment devices to ensure all wastewater from the operation was collected. As the operators from Comfort Engineers prepared to clean the HVAC unit, a sample of the initial cleaning mixture was taken. An in-line water meter was also installed on the operators' water line to quantify how much water was used during the cleaning process.

As the HVAC unit was cleaned by Comfort Engineers personnel, grab samples of the accumulated waste water were taken on regular intervals with a programmed ISCO Avalanche automatic sampler to yield a composite sample for the event. The size and frequency of the grab samples varied for each site and largely depended on how long the Comfort Engineers personnel estimated the operation would take, but the composite sample target volume was 9L in total. At the same time each grab sample was collected, field measurements of pH and conductivity of the accumulated wastewater were collected with an Oakton PCTestr 35. The field measurements and grab sampling continued on regular intervals until the cleaning operation was completed and 9L of wastewater was collected.

At the conclusion of the sampling event, the composite sample was deposited into a 15L churn split sampler and consistently agitated. With agitation still occurring, the composite sample was then split into subsamples for lab analysis. Composite wastewater subsamples were analyzed for total and dissolved cadmium, total and

dissolved copper, total and dissolved aluminum, total and dissolved zinc, methylene blue active substances (MBAS), nitrate+nitrite nitrogen, total Kjeldahl nitrogen (TKN), ammonia, total phosphorus, 5-day biochemical oxygen demand (BOD₅), and total suspended solids (TSS) (Table 1). Wastewater subsamples designated for analysis of dissolved metal content were also pumped through a 0.45 µm in-line filter using a Geotech peristaltic pump. The sample of the initial cleaning mixture accompanied the wastewater sample and was analyzed for the same parameters. Chemistry samples were analyzed by the North Carolina certified laboratory Environmental Conservation Laboratories, Inc. (ENCO); located in Cary, North Carolina (certification number 591).

Table 1. Parameters analyzed for wastewater composite samples

Parameter	Units of Measurement
Field Measurements	
Conductivity	µS/cm
pH	S.U.
Temperature	°C
Dissolved Oxygen Saturation	%
Dissolved Oxygen Concentration	mg/L
Turbidity	Nephelometric Turbidity Units (NTU)
Laboratory Analytes	
Ammonia (NH ₃)	mg/L
Biochemical Oxygen Demand (BOD ₅)	mg/L
Cadmium (Cd), total	µg/L
Cadmium (Cd), dissolved	µg/L
Copper (Cu), total	µg/L
Copper (Cu), dissolved	µg/L
Aluminum (Al), total	µg/L
Aluminum (Al), dissolved	µg/L
Methylene Blue Active Substances (MBAS)	mg/L
Nitrate+Nitrite Nitrogen (NO ₂ +NO ₃)	mg/L
Solids, Total Suspended (TSS)	mg/L
Total Kjeldahl Nitrogen (TKN)	mg/L
Total Phosphorus (TP)	mg/L
Zinc (Zn), total	µg/L
Zinc (Zn), dissolved	µg/L

The composite sample was analyzed for field parameters following sample collection. Conductivity and pH were measured with an Oakton PCTestr 35. Temperature, dissolved oxygen, and dissolved oxygen saturation were measured with a YSI ProODO (optical dissolved oxygen meter). Turbidity was measured with a Hach 2100P turbidimeter.

Quality Assurance and Quality Control Measures

In order to minimize sample contamination and produce reliable data, several quality control measures were followed in the field. First, all tools and instruments were either new or thoroughly cleaned before each use. Only new tubing was used during the study and it was cut to length using ceramic scissors. For transport to the field, all items that would directly contact the wastewater (tubing, churn split sampler, etc.) were individually placed in clean plastic bags and were not exposed until they were to be used. Throughout the process of sampling, all sample collectors wore nitrile gloves. Chain of custody forms accompanied all samples and all were delivered to the laboratory within the required hold times. All field instruments used for wastewater analysis were calibrated on the sampling day before use and post calibration checked after the sampling event.

To reduce laboratory costs, combined equipment and field blanks were collected in the field immediately preceding sampling events at all three sites. Once a new containment tarp was secured under or around the HVAC unit, laboratory supplied deionized water was poured over a majority of the surface of the tarp. The deionized water was pumped using an ISCO automated sampler from the tarp through new plastic tubing and directly into a clean 15-liter churn split sampler. The deionized water was continuously churned in the sampler and collected from the churn split sampler nozzle. A sample was then collected in the same manner as the wastewater samples and sent to ENCO Laboratories for analysis as a blank.

Lastly, a laboratory-blind duplicate composite wastewater sample was collected at the second site and analyzed by ENCO to evaluate laboratory performance.



Figure 1. City of Durham staff pouring deionized water over a containment tarp prior to collection of the combined equipment blank and field blank.

STUDY RESULTS

Quality Control Sample Results – Field and Equipment Blanks

City of Durham staff followed the quality assurance project plan to minimize equipment and field blank contamination at each site; however, five analytes at Site 3 measured greater than the laboratory practical quantitation limit (PQL). As shown in Table 2, Site 3 field blank results for total aluminum, total copper, total and dissolved zinc, and total suspended solids were all detected above the associated PQLs. The Site 3 field blank results for total and dissolved zinc were five times higher than the associated wastewater composite results, which indicate blank contamination for these analytes. Therefore, the Site 3 water only sample results for total and dissolved zinc were rejected and not used in data analysis for the study. Staff suspect that blank contamination may have occurred during preparation of the containment tarp at Site 3. The tarp was secured over a rectangular PVC pipe structure, which was then placed under the large HVAC unit on the rooftop of the building (Figures 2 and 3). As the containment tarp and berm structure were pushed under the unit, the windy conditions forced the tarp upward and came into contact with any dirt and particulates on the metal beams supporting the HVAC unit.



Figure 2. Containment tarp and PVC pipe structure shown underneath HVAC unit prior to field blank collection at Site 3.



Figure 3. Metal beams and pipes that came into contact with the containment tarp prior to field blank collection at Site 3.

Site 1 field blank results for total copper, dissolved zinc, and total zinc were estimated or “J” qualified values, and all other field blank analytes were not detected in the samples. Similarly, Site 2 field blank results for total and dissolved zinc were estimated or “J” qualified values.

Table 2. Field and equipment blank sample results with the associated Method Detection Limit (MDL) and Practical Quantitation Limit (PQL).

	Analyte	Units	MDL	PQL	Field Blank Site 1		Field Blank Site 2		Field Blank Site 3	
					Result	Qualifier	Result	Qualifier	Result	Qualifier
Metals	Aluminum, Dissolved	ug/L	42	100	42	U	42	U	42	U
	Aluminum, Total	ug/L	42	100	42	U	42	U	176	
	Cadmium, Dissolved	ug/L	0.36	1	0.36	U	0.36	U	0.36	U
	Cadmium, Total	ug/L	0.36	1	0.36	U	0.36	U	0.36	U
	Copper, Dissolved	ug/L	1.6	10	1.6	U	1.6	U	3.89	J
	Copper, Total	ug/L	1.6	10	1.86	J	1.6	U	24.4	
	Zinc, Dissolved	ug/L	3.8	10	4.6	J	4	J	410	
	Zinc, Total	ug/L	3.8	10	7.7	J	4.4	J	2290	
Nutrients	Ammonia as N	mg/L	0.045	0.1	0.045	U	0.045	U	0.045	U
	Nitrate+Nitrite as N	mg/L	0.041	0.1	0.041	U	0.041	U	0.041	U
	Total Kjeldahl Nitrogen	mg/L	0.26	0.48	0.26	U	0.26	U	0.26	U
	Total Phosphorus	mg/L	0.025	0.1	0.025	U	0.025	U	0.025	U
Other	Biochemical Oxygen Demand	mg/L	2	2	2	U	2	U	2	U
	Methylene Blue Active Substances	mg/L	0.021	0.1	0.021	U	0.021	U	0.021	J
	Total Suspended Solids	mg/L	2.5	2.5	3	U	2.5	U	9.7	

Pink cells: Sample measurements that exceeded the PQLs.

Yellow cells: Sample measurements between the MDL and PQL.

J: Qualifier indicates the estimated reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.

U: Qualifier indicates the analyte was not detected at a concentration greater than the method detection limit.

Quality Control Sample Results - Duplicates

Duplicate samples were collected at Site 2, which was estimated as having the dirtiest HVAC unit and was cleaned with the higher pH product (Table 3). All duplicate concentrations were within 10% of the associated wastewater composite concentrations. The duplicate results indicate that the sampling teams properly mixed each wastewater composite in the churn split samplers and there was acceptable precision from the laboratory. With the exception of duplicate results presented in Table 3, wastewater composite duplicate results at Site 2 are shown in all tables and figures as average values.

Table 3. Duplicate composite sample results at Site 2.

	Sample ID	Duplicate ID	Analyte	Unit	Result	Qualifier	Duplicate		
							Result	Qualifier	% Difference
Metals	ACS-2B	ACS-2C	Aluminum, Dissolved	ug/L	186000		183000		1.63
	ACS-2B	ACS-2C	Aluminum, Total	ug/L	189000		195000		3.13
	ACS-2B	ACS-2C	Cadmium, Dissolved	ug/L	1.31		1.26		3.89
	ACS-2B	ACS-2C	Cadmium, Total	ug/L	1.72		1.75		1.73
	ACS-2B	ACS-2C	Copper, Dissolved	ug/L	1760		1740		1.14
	ACS-2B	ACS-2C	Copper, Total	ug/L	2420		2600		7.17
	ACS-2B	ACS-2C	Zinc, Dissolved	ug/L	18600		18400		1.08
ACS-2B	ACS-2C	Zinc, Total	ug/L	23300		23500		0.85	
Nutrients	ACS-2B	ACS-2C	Ammonia as N	mg/L	2.8	D	2.8	D	0.00
	ACS-2B	ACS-2C	Nitrate+Nitrite as N	mg/L	25	D	26	D	3.92
	ACS-2B	ACS-2C	Total Kjeldahl Nitrogen	mg/L	32	D	32	D	0.00
	ACS-2B	ACS-2C	Total Phosphorus	mg/L	5.2	D	5.2	D	0.00
Other	ACS-2B	ACS-2C	Biochemical Oxygen Demand	mg/L	580	D	590	D	1.71
	ACS-2B	ACS-2C	Methylene Blue Active Substances	mg/L	2.2	J	2.1	U	4.65
	ACS-2B	ACS-2C	Total Suspended Solids	mg/L	910		930		2.17

D: Qualifier indicates the sample was analyzed at dilution.

J: Qualifier indicates the estimated reported value is between the laboratory method detection limit and the method reporting limit.

U: Qualifier indicates the analyte was not detected at a concentration greater than the detection limit.

Sampling Locations and Conditions

Field teams collected samples at three separate buildings in Durham, North Carolina in coordination with Comfort Engineers, Inc. All three sites were commercial buildings and were regular customers of Comfort Engineers. The HVAC units at each site were generally comparable (commercial HVAC units), but did vary in size. Samples were collected at Site 1 (407 Morris Street) on May 14, 2015, at Site 2 (423 Morris Street) on May 21, 2015, and at Site 3 (404 Hunt Street) on July 23, 2015. Sampling was conducted during dry weather. Additional weather conditions for each sampling day are summarized by site in Table 4.

Table 4. Summary of weather conditions, previous rainfall, and sampling site details.

Site ID	1	2	3
Location	407 Morris St	423 Morris St	404 Hunt St
Sampling Date	5/14/2015	5/21/2015	7/23/2015
Weather Conditions	Overcast	Overcast	Overcast and Windy
Previous Rain Event	5/11/2015	5/11/2015	7/21/2015
Previous Rainfall Amount ¹	0.12 inches	0.12 inches	0.31 inches
AC Unit Location	Ground level adjacent to building	Ground level adjacent to building	Rooftop of building
Estimated Condition of AC Unit	Normal level of dirtiness	High level of dirtiness	Low level of dirtiness
Cleaning method	Tap water mixed with Cal-Green	Tap water mixed with Nu-Brite	Tap water only

pH of Concentrated Cleaning Product	9	14	7.4
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¹Rainfall data from the State Climate Office's ECONET weather station in Durham, NC.

At the first site, the HVAC unit was located at the side of the building on a raised concrete pad. It was manufactured by Carrier and measured approximately 9'L x 7.5'W x 4.8' H. Wastewater runoff from the HVAC unit area usually runs out of the lot and into the gutter pan along the street, where it eventually enters a stormwater inlet. The unit was moderately dirty, and therefore was cleaned with Cal-Green coil condenser cleaner (pH = 9 concentrated). Since the space directly under the unit was minimal, tarps were spread around the base and firmly taped to the ground. Berms were then installed around the edges of the tarp to ensure no wastewater escaped. The wastewater collected during the process of the study was disposed of into a private sewer vent via a submersible pump. Prior to the date of the study, the most recent significant rainfall occurred 3 days before and produced 0.12" of precipitation.



Figure 4. Study setup at Site 1

The second site also had HVAC units stationed on the ground. The unit used for the study was manufactured by Trane and measured approximately 7.8'L x 3.7'W x 4.8'H. Wastewater in this area generally discharges to a concrete channel which runs along the side of the building. This channel eventually directs flow into a storm drain inlet. This unit was described as exceptionally dirty, and was chosen to be cleaned with Nu-Brite coil condenser cleaner (pH = 14 concentrated). The HVAC unit was on a metal frame that elevated it approximately 6" – 12" above the ground, so to collect wastewater for the study, a tarp was staged below the unit. The edges of the tarp were then suspended with elastic cords to create a basin to capture all wash water. The wastewater collected at Site 2 was pumped into portable tanks via a submersible pump and disposed of into

the sanitary sewer off site. Prior to the event at this site, the most recent significant rainfall occurred 10 days before and produced 0.12" of precipitation.



Figure 5. Study setup at Site 2

The HVAC unit at the third site was on the building's roof. It was manufactured by Trane and measured 29.9'L x 9.7'W x 7.4'H. All wastewater from cleaning operations on this unit usually flows down the roof drains, which direct it onto the pavement, and eventually into the storm drainage system. In observance of the manufacturer's recommendations, this unit was only cleaned with pressurized tap water (pH \approx 7). The unit was raised a few inches off the roof, so a tarp with berms was placed underneath the unit to catch the cleaning operation's runoff. Similar to the first site, all collected wastewater was disposed of into a sanitary sewer vent via a submersible pump. At the third site, the most recent precipitation event produced 0.31" of rainfall and took place 2 days prior to collecting samples.



Figure 6. Study setup at Site 3

Water and Cleaner Mixture

Samples were collected for each cleaning product mixed with City tap water prior to the start of the cleaning operation. The same analytes were measured in the water and cleaner mixture samples and the wastewater composite samples to compare concentrations prior to and after washing the air conditioning units. The HVAC unit at Site 1 was cleaned with a product manufactured by Nu-Calgon called Cal-Green. The concentrated product has a pH of 9 and lists sodium citrate as the main active ingredient. The HVAC unit at Site 2 was cleaned with a product also manufactured by Nu-Calgon called Nu-Brite. The concentrated product has a pH of 14 and lists sodium hydroxide as the main active ingredient. Table 5 lists basic information from the material safety data sheet (MSDS) for each product.

The water and cleaner mixtures were applied to the HVAC units at Site 1 and Site 2 using a Nu-Calgon coil gun attached to a garden hose. The coil gun canister has a 2-quart capacity and five mix ratio (dilution ratio) settings. A dilution ratio of 4 to 1 (water: cleaning product) was used for Cal-Green application at Site 1. A dilution ratio of 6 to 1 was used for Nu-Brite application at Site 2. Only tap water was applied to the HVAC unit at Site 3 using pressure washing equipment.

Table 5. Comparison of MSDS information for HVAC coil cleaning products used in this study.

Product	pH	Toxicity	NFPA Designation	Active Ingredients
Cal-Green	9	May cause eye, skin, and respiratory irritation	Health - 1 Flammability - 0 Instability - 0 Special Hazards - None	1-5% Sodium Citrate; 0.5-1.5% Alcohols, C9-11, ethoxylated
Nu-Brite	14	Causes eye and skin burns	Health - 3 Flammability - 0 Instability - 1 Special Hazards - None	15-40% Sodium Hydroxide; 1-5% Alkyl polyglycoside

Water and cleaner mixture sample results are summarized below in Table 6. Total and dissolved concentrations for aluminum and cadmium were not detected in the water and cleaner mixtures or the water only sample. The Cal-Green mixture (Site 1) had a dissolved copper concentration of 23 µg/L and total copper concentration of 43.5 µg/L. Due to matrix interference with analyses of total and dissolved copper for the Nu-Brite mixture (Site 2), the reporting limits were raised and the results were reported as estimated or “J” qualified. The Nu-Brite mixture concentrations for copper were 74.8 µg/L (dissolved) and 83.1 µg/L (total). The total and dissolved copper concentrations in the water only sample were slightly higher than the cleaning product mixture samples. Zinc concentrations ranged from 310 µg/L (dissolved) and 252 µg/L (total) in the Cal-Green mixture to 452 µg/L (dissolved) and 486 µg/L (total) in the Nu-Brite mixture. The zinc concentrations for the water only sample at Site 3 could not be compared because of suspected blank contamination for total and dissolved zinc.

Nutrient concentrations were relatively low in the cleaning product mixtures; however, the TKN concentration in the Cal-Green mixture sample measured 120 mg/L. When compared to the low ammonia nitrogen concentration, the TKN measurement indicates a higher amount of organic nitrogen in the Cal-Green mixture sample. In comparison, TKN was not detected in the Nu-Brite mixture sample or the water only sample.

The BOD concentrations were very high in both cleaning mixture samples. The Cal-Green mixture had the highest BOD concentration of 6500 mg/L and the Nu-Brite mixture had a BOD concentration of 2600 mg/L. These elevated results for BOD are approximately 10 to 26 times higher than average BOD concentrations of wastewater influent at the City of Durham’s Water Reclamation Facilities (Refer to Table 9).

TSS concentrations also differed significantly between the two cleaning product mixtures. The Cal-Green mixture had a TSS concentration of 120 mg/L, whereas, the Nu-Brite mixture had a TSS concentration of 2.7 mg/L. The field turbidity result for the Cal-Green mixture was 2.31 NTUs and the field turbidity result for the Nu-Brite mixture measured 2.12 NTUs. A comparison of the TSS and turbidity results of all three sites calls into question the validity of the TSS concentration for the Cal-Green mixture sample. The results suggest that TSS values for the water and cleaner mixture and wastewater composite at Site 1 were reported incorrectly by the laboratory.

Table 6. Water and cleaner mixture sample results for all sites.

Analyte	Units	Site 1 (Cal-Green)		Site 2 (Nu-Brite)		Site 3 (Tap Water)		
		Result	Qualifier	Result	Qualifier	Result	Qualifier	
Metals	Aluminum, Dissolved	µg/L	42	U	420	U,D	42	U
	Aluminum, Total	µg/L	42	U	420	U,D	42	U
	Cadmium, Dissolved	µg/L	0.36	U	3.6	U,D	0.36	U
	Cadmium, Total	µg/L	0.36	U	3.6	U,D	0.36	U
	Copper, Dissolved	µg/L	23		74.8	J,D	104	
	Copper, Total	µg/L	43.5		83.1	J,D	135	J7
	Zinc, Dissolved	µg/L	310		452	D	Rejected	
	Zinc, Total	µg/L	252		486	D	Rejected	
Nutrients	Ammonia Nitrogen	mg/L	0.28		1.1	D	0.045	U
	Nitrate/Nitrite (as N)	mg/L	0.32		0.39		0.47	
	Total Kjeldahl Nitrogen	mg/L	120	D	26	U,D	2.6	U,D
	Total Nitrogen	mg/L	120.32					
	Total Phosphorus	mg/L	2.5	U,D	2.5	U,D	0.37	J,D
Other	Biochemical Oxygen Demand	mg/L	6500	D	2600	D	2	U
	MBAS	mg/L	0.21	U	2.2	J	0.1	U
	Total Suspended Solids	mg/L	120		2.7		2.5	U

D: Qualifier indicates the sample was analyzed at dilution.

J: Qualifier indicates the estimated reported value is between the laboratory MDL and the PQL.

J7: Qualifier indicates the estimated reported value is between the laboratory MDL and PQL, although the value may not be accurate because blank contamination is evident.

U: Qualifier indicates the analyte was not detected at a concentration greater than the detection limit.

Gray Cells: Total Nitrogen was not able to be calculated at Sites 2 and 3 because of U qualifier on the corresponding TKN results.

Wastewater Composites

HVAC coil cleaning wastewater samples were collected from one composite at each site (1 HVAC unit washed per composite). The duration of the cleaning process ranged from 27 minutes to 43 minutes and the amount of water used ranged from 67 gallons (253.6 liters) to 118.2 gallons (447.4 liters). Sampling event details are summarized below in Table 7.

Table 7. Summary of site information and sample volumes collected at each site.

Site ID	1	2	3
Location	407 Morris St	423 Morris St	404 Hunt St
Sampling Date	5/14/2015	5/21/2015	7/23/2015
Cleaning Product	Cal-green	Nu-Brite	Tap water only
Volume of Product Used	0.75 gallons	1.0 gallon	n/a
Dilution Factor (Water: Product)	4 : 1	6 : 1	n/a

Estimated Duration of Sampling Event	60 minutes	30 minutes	30 minutes
Duration of Sampling Event	43 minutes	33 minutes	27 minutes
Volume of Wastewater	118.2 gallons	100.5 gallons	67 gallons
Volume of Wastewater (converted to liters)	447	380	254
Volume of Grab Samples	750 mL	900 mL	900 mL
Interval Between Samples	5 minutes	3 minutes	3 minutes
Total Number of Samples	9	10	10
Total Composite Volume	6,750 mL	9,000 mL	9,000 mL

Elevated levels of aluminum, cadmium, copper and zinc were observed in all wastewater composite samples (Figure 7 and Figure 8). Dissolved aluminum results ranged from 5,000 µg/L at Site 1 (Cal-Green) to 184,500 µg/L at Site 2 (Nu-Brite). Total aluminum ranged from 9,070 µg/L at Site 1 to 192,000 µg/L at Site 2. Dissolved cadmium ranged from 1.29 µg/L at Site 2 to 4.6 µg/L at Site 1, and total cadmium ranged from 1.65 µg/L at Site 3 (Tap Water) to 7.61 µg/L at Site 1. Dissolved copper concentrations ranged from 156 µg/L at Site 3 to 1,750 µg/L at Site 2. Similarly, total copper concentrations ranged from 301 µg/L at Site 3 to 2,510 µg/L at Site 2. Dissolved zinc concentrations ranged from 2,430 µg/L at Site 1 to 185,000 µg/L at Site 2. Total zinc ranged from 2,780 µg/L at Site 1 to 23,400 µg/L at Site 2.

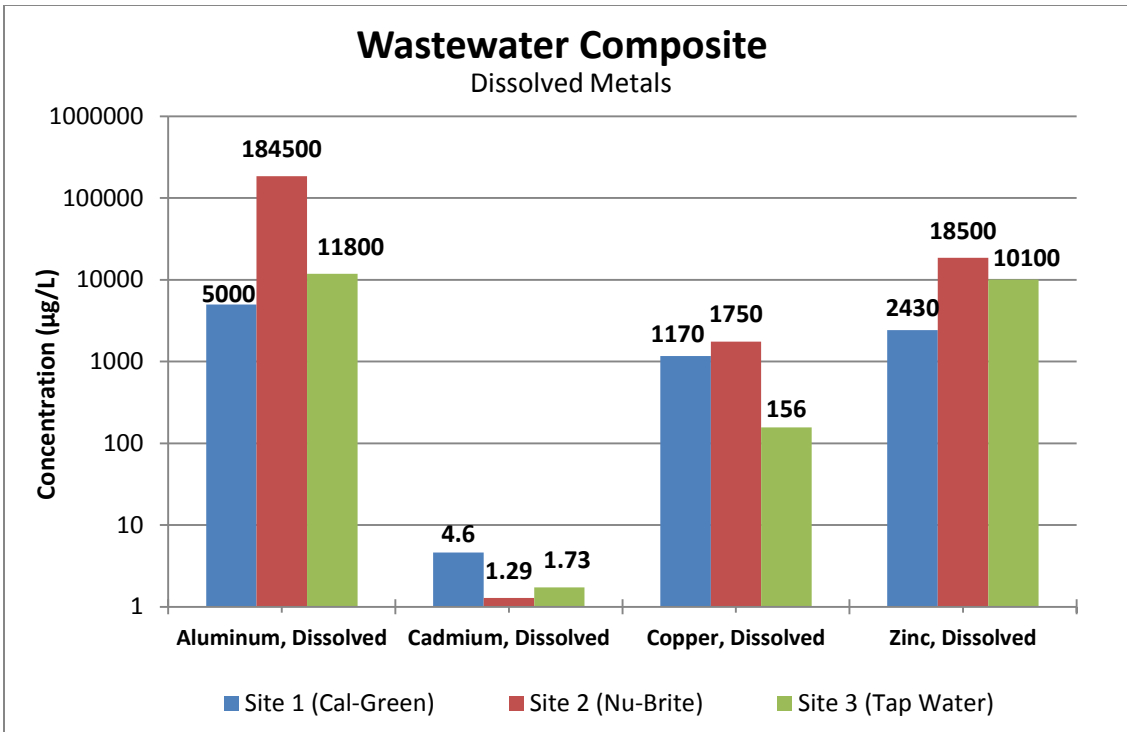


Figure 7. Dissolved metals concentrations for wastewater composite samples at all 3 sites.

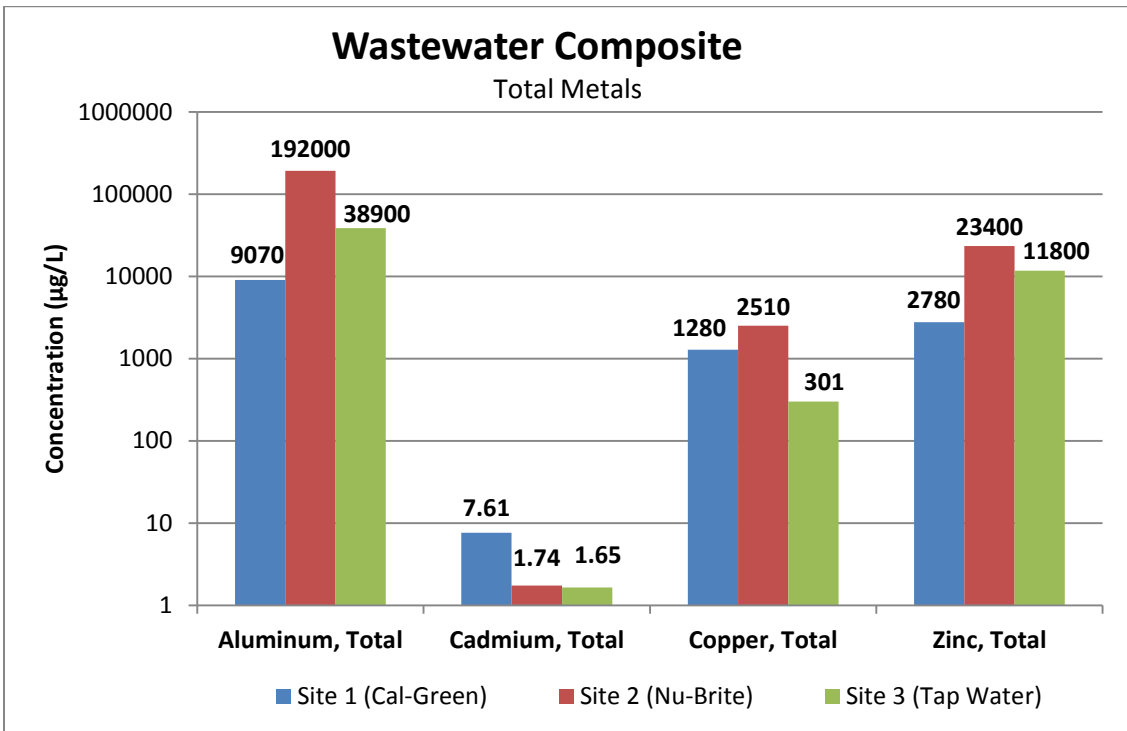


Figure 8. Total metals concentrations for wastewater composite samples at all 3 sites.

Both copper and aluminum are common metals used to make condenser coils and fins in HVAC units. The dissolved and total metals data from this study suggest that high concentrations of aluminum, copper, and zinc were removed from the HVAC units

during the washing process. The metals data also show that a high percentage of the metals concentrations were present in the dissolved form. The highest metals concentrations were found in the wastewater from the HVAC unit at Site 2 which was cleaned with Nu-Brite, an alkaline and corrosive product. Although Site 3 was thought to have the cleanest unit and was washed only using pressurized tap water, the aluminum and zinc concentrations were higher than the concentrations in the wastewater composite for Site 1 (Cal-Green).

Nitrogen and phosphorus concentrations for the wastewater composites are summarized below in Figure 9. Total nitrogen concentrations were calculated by adding TKN concentrations to nitrate+nitrite concentrations. The total nitrogen concentrations ranged from 24 mg/L at Site 1 to 123 mg/L at Site 3. Site 3 had a considerably higher concentration of nitrate+nitrite than the other two sites; however, Site 2 had the highest concentrations of ammonia-nitrogen and TKN. Total phosphorus concentrations ranged from 0.9 mg/L at Site 1 to 5.2 mg/L at Site 2.

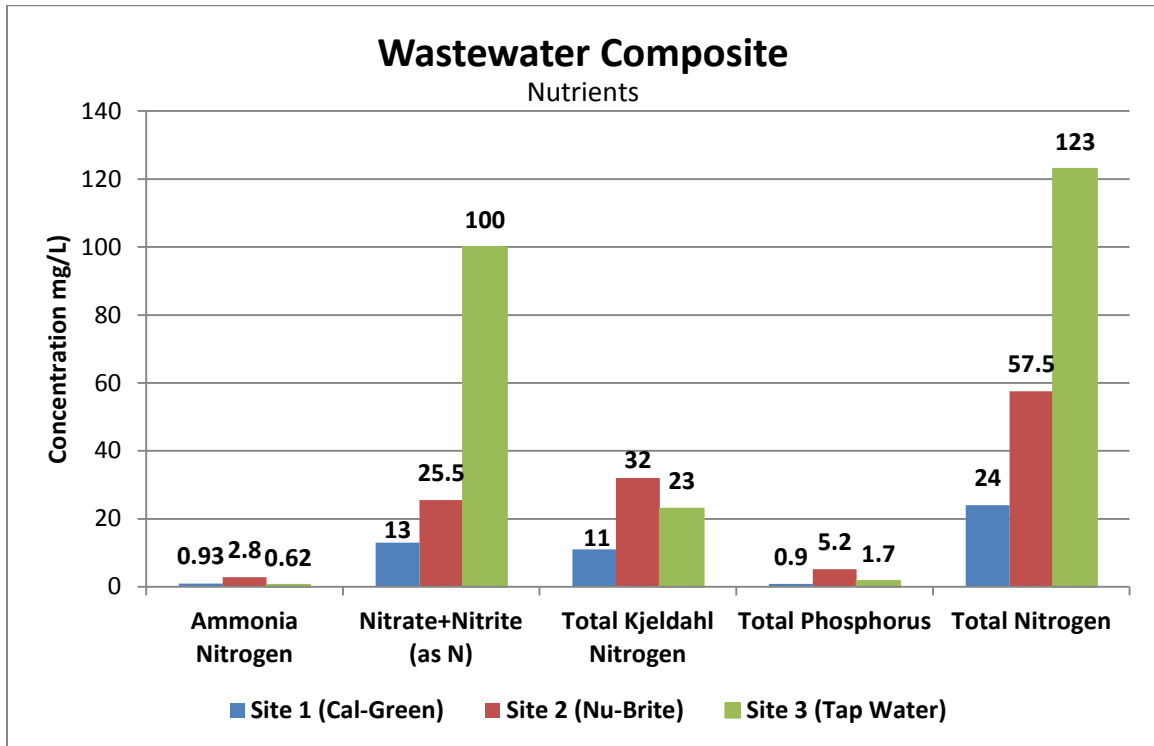


Figure 9. Nutrient concentrations for wastewater composite samples at all 3 sites.

BOD and TSS concentrations for wastewater composites are summarized below in Figure 10. The wastewater samples contained very high concentrations of BOD and TSS. BOD concentrations ranged from 130 mg/L at Site 3 to 580 mg/L at Site 2, and the mean concentration was 390 mg/L. TSS concentrations were below the method detection limit for the wastewater composite at Site 1; however, the turbidity measurement at Site 1 was 94.5 NTUs. There was more correlation between the TSS and turbidity results at Site 2 and Site 3. TSS concentrations ranged from 440 mg/L at Site 3 to 910 mg/L at Site 2.

The turbidity measured 632 NTUs at Site 3 and greater than 1000 NTUs at Site 2. The Hach 2100P turbidimeter used for this study has a maximum range of 1000 NTUs.

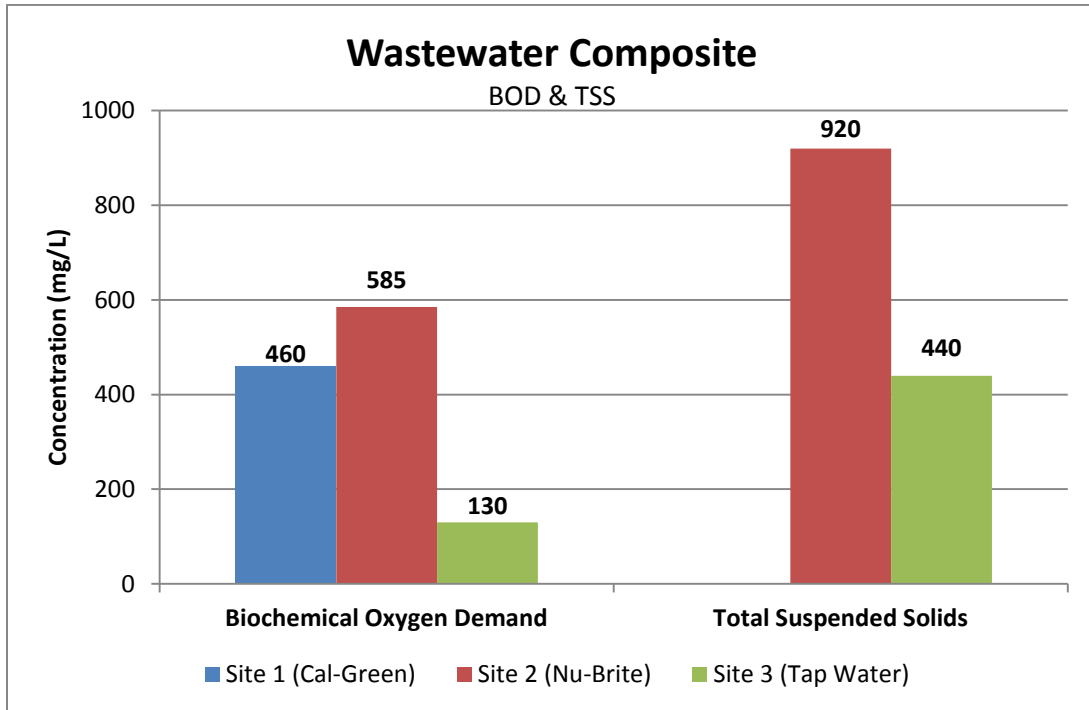


Figure 10. BOD and TSS concentrations for wastewater composite samples at all 3 sites. TSS in the sample from Site 1 was not detected at a concentration greater than the detection limit.

MBAS concentrations were below detection limits in wastewater composites for Site 1 and Site 3. MBAS measured 2.2 mg/L at Site 2, however, the result was estimated or “J” qualified. The laboratory raised the reporting limit to account for matrix interference in the samples analyzed for MBAS in all wastewater composite samples. Refer to Appendix A for more information about the laboratory qualifier notes.

Field measurements for pH and conductivity were collected at consistent intervals throughout the cleaning process at each site. Due to variations in the estimated durations for the cleaning process, grab samples and in-situ measurements were collected every 5 minutes at Site 1 and every 3 minutes at Site 2 and Site 3. Results for pH and conductivity are shown below in Figures 11 and 12.

The Cal-Green cleaning mixture started with a pH of 9 prior to application at Site 1. During the cleaning process and further dilution of the Cal-Green cleaning mixture, the pH ranged from 6.9 to 7.2, and the wastewater composite measured 7.4. The Nu-Brite cleaning mixture started with a pH of 11.9. Despite further dilution of the Nu-Brite cleaning mixture during the cleaning process, the pH ranged from 12.2 to 12.7, and the wastewater composite measured 12.4. Although the tap water at Site 1 started with a pH of 7.4, the pH value dropped during the cleaning process and remained between 6.1 and 6.2. The wastewater composite at Site 3 measured a pH of 6.2.

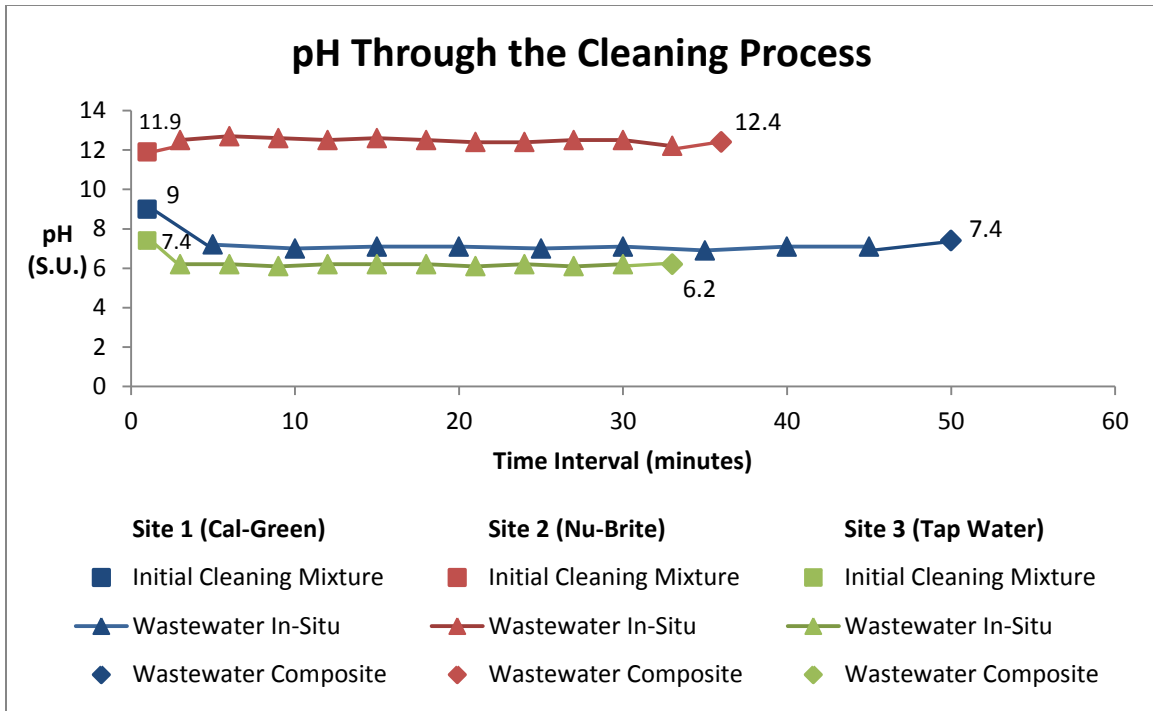


Figure 11. Series of pH measurements for cleaning mixtures prior to washing activities, wastewater grab samples during washing activities, and wastewater composite samples after washing activities.

Conductivity measured 4,760 μS in the Cal-Green cleaning mixture prior to application to the HVAC unit at Site 1. There was a noticeable decrease in conductivity after the cleaning mixture and water were applied to the HVAC unit at Site 1. The conductivity at Site 1 ranged from 508 μS to 729 μS during the cleaning process, and the wastewater composite measured 620 μS . The Nu-Brite cleaning mixture measured the highest conductivity at greater than 20,000 μS . The Oakton PCTestr 35 meter was used to measure conductivity in the field, which has a maximum range of 20,000 μS . After application of the Nu-Brite cleaning mixture, the conductivity decreased to 15,050 μS and measured as low as 4,060 μS during the cleaning process. The conductivity of the wastewater composite at Site 2 measured 16,270 μS . The initial conductivity of the tap water used at Site 3 measured 205 μS . At the beginning of the cleaning process at Site 1, the conductivity increased to 1,526 μS and then gradually decreased to 1,144 μS . The conductivity of the wastewater composite at Site 3 measured 1,292 μS . The elevated conductivity values at all three sites indicate a high amount of dissolved solids in the HVAC coil cleaning wastewater.

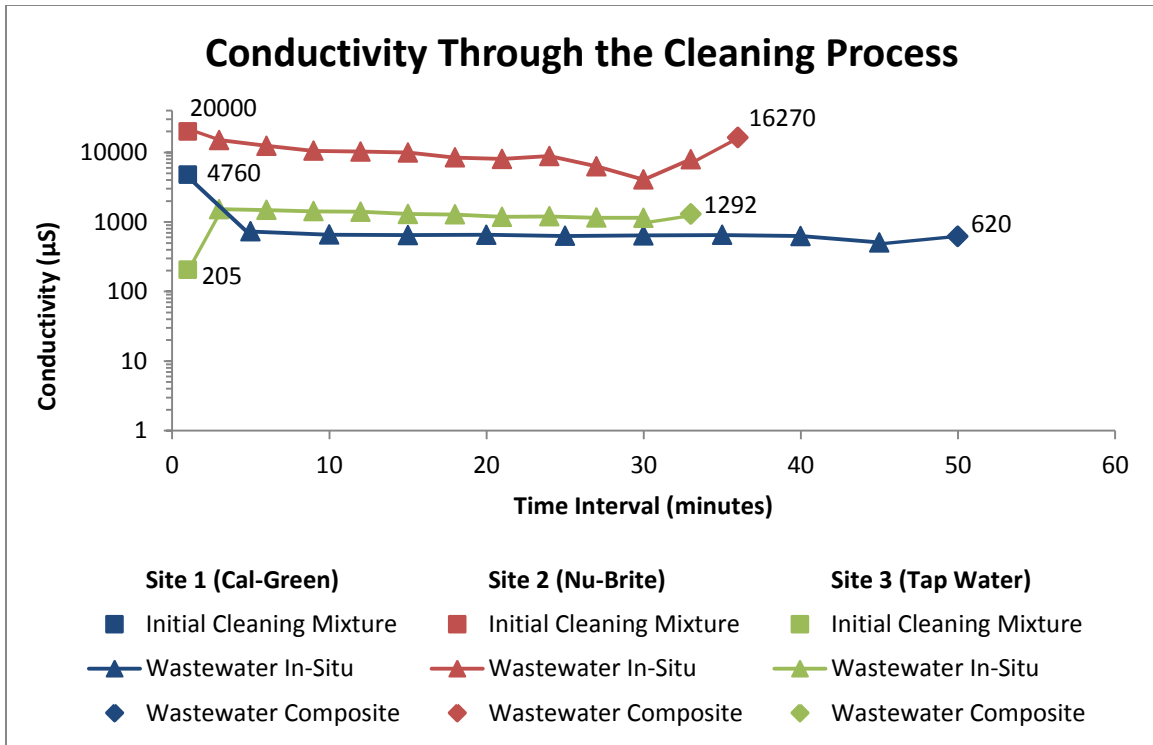


Figure 12. Series of conductivity measurements for cleaning mixtures prior to washing activities, wastewater grab samples during washing activities, and wastewater composite samples after washing activities.

Effluent Comparison

To better understand the condition of the wastewater from the HVAC coil cleaning operations, mean concentrations of analytes from this study were compared with those of known domestic wastewater. Table 8 presents data for three categories of untreated domestic wastewater reported by *Metcalf and Eddy* (2003). Low strength is an estimate for a wastewater flow rate of 750 liters per capita per day (L/cap-day). Medium strength is an estimate for a wastewater flow rate of 460 L/cap-day. High strength is an estimate for a wastewater flow rate of 240 L/cap-day. In comparison, the average volume of wastewater generated for this study was 360 liters. Although no average metals concentrations were reported by *Metcalf and Eddy* (2003), several of the analyte concentrations in this study are comparable to those of wastewater of varying strength. Analytes of particular note are BOD, TSS, TKN, nitrate+nitrite and total nitrogen. Mean results for BOD, TSS, and nitrate+nitrite exceeded the high strength wastewater category, meaning the wastewater from the HVAC coil cleaning operation has much higher concentrations of these analytes than would be expected in most untreated municipal wastewater. Similarly, HVAC coil cleaning wastewater had a mean concentration for total nitrogen that was 2 mg/L less than the high strength wastewater category. The mean TKN concentration for the HVAC coil cleaning wastewater was 2 mg/L greater than the low strength untreated domestic wastewater.

The data from this study were also compared to influent data for untreated domestic wastewater at both of Durham’s Water Reclamation Facilities (WRFs), also shown in Table 8. These data further support the conclusion that the wastewater from HVAC coil cleaning is comparable to untreated municipal wastewater. A comparison of the data for total metals in the wastewater composite samples to the corresponding data from the water reclamation facilities show that the concentrations of cadmium, copper, and zinc in HVAC coil cleaning wastewater are much higher than what is typically seen in municipal wastewater. Copper is 38 times higher and zinc is 27 times higher than the mean concentrations reported at the Durham WRFs. The HVAC coil cleaning wastewater also had higher BOD and TSS concentrations than untreated wastewater at Durham’s WRFs. Comparisons of the data in Table 8 show that in terms of the analytes in this study, the wastewater from HVAC coil cleaning is comparable to, and in some cases, even more pollutant-rich than untreated domestic wastewater.

In 2011, the City of Durham conducted a study to evaluate wastewater produced from mobile car washing operations. Table 8 also shows a comparison between mean concentrations for parameters analyzed in the Mobile Car Wash Study and this study. The mean volume of water per vehicle washing was approximately 20 L compared to a mean volume of 360 L of water used per HVAC unit cleaning event. HVAC coil cleaning wastewater has higher mean concentrations of total copper, total zinc, total nitrogen, TKN, nitrate+nitrite, BOD and TSS than mobile car wash wastewater.

Table 8. Untreated domestic wastewater compared to HVAC coil cleaning wastewater.

Analyte	Units	Metcalf and	Metcalf and	Metcalf and	Durham	Durham	AC Coil
		Eddy, 2003 ¹ (Low Strength)	Eddy, 2003 ¹ (Medium Strength)	Eddy, 2003 ¹ (High Strength)	WRFs ² (Mean)	Mobile Car Wash Study ³ (Mean)	Cleaning Study (Mean)
Metals	Aluminum, Dissolved	ug/L	-	-	-	-	67100
	Aluminum, Total	ug/L	-	-	-	-	79990
	Cadmium, Dissolved	ug/L	-	-	-	-	2.5
	Cadmium, Total	ug/L	-	-	-	1.2	3.69
	Copper, Dissolved	ug/L	-	-	-	-	1026
	Copper, Total	ug/L	-	-	-	34.7	1050
	Zinc, Dissolved	ug/L	-	-	-	-	10343
	Zinc, Total	ug/L	-	-	-	465	1897
Nutrients	Total Nitrogen	mg/L	20	40	70	-	15.9
	Total Kjeldahl Nitrogen	mg/L	20*	40*	70*	41.3	14.97
	Nitrate+Nitrite as N	mg/L	0	0	0	-	0.95
	Ammonia Nitrogen	mg/L	-	-	-	29.2	-
	Total Phosphorus	mg/L	4	7	14	5.57	2.70
Other	Biochemical Oxygen Demand	mg/L	110	190	350	252	213
	Total Suspended Solids	mg/L	120	210	400	164	327

¹Metcalf and Eddy (2003) reported three categories of wastewater strength based on flow rates: low, medium, and high.

²Mean concentrations of untreated domestic wastewater are reported from Durham’s two Water Reclamation Facilities (measurement date range from 2008 to 2015).

³Mean concentrations of car wash wastewater are reported from Durham’s Mobile Car Wash Study (Water Quality Report #11-001)

Surface Water Quality Standards

Table 9 summarizes the North Carolina Department of Environmental Quality (NCDEQ) surface water quality standards and EPA recommended water quality criteria for parameters that were analyzed during this study. The dissolved metals concentrations were significantly higher than the NCDEQ surface water quality standards for dissolved copper (3.6 µg/L and 2.7 µg/L for acute and chronic toxicity, respectively) and dissolved zinc (36 µg/L for acute and chronic toxicity). Concentrations for dissolved copper were 43 to 486 times higher than the acute toxicity surface water quality standard, and 58 to 648 times higher than the chronic toxicity surface water quality standard.

Concentrations for dissolved zinc were 67 to 514 times higher than the state surface water quality standard. Although the dissolved cadmium concentrations were much lower than the other metal concentrations, the results were 1.6 to 5.6 times higher than the state's acute toxicity surface water quality standard for dissolved cadmium (0.82 µg/L) and 8.6 to 31 times higher than the state's chronic toxicity surface water quality standard for dissolved cadmium (0.15 µg/L). The state surface water quality standards for dissolved metals are hardness-dependent and assume an in-stream hardness value less than or equal to 25 mg/L. Since calcium and magnesium were not measured during this study, hardness (CaCO₃) could not be calculated. Therefore, dissolved metals numeric standards calculated at 25 mg/L hardness were compared to the dissolved metals results for this study.

Turbidity measurements of the wastewater composite samples were also considerably higher than the state's surface water quality standard for turbidity (50 NTUs in streams and 25 NTUs in lakes). Turbidity results were 1.9 to 20 times higher than the in-stream water quality standard for turbidity.

The mean pH of the wastewater composites was within the acceptable range for the state's water quality standard. However, the mean pH of the wastewater composite samples at the sites cleaned with a cleaning product yielded a value of 9.9, which is above the acceptable range for freshwater aquatic life.

Table 9. HVAC coil cleaning wastewater compared to NCDEQ surface water quality standards and EPA recommended water quality criteria.

Analyte	Units	WQ Standards ¹	15A NCAC 02B Standard? ¹	AC Coil Cleaning Study (Mean)
		Freshwater - Aquatic Life		
Metals	Aluminum, Dissolved	ug/L	-	67100
	Aluminum, Total	ug/L	87	79990
	Cadmium, Dissolved	ug/L	Acute: 0.82 Chronic: 0.15	2.5
	Cadmium, Total	ug/L	-	3.7
	Copper, Dissolved	ug/L	Acute: 3.6 Chronic: 2.7	1026
	Copper, Total	ug/L	-	1364
	Zinc, Dissolved	ug/L	Acute: 36 Chronic: 36	10343
	Zinc, Total	ug/L	-	12660
Nutrients	Total Nitrogen	mg/L	-	68.2
	Total Kjeldahl Nitrogen	mg/L	-	22.0
	Nitrate+Nitrite as N	mg/L	-	46.2
	Ammonia Nitrogen	mg/L	-	1.5
	Total Phosphorus	mg/L	-	2.6
Other	Biochemical Oxygen Demand	mg/L	-	392
	Total Suspended Solids	mg/L	-	454
	pH	S.U.	6.0-9.0	8.7
	Turbidity	NTU	50/25	576

¹Information from NCDEQ table *North Carolina 15A NCAC 02B Surface Water Standards and Protective Values & EPA Nationally Recommended Water Quality Criteria*.

POLLUTANT LOADS

Survey

To estimate a city-wide impact from the results of the study, a survey was sent to local HVAC service companies. A list of companies that provide heating and air conditioning services in the City of Durham was compiled using the business license registry. From that list, companies that serviced commercial HVAC units were contacted and asked to participate in the survey. To keep within the bounds of this study, the survey asked questions specifically pertaining to the service of commercial HVAC units. Any company that only serviced single-family residential HVAC units was omitted.

Surveys were distributed to representatives of seventeen different companies and the City received responses from six companies. The questions on the survey were aimed at determining how many commercial HVAC units they clean in an average year, how often they use cleaning products, and what those products may be. The answers provided a basis for estimating how much HVAC cleaning wastewater may be entering Durham’s MS4, and what characteristics that wastewater may have. Based on survey responses from six companies, an estimated 2,150 HVAC units are cleaned on an annual basis (Figure 13). The companies also estimated the percentage of units cleaned with a high pH cleaning product, a moderate pH cleaning product, and water only. Approximately

60% of the units (1,306) were cleaned with a product having a moderate pH, 24% of the units (506) were cleaned with a product having a high pH, and 16% of the units (338) were cleaned only with water. Since there were no estimates made for the number of units cleaned by the eleven companies that did not respond to the survey, the annual total of units cleaned may be a conservative estimate.

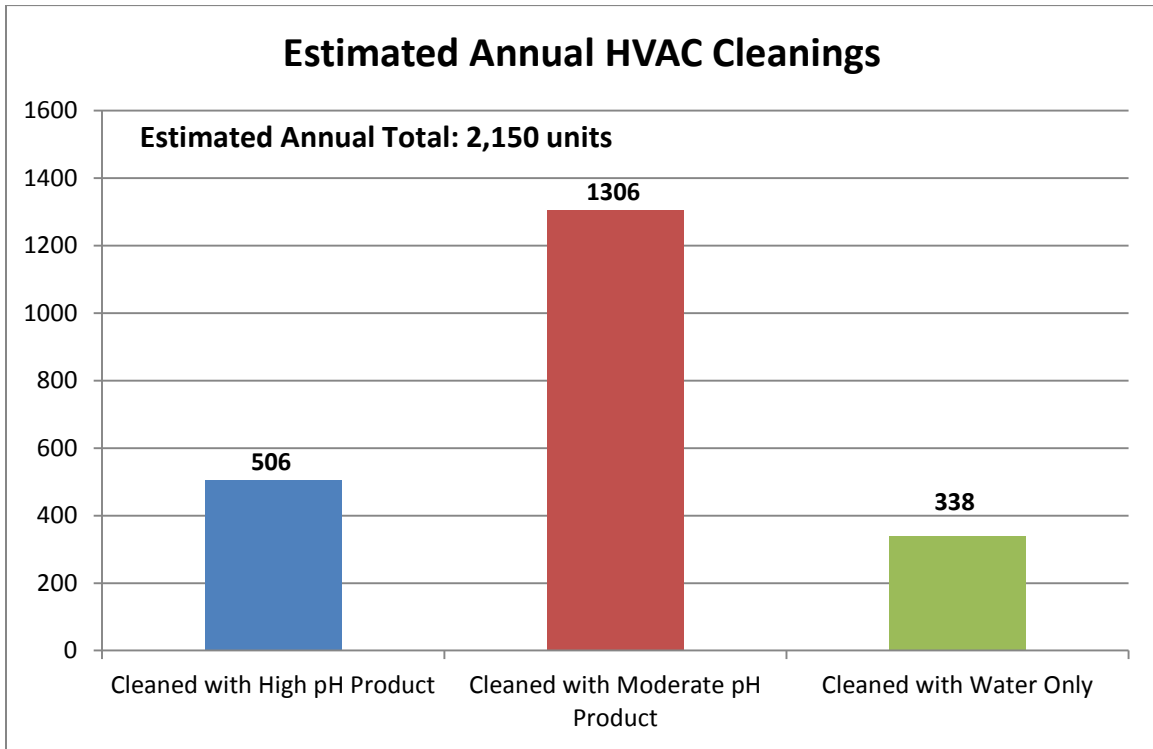


Figure 13. Estimated number of HVAC units cleaned with different products annually within Durham County based on survey results.

Annual Pollutant Loads from HVAC Unit Cleanings

Pollutant loads were calculated for each composite sample per cleaning event, which resulted in three pollutant loads for each analyte (Table 10). The table in Appendix B also shows wastewater composite concentrations with associated pollutant loads for each sampling event. The following equation was used to calculate the pollutant load per cleaning event:

$$L_p = C * V * 2.20462 * 10^{-6}$$

where:

L_p = total pollutant load per cleaning event (lbs)

C = pollutant concentration (mg/L)

V = volume of water per cleaning event (L)

$2.20462 * 10^{-6}$ = unit conversion factor (mg to lbs)

The volume of water per cleaning event (V) used for the pollutant load equation are:

Site 1 = 447.4 L

Site 2 = 380.4 L

Site 3 = 253.6 L

Table 10. Wastewater composite concentrations with associated pollutant load for each sampling event.

Analyte	Site 1	Site 2 ¹	Site 3	Site 1	Site 2	Site 3	
	Composite Concentration (mg/L)	Composite Concentration (mg/L)	Composite Concentration (mg/L)	Total Load per AC Unit (lbs)	Total Load per AC Unit (lbs)	Total Load per AC Unit (lbs)	
Metals	Aluminum, Dissolved	5.00	184.5	11.8	0.0049	0.1547	0.0066
	Aluminum, Total	9.07	192	38.9	0.0089	0.1610	0.0217
	Cadmium, Dissolved	0.0046	0.0013	0.0017	0.0000	0.0000	0.0000
	Cadmium, Total	0.0076	0.0017	0.0017	0.0000	0.0000	0.0000
	Copper, Dissolved	1.17	1.75	0.156	0.0012	0.0015	0.0001
	Copper, Total	1.28	2.51	0.301	0.0013	0.0021	0.0002
	Zinc, Dissolved	2.43	18.5	10.1	0.0024	0.0155	0.0056
	Zinc, Total	2.78	23.4	11.8	0.0027	0.0196	0.0066
Nutrients	Ammonia Nitrogen	0.93	2.8	0.62	0.0009	0.0023	0.0003
	Nitrate+Nitrite (as N)	13.0	25.5	100	0.0128	0.0214	0.0559
	Total Kjeldahl Nitrogen	11.0	32.0	23	0.0108	0.0268	0.0129
	Total Nitrogen	24.0	57.5	123	0.0237	0.0482	0.0688
	Total Phosphorus	0.90	5.20	1.7	0.0009	0.0044	0.0010
Other	Biochemical Oxygen Demand	460	585	130	0.454	0.491	0.0727
	Total Suspended Solids	2.50	920	440	0.0025	0.772	0.246

¹Site 2 duplicate wastewater composite sample results were averaged.

The equation shown below was used to calculate the annual pollutant loads in Table 11:

$$L_a = L_p * N$$

where:

L_a = annual pollutant load (lbs)

L_p = total pollutant load per cleaning event (lbs)

N = total number of HVAC units cleaned on an annual basis (2,150)

Theoretical annual loads were calculated for the lowest potential load (i.e. best case scenario) and highest potential load (i.e. worst case scenario) for each pollutant (Table 11). The lowest concentration for each pollutant was multiplied by the lowest volume of

water (253.6 L) and converted into pounds to represent the minimum pollutant load generated from cleaning an HVAC unit in Durham. The highest concentration for each pollutant was also multiplied by the highest volume of water (447.4 L) and converted into pounds to characterize the maximum pollutant load generated from cleaning an HVAC unit in Durham.

Table 11. Total annual pollutant loads for each sampling event with low and high theoretical annual loads.

		Site 1	Site 2	Site 3	Low	High
		Annual Load	Annual Load	Annual Load	Theoretical	Theoretical
		(lbs)	(lbs)	(lbs)	Annual Load	Annual Load
		(lbs)	(lbs)	(lbs)	(lbs)	(lbs)
Metals	Aluminum, Dissolved	10.6	333	14.2	6.01	391
	Aluminum, Total	19.2	346	46.8	10.9	407
	Cadmium, Dissolved	0.0098	0.0023	0.0021	0.0015	0.0098
	Cadmium, Total	0.016	0.0031	0.0020	0.0020	0.016
	Copper, Dissolved	2.48	3.16	0.188	0.188	3.71
	Copper, Total	2.71	4.53	0.362	0.362	5.32
	Zinc, Dissolved	5.15	33.4	12.1	2.92	39.2
	Zinc, Total	5.90	42.2	14.2	3.34	49.6
Nutrients	Ammonia Nitrogen	1.97	5.05	0.745	0.745	5.94
	Nitrate+Nitrite (as N)	27.6	46.0	120	15.6	212
	Total Kjeldahl Nitrogen	23.3	57.7	27.6	13.2	67.9
	Total Nitrogen	50.9	104	148	28.8	280
	Total Phosphorus	1.91	9.38	2.04	1.08	11.0
Other	Biochemical Oxygen Demand	975	1055	156	156	1241
	Total Suspended Solids	5.30	1659	529	3.01	1951

The total and dissolved forms of aluminum and zinc had the highest annual loads of all the metals. Annual dissolved aluminum loads ranged from 10.6 lbs to 333 lbs and annual total aluminum loads ranged from 19.2 lbs to 346 lbs. Annual dissolved zinc ranged from 5.15 lbs to 33.4 lbs and annual total zinc loads ranged from 5.90 lbs to 42.2 lbs. Annual loads for total and dissolved copper ranged from less than one pound to 4.53 lbs. All annual loads for total and dissolved cadmium were less than one pound.

The annual loads for total nitrogen ranged from 50.9 lbs to 148 lbs and the “high” theoretical annual load for total nitrogen was 280 lbs. By comparison, the annual total nitrogen loads for the City’s Mobile Car Wash Study ranged from 14.0 lbs to 49.8 lbs. Annual total phosphorus loads ranged from 1.91 lbs to 9.38 lbs and the “high” theoretical annual load was 11.0 lbs. The annual total phosphorus loads for the Mobile Car Was Study were similar to this study, which ranged between 3.1 lbs to 7.5 lbs.

BOD and TSS had the highest annual loads of all analytes in this study. BOD annual loads ranged from 156 lbs to 1,055 lbs and had a “high” theoretical annual load of 1,241 lbs. Although Site 1 (moderate pH product) had a calculated annual TSS load of 5.3 lbs, the annual TSS load at Site 2 (high pH product) was 1,659 lbs and the annual TSS load at Site 3 (water only) was 529 lbs. TSS had the highest theoretical annual load of 1,951 lbs.

Site 2 (high pH product) had the highest annual loads for most analytes, except total and dissolved cadmium, nitrate+nitrite, and total nitrogen. Although the HVAC unit at Site 3 was cleaned only with water, it had the highest annual loads for nitrate+nitrite and total nitrogen, and the second highest annual loads for aluminum, zinc, TKN, total phosphorus, and TSS. Site 3 also had the newest HVAC unit that was estimated as having the lowest level of dirtiness. It was estimated that Site 1 (moderate pH product) had the HVAC unit with a medium level of dirtiness; however, Site 1 had the lowest annual loads for nine out of fifteen analytes.

SUMMARY

The City of Durham conducted this study to evaluate parameters of concern and quantify pollutant loads associated with HVAC coil cleaning wastewater in Durham, North Carolina. With the assistance of a local HVAC maintenance company, composite samples were collected at three separate sites with HVAC units of varying levels of cleanliness that were each washed using a different cleaning product. Cleaning product mixtures and wastewater composites were analyzed for metals, nutrients, BOD, MBAS, and TSS.

The concentrations of total cadmium, total copper, total zinc, total nitrogen, BOD, and TSS measured in the HVAC coil cleaning wastewater were higher than average concentrations in untreated domestic wastewater. High concentrations of dissolved metals and dissolved solids were removed from the HVAC units with all cleaning methods used in this study: a moderate alkaline cleaning product, a strong alkaline and corrosive cleaning product, and pressurized tap water. The HVAC coil cleaning wastewater had dissolved metals concentrations of cadmium, copper, and zinc that ranged from 1.6 to 648 times higher than NCDEQ’s surface water quality standards. It is important to note these high concentrations of pollutants because the City of Durham also has streams on the state’s 303(d) list for copper and zinc.

The high nitrogen concentrations (24 mg/L to 123 mg/L) and phosphorus concentrations (0.9 mg/L to 5.2 mg/L) observed during this study are important to consider because the City of Durham is required to reduce the amount of nitrogen and phosphorus entering Falls Lake and Jordan Lake. Even though the BOD concentrations dropped during the cleaning process, the elevated BOD concentrations (130 mg/L to 585 mg/L) are of

concern because the City of Durham currently has streams on the state's 303(d) list for dissolved oxygen.

There was a wide range between many of the calculated annual pollutant loads at the three sites and between the "low" and "high" theoretical annual loads. Many variables should be considered when comparing the range of annual pollutant loads in this study, such as the type of cleaning product used, the volume of water used, the amount of material that accumulated on each HVAC unit's fins and coils prior to a cleaning event, the amount of rainfall prior to a cleaning event, and the small number of composite samples analyzed.

The average annual pollutant loads are summarized below:

- Annual loads were highest for BOD (729 lbs/year) and TSS (731 lbs/year)
- Annual total nitrogen loads were 101 lbs/year and total phosphorus loads were 4.44 lbs/year
- Aluminum and zinc had the highest annual metals loads (119 lbs/year of dissolved aluminum and 137 lbs/year of total aluminum; 16.9 lbs/year of dissolved zinc and 20.8 lbs/year of total zinc)

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APPENDIX A: Laboratory Qualifier Definitions and Notes

Site 1: Cal-green cleaning product (pH of 9)

Analyte	Sample Description	Qualifier	Laboratory Qualifier Definitions	City Staff Notes
Ammonia as N	Matrix Spike 1 and Matrix Spike 1 Duplicate	QM-05	The spike recovery was outside acceptance limits for the Matrix Spike (MS) and Matrix Spike Duplicate (MSD) due to matrix interference. The Laboratory Control Sample (LCS) was within acceptance limits showing that the laboratory is in control and the data is acceptable.	The laboratory reported that there was a high level of the target analyte in the sample prior to spiking. Spiking the sample caused a “topping of the tank” which resulted in a poor percent recovery or relative percent difference. When there are high concentrations of the target analyte in the sample and then it is spiked, there are often difficulties with percent recoveries. MS 1 and MSD 1 were outside acceptable percent recoveries, 128% and 81% respectively. This resulted in the QM-11 qualifier, which meant that the precision between the matrix spike and duplicate matrix spike was outside acceptable limits. However, MS 2 and the LCS were both within percent recovery limits (90-110%). The laboratory believes the data is acceptable for ammonia.
Ammonia as N	Matrix Spike 1 Duplicate	QM-11	Precision between duplicate matrix spikes of the same sample was outside acceptance limits.	See notes above for QM-05 qualifier.
Biochemical Oxygen Demand	Lab Quality Control Blank	B-03	Blank exceeds the method required oxygen depletion of <0.20 mg/L	None
Methylene Blue Active Substances	Water/Cleaner Mixture and Wastewater Composite	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	The laboratory reported that the MBAS matrix interference may have been caused by sample color or turbidity because it is a colorimetric test measured by a spectrophotometer. The foam in the samples could also cause interference. There was significantly more foam in the water and cleaner mixture sample.
Total Kjeldhal Nitrogen	Matrix Spike 1 and Matrix Spike 1 Duplicate	QM-16	Matrix spike recovery could not be calculated due to high concentrations of analyte in source sample.	The laboratory reported that there was a high level of the target analyte in the sample prior to spiking. Spiking the sample caused a “topping of the tank” which resulted in a poor percent recovery or relative percent difference. When there are high concentrations of the target analyte in the sample and then it is spiked, there are often difficulties with percent recoveries.
Total Kjeldhal Nitrogen	Matrix Spike 2	QM-05	The spike recovery was outside acceptance limits for the Matrix Spike (MS) due to matrix interference. The Laboratory Control Sample (LCS) was within acceptance limits showing that the laboratory is in control and the data is acceptable.	The LCS for TKN had a good percent recovery (98%). The laboratory believes the data is acceptable for both analytes.
Total Phosphorus	Water/Cleaner Mixture and Wastewater Composite	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	EPA Method 365.4 is the determination of phosphorus by colorimetry. The color and particulates in these samples may have caused matrix interference.

Site 2: Nu-Brite cleaning product (pH of 14)

Analyte	Sample Description	Qualifier	Laboratory Qualifier Definitions	City Staff Notes
Total and dissolved metals (Aluminum, Cadmium, Copper, Zinc)	Water/Cleaner Mixture	R-01	The reporting limit for these analytes has been raised to account for matrix interference.	High particulate levels in a sample can cause physical interference for EPA Method 200.7. All total and dissolved metals were analyzed with a dilution factor of 10 for the water/cleaner mixture sample.
Ammonia as N	Matrix Spike Duplicate 1	QM-05	The spike recovery was outside acceptance limits for the Matrix Spike Duplicate (MSD) due to matrix interference. The Laboratory Control Sample (LCS) was within acceptance limits showing that the laboratory is in control and the data is acceptable.	The laboratory blank sample, LCS, MS 1, and MS 2 were all within acceptable percent recovery limits (90-110%).
Methylene Blue Active Substances	Water/Cleaner Mixture, Wastewater Composite, and Wastewater Composite Duplicate	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	The laboratory reported that the MBAS matrix interference may have been caused by sample color or turbidity because it is a colorimetric test measured by a spectrophotometer. The foam in the samples could also cause interference. There was significantly more foam in the water and cleaner mixture sample.
Nitrate+Nitrite as N	Matrix Spike 1 and Matrix Spike 2	QM-05	The spike recovery was outside acceptance limits for the Matrix Matrix Spike (MS) due to matrix interference. The Laboratory Control Sample (LCS) was within acceptance limits showing that the laboratory is in control and the data is acceptable.	The laboratory blank sample and LCS were within acceptable limits.
Total Kjeldahl Nitrogen	Water/Cleaner Mixture	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	TKN was analyzed at a dilution factor of 100. TKN was not detected in the water/cleaner mixture sample. Laboratory QC samples (blank, LCS, matrix spikes) were all within acceptable limits.
Total Phosphorus	Water/Cleaner Mixture	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	EPA Method 365.4 is the determination of phosphorus by colorimetry. The color and particulates in these samples may have caused matrix interference.
Total Suspended Solids	Laboratory Duplicate 1	QM-12	Precision between duplicate samples was outside acceptance limits.	The acceptable relative percent difference (RPD) limit is 20. The TSS lab duplicate samples had an RPD of 25. Variations in TSS samples can be caused by differences in mixing between tests. The LCS had a percent recovery of 100 which shows that the data is acceptable.

Site 3: Tap water only

Analyte	Sample Description	Qualifier	Laboratory Qualifier Definitions	City Staff Notes
Methylene Blue Active Substances	Water/Cleaner Mixture and Wastewater Composite	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	A sample of City tap water was collected at Site 3 and analyzed for all the same analytes as the other water/cleaner mixtures and wastewater composites. It is unclear what may have caused matrix interference for the tap water sample. The MBAS matrix interference may have been caused by turbidity for the wastewater composite sample.
Total Kjeldahl Nitrogen	Water/Cleaner Mixture	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	TKN was analyzed at a dilution factor of 100. TKN was not detected in the water/cleaner mixture sample. Laboratory QC samples (blank, LCS, matrix spikes) were all within acceptance limits.
Total Kjeldahl Nitrogen	Matrix Spike 2	QM-17	Matrix spike recovery was outside acceptance limits due to high concentrations of analyte in source sample.	The laboratory blank, LCS, MS 1, and MSD 1 were all within acceptance limits
Total Phosphorus	Water/Cleaner Mixture	R-01	The reporting limit for this analyte has been raised to account for matrix interference.	EPA Method 365.4 is the determination of phosphorus by colorimetry. The color and particulates in this sample may have caused matrix interference.

APPENDIX B: Wastewater Composite Concentrations and Pollutant Loads

Analyte	Site	Composite Number	Water Use per Cleaning Event (L)	Composite Concentration (mg/L)	Qualifier	Total Load for Event (mg)
Aluminum, Dissolved	Site 1	ACS-1B	447.39	5	D	2237
	Site 2	ACS-2B	380.39	186		70753
	Site 2	ACS-2C	380.39	183		69612
	Site 3	ACS-3B	253.60	11.8		2992
Aluminum, Total	Site 1	ACS-1B	447.39	9.07	D	4058
	Site 2	ACS-2B	380.39	189		71894
	Site 2	ACS-2C	380.39	195		74177
	Site 3	ACS-3B	253.60	38.9	J7	9865
Cadmium, Dissolved	Site 1	ACS-1B	447.39	0.0046	J,D	2.1
	Site 2	ACS-2B	380.39	0.00131		0.498
	Site 2	ACS-2C	380.39	0.00126		0.479
	Site 3	ACS-3B	253.60	0.00173		0.439
Cadmium, Total	Site 1	ACS-1B	447.39	0.00761	J,D	3.40
	Site 2	ACS-2B	380.39	0.00172		0.654
	Site 2	ACS-2C	380.39	0.00175		0.666
	Site 3	ACS-3B	253.60	0.00165		0.418
Copper, Dissolved	Site 1	ACS-1B	447.39	1.17	D	523
	Site 2	ACS-2B	380.39	1.76		669
	Site 2	ACS-2C	380.39	1.74		662
	Site 3	ACS-3B	253.60	0.156		39.6
Copper, Total	Site 1	ACS-1B	447.39	1.28	D	573
	Site 2	ACS-2B	380.39	2.42		921
	Site 2	ACS-2C	380.39	2.6		989
	Site 3	ACS-3B	253.60	0.301	J7	76.3
Zinc, Dissolved	Site 1	ACS-1B	447.39	2.43	D	1087
	Site 2	ACS-2B	380.39	18.6		7075
	Site 2	ACS-2C	380.39	18.4		6999
	Site 3	ACS-3B	253.60	10.1	J7	2561
Zinc, Total	Site 1	ACS-1B	447.39	2.78	D	1244
	Site 2	ACS-2B	380.39	23.3		8863
	Site 2	ACS-2C	380.39	23.5		8939
	Site 3	ACS-3B	253.60	11.8	J7	2992
Ammonia as N	Site 1	ACS-1B	447.39	0.93		416

	Site 2	ACS-2B	380.39	2.8	D	1065
	Site 2	ACS-2C	380.39	2.8	D	1065
	Site 3	ACS-3B	253.60	0.62		157
Nitrate/Nitrite as N	Site 1	ACS-1B	447.39	13	D	5816
	Site 2	ACS-2B	380.39	25	D	9510
	Site 2	ACS-2C	380.39	26	D	9890
	Site 3	ACS-3B	253.60	100	D	25360
Total Kjeldahl Nitrogen	Site 1	ACS-1B	447.39	11	D	4921
	Site 2	ACS-2B	380.39	32	D	12173
	Site 2	ACS-2C	380.39	32	D	12173
	Site 3	ACS-3B	253.60	23	D	5833
Total Phosphorus	Site 1	ACS-1B	447.39	0.9	J,D	403
	Site 2	ACS-2B	380.39	5.2	D	1978
	Site 2	ACS-2C	380.39	5.2	D	1978
	Site 3	ACS-3B	253.60	1.7	D	431
Biochemical Oxygen Demand	Site 1	ACS-1B	447.39	460	D	205798
	Site 2	ACS-2B	380.39	580	D	220628
	Site 2	ACS-2C	380.39	590	D	224432
	Site 3	ACS-3B	253.60	130		32967
Methylene Blue Active Substances	Site 1	ACS-1B	447.39	2.1	U	940
	Site 2	ACS-2B	380.39	2.2	J	837
	Site 2	ACS-2C	380.39	2.1	U	799
	Site 3	ACS-3B	253.60	2.1	U	533
Total Suspended Solids	Site 1	ACS-1B	447.39	2.5	U	1118
	Site 2	ACS-2B	380.39	910		346157
	Site 2	ACS-2C	380.39	930		353765
	Site 3	ACS-3B	253.60	440	J7	111582