Pollutant Analysis of HVAC Discharges in Montgomery County, Maryland

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Abstract

In the Chesapeake Bay watershed, a Bay-wide total maximum daily load for nutrients and sediment is driving state and local efforts to account for every pound of pollutant that can be prevented from entering the Bay. Much of the effort focuses on the treatment of uncontrolled stormwater runoff; however, nonstormwater discharges have a significant and quantifiable pollutant load, much of which can be detected and eliminated through the effective implementation of an illicit discharge detection and elimination (IDDE) program. Montgomery County, Maryland, a Phase I municipal separate storm sewer system (MS4) operator, found an unexpected and ubiquitous source of pollution to the MS4 during routine IDDE investigations. The County initiated a special IDDE study on pollutant contributions from heating, ventilation, and air conditioning (HVAC) system discharges. Of the 73 buildings assessed, 27% had a potential HVAC discharge. The study found elevated concentrations of nitrogen and heavy metals, most of them exceeding water quality standards. The sources of contamination were biocide products, illicit cooling tower connections, water from condenser coil washdown, and refrigeration leaks. Given the ability to identify and quantify HVAC discharges, we provide management and research recommendations to eliminate this illicit discharge and improve methods to detect this source through IDDE programs.

Introduction

Medium and large jurisdictions are regulated under National Pollutant Discharge Elimination System via municipal separate storm sewer system (MS4) permits to control dry weather sources of pollution to the storm drain system. The MS4 permit requires the implementation of an illicit discharge detection and elimination (IDDE) program to prohibit, detect, and eliminate dry weather pollution sources. Studies have shown that, for some pollutants, dry weather flows from the storm drain system may contribute a larger annual discharge mass than wet weather stormwater flows (US Environmental Protection Agency [USEPA] 1983; Duke 1997; Pitt and McLean 1986; Lilly et al. 2012). Some illicit discharges, such as sewage discharges, can have a have a significant water quality impact by introducing high nutrient loads and pathogenic bacteria. These small leaks can be overlooked by ineffective and/or inefficiently implemented IDDE programs.

Incentives for implementing *effective* IDDE programs are lacking. For example, the USEPA's Chesapeake Bay Program does not currently have a system to credit local governments for fixing illicit discharges through the local or Chesapeake Bay-wide total maximum daily load (TMDL) process.[1] Local governments face the enormous task of accounting for pollutant load reductions associated with low-impact development practices in highly urban landscapes, despite the potential for substantial benefit—to both the water and the government agency—from investments in nonstormwater discharge elimination in such areas. In addition, when the federal and state regulatory framework lacks the resources or knowledge to guide program efforts, program implementation at the local level is diluted and may be unable to achieve substantial improvements to water quality. This study illustrates that illicit discharges have a measurable pollutant load that one can account for by using the TMDL process.

A literature review revealed limited information regarding pollution contributions from HVAC discharges to surface waters. This research, along with discussions with representatives from other local governments, demonstrated the potential significance of this source as an illicit discharge. For example, water quality samples collected from A/C condensate by the Center for Watershed Protection (2012) were 1.9 to 7.4 mg/L for ammonia using field tests, and total nitrogen concentrations ranged from 3.8 to 7.0 mg/L based on laboratory analysis. M. Raber (water quality specialist, City of Durham, North Carolina, pers. comm., April 26, 2013) reported concentrations of copper in A/C condensate as high as 175 μg/L and concentrations of zinc as high as 350 μg/L in A/C condensate. Multiple localities in the Chesapeake Bay region have also reported contamination from HVAC discharges, including Fairfax County, Virginia (A. Smith

[1] This is currently under review by the Chesapeake Stormwater Network for the Chesapeake Bay Program's Urban Stormwater Workgroup: http://chesapeakestormwater.net/bay-stormwater/baywide-stormwater-policy/urban-stormwater-workgroup/.

Young, code specialist II, Fairfax County, Virginia, pers. comm., May 1, 2013), and Baltimore City, Maryland (M. Schlenoff, pollution control analyst II, City of Baltimore, Maryland, pers. comm., May 8, 2013). The Stormwater Pollution Prevention Department in San Diego traced exceedances of dissolved copper to A/C condensate from large rooftop units. The range of dissolved copper in these samples was between 29 and 3,400 ppb from three different sites (A. Sonsken, biologist, City of San Diego Transportation and Storm Water Department, pers. comm., November 21, 2013). In a water quality analysis of A/C condensate, Kant et al. (2012) found copper concentrations from 0.04 to 1.69 mg/L and zinc concentrations up to 1.19 mg/L[2].

The prevalence of discharges from HVAC units with high levels of nutrients and heavy metals motivated the present study led by Montgomery County, Maryland, the Department of Environmental Protection (DEP) and Center for Watershed Protection (the Center). The objective was to assess potential water quality impacts associated with discharges from this source in the Sligo Creek watershed. The following questions guided this research project:

- What is the extent of nitrogen compounds and heavy metals in HVAC discharges to the storm drain system?
- What is the source of pollutants found in HVAC discharges? Is it the result of a particular HVAC system management practice (e.g., a product additive)?
- What is the estimated pollutant load contribution from this source in the study area?
- What recommendations can be provided to best address this pollution source?

Study Site

Montgomery County, Maryland, encompasses a total area of 507 square miles (1,313 km^2) and lies primarily inside the Piedmont plateau. The project was conducted in the Sligo Creek watershed of the Anacostia River, which drains to the Potomac River and then to the Chesapeake Bay (Figure 1). Sligo Creek is a highly urbanized watershed with a 9.6-square-mile (24-km^2) drainage area in Montgomery County[3]. Land use in the watershed is primarily residential; imperviousness is estimated at 33% (Anacostia Watershed Restoration Partnership 2010). Major

[2] Maryland's water quality standard for zinc is 0.12 mg/L; for copper, it is 0.013 mg/L (acute) and 0.009 mg/L (chronic). Maryland does not have water quality standards for ammonia; however, USEPA recently updated its ammonia water quality standards to 1.9 mg/L for chronic conditions (30-day rolling average) and 17 mg/L for acute conditions (1-hour average).

[3] The remainder of the watershed is in Prince George's County, Maryland and the District of Columbia.

population centers include Wheaton, Silver Spring, and Takoma Park. DEP, which manages surface waters in the County, has a robust watershed management program that includes monitoring, restoration, and stormwater management and protection strategies. As a Phase 1 MS4 jurisdiction, the County regulates illicit discharges through an established IDDE program.

Local and regional TMDLs regulate the quantity of nutrients and other pollutants in the Anacostia watershed to which Sligo Creek drains. The Anacostia watershed is included in a Maryland TMDL for nutrients that requires a 79% reduction in nitrogen[4]. In addition to nutrients, the Anacostia watershed is impaired for bacteria, sediment, polychlorinated biphenyls, and trash.

Materials and Methods

This study used information generated from fieldwork, sample collection and analysis, and interviews to characterize and estimate the potential nutrient load from HVAC discharges. Initially, we limited the investigation to residential, institutional, and commercial buildings with a roof area of at least 20,000 square feet (sq. ft.)—a threshold meant to ensure sufficient visibility of rooftop HVAC units from aerial imagery. During the field assessments, however, discharges were encountered from buildings below this threshold; samples were opportunistically collected from these sites for water characterization.

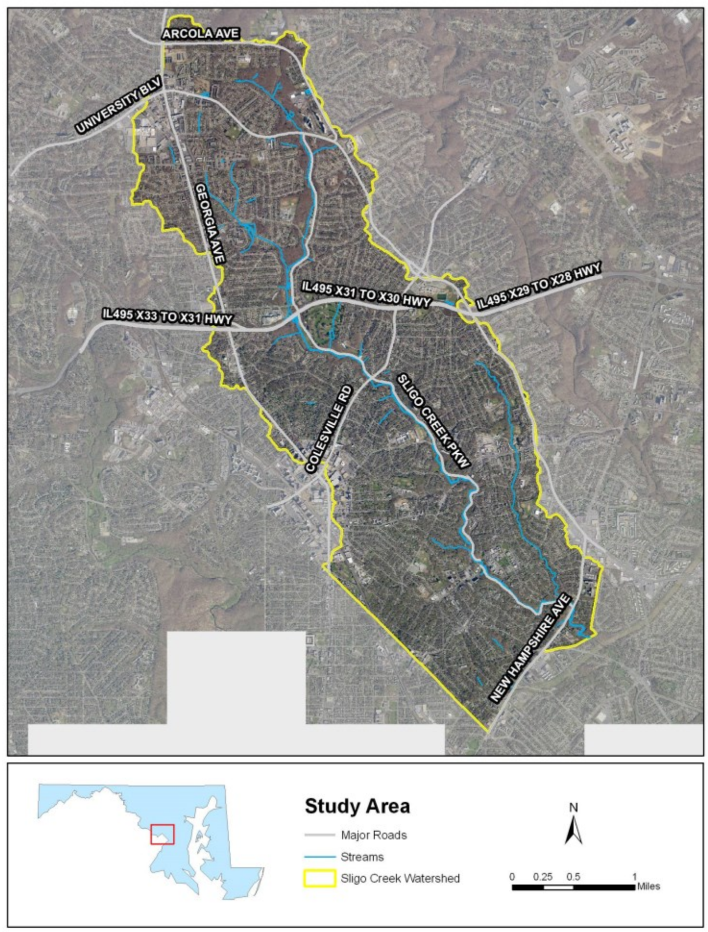

Figure 1. Project study area, Sligo Creek watershed, Maryland. Data from Montgomery County Department of Environmental Protection.

[4] The wasteload allocation (WLA) assigned to the MD non-tidal portion of the watershed is 119,827 lbs TN/yr.

Montgomery County DEP provided a list of 118 buildings in the Sligo Creek watershed with roof areas greater than 20,000 sq. ft. Because of limited field time, field crews sampled 73 of the 118 sites as well as 13 buildings with roof areas less than 20,000 sq. ft. encountered during field work that had a discharge. Two field teams were established and walked the perimeter of each selected building during a street-level inspection to look for rooftop discharges that outlet to the sidewalk, street, or storm drain system. Field crews collected 33 total nitrogen samples, 9 copper and 9 zinc samples for laboratory analysis along with 4 total nitrogen duplicate samples for quality control. Parameters analyzed in the field included ammonia, copper, temperature, and pH (Tables 1 and 2). An action-level threshold[5] in the field was defined as the presence of ammonia (> 0.2 mg/L) and/or the presence of copper (> 0.1 mg/L). These thresholds were based on the County's MS4 permit requirements as well as guidelines established in Brown et al. (2004). The maximum detection limits (MDLs; the maximum amount of pollutant detectable by the instruments used) were 5.0 mg/L for ammonia and 1.0 mg/L for copper (see Table 1 for field parameters). We calculated concentrations exceeding the MDL as a concentration equal to the MDL. We assigned a value of 0.0 mg/L to non-detect amounts.

Lab samples were sent them to the Chesapeake Bay Laboratory, Solomons, Maryland, for analysis of total dissolved nitrogen, copper (dissolved), and zinc (dissolved). Crews collected these copper and zinc samples at every fifth site with a discharge. Each of the two field teams collected duplicate samples of total nitrogen once daily for each of the three field days to determine reproducibility and consistency of the laboratory methods. Field crews took appropriate measures to avoid sample contamination.

Results from a previous study in Sligo Creek (Center for Watershed Protection, 2012) served as a guide for expected water quality parameters to develop the sample size and extrapolate results from this study, watershed-wide for similar building types.

We estimated the pollutant load using flow measurements collected in the field and average sample concentrations. To estimate flow, field crews captured the discharge in a 100-mL

[5] An action-level threshold is a threshold for follow-up investigation.

graduated cylinder and timed the collection using a stopwatch. They repeated this three times at each site with a discharge, using the average as the reported value. If field crews found more than one discharge at a building, they measured flow at each point and summed the points to obtain flow per building. In one case, where multiple flows were inaccessible, we made a flow estimate from one discharge and multiplied by the total number of discharges to obtain a flow estimate for the building.

We estimated total nitrogen, copper, and zinc pollutant loadings using the following equation, with conversion factors:

$$\text{pollutant load (pounds/day)} = [(\text{concentration of pollutant (mg/L)} \times \text{flow (L/s)})/453{,}592] \times 86{,}400$$

This study used the pollutant load estimates to assess the potential water quality impact in Sligo Creek relative to waste load allocations assigned in the Anacostia TMDL for nutrients and biochemical oxygen demand (Maryland Department of the Environment 2008). To determine the initial load, we assumed that the flow from each building was continuous throughout the day for 150 days/year. We used a 150-day "year" as a conservative estimate for the number of days that the air conditioning systems would be in use. However, we report a range of 50%–100% to acknowledge the intermittent flow of HVAC systems throughout the day.

We conducted follow-up interviews with building managers or those familiar with management of the HVAC system with the intention of (1) isolating the source of the discharge within the HVAC system; (2) determining whether the contamination was associated with product usage and therefore could be addressed through a management approach; (3) collecting additional samples directly from rooftop units and, if possible, inspecting the condition and degree of fouling of the condenser coils; and (4) determining trends and correlations between water quality sample results and other qualitative indicators.

Table 1. Sampling information and water quality measurements.

Parameter	Water Quality Analysis Location	Laboratory	Water Quality Measurement Instrument
Total Nitrogen	Laboratory	Chesapeake Bay Lab, Solomons, MD	Refer to Laboratory SOP
Copper[a]	Laboratory	Chesapeake Bay Lab, Solomons, MD	Refer to Laboratory SOP
Zinc[a]	Laboratory	Chesapeake Bay Lab, Solomons, MD	Refer to Laboratory SOP
Copper	Field	N/A	Chemetrics Test Kits
Ammonia	Field	N/A	LaMotte 1200 Colorimeter
Water Temperature	Field	N/A	YSI EcoSense
pH	Field	N/A	YSI EcoSense
Flow	Field	N/A	N/A

Notes: SOP = standard operating procedure.
[a] Collected for every fifth sample.

Table 2. Analytical parameters study samples.

Parameter	Code	Method	Reporting Limit	Maximum Detection Limit	Holding Time
Total Dissolved Nitrogen	TN	USEPA 353.2 [a]	0.1 mg/L	N/A	28 days
Total Dissolved Copper	Cu - lab	USEPA 200.7 [b]	0.3 ppb	N/A	6 months
Total Dissolved Zinc	Zn	USEPA 200.7 [b]	0.4 ppb	N/A	6 months
Total Copper	Cu - kit	American Public Health Association [c]	0.05 mg/L	1.0 mg/L	6 months
Ammonia Nitrogen	NH_4-N	Nessler [d]	0.05 mg/L	5.0 mg/L	Immediately, or 28 days with preservative

[a] USEPA (1993)
[b] USEPA (1994)
[c] APHA (2005)
[d] http://www.lamotte.com/en/industrial/individual-test-kits/3680-01.html

Results and Discussion

Water Quality

Field crews sampled 73 sites with roof areas greater than 20,000 sq. ft. as well as 13 buildings with roof areas less than this threshold. Figure 2 shows all sites by land use type. Of the 73 sampled buildings, 20 (27.4%) had a discharge. Thirty percent of these 20 sites were confirmed or likely to have HVAC sources. All discharges exceeded the ammonia threshold of 0.2 mg/L. The majority (58%) of the ammonia samples exceeded the MDL of the field colorimeter (> 5 mg/L). To estimate these sample concentrations, we diluted four of the samples that exceeded the MDL using a proportion of 1:1 for sample and distilled water; two of these still exceeded the MDL. The Maryland Department of the Environment does not have water quality standards for ammonia; however, USEPA recently updated its ammonia water quality standards to 1.9 mg/L for chronic conditions (30-day rolling average) and 17 mg/L for acute conditions (1-hour average) to protect aquatic life from ammonia toxicity. Two samples also exceeded the copper field test MDL (>1.0 mg/L). Five samples were between 0.2 and 0.8 mg/L, and the remaining were non-detect using the field test kit. All of the laboratory-analyzed samples for metals were approximately ten times greater than the Maryland water quality standards (Figure 3). Maryland's water quality standard for zinc is 0.12 mg/L; for copper, it is 0.013 mg/L (acute) and 0.009 mg/L (chronic) to protect aquatic life from toxicity.

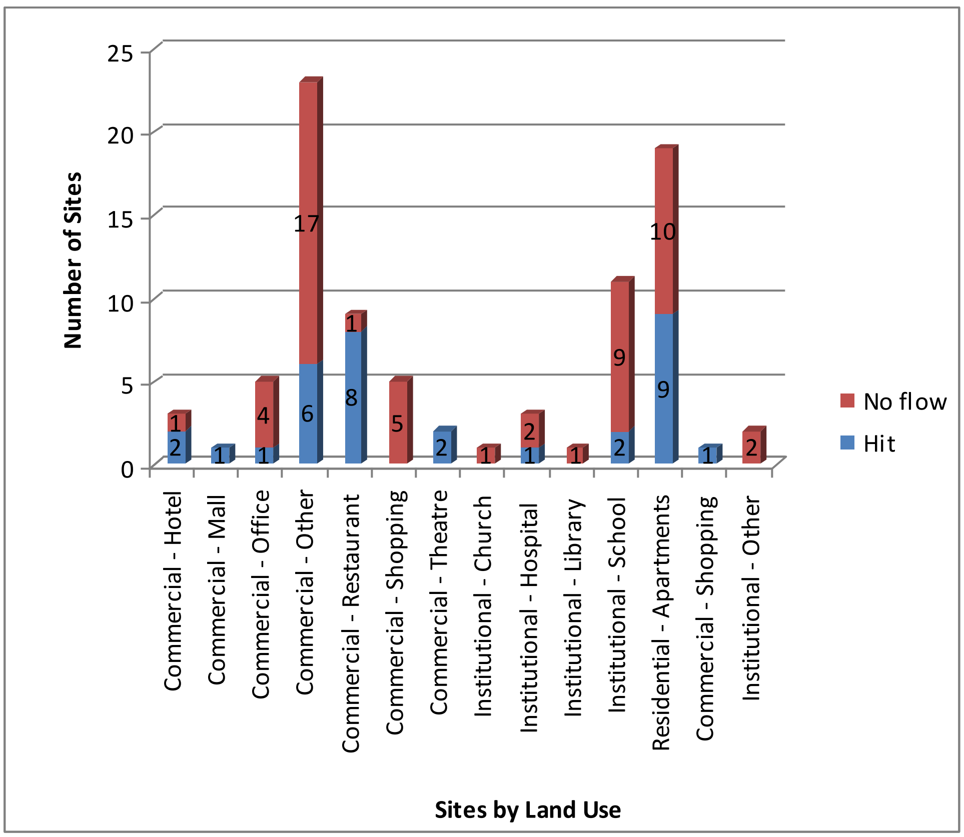

Figure 2. Site visits by land use, indicating the presence or lack of a discharge.

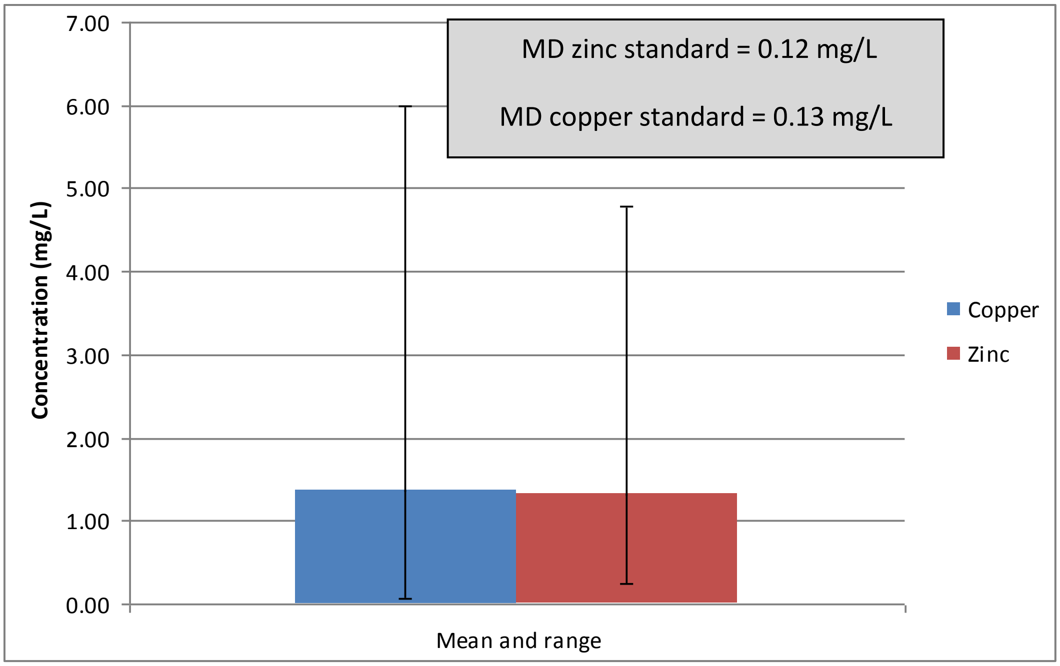

Figure 3. Heavy metal concentrations from HVAC discharges (n = 9).

Water analysis results from the street-level inspections are summarized in Table 3. Mean ammonia concentrations from this study were well above the USEPA chronic water quality standard at 4.17 mg/L, a conservative figure given that that 58% of samples exceeded the MDL for the field instrument. Mean total nitrogen concentrations were 4.56 mg/L. The pH values ranged from 4.7 to 8.7, and temperature ranged from 19.8°C to 37.7°C. Mean metal concentrations were similar to those reported by A. Sonsken (biologist, City of San Diego Transportation and Storm Water Department, pers. comm., November 21, 2013) and Kant et al. (2012). However, the maximum value of copper was 1.7 times greater than that reported by Sonsken, and the maximum value for zinc was 4 times greater than that reported by Kant et al. (2012). Flows were within the range reported by the Alliance for Water Efficiency (n.d.). We excluded from further analysis one high flow found in the field as we determined that it was a sump pump discharge rather than an HVAC discharge.

Table 3. Suspected HVAC discharge water sample analysis results[a].

	Field					Laboratory		
	Ammonia	Copper	Flow	Temperature	pH	Total Nitrogen	Copper	Zinc[c]
	mg/L	ppm	gallons/day	°C		mg/L	mg/L	mg/L
Mean	4.6	0.1	137.1	29.2	6.3	4.6	1.4	1.3
Median	5.0	0.0	57.0	29.5	6.7	4.2	0.3	0.7
Standard Deviation	1.9	0.3	196.4	3.6	0.9	2.3	2.3	1.5
COV[b]	0.4	0.4	1.4	0.1	0.1	0.5	1.7	1.1
Minimum	0.3	0.0	9.7	19.8	4.7	0.8	0.1	0.3
Maximum	10.0	1.0	799.1	37.7	8.7	10.5	6.0	4.8

[a] Number samples (n)=33, except for zinc
[b] COV = Coefficient of Variation
[c] Number samples (n)=9

Pollutant Load

The total flow from all 33 buildings with discharges was 4,523 gallons/day, with a mean flow of approximately 137 gallons/day. We generated annual pollutant load estimates for total nitrogen, copper, and zinc for each building and all buildings combined, assuming that the flow occurred for 150 days/year, either continuously or intermittently (i.e., 50% of the time). Field crews noted during field work that some flows were not encountered on consecutive days in the field, suggesting that some of these discharges may be intermittent rather than continuous discharges. The actual load from buildings with a roof area greater than 20,000 sq. ft. was 23.94 lb/year (Table 4); the load from smaller buildings was 4.08 lb/year. In addition, field investigations indicated that 27% of the discharges drained to landscaped or turf areas, and the remaining 73% drained to impervious surfaces or directly to the storm drain system.

Table 4. Measured pollutant load estimates from all discharges (n = 33).

	50%–100% Annual Load, 150 Days (lb/year)
Total Nitrogen	14.0–28.0
Copper	0.6–1.1
Zinc	0.5–1.0

Note: lb = pounds.

We then estimated the pollutant load from HVAC sources in the study area. We multiplied the original sample number of 118 buildings with a roof area greater than 20,000 sq. ft. by the percentage of sampled buildings with a discharge (27.4%) to equal 32 buildings with a discharge. We multiplied this by the average pollutant load generated from buildings with a roof area greater than 20,000 sq. ft. (0.008 pounds [lb]/day) and, with a 90% confidence interval, computed an annual (150-day) load as 19.3–38.7 lb/year. The lower bound of this range assumes that the discharges are not continuous, flowing only 50% of the time, and the upper bound assumes that the discharges are continuous during the 150-day period. The lower and upper estimates also assume that all of the discharge eventually enters the local waterways. The inclusion of the contribution from smaller buildings (with roof area < 20,000 sq. ft.) would increase the potential contribution from HVAC sources.

Interviews and Rooftop Inspections

We conducted interviews at nine sites. HVAC systems ranged in age from 2 to 55 years old; five of the nine sites had cooling towers. Interviewees generally lacked knowledge as to whether condensate or cooling tower water drained to the storm drain or sanitary system. All interviewees reported that their systems received regular service by an external contractor. Condenser coils were generally cleaned on an annual or semi-annual frequency either by vacuum or high-pressure water jet; interviewees reported that cleaning products, including ammonia-based products, were used in some instances for this process. Annual or semi-annual cleaning of coils may not be sufficient to prevent buildup and therefore high concentrations of ammonia on the coils. We found that biocide products were used in A/C drip pans at several, but not all, sites to control the growth of algae, mold, and fungi and to eliminate odors and pan corrosion. Biocides and ammonia-based cleaners are known toxic contaminants and, if released into the environment, may be detrimental to human health or to aquatic and other organisms, according to Material Safety Data Sheets accompanying these products.

Rooftop inspections confirmed HVAC discharges to the storm drain at two locations. One inspection determined that the discharge was not associated with an HVAC system but was actually tied to a first-floor refrigeration unit at a restaurant. Two other inspections were inconclusive: one was confounded by a green roof (Figure 4), and the other indicated the discharge of cooling tower water to a roof drain at an apartment complex (Figure 5) that may or may not have been associated with the discharge sampled at the street level. Washdown water from the coil cleaning process, cooling tower "bleeding[6]," biocide products, and refrigeration leaks are implicated as likely sources based on these interviews and inspections.

Restaurants were particularly difficult to interview in this study. Refrigerant leaks are regulated by USEPA. Owners or operators of refrigeration and A/C equipment with refrigerant charges greater than 50 lb are required to repair leaks within 30 days when those leaks would result in the loss of more than a certain percentage of the equipment's refrigerant charge over the course of a year. USEPA regulations prohibit the intentional release of all refrigerants during the maintenance, service, repair, or disposal of A/C and refrigeration equipment. If a refrigerant leak is suspected, a self-audit can be conducted (see USEPA's self-audit checklist: http://www.epa.gov/ozone/title6/608/compguid/SelfAuditChecklist.pdf).

Figure 4. Sample point and discharge on street (left) and green roof and HVAC discharge point on roof of the same building (right).

[6] The water that is drained from cooling equipment to remove mineral build-up is called "blow-down" water or "bleed" water.

Figure 5. Sample point (left) and cooling tower discharge to roof drain of the same building (right). The roof drains are probably connected to the MS4 underground.

We contacted the Maryland Department of the Environment's Western Maryland Regional Office, USEPA's Office of Water, and USEPA's Office of Pesticides regarding the results of this study. The Office of Water responded with a statement indicating that uncontaminated condensate from A/C units is a permitted discharge to the MS4, but the permittee is responsible for determining whether the discharge is contaminated (K. Bendick, NPDES Permitting, USEPA, pers. comm., November 6, 2013). USEPA's Industrial Stormwater staff noted that certain nonstormwater discharges are "exempt" only as a permitting courtesy and that it is incumbent on MS4 operators to make sure that these are not in violation; this would most likely be determined through water quality testing (B. Rittenhouse, Industrial Stormwater Program, USEPA, pers. comm., November 25, 2013).

Conclusions and Recommendations

The results of this study suggest that HVAC discharges contain elevated levels of nutrients and heavy metals and can be an illicit discharge contributing to surface waters. The source of contamination appears to be biocide products, illicit cooling tower connections, water from condenser coil washdown, and refrigeration leaks. In this study, 27.4% of sites visited had a discharge that was contaminated with ammonia and heavy metals; 30% of these sites were confirmed or likely HVAC sources. However, the results suggest that contaminated HVAC discharges may be more prevalent when smaller buildings are taken into consideration (i.e., those with roof area < 20,000 sq. ft). This source of pollution has a measurable pollutant load originally detected through dry weather water quality screening. The detection points to the importance of IDDE programs for finding and eliminating point sources of pollution such as these.

Although the pollutant load contribution from this source was relatively small at 19.3–38.7 lb/year for the study area, the actual load may be greater when considering loads from smaller buildings as well as from buildings with discharges piped underground directly into the MS4 system. Elimination of these pollutant problems represents real source reduction and, when jurisdictions are looking for more tools and best management practices to cost-effectively achieve load reduction targets, point source elimination is highly viable. USEPA Chesapeake Bay Program is currently evaluating whether to allow nonstormwater discharge elimination as a creditable strategy for meeting Chesapeake Bay pollutant reduction targets; this could provide an incentive for jurisdictions to find and eliminate problems such as these.

Because of the common use of biocides and ammonia-based cleaners in HVAC systems, the uncertainty as to where rooftop HVAC system components drain, and the probable frequent use of copper piping in HVAC systems, we recommend that property owners prevent the release into the environment of condensate or any water discharged from HVAC systems, particularly where biocide products are used in drip pans or toxic cleaners are used on condenser coils. Where possible and allowed by wastewater treatment system operators, this water can be directed to the sanitary system instead of the environment and the storm drain system.

If piping the discharges to the sanitary system or reusing them for internal or external building needs is not possible, HVAC cleaning and microbial product usage should be minimized as much as possible and, where feasible, condensate should be discharged to landscaped areas. If the water is to be used for surface irrigation, it should first be treated for bacteria so that human contact with potential pathogens is limited. Condensate can also be reused in cooling towers according to the Alliance for Water Efficiency (n.d.), particularly on nonresidential sites.

General maintenance practice suggests that property owners and managers should be encouraged to regularly clean condenser coils and condensate drip pans using vacuum methods or with soapy water unless significant buildup of scale, or other materials has occurred. Coil cleaning should be performed with a frequency sufficient to prevent deterioration of the coils. This can be as often four times a year but may be as often as monthly if air quality is poor, as it frequently is during the summer months within the study area. If the coil is contaminated with a light dust or dirt not adhered to the fins, blowing low-pressure compressed air across the fins or the use of a soft bristle brush may be sufficient. One could apply a plain water or mild detergent solution to the surface, allowing it to sit for a short time before rinsing.

Additional work is needed to define an "HVAC fingerprint" to aid illicit discharge investigations. The following characteristics provide a starting point.

- Ammonia concentration greater than 4.0 mg/L, the average ammonia concentration from this study.
- Copper concentrations greater than 0.2 mg/L. Copper field test kits may not be sufficient for copper detection so samples may require laboratory analysis.
- An absence of detergents. Although this study did not analyze detergents, we would not expect detergents to be present in condensate as it would be in sewage. This should be confirmed in future studies on this topic.

We recommend follow-up sampling at sites where biocide application is eliminated to see if condensate water quality improves. Although refrigerant leaks may be a significant component, this study did not specifically assess this source. We recommend additional research on the role of refrigerant leaks, atmospheric deposition, and pollutant contributions from small buildings, particularly restaurants.

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