Minneapolis Health Department

Air Quality in Minneapolis: A Neighborhood Approach

Report

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Abstract

The *Air Quality in Minneapolis: A Neighborhood Approach* study expands on the *Minneapolis Air Quality Study* published in 2007 to provide a more extensive look at air quality in Minneapolis. The *Minneapolis Air Quality Study* published in 2007 used 3M™ organic vapor monitors and sampled quarterly. The study found two volatile organic compounds (VOCs) above inhalation benchmarks, benzene and tetrachloroethylene. Prior to this study, information on VOC concentrations in Minneapolis was only available from the three Minnesota Pollution Control Agency (MPCA) VOC air monitoring sites in Minneapolis. These sites are used to determine whether Minnesota meets federal and state air quality standards and health benchmarks. The intent of the *Air Quality in Minneapolis: A Neighborhood Approach* study is to evaluate air quality on a more local scale than the MPCA monitoring data, where people live, work and play. The *Air Quality in Minneapolis: A Neighborhood Approach* study used the EPA TO-15 sampling method. Sampling was conducted quarterly between 2013 and 2015. During each of the eight sampling events, approximately 120 Summa canisters were placed throughout the City. Each canister was sent to Pace Analytical Services, Inc. for analysis of 61 VOCs. Additionally, during seven of the sampling events, approximately 20 SKM UMEx 100 passive sampling devices were placed to analyze formaldehyde by OSHA method 1007. The results were compared to chronic health benchmarks for inhalation of chemicals in ambient air. Of the 62 VOCs analyzed in the study, five were selected for detailed consideration in this report due to their results over the Minnesota Department of Health (MDH) defined health benchmark. There were 78 benzene results detected over the lower end of its health benchmark of 1.3 – 4.5 $\mu g/m^3$, with a high value of 50.3 $\mu g/m^3$. There were 8 naphthalene results found over its health benchmark of 9 $\mu g/m^3$, with a high value of 127 $\mu g/m^3$. There were 100 tetrachloroethylene results found over its health benchmark of 2 $\mu g/m^3$, with a high value of 1150 $\mu g/m^3$. There were 14 trichloroethylene results found over its health benchmark of 2 $\mu g/m^3$, with a high value of 79.8 $\mu g/m^3$. There were 93 formaldehyde results found over its health benchmark of 2 $\mu g/m^3$, with a high value of 8.5 2 $\mu g/m^3$.

Introduction and Background

General Air Quality

The *Air Quality in Minneapolis: A Neighborhood Approach* study was conducted to determine what volatile organic compounds (VOCs) residents of Minneapolis are exposed to where they live, work, and play. The residents of Minneapolis value a clean and healthy environment. In a citywide resident survey, 81% of residents indicated “protecting the environment, including air, water, and land” was either “very important” or “extremely important” in terms of city priorities (City of Minneapolis, 2013). Clean air is a staple expectation of having a clean environment. For that reason this study closely examines the quality of the air we breathe, the potential health hazards of air pollution, affected populations, and actions that can be taken to reduce harmful pollutants.

According to the Minnesota Pollution Control Agency, in general, air quality in the Twin Cities region is good and has been improving for most pollutants over the last couple decades. The improvements are largely due to significantly lower emissions from major industrial facilities and more efficient cars due to enforcement of the Clean Air Act, as well as voluntary reductions implemented at some facilities. However, this is a general trend in air quality and these results are based on averages for the entire Metro region or for large subsets of the Metro region. This trend does not necessarily represent every location in the Metro, including the neighborhoods of Minneapolis. When the air quality data are examined more closely, there are potential areas of concern as well as potential chemicals of concern.

In the past few decades, our understanding of the science and the health effects of poor air quality have also improved. Standards have become stricter to meet our better understanding of air quality and its effects on health. Therefore, while the emissions and air concentrations of traditional air pollutants have decreased, the stricter standards have resulted in more poor air quality days. Poor air quality days in the Twin Cities Metro are often due to high levels of ground-level ozone. As air quality standards continue to lower, we are seeing the potential for the Twin Cities area to fall into non-attainment for certain standards, such as ground-level ozone.

Ground-Level Ozone

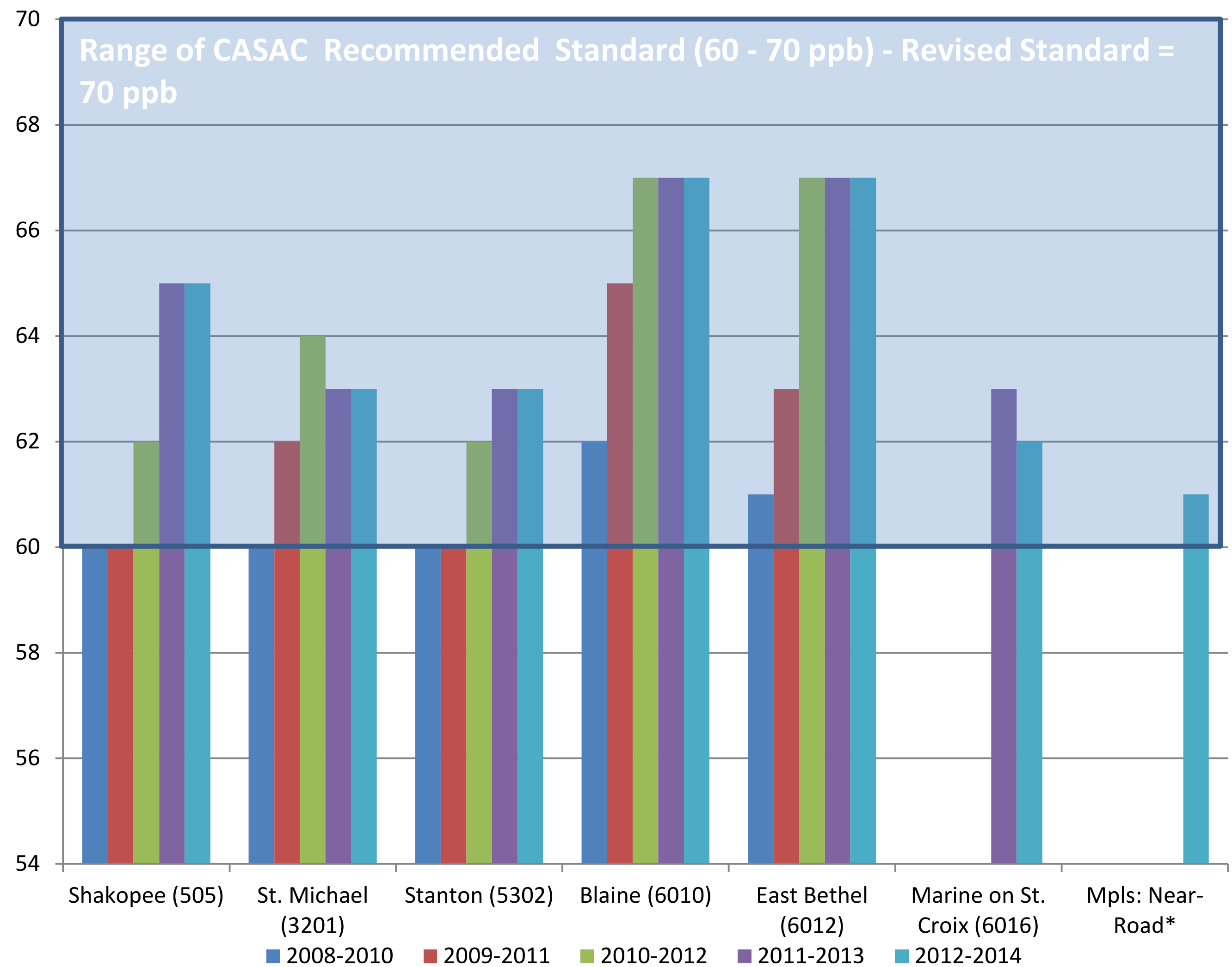
Substances that are emitted directly from sources are called primary pollutants. Pollutants that are created through chemical reactions among the primary pollutants in the atmosphere are called secondary pollutants. Ground-level ozone is a secondary pollutant. As secondary pollutants are due to specific chemical reactions involving primary pollutants, controlling secondary pollutants, such as ground-level ozone, are directly related to controlling the levels of primary pollutants emitted.

Ground-level ozone is a primary component of smog. Ground-level ozone is not emitted directly, but is created in the air on hot, sunny days by a chemical reaction between VOCs and nitrogen oxides (NOx). The amount of VOCs and NOx in the air, as well as weather conditions such as temperature, sunlight, and wind will all affect the levels of ground-level ozone. This section focuses on the relationship of VOCs to ground level ozone while VOCs are further explained in detail in the sections below.

High temperatures and sunny days increase ozone formation and with rising temperatures due to climate change, the risk of ozone exposure increases. Ground-level ozone is a concern to human health. Repeated exposure can make people more susceptible to respiratory infections and lung inflammation and it also can aggravate pre-existing respiratory diseases, such as asthma. Ozone destroys living tissue and is damaging to vegetation and the urban canopy.

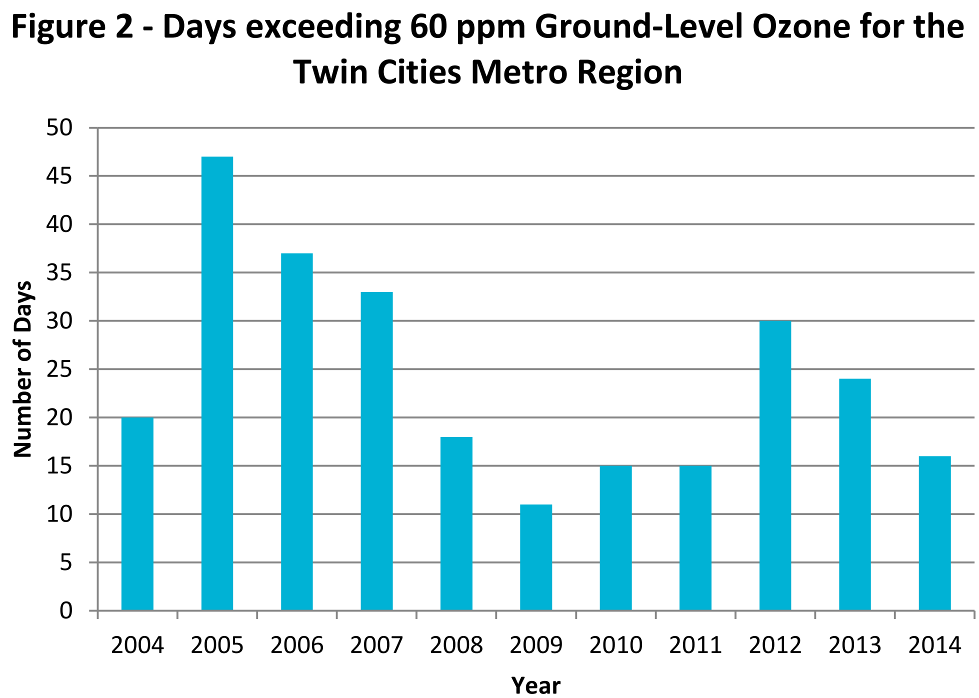
In October 2015, the U.S. Environmental Protection Agency (EPA) revised the primary and secondary national ambient air quality standards (NAAQS) for ground-level ozone in order to provide greater protection of public health and welfare (EPA, 2015). The EPA strengthened the levels of both standards from 75 ppb, set in 2008, to 70 ppb. Figure 1 shows the 3-year averages of the annual 4th-highest daily maximum 8-hour ground-level ozone concentration (known as the design value) for the five most recent 3-year calculations. To meet the standard, this value must be less than or equal to the level of the standard (70 ppb) (EPA, 2015). Figure 1 shows the design value for some monitoring stations in the Metro region approaching 70 ppb.

Figure 1 - Ground-Level Ozone Levels for the Twin Cities Metro Region



In addition to falling into non-attainment under the stricter standards, there are other areas of concern. Figure 1 also shows almost all design values at or above the 60 ppb, which is the lowest end of the recommended revised level by the Clean Air Scientific Advisory Committee (CASAC) of the EPA. 60 ppb is the level at which the EPA notes adverse health effects can occur, with more studies needed to support lowering the standard to that level

(EPA, 2015). In 2012, the Minnesota Pollution Control Agency reported that 30 days (Figure 2) exceeded 60 ppb for ground-level ozone.



2012 was the year with the most days over this level since 2007. This human-health based standard of the CASAC is not a regulatory standard, but a level at which human health may be impacted. Thus, it is important to the Minneapolis Health Department to continue to look at our ground-level ozone levels in relation to the most conservative health level in an effort to protect our most vulnerable populations. While the number of days exceeding 60 ppb has been lower in the years since 2012, with rising temperatures due to climate change the number of high ground-level ozone days is expected to increase.

Volatile Organic Compounds

VOCs are a large group of carbon-based chemicals that easily evaporate at room temperature. While most people can smell high levels of some VOCs, other VOCs have no odor. Odor does not indicate the level of risk from inhalation of VOCs. These compounds are of concern because they are both direct pollutants, with associated health risks, and indirect pollutants that lead to the formation of ground level ozone which has its own associated health effects.

In addition to contributing to ozone formation, each VOC has its own associated toxicity and health risks. As VOCs refer to a group of chemicals, each individual VOC has its own toxicity and potential for causing different health effects. The risk of health effects from inhaling any chemical depends on the concentration of the chemical in the air and how long the person breathing it is exposed to it. Exposures can be short-term (acute) lasting only hours or days. They can also be long-term (chronic) where a person may be exposed to a chemical for years to even lifetime. Breathing low levels of VOCs for long periods of time may increase some people's risk of health problems.

There are thousands of different VOCs produced and used in our daily lives. In Minneapolis, VOCs are emitted from commercial sources such as gasoline stations, printing shops, and auto body and maintenance shops. They are also emitted from non-commercial sources such as motor vehicles, house painting, gasoline-powered lawn and garden equipment, and common household cleaners and solvents. Examples of common VOCs in Minneapolis are benzene and formaldehyde, which are both automobile tailpipe emissions. NOx is produced when cars and other sources burn fuels such as gasoline, coal, or oil. In general, levels of VOC are higher indoors than out.

Volatile Organic Compounds Detailed in this Report

Of the 62 VOCs analyzed in the study, five were selected for detailed consideration in this report due to their results over the Minnesota Department of Health (MDH) defined health benchmark. There were 78 benzene results detected over the lower end of its health benchmark of 1.3 – 4.5 µg/m^3, with a high value of 50.3 µg/m^3. There were 8 naphthalene results found over its health benchmark of 9 µg/m^3, with a high value of 127 µg/m^3. There were 100 tetrachloroethylene results found over its health benchmark of 2 µg/m^3, with a high value of 1150 µg/m^3. There were 14 trichloroethylene results found over its health benchmark of 2 µg/m^3, with a high value of 79.8 µg/m^3. There were 93 formaldehyde results found over its health benchmark of 2 µg/m^3, with a high value of 8.5 2 µg/m^3.

Benzene

Benzene is a colorless liquid with a sweet odor that evaporates into air very quickly. Benzene comes from both industrial and natural sources. It is found in the air due to emissions from burning coal and oil, gasoline service stations, and motor vehicle exhaust. Benzene is made primarily from petroleum and has a wide range of uses, making it one of the top 20 produced chemicals in the United States. Benzene occurs naturally in emissions from volcanoes and forest fires and is also present in crude oil, gasoline, and cigarette smoke.

Exposure to benzene in the air primarily comes from tobacco smoke, evaporation from gas stations, motor vehicle exhaust, industrial emissions, and industrial solvents. Gasoline and cigarette smoke are two main sources of human exposure to benzene and exposure can be reduced by limiting contact with these sources. Approximately 50% of the exposure to benzene in the U.S. is from tobacco smoke while 20% is from motor vehicle exhaust and industrial sources. Additional sources of benzene include vapors from common household products, such as glues, paints, and detergents.

People living in cities or industrial areas are generally exposed to higher levels of benzene in the air than those living in rural areas. Within cities, exposure is highest in areas of heavy traffic, near gas stations, and inside homes. Benzene levels in the home are usually higher than outdoor levels. Families are urged not to smoke indoors because smoking indoors causes the majority of high, indoor benzene levels. Increased incidences of leukemia have been observed in humans occupationally exposed to benzene and the EPA has classified benzene as a known human carcinogen for all routes of exposure.

The sources of information for this benzene summary are the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Benzene (ATSDR, 2007) and EPA's Integrated Risk Information System (IRIS) (EPA, 2009).

Naphthalene

Naphthalene is a white solid that evaporates easily and is naturally occurring in fossil fuels, such as petroleum and coal. The major commercial use of naphthalene is the production of chemicals that are used in the production of polyvinyl chloride (PVC) plastics. There are consumer products made from naphthalene, such as moth repellents (mothballs or crystals) and toilet deodorant blocks. Burning fossil fuels, wood, and tobacco produces naphthalene. The majority of naphthalene in the environment is from the burning of firewood and fossil fuels in the home and the second greatest release is through the use of moth repellents.

Exposure to naphthalene is associated with hemolytic anemia, damage to the liver, neurological damage (in infants), cataracts, and retinal hemorrhage. The EPA has classified naphthalene as a possible human carcinogen; available data are inadequate to determine that naphthalene causes cancer in humans.

The sources of information for this naphthalene summary are the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Naphthalene (ATSDR, 1995) the EPA's Toxicological Review of Naphthalene (EPA, 1998).

Tetrachloroethylene

Tetrachloroethylene is a nonflammable colorless liquid that is known as perchloroethylene, PCE, PERC, tetrachloroethene, and perchlor. It is commonly used as a dry cleaning agent and a metal degreasing solvent. Much of the tetrachloroethylene released into the air comes from the dry cleaning industry. Once released to the air, tetrachloroethylene is slow to degrade and is subject to long-range transport. Outdoors, the high volatility of tetrachloroethylene leads to increased ambient air concentrations near points of use.

Tetrachloroethylene is common in household products and is wildly used as a scouring solvent that removes oils from fabrics, as a carrier solvent, as a fabric finisher or water repellant, and as a metal degreaser/cleaner. It is recommended that items containing tetrachloroethylene be stored in a shed or outside location to reduce exposure in indoor air. Over the past couple of decades, levels of tetrachloroethylene in the ambient air and in occupational settings such as dry cleaning facilities have declined due to reductions in the use of tetrachloroethylene.

The major effects of chronic inhalation exposure to tetrachloroethylene are neurological and exposure may result in changes in mood, memory, attention, reaction time, or vision. Tetrachloroethylene exposure may also cause adverse effects in the kidney, liver, immune system and hematologic system, and on development and reproduction. Chronic exposure to tetrachloroethylene may lead to a higher risk of developing cancer, but the type of cancer that may occur is not well-understood. While the evidence is not strong, some studies in humans exposed in the workplace suggest that exposure may lead to a higher risk of bladder cancer, multiple myeloma, or non-Hodgkin’s lymphoma. In animal studies, tetrachloroethylene has been shown to cause cancers of the liver, kidneys, and blood systems. As a result of this limited evidence, the EPA has classified tetrachloroethylene as likely to be carcinogenic to humans.

The sources of information for this tetrachloroethylene summary are the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Tetrachloroethylene (ATSDR, 1997a) and the EPA's Integrated Risk Information System (IRIS) (EPA, 2012).

Trichloroethylene

Trichloroethylene is a colorless, nonflammable liquid with a sweet odor that evaporates quickly into the air. The main use of trichloroethylene is as a solvent to remove grease from metal parts. Most of the trichloroethylene that is released into the atmosphere is from industrial degreasing operations. Trichloroethylene is also used to make other chemicals. It has also been used as an extraction solvent for greases, oils, fats, waxes, and tars and in dry cleaning operations. It can be found in consumer products such as typewriter correction fluids, paint removers/strippers, adhesives, spot removers, and rug-cleaning fluids.

In air, trichloroethylene breaks down quickly. Tetrachloroethylene can also biodegrade to trichloroethylene and people may be exposed to this degradation product, which is often found as a contaminant in products with tetrachloroethylene.

Central nervous system effects are the primary effects of acute inhalation exposure to trichloroethylene in humans, with symptoms including sleepiness, fatigue, headache, and confusion. The EPA classifies trichloroethylene as a known human carcinogen by all routes of exposure (EPA, 2011).

The sources of information for this trichloroethylene summary are the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Trichloroethylene (ATSDR, 1997b) and the EPA's Health Assessment Document for Trichloroethylene (EPA, 1985).

Formaldehyde

Formaldehyde is a colorless, flammable gas with a pungent odor. Formaldehyde occurs from both natural and man-made sources and combustion is the largest source. One of the most common uses of formaldehyde in the U.S. is manufacturing urea-formaldehyde resins, used in particleboard products. Automobile exhaust from cars without catalytic converters or those using oxygenated gasoline contain formaldehyde and as a result there are higher levels of formaldehyde in areas of heavy traffic.

Formaldehyde levels are also typically higher indoors than outdoors due to its release from many home products such as latex paint, fingernail hardener, fingernail polish, household cleaners, carpet cleaners, disinfectants, cosmetics, medicines, dish-washing liquids, shoe-care agents, fabric softeners, glues, adhesives, lacquers, paper, plastics, and antiseptics. It also off-gasses from furniture and cabinets made from plywood and particle board, fiberglass products, new carpets, laminates, and some fabrics. Formaldehyde is also produced by tobacco products, gas cookers, and open fireplaces.

Inhalation exposure to formaldehyde can result in respiratory symptoms; eye, nose, and throat irritation. ATSDR lists formaldehyde as a known human carcinogen; EPA is in the process of updating its IRIS assessment of formaldehyde.

The sources of information for this formaldehyde summary are the Agency for Toxic Substances and Disease Registry's (ATSDR's) Toxicological Profile for Formaldehyde (ATSDR, 1999) and the EPA's Health and Environmental Effects Profile for Formaldehyde (EPA, 1988) and the Integrated Risk Information System (IRIS) (EPA, 1999a).

Minnesota Pollution Control Air Monitoring

The Minnesota Pollution Control Agency (MPCA) monitors outdoor air quality throughout Minnesota. The purpose of the MPCA air monitoring is to help determine major sources of ambient air pollution, whether the MPCA is protecting the public from harmful health effects, ways to reduce pollution levels, and to track concentrations of pollutants over time (MPCA, 2016a). The MPCA monitoring data are also used to determine compliance with the National Ambient Air Quality Standards (NAAQS) and the Minnesota Ambient Air Quality Standards (MAAQS). Since it is not possible for the MPCA to monitor everywhere in the state, their goal is to determine representative concentrations and exposure in areas of high population density (MPCA, 2016a). There are seven MPCA monitoring sites in Minneapolis (Figure 3).

It is important to understand the difference between the *Air Quality in Minneapolis: A Neighborhood Approach* study and Minnesota Pollution Control Agency (MPCA) air monitoring. They are significantly different forms of evaluating air quality and cannot be directly compared. MPCA air monitoring examines regional air quality on a continuous basis while the *Air Quality in Minneapolis: A Neighborhood Approach* study measured specific pollutants on a local neighborhood level at single points in time.

Figure 3 - MPCA Monitoring Sites in Minneapolis

The MPCA monitoring sites in Minneapolis monitor for total suspended particulate (TSP), metals, particulate matter (PM 10), fine particles (PM 2.5), fine particles (PM 2.5) – speciation, meteorological data, carbonyls, volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_X), sulfur dioxide (SO_X), and ozone (O_3). Table 1 details which pollutant is monitored at each site.

Table 1 - MPCA Monitoring Sites and Pollutants Measured

Site Name	MPCA Site Id	TSP	Metals	PM 10	PM 2.5	PM2.5 Spc.	Met Data	Carbonyls	VOCs	CO	NOx	SOx	O3
Pacific Street	910	x	x	x									
Near-Road Minneapolis	962	x	x		x		x	x	x	x	x		x
Lowry Ave	909	x	x	x			x	x	x				
Humboldt Ave	907	x	x					x	x				
HC Anderson School	963	x	x		x	x		x	x				
City of Lakes	966	x	x	x				x	x				
Arts Center	954									x		x	

The 2007 Minneapolis Air Quality Study

In 2007, the *Minneapolis Air Quality Study* was conducted in order to examine air quality across the entire city in each season. It was a small study with samples collected in May 2005, August 2005, October 2005, and January 2006. Samples were collected using 3M™ organic vapor monitors (OVMs) and were analyzed for 31 VOCs. The results showed that all but two of the VOCs were well below their health benchmarks. The two VOCs that exceeded their health benchmarks were benzene and tetrachloroethylene. Future study was recommended that would include formaldehyde, more sampling sets, and sampling at hot spots.

Methods

Study Summary

The methods for the *Air Quality in Minneapolis: A Neighborhood Approach* study were modeled after the *Minneapolis Air Quality Study* published in 2007 with the goal of taking a more extensive look at air quality in Minneapolis. The mission was similar: to utilize a cost-effective way to evaluate air quality where people live, work, and play. VOCs were chosen as the group of air pollutants to analyze due to their contribution to the formation of ground-level ozone as well as the concern over health effects associated with each VOC individually. An additional reason for the selection of VOCs is that the Minneapolis Health Department has a Green Business Cost Sharing Program which is a one-third (City) to two-third (business) monetary match to support businesses in reducing pollution, in particular VOCs. The program can specifically target pollutants discovered from this study and reduce the release of those chemicals into the air in Minneapolis.

Sample Collection – Summa Canisters and TO-15

The *Air Quality in Minneapolis: A Neighborhood Approach* study (herein referred to as "the study") used an air sampling method known as EPA TO-15 and analyzed 61 VOCs (62 including formaldehyde, which used a different sampling method). In contrast, The *Minneapolis Air Quality Study* published in 2007 used 3M™ Organic Vapor Monitors and analyzed 31 VOCs. TO-15 is a more accurate sampling method. TO-15 a performance-based method prepared by the United States Environmental Protection Agency (EPA) as a guidance document for monitoring subsets of the 97 VOCs that are included in the 189 hazardous air pollutants (HAPs) in Title III of the Clean Air Act Amendments of 1990 (EPA, 1999b).

Samples were collected using passivated stainless steel (Summa) sampling canisters (Figure 4). Summa canisters are a spherical container constructed of stainless steel whose interior surface has been rendered inactive to most organic compounds through a rigorous chemical cleaning and electropolishing process (Summa process). We used 1-liter canisters with air-flow controllers containing 72-hour restrictors. The top of the air-flow controller was outfitted with a cane that helped prevent moisture from entering the canister during precipitation. The Summa canisters were prepared and the samples analyzed by Pace Analytical Services, Inc. Each sample was analyzed for 61 VOCs (Table 2). Explanation of the health benchmarks is later in this section.

Figure 4 - Summa Canister at Sampling Location

Table 2 - Volatile Organic Compound Analyte List with Health Benchmarks

Analyte	CAS	Health Benchmark (µg/m^3)	Health Benchmark Source
1,1,1-Trichloroethane	71-55-6	5,000	EPA IRIS RfC
1,1,2,2-Tetrachloroethane	79-34-5	7,000	CDC REL
1,1,2-Trichloroethane	79-00-5	0.6	EPA IRIS
1,1,2-Trichlorotrifluoroethane	76-13-1	7,600,000	CDC REL
1,1-Dichloroethane	75-34-3	400,000	CDC REL
1,1-Dichloroethene	75-35-4	200	EPA IRIS RfC
1,2,4-Trichlorobenzene	120-82-1	2	EPA PPRTV p-RfC
1,2,4-Trimethylbenzene	95-63-6	7	EPA PPRTV p-RfC
1,2-Dibromoethane (EDB)	106-93-4	0.05	MDH HRV
1,2-Dichlorobenzene	95-50-1	300,000	CDC REL
1,2-Dichloroethane	107-06-2	0.4	EPA IRIS
1,2-Dichloropropane	78-87-5	4	EPA IRIS RfC
1,3,5-Trimethylbenzene	108-67-8	125,000	CDC REL
1,3-Butadiene	106-99-0	0.2	MDH HRV
1,3-Dichlorobenzene	541-73-1	Not Available	
1,4-Dichlorobenzene	106-46-7	800	EPA IRIS RfC
2-Butanone (MEK)	78-93-3	5,000	EPA IRIS RfC
2-Hexanone	591-78-6	30	EPA IRIS RfC
2-Propanol	67-63-0	980,000	CDC REL
4-Ethyltoluene	622-96-8	Not Available	
4-Methyl-2-pentanone (MIBK)	108-10-1	205,000	CDC REL
Acetone	67-64-1	30	ATSDR MRL
Benzene	71-43-2	1.3	MDH HRV
Benzyl chloride	100-44-7	1	EPA PPRTV p-RfC
Bromodichloromethane	75-27-4	Not Available	
Bromoform	75-25-2	9	EPA IRIS
Bromomethane	74-83-9	5	MDH HRV
Carbon disulfide	75-15-0	700	MDH HRV
Carbon tetrachloride	56-23-5	1.7	EPA IRIS
Chlorobenzene	108-90-7	1,000	CalEPA REL
Chloroethane	75-00-3	10,000	EPA IRIS RfC
Chloroform	67-66-3	0.4	EPA IRIS
Chloromethane	74-87-3	90	EPA IRIS RfC
cis-1,2-Dichloroethene	156-59-2	Not Available	
cis-1,3-Dichloropropene	10061-01-5	Not Available	
Cyclohexane	110-82-7	6,000	EPA IRIS RfC
Dibromochloromethane	124-48-1	Not Available	
Dichlorodifluoromethane	75-71-8	4,950,000	CDC REL

Dichlorotetrafluoroethane	76-14-2	7,000,000	CDC REL
Ethanol	64-17-5	1,900,000	CDC REL
Ethyl acetate	141-78-6	1,400,000	CDC REL
Ethylbenzene	100-41-4	1,000	EPA IRIS RfC
Formaldehyde	50-00-0	2	MDH RAA
Hexachloro-1,3-butadiene	87-68-3	0.5	EPA IRIS
m&p-Xylene	179601-23-1	Not Available	
Methylene Chloride	75-09-2	20	MDH HRV
Methyl-tert-butyl ether	1634-04-4	3,000	EPA IRIS RfC
Naphthalene	91-20-3	9	MDH HRV
n-Heptane	142-82-5	350,000	CDC REL
n-Hexane	110-54-3	2,000	MDH HRV
o-Xylene	95-47-6	100	CDC IRIS RfC
Propylene	115-07-1	3,000	CalEPA REL
Styrene	100-42-5	1,000	MDH HRV
Tetrachloroethene	127-18-4	2	MDH RAA
Tetrahydrofuran	109-99-9	2,000	EPA IRIS RfC
Toluene	108-88-3	400	MDH HRV
trans-1,2-Dichloroethene	156-60-5	Not Available	
trans-1,3-Dichloropropene	10061-02-6	Not Available	
Trichloroethene	79-01-6	2	MDH RAA
Trichlorofluoromethane	75-69-4	5,600,000	CDC REL
Vinyl acetate	108-05-4	200	MDH HRV
Vinyl chloride	75-01-4	1	MDH HRV

Air samples were collected during eight sampling events, one each in November 2013, February 2014, May 2014, August 2014, November 2014, February 2015, May 2015, and August 2015. Between 100 and 130 samples were collected during each sampling event, for a total of 900 air samples collected during this study. During each sampling event all canisters were opened at approximately 5:00 pm on the first day of sampling and closed at approximately 5:00 pm three days later, to collect the sample over 72 hours. Once a Summa canister was opened, it would slowly draw in air over the 72-hour collection period. At the end of 72 hours, the canister would fill completely, to atmospheric pressure, and stop drawing in air.

Information about date, time opened, time closed, sample number were collected by the volunteer, as mentioned below, or staff member responsible for the canister. The majority of canisters were either dropped off at the City of Minneapolis the following morning or at Pace Analytical Services, Inc. receiving lab. All canisters were returned within the appropriate sampling timeline for analysis as set by Pace Analytical Services, Inc.

Sample Locations

Because our work unit does not have the capacity to place and open over 100 canisters at the same time, we employed the use of volunteers. Throughout the study, we had 130 volunteers who took canisters and placed them on their property. Each volunteer received training in operating the canister and was asked to pick up their canister prior to the beginning of the sampling event and return it upon completion. The volunteers all recorded the time their canister was opened and closed as well as any emissions or odors they noted near their home during the sampling time. We asked that volunteers place their canisters with the opening to the air-flow controller as close to breathing height as possible (such as on a chair or table). More than half (approximately 56%) of the total samples were collected at residential locations.

The remaining canisters were placed by employees of the Minneapolis Health Department Environmental Services unit. Approximately 20% of the samples were collected at participating businesses. These businesses were all chosen because of their use of VOCs. The businesses included two automotive paint and body shops, two dry cleaning facilities that do not use tetrachloroethylene, one dry cleaning facility that uses tetrachloroethylene, one rug cleaning facility, one manufacturer of foam products, and three industrial printing facilities. All ten of these businesses volunteered their participation in the study, allowing us access to their property to place multiple canisters. For the business sites, when possible, canisters were placed on the roof at up to four different locations. If the roof was not accessible, the canisters were placed on the property near breathing height.

The next greatest number of samples (approximately 17%) was collected on Minneapolis Park and Recreation Board (MPRB) properties. The canisters placed at MPRB property by Minneapolis Health Department employees were secured to permanent fixtures in the park using padlocks and chains. Approximately 2% of the samples were collected by MPCA employees who placed the canisters at the same location as their VOC monitoring sites. Approximately 2% of the samples were collected by Minneapolis Health Department employees at the same sites where formaldehyde was sampled; these are referred to as formaldehyde colocated samples. The remaining 2% of samples were collected by residents of Minneapolis who chose to sponsor canisters. Residents were given the option to sponsor canisters in order to have more canisters placed in areas they selected. The cost of sponsoring a canister was $165 per canister. Table 3 shows the complete breakdown of how the samples were collected at each sampling event.

Table 3 - Breakdown of Sampling Locations

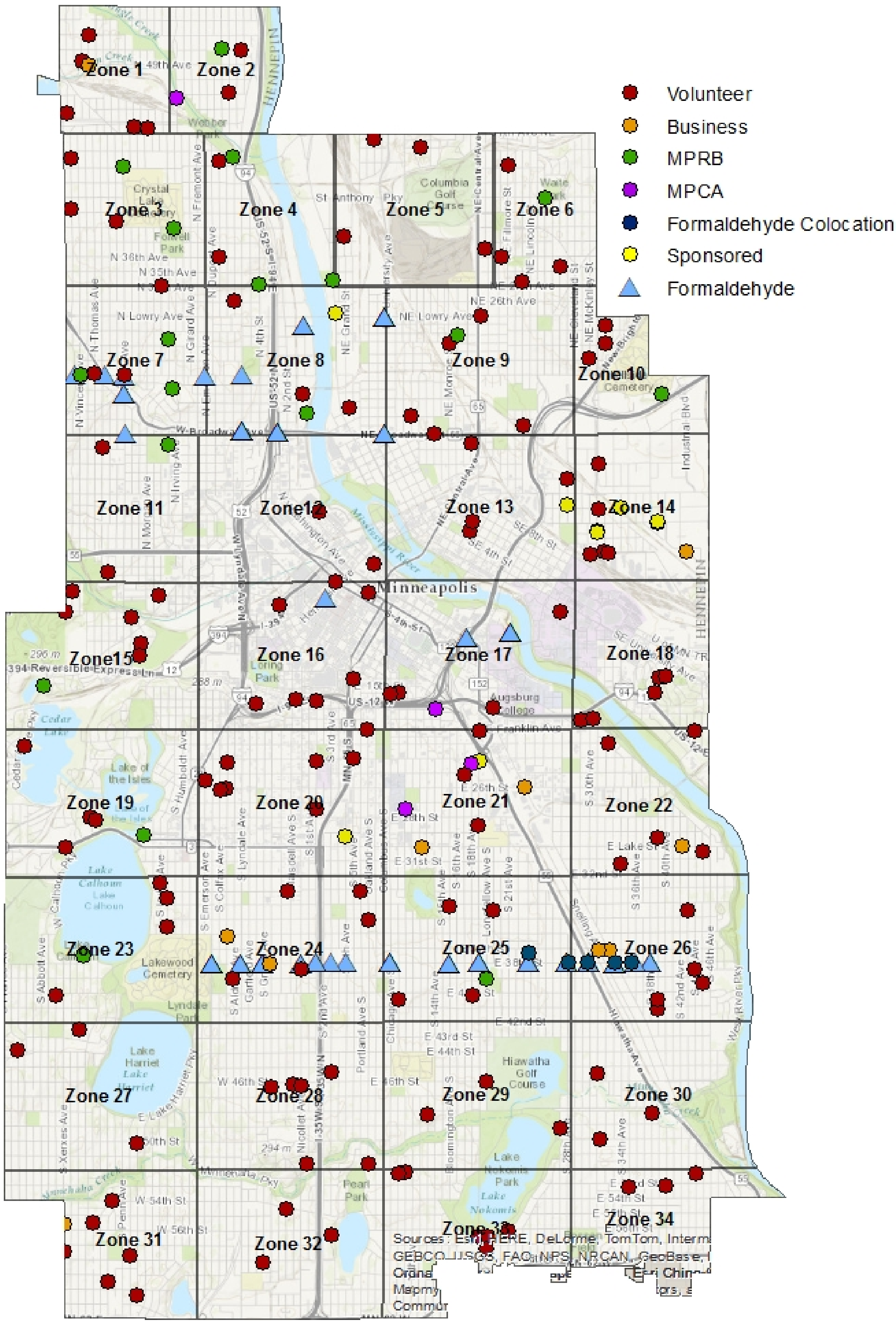
Date	Residential/ Volunteer	Business Locations	Minneapolis Park and Rec Board Locations	MPCA Monitor Colocated Locations	Formaldehyde Sample Colocated Locations	Sponsored Locations	Total
Nov 2013	68	18	13	5	0	0	104
Feb 2014	66	18	13	2	0	0	99
May 2014	71	24	15	3	0	0	113
Aug 2014	66	25	20	3	0	4	118
Nov 2014	67	25	22	3	5	4	126
Feb 2015	68	25	23	3	5	6	130
May 2015	50	23	25	2	5	0	105
Aug 2015	50	23	23	0	5	4	105
Total	506	181	154	21	20	18	900

Occasionally throughout the study canisters were placed that did not collect a sample properly. These canisters may not have been opened properly, may have been tampered with, or may have malfunctioned. One canister was vandalized. These canisters were not included in the breakdown of samples collected in Table 3, nor were the results from those canisters used in this study.

Sample locations were selected by dividing the City of Minneapolis into a grid of 34 cells, or zones. Figure 5 shows the residential/volunteer, business, MPRB, MPCA, formaldehyde colocated samples, sponsored sampling, and formaldehyde sampling locations over the grid of 34 zones. Our objectives in determining sample locations were:

1) Sample evenly across the City of Minneapolis
2) Sample at a minimum of two locations in each zone at each sampling event
3) As much as possible, sample at the same locations at each sampling event
4) Sample at businesses in Minneapolis that use VOCs

Figure 5 - Sampling Locations



Volunteer Recruitment and Selection

For the initial sampling event in November 2013, volunteers were first recruited from within the Minneapolis Health Department, since many employees also live in the City. Using the grid in Figure 5, volunteer locations were added to the map as volunteers signed up to participate in the study. Once a zone had two volunteers, no additional volunteers were selected from that zone. Once we had utilized all of the volunteers available from the Minneapolis Health Department, we put a notice out to all City of Minneapolis employees through our All Employee Email Newsletter. We then contacted the neighborhood groups in the City and requested that they inform their residents of the study and have any interested volunteers contact us. As we neared the start of the study, we filled in any gaps in residential volunteers with locations on MPRB property.

Several days before the start of sampling in November 2013, we held two training events for the volunteers. During these events we explained the study to the volunteers and trained them in the operation of the Summa canisters. We had each volunteer sign a waiver (Appendix E). We also prepared record sheets for the volunteers to fill out during the study (Appendix E). The record sheet was called the emissions activity form and was provided to gain a better understanding of emissions around the location of the air monitoring canister. We asked the volunteer to fill-in information to the best of their ability. Upon completion of the training, we sent each volunteer home with their Summa canister, a padlock, a chain, and an emissions activity form.

Prior to the next sampling event, in February 2014, we held another training event for new volunteers. By the third sampling event, in May 2014, most of our volunteers were returning volunteers and beginning with that event through the end of the study we trained new volunteers on an individual basis when they came to pick up their canister. Throughout the study we had many volunteers who participated multiple times and even some who participated in each of the eight sampling events.

Formaldehyde

Formaldehyde sampling was conducted independently of the other analytes using SKM UMEx 100 passive sampling devices and analyzed by OSHA method 1007. The sampling device can be used as an area or personal sampler. For our study, it was used as an area sampler and hung from street signs using zip ties as close to breathing level as possible (approximately 5 feet). Figure 5 shows the locations where the formaldehyde monitors were hung. Volunteers were not used in this sample collection.

Geographic Information Systems

Geographic Information Systems (GIS) played a vital role in this study. The program used was ArcGIS 10.2.2 for Desktop. GIS was used during the study design to create the grid of 34 zones and subsequently used to determine even sampling locations across the City.

GIS was used for the initial data analysis. The first step was matching the data received from Pace Analytical Services, Inc. with the location data. When a sample was collected at a location, that location was entered into a spreadsheet in Microsoft Excel and given a unique sample identified (Sample ID) made up of the Summa canister identification number, the month of the sampling event, and the year. When data were received from Pace Analytical Services, Inc. and downloaded into Excel a column was inserted to include the unique Sample ID for each sample. The sample location table and data results table were both uploaded into ArcGIS where they could be joined based on the Sample ID. This correlated every result from the data results table with a matching address which could be geocoded.

At the Minneapolis Health Department, health related data are typically analyzed at the community level. In Minneapolis there are eleven communities. In ArcGIS, a layer was added with the communities. The results data layer was then selected by location to the selected community and the results were exported individually for each community and analyzed at the community level.

Health Benchmarks

Air toxics, such as the VOCs analyzed in this study, do not have standards. When characterizing the risk of human exposure to these chemicals, we use health benchmarks. Health benchmarks are developed to protect human health for a specified length of exposure such as one hour (acute), 13 weeks (subchronic), or a lifetime (chronic). Health benchmarks are the concentration of a chemical that is likely to pose little or no risk to human health. These values are designed to protect vulnerable subpopulations such as infants and children.

For the Air Quality study, we took an approach that compared averages, as well as individual results, to chronic health benchmarks. While each individual 72-hour sample does not represent the typical level of that VOC in the air at all times due to weather influences and spikes in emissions, we decided to compare each result to the chronic health benchmark as a screening level by which we could preliminarily evaluate the data. If we had chosen acute health benchmarks for comparison, all results would have been well under the health benchmark, giving us little means to preliminarily differentiate the data and determine potential locations and VOCs of concern. If we had only compared long-term averages to the chronic health benchmarks, we may have missed areas where there were concentrated spikes above the chronic health benchmark, a tool for us to follow up in certain areas and determine if there is the potential for long-term averages to remain above health benchmarks. Upon completion of the data collection portion of the study we then more accurately compared the averages to the health benchmarks.

There are a variety of health benchmarks available and we selected health benchmarks for comparisons in our study based on an order of availability. The health benchmarks are listed in Table 2. When available, we first selected chronic health benchmarks from the Minnesota Department of Health Air Values Table. Of the 62 VOCs analyzed in this study, 15 were assigned either a Health Risk Value (HRV) or Risk Assessment Advice (RAA) by MDH (MDH, 2016a). For the VOCs without an HRV or RAA, we then searched for chronic toxicity values in the Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS). Of the 47 VOCs without an HRV or RAA, 19 had either a reference air concentration (RfC) or air concentration at a specified cancer risk level of 1 in 100,000 (EPA, 2016a). For the remaining 28 VOCs, we then searched the EPA's Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV). Three VOCs were assigned a provisional RfC (p-RfC) (EPA, 2016b). For the remaining VOCs, we then searched the California Environmental Protection Agency (CalEPA) Office of Environmental Health and Hazard Assessment Acute (OEHHA), 8-hour, and Reference Exposure Level (REL) Summary table for chronic inhalation RELs (CalEPA), 2016). Of the remaining 25 VOCs, two had an OEHHA REL. Next we searched the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) and found one VOC with a chronic, inhalation MRL (ATSDR, 2016). Finally, we used Centers for Disease Control and Prevention (CDC) National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (RELs) and found 13 VOCs with an assigned REL (CDC, 2016). The NIOSH RELs are intended to control occupational hazards and are not intended as a health benchmark.

However, there are many chemicals that have not yet been assigned a chronic health benchmark and this gave us a tool for comparison. After reviewing the NIOSH RELS there were 9 VOCs remaining without any health benchmark for comparison. All of the health benchmarks that were used in this study, along with their sources, are found in Table 4.

Detection Limits and Handling Non-Detects

There are two types of analytical lower limits. The method detection limit (MDL), is the lowest concentration that can distinguished from zero with reliability, but is below the level which is quantifiable with acceptable precision, the practical quantitation limit (PQL). The MDL is always lower than the PQL. At levels between the PQL and the MDL, the analyte is proven to be present, but its reported concentration is an estimate. The PQL is the lowest concentration which can be not only detected, but also quantified with a specified degree of precision. At the PQL, the analyte is both proven present and reliably measured. Data were reported by Pace Analytical, Inc. and we requested they report all data down to the MDL.

Following advice in EPA (1991) and Wendelberger and Campbell (1994), the decision was made to replace all non-detects with zeros. Determining the most appropriate method of handling non-detects in environmental data varies and depends partially the intended use of the data. For the Air Quality Study, individual values and sample means are being compared to specific fixed levels, the health benchmarks, as a screening level. In all cases for this study, the detection limits are well below the health benchmarks and the undetected substances do not pose a significant health risk at the detection limit, therefor for our purposes they are best represented as zeros.

Quality Assurance

We used two methods to check the results for precision, colocating canisters and replicate canisters. We initially began by colocating at least 10% of our samples. This was done by placing two canisters side-by-side at the location site. We ran colocated samples for the first three sampling events. After reviewing three sampling events of colocated data and consulting with Pace Analytical Services, Inc. we made a joint decision to use replicates to ensure improved data quality. Pace Analytical Services, Inc. created a new cane for the top of the air-flow controller that connected two Summa canisters together, so the same air sample would be collected by each of the two canisters (Figure 6).

Figure 6 - Replicate Summa Canisters

Table 5 shows the number and percent of colocated and replicate canisters. There were instances when one of the colocated or replicate canisters did not collect a sample properly. In such cases, neither canister was included in the count of colocated or replicate canisters. If the other canister still collected a sample properly, the result from it was included in the data analysis.

Table 4 - Colocated and Replicate Canisters

Date	Colocated with Summa Canister	Percent Colocated	Duplicate	Percent Duplicate	Colocated with MPCA Monitor	Total Canisters
Nov 2013	14	13	0	0	5	104
Feb 2014	12	12	0	0	2	99
May 2014	16	14	0	0	3	113
Aug 2014	0	0	20	17	3	118
Nov 2014	0	0	20	16	3	126
Feb 2015	0	0	18	14	3	130
May 2015	0	0	16	15	2	105
Aug 2015	2	2	14	13	0	105

Replicate precision is determined from two canisters filled from the same air mass over the same time period (EPA, 1999b). The standard formula for the grading of replicate measurements is to calculate the relative percent difference (RPD) using the formula RPD = ABS(D1-D2) / AVERAGE(D1+D2) x 100%, where: D1 = measured value of the first replicate, D2 = measured value of the second replicate, ABS = absolute value of D1-D2, and AVG = average value of D1 and D2. The RPD was calculated for both colocated canisters and replicate canisters. RPDs were calculated when both canisters had a detect result for a particular analyte.

The nature of the particular analyte, such as molecular weight, water solubility, polarizability, etc., may affect the precision of the measurement (EPA, 1999b). In addition, a primary influence on precision is the concentration level of the analyte in the sample. The precision lowers as the concentration approaches the detection limit. For this study we asked the lab to report data to us down to the method detection limit (MDL). Because the purpose of this study is to complete a screening of levels of VOCs in Minneapolis, we made the decision to sacrifice some levels of precision for a greater number reported detect results. Sample replicate data are validated when both values are greater than five times the practical quantitation limit (PQL) and within 20% RPD. This takes into account any statistically inflated results for RPDs due to the number being so close to the reporting limits (i.e., small numbers). Sample colocated data are validated when both values are greater than five times the practical quantitation limit (PQL) and within 40% RPD.

Of 348 replicate analyte measurements compared, five (1%) were both greater than five times the PQL and over 20% RPD. Of the 141 colocated analyte measurements compared, four (3%) were both greater than five times the PQL and over 40% RPD.

Methylene chloride was one of the 61 analytes but is not reported in the study. Working in conjunction with Pace Analytical Services, Inc., we made the decision to remove it from the data set. This decision was made based on the use of methylene chloride in the extraction laboratory. Methylene chloride is a common lab contaminate, or artifact. This means it may appear in the sample, but was not present at the sample collection site. A lab artifact may enter the sample during the analysis in the lab and produce a false positive. Contamination by diffusion of VOCs may occur during analysis. Pace Analytical Services, Inc. attempted to remove only the results that were in a specific range signifying possible contamination. However, after discussion with the lab, it was determined that all of the samples could have some level of contamination and for validity of the study we have decided to remove all samples.

In addition to the methods used to check our results for precision, we also set standards for collecting data, established processes for acquiring data, listed requirements and guidelines for volunteers, and established detailed procedures for collecting samples. Prior to air sampling placement, all City of Minneapolis volunteers were trained on the operation of opening and closing the canister valve to begin sampling and conclude collection. Each volunteer recorded air collection times on a designated badge located on the canister as well as in a volunteer form (Appendix A). Minneapolis Health Department employees and Pace Analytical Services, Inc. collaborated during sampling events to ensure that proper chain of custody procedures and documentation were maintained.

Results

The study found that the air in Minneapolis, for the most part, doesn't contain high levels of VOC pollution. However, there were a significant number of samples taken across the city that were of potential concern for public health. Of the 62 VOCs analyzed in this study, 47 had no results above their health benchmark. The analytes that are detailed in this section and the conclusion are the five analytes that had results above their Minnesota Department of Health (MDH) defined health benchmarks. These five analytes are benzene, naphthalene, tetrachloroethylene, trichloroethylene, and formaldehyde.

In addition to the five analytes with results over their MDH defined health benchmark, ten analytes had results over their health benchmarks defined by the EPA, ATSDR, or the CDC. They were not selected for detailed consideration in this report because their health benchmarks are not defined by MDH and, for some; there is less certainty in the health benchmark. Table 6 shows all analytes that had one or more result over the chronic health benchmark.

Table 5 - Analytes with Results over Health Benchmark

Analyte	Health Benchmark (µg/m3)	Average	Max	Number of Detect Results	Number of Results Over Benchmark
1,2,4-Trichlorobenzene	2	0.1	22.4	13	10
1,2,4-Trimethylbenzene	7	2.0	926.0	206	17
1,2-Dichloroethane	0.4	0.0	2.2	1	1
Acetone	30	14.3	271.0	870	75
Benzene	1.3	0.7	50.3	534	78
Benzyl chloride	1	0.0	4.2	3	3
Bromomethane	5	0.0	14.3	1	1
Carbon tetrachloride	1.7	0.1	2.8	90	6
Chloroform	0.4	0.0	5.6	8	7
Formaldehyde*	2	3.6	8.5	93	93
Hexachloro-1,3-butadiene	0.5	0.0	11.4	6	6
Naphthalene	9	0.8	127.0	184	8
o-Xylene	100	0.7	140.0	144	2
Tetrachloroethylene**	2	1.1	151.0	132	100
Trichloroethylene	2	0.3	79.8	67	14

***** All analytes had a total of 900 samples except for formaldehyde, which had 114.
****** Twenty-nine tetrachloroethylene results were not included in this average. Those results were taken at a dry cleaning facility and biased the neighborhood results for Powderhorn. Those results are detailed separately in Table 12.

All averages have been calculated with the non-detect results replaced by zeros. In the following results, the average analyte by sampling date tables, the total averages across all sampling events for each community are in the right column. The total averages across all communities for each sampling event are in the bottom row. In the average, maximum, and minimum tables the calculations are also done with the non-detects replaced by zeros. The average, maximum, and minimum across all communities and across all sampling events is shown in the bottom row. The data shown highlighted in red are results above the health benchmark.

Benzene

Benzene was detected at locations across the entire City. Of the 900 samples collected, benzene was detected a total of 534 times. Of those detects, 78 were above and 456 were at or below the health benchmark of 1.3 µg/m^3 (with 88 of the 456 within 10% of the health benchmark). There were 366 non-detect (zero) results recorded for benzene. The average level of benzene across all communities and across all sampling events was 0.7 µg/m^3.

Figure 7 shows the locations where benzene was detected with results less than or equal to the health benchmark. Figure 8 shows the locations where benzene was detected above the health benchmark. Table 6 shows the average benzene levels for each community by sampling event. Table 7 shows the average, maximum, and minimum result for each community across all sampling events, as well as the total number of samples from each community. Any result (average, maximum, or minimum) above the health benchmark is highlighted in red. Figure 9 shows all results for benzene by community compared to the health benchmark with non-detects replaced by zeros. Figure 10 shows a close up of the cluster of results found below 10 µg/m^3.

Figure 7 - Benzene Results Less Than or Equal to Health Benchmark

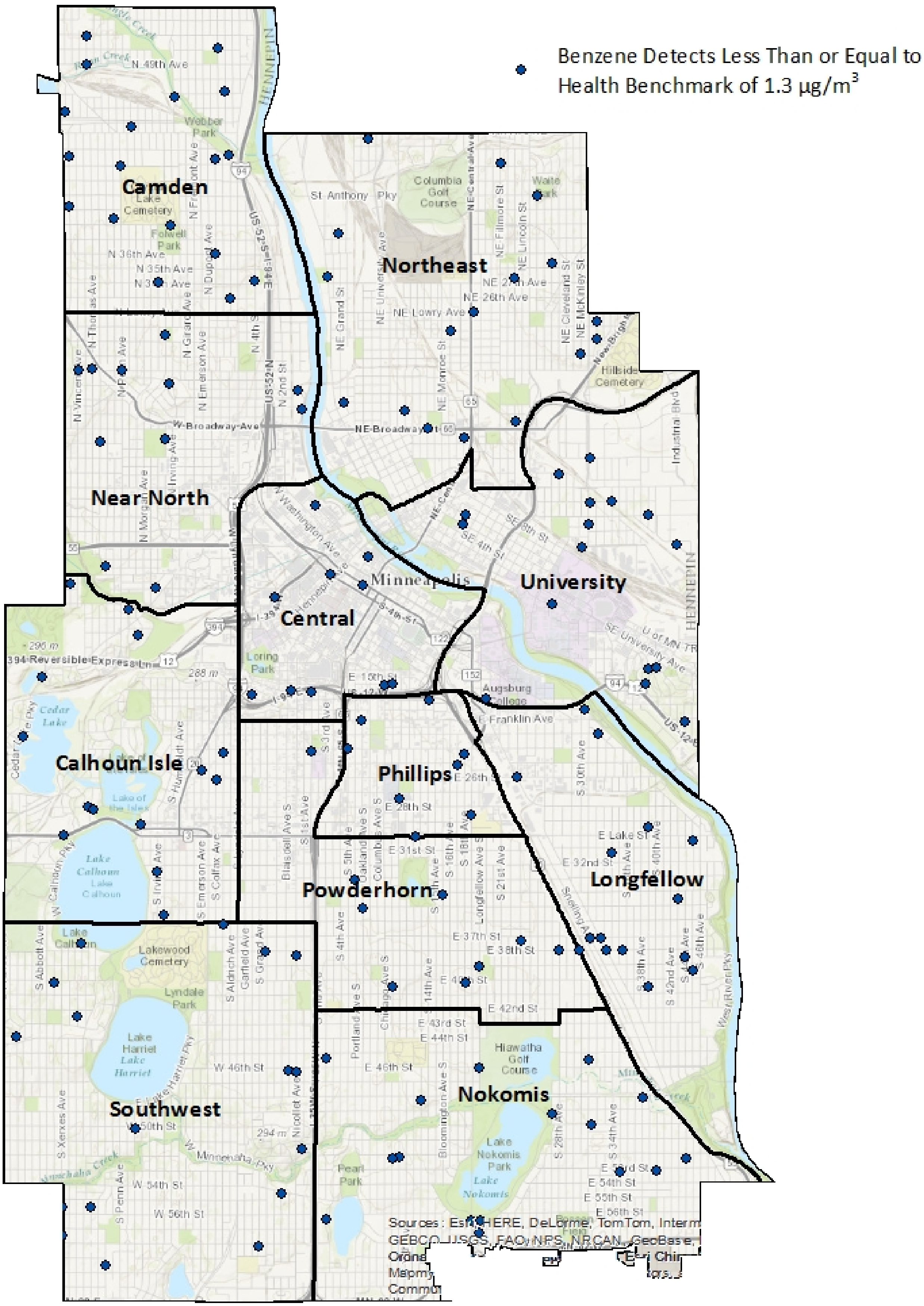


Figure 8 - Benzene Results above Health Benchmark

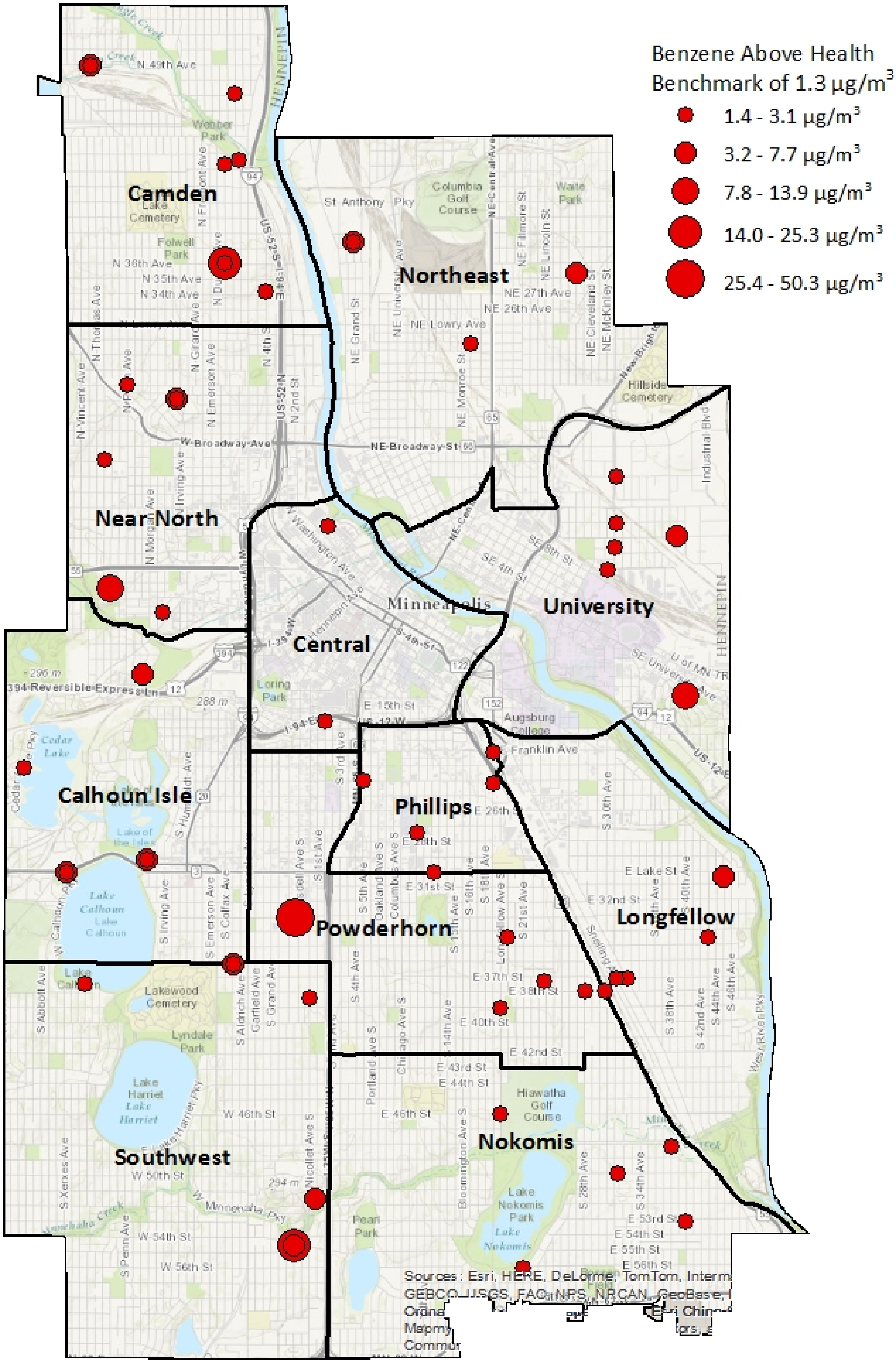


Table 6 - Averages of Benzene Results by Sampling Date (µg/m^3)

Community	Nov 2013	Feb 2014	May 2014	Aug 2014	Nov 2014	Feb 2015	May 2015	Aug 2015	Total
Calhoun Isle	0.3	1.7	1.0	0.1	0.3	0.5	0.2	0.8	**0.6**
Camden	0.4	1.1	1.1	1.2	0.1	0.9	0.1	0.6	**0.7**
Central	0.4	0.9	1.1	0.2	0.1	0.6	0.1	0.6	**0.5**
Longfellow	0.5	1.6	1.1	0.1	0.3	0.9	0.3	0.8	**0.7**
Near North	0.1	1.0	1.1	0.0	0.4	1.7	0.1	0.9	**0.7**
Nokomis	0.6	1.2	1.0	0.4	0.2	0.8	0.1	0.5	**0.6**
Northeast	0.6	1.2	0.4	0.2	0.1	0.6	0.5	0.6	**0.5**
Phillips	1.2	1.0	0.9	N/A	0.7	1.3	0.4	0.7	**1.0**
Powderhorn	0.7	0.9	1.2	0.1	0.5	5.0	0.1	0.9	1.4
Southwest	0.4	1.4	3.2	0.0	0.2	0.5	0.2	0.6	**0.9**
University	0.5	1.2	1.9	0.1	0.1	0.7	0.1	0.7	**0.6**
Total	**0.5**	**1.3**	**1.3**	**0.3**	**0.3**	**1.2**	**0.2**	**0.7**	**0.7**

Table 7 - Averages, Maximums, and Minimums of Benzene Results (µg/m^3)

Community	Average	Max	Min	Number of Samples
Calhoun Isle	0.6	5.1	0.0	67
Camden	0.7	20.3	0.0	130
Central	0.5	1.9	0.0	41
Longfellow	0.7	4.0	0.0	119
Near North	0.7	10.2	0.0	83
Nokomis	0.6	2.7	0.0	78
Northeast	0.5	3.8	0.0	89
Phillips	1.0	2.4	0.4	33
Powderhorn	1.4	50.3	0.0	69
Southwest	0.9	25.3	0.0	95
University	0.6	13.9	0.0	96
Total	**0.7**	50.3	**0.0**	**900**

Figure 9 - All Benzene Results by Community

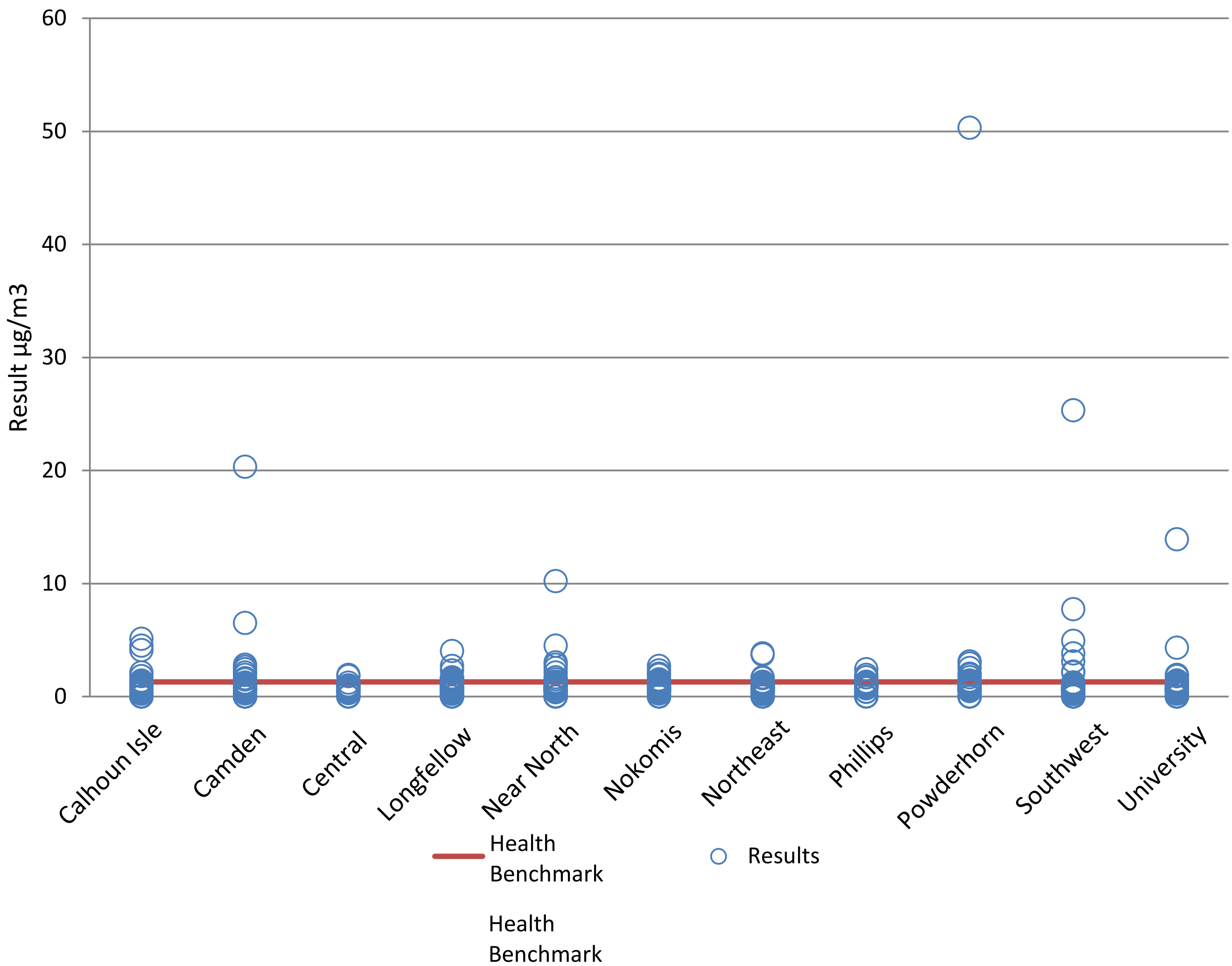
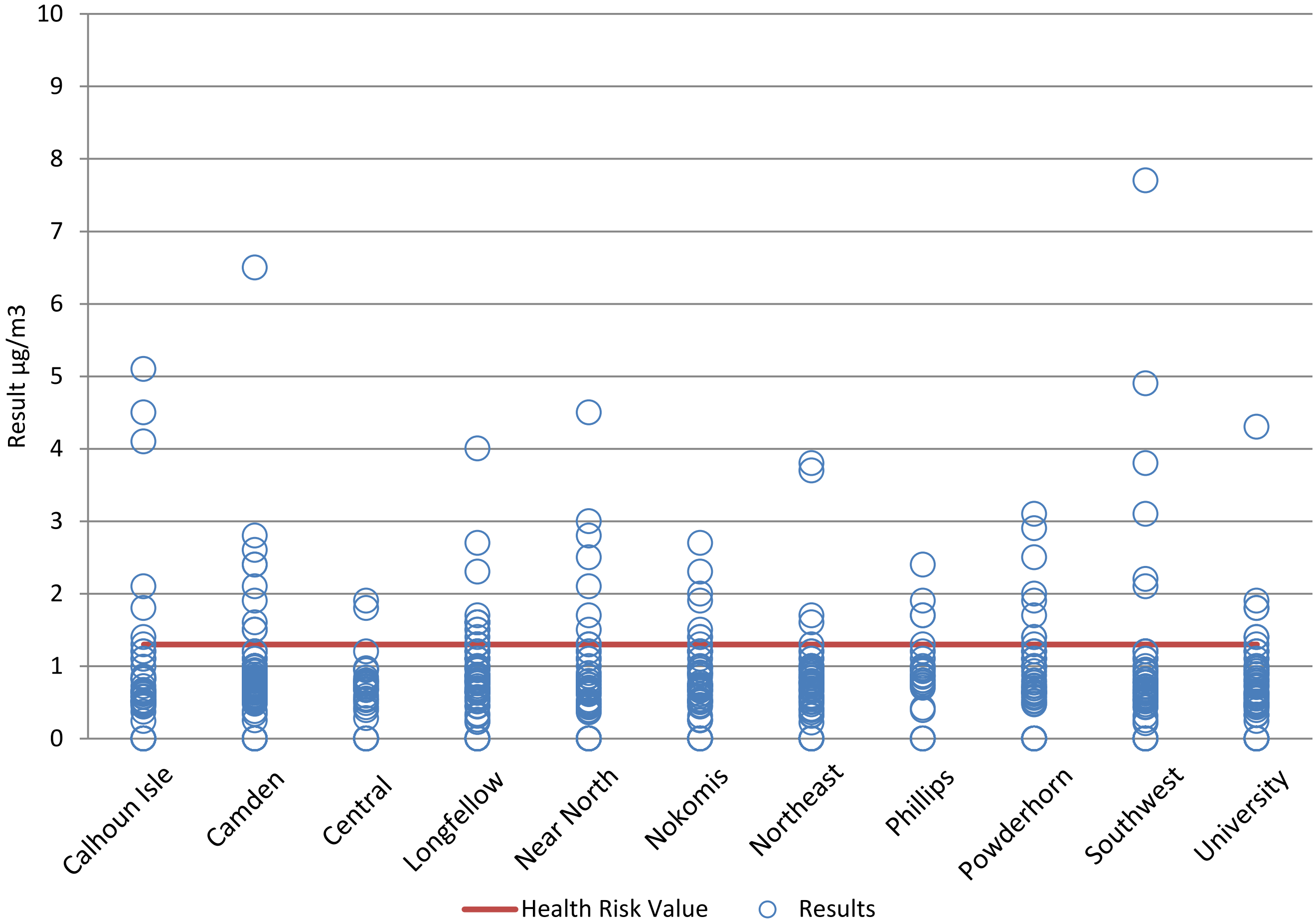


Figure 10 - Benzene Results under 10 µg/m^3 by Community



Naphthalene

Naphthalene was detected at locations across the entire City. Of the 900 samples collected, naphthalene was detected a total of 184 times (one detect was thrown out and not included as a result of canister tampering). Of the 184 detects, eight were above and 176 were at or below the health benchmark of 9 $\mu g/m^3$ (with only one of the 176 within 10% of the health benchmark). There were 715 non-detect (zero) results recorded for naphthalene. The average level of naphthalene across all communities and across all sampling events was 0.8 $\mu g/m^3$.

Figure 11 shows the locations where naphthalene was detected with results less than or equal to the health benchmark. Figure 12 shows the locations where naphthalene was detected above the health benchmark. Table 8 shows the average naphthalene levels for each community by sampling event. Table 9 shows the average, maximum, and minimum result for each community across all sampling events, as well as the total number of samples from each community. Any result (average, maximum, or minimum) above the health benchmark is highlighted in red. Figure 13 shows all results for naphthalene by community compared to the health benchmark with non-detects replaced by zeros. Figure 14 shows a close up of the cluster of results found below 20 $\mu g/m^3$.

Figure 11 - Naphthalene Results Less Than or Equal to Health Benchmark

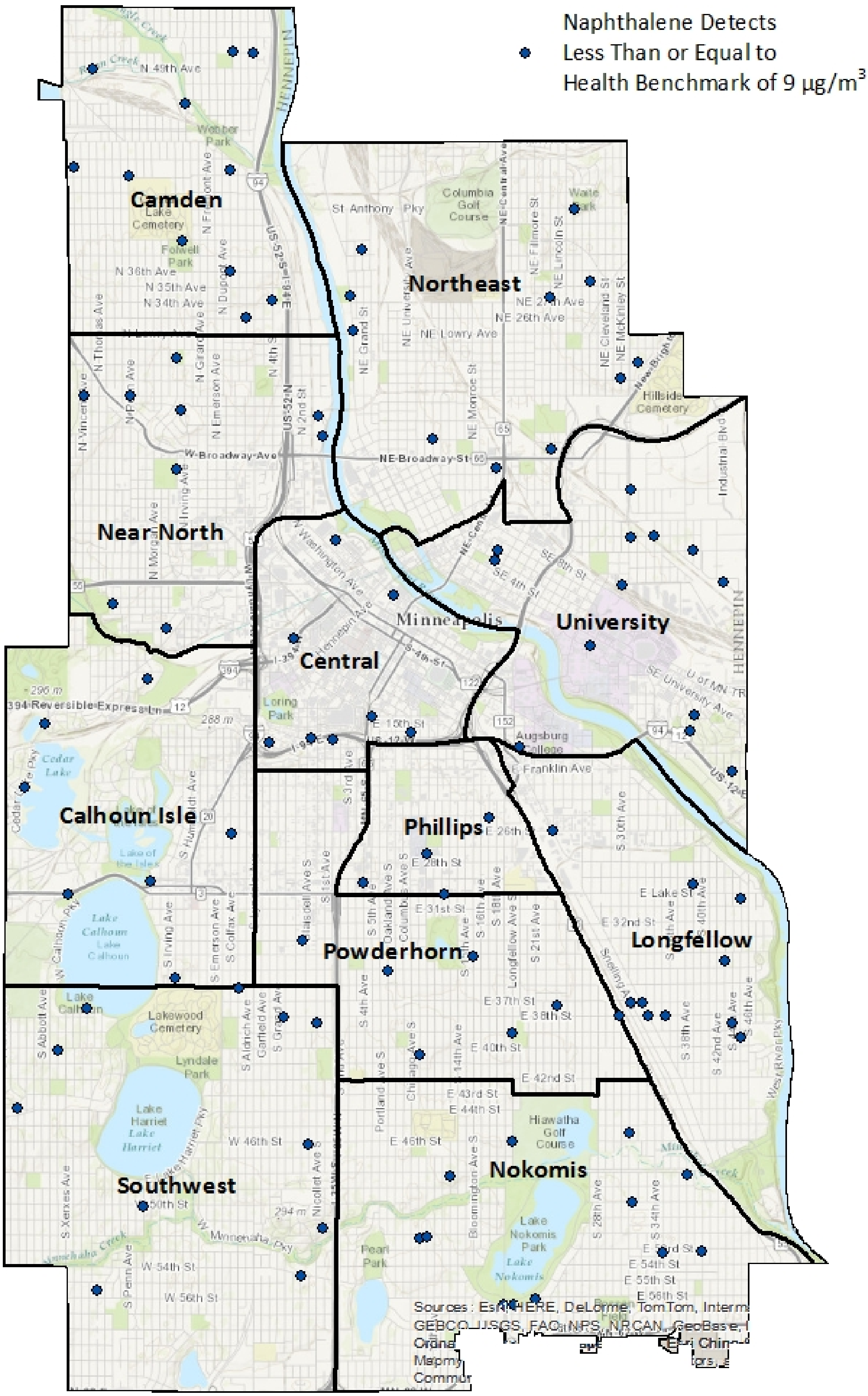


Figure 12 - Naphthalene Results above Health Benchmark

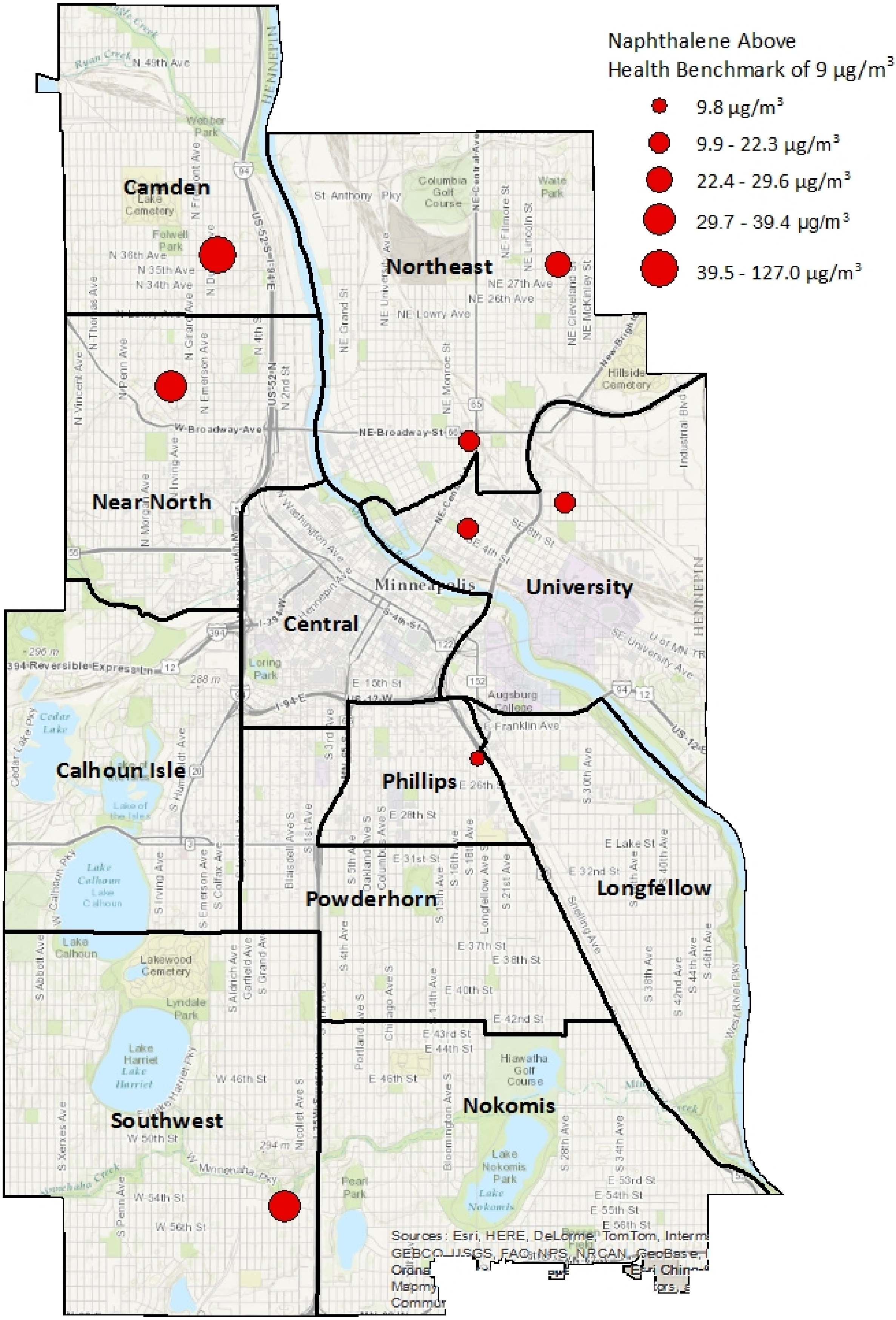


Table 8 - Averages of Naphthalene Results by Sampling Date (µg/m^3)

Community	Nov 2013	Feb 2014	May 2014	Aug 2014	Nov 2014	Feb 2015	May 2015	Aug 2015	Total
Calhoun Isle	0.3	0.1	0.7	0.9	0.0	0.3	0.0	1.2	**0.4**
Camden*	0.1	0.0	0.8	7.3	0.1	1.2	0.2	0.6	**1.4**
Central	1.1	0.4	1.2	0.0	0.0	1.1	0.0	0.5	**0.6**
Longfellow	0.4	0.8	1.0	0.2	0.1	1.1	0.3	0.5	**0.5**
Near North	0.2	3.8	0.6	0.0	0.0	0.8	0.4	0.3	**0.8**
Nokomis	0.2	0.1	1.3	0.4	0.0	1.5	0.0	1.0	**0.6**
Northeast	0.4	0.0	0.7	0.6	0.0	2.0	2.5	1.4	**1.0**
Phillips	0.7	0.3	1.2	0.0	0.0	2.2	0.0	0.0	**0.7**
Powderhorn	0.0	0.0	0.2	0.0	0.0	1.8	0.0	0.7	**0.4**
Southwest	0.6	0.0	0.3	0.1	0.0	3.6	0.3	0.9	**0.7**
University	0.3	2.2	0.9	0.1	0.2	1.9	0.2	0.9	**0.9**
Total	**0.4**	**0.8**	**0.8**	**1.3**	**0.0**	**1.6**	**0.5**	**0.8**	**0.8**

Table 9 - Averages, Maximums, and Minimums of Naphthalene (µg/m^3)

Community	Average	Max	Min	Number of Samples
Calhoun Isle	0.4	5.4	0.0	67
Camden	1.4	127.0	0.0	129*
Central	0.6	3.7	0.0	41
Longfellow	0.5	7.5	0.0	119
Near North	0.8	37.6	0.0	83
Nokomis	0.6	6.8	0.0	78
Northeast	1.0	29.6	0.0	89
Phillips	0.7	9.8	0.0	33
Powderhorn	0.4	4.5	0.0	69
Southwest	0.7	39.4	0.0	95
University	0.9	22.3	0.0	96
Total	**0.8**	127.0	**0.0**	**899***

*One Naphthalene result was removed from the dataset. It was determined to be an outlier that resulted from tampering with a canister.

Figure 13 - All Naphthalene Results by Community

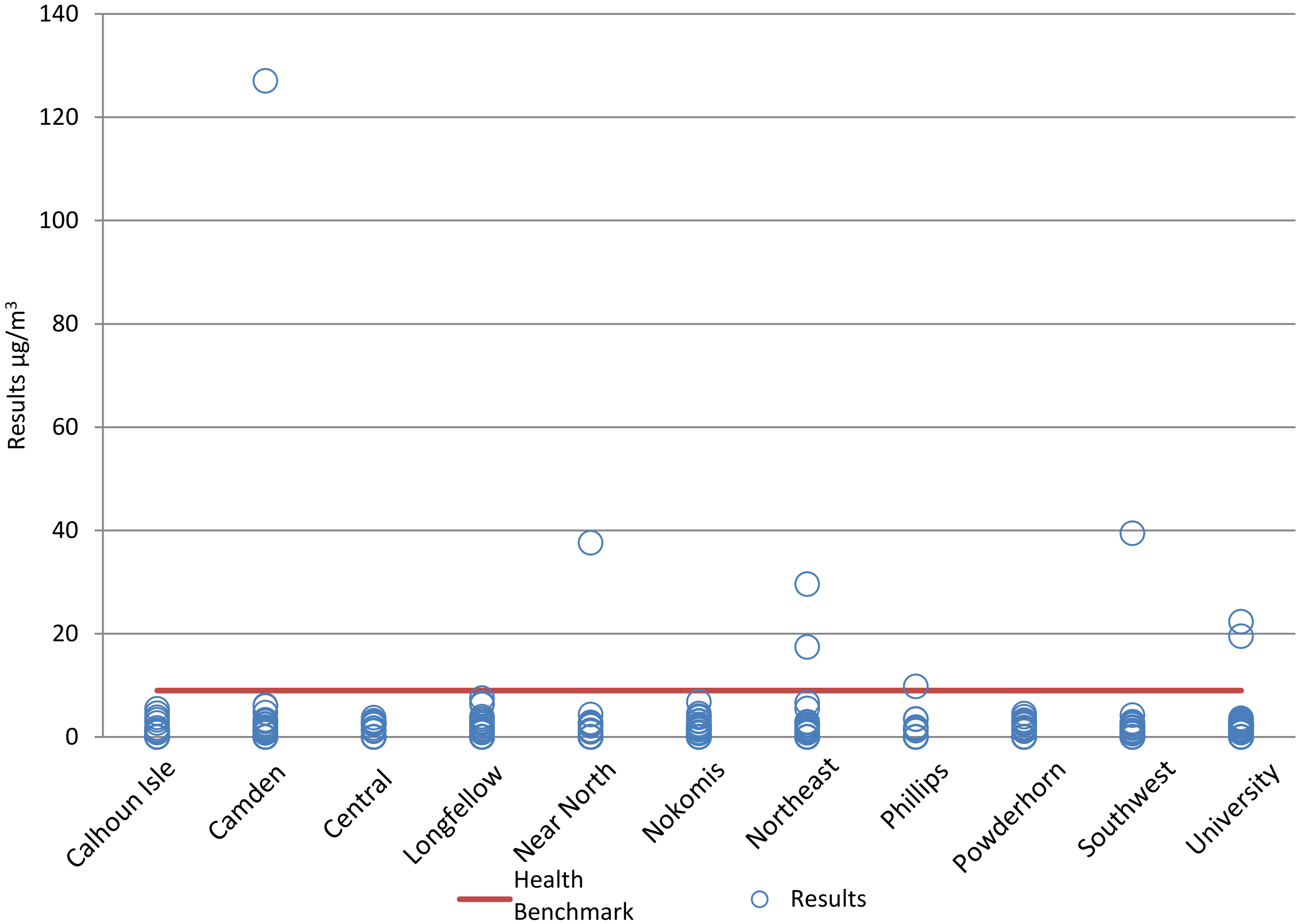
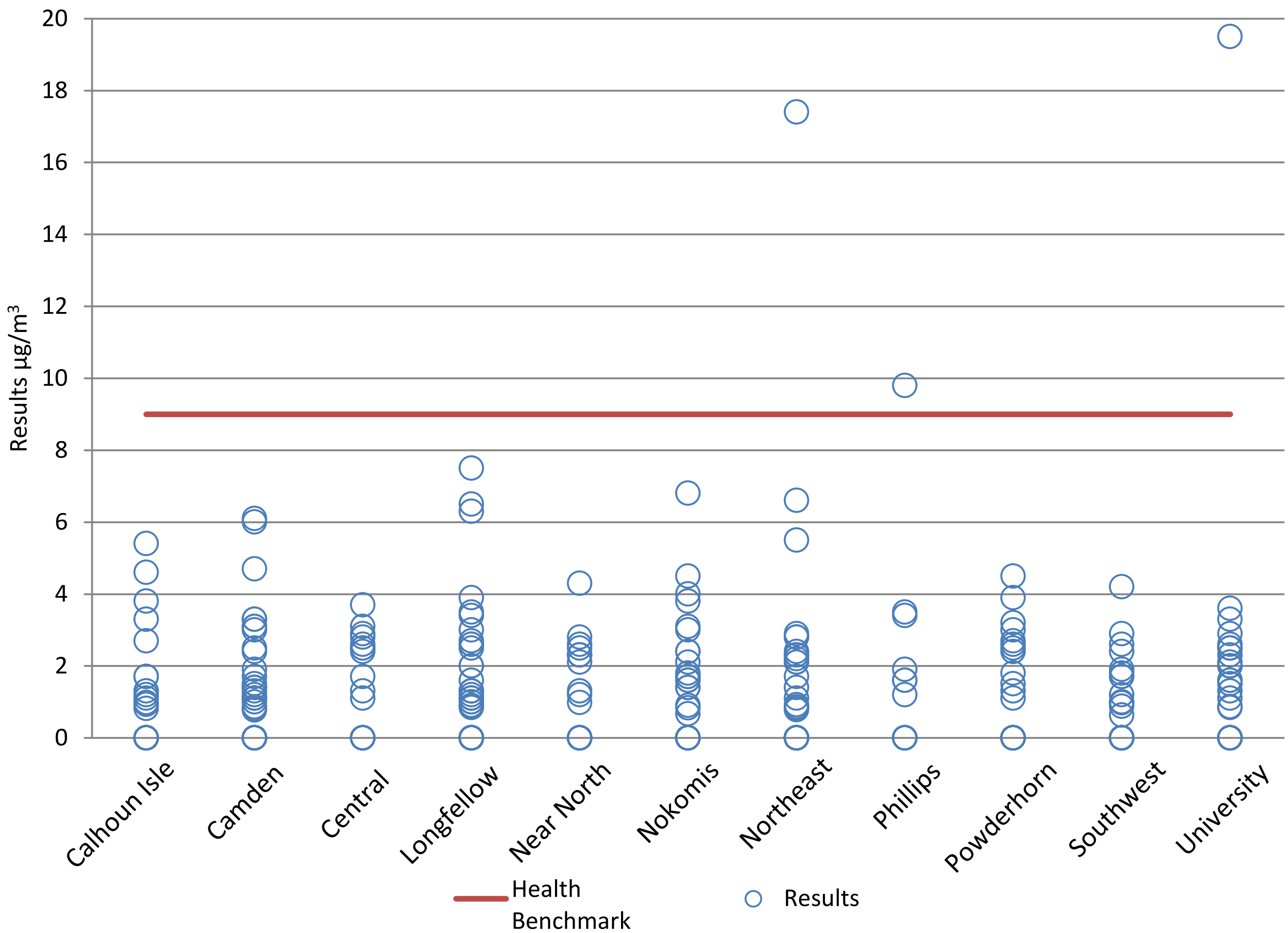


Figure 14 - Naphthalene Results under 20 µg/m³ by Community



Tetrachloroethylene

Tetrachloroethylene was detected at locations across the entire City. Of the 900 samples collected, tetrachloroethylene was detected a total of 132 times. Of those detects, 100 were above and 32 were at or below the health benchmark of 2 $\mu g/m^3$ (with three of the 32 within 10% of the health benchmark). Of the 100 detects above the health benchmark, 29 were results from samples collected outside a dry cleaning facility that uses tetrachloroethylene. There were 768 non-detect (zero) results recorded for tetrachloroethylene. The average level of tetrachloroethylene across all communities and across all sampling events was 1.1 $\mu g/m^3$. This average does not include results from samples collected at a dry cleaning facility.

Figure 15 shows the locations where tetrachloroethylene was detected with results less than or equal to the health benchmark. Figure 16 shows the locations where tetrachloroethylene was detected above the health benchmark. Table 10 shows the average tetrachloroethylene levels for each community by sampling event. Table 11 shows the average, maximum, and minimum result for each community across all sampling events, as well as the total number of samples from each community. Any result (average, maximum, or minimum) above the health benchmark is highlighted in red. Figure 17 shows all results for tetrachloroethylene by community compared to the health benchmark with non-detects replaced by zeros. Figure 18 shows a close up of the cluster of results found below 20 $\mu g/m^3$.

Special consideration was taken for tetrachloroethylene results obtained from sampling outside a dry cleaning facility in Powderhorn. At each sampling event, two to four canisters were placed on the roof of this dry cleaning facility. When combined with the other results for the community, the results from the one dry cleaning facility inflated the averages. Because this was the only dry cleaning facility using tetrachloroethylene where samples were collected, we chose to examine the results separately. The average level of tetrachloroethylene at the dry cleaning facility was 176.8 $\mu g/m^3$. Table 12 shows the average, maximum, and minimum result for each sampling date at the dry cleaning facility in Powderhorn. Figure 19 shows the results at the dry cleaning facility in Powderhorn by date sampled.

Figure 15 - Tetrachloroethylene Results Less Than or Equal to Health Benchmark

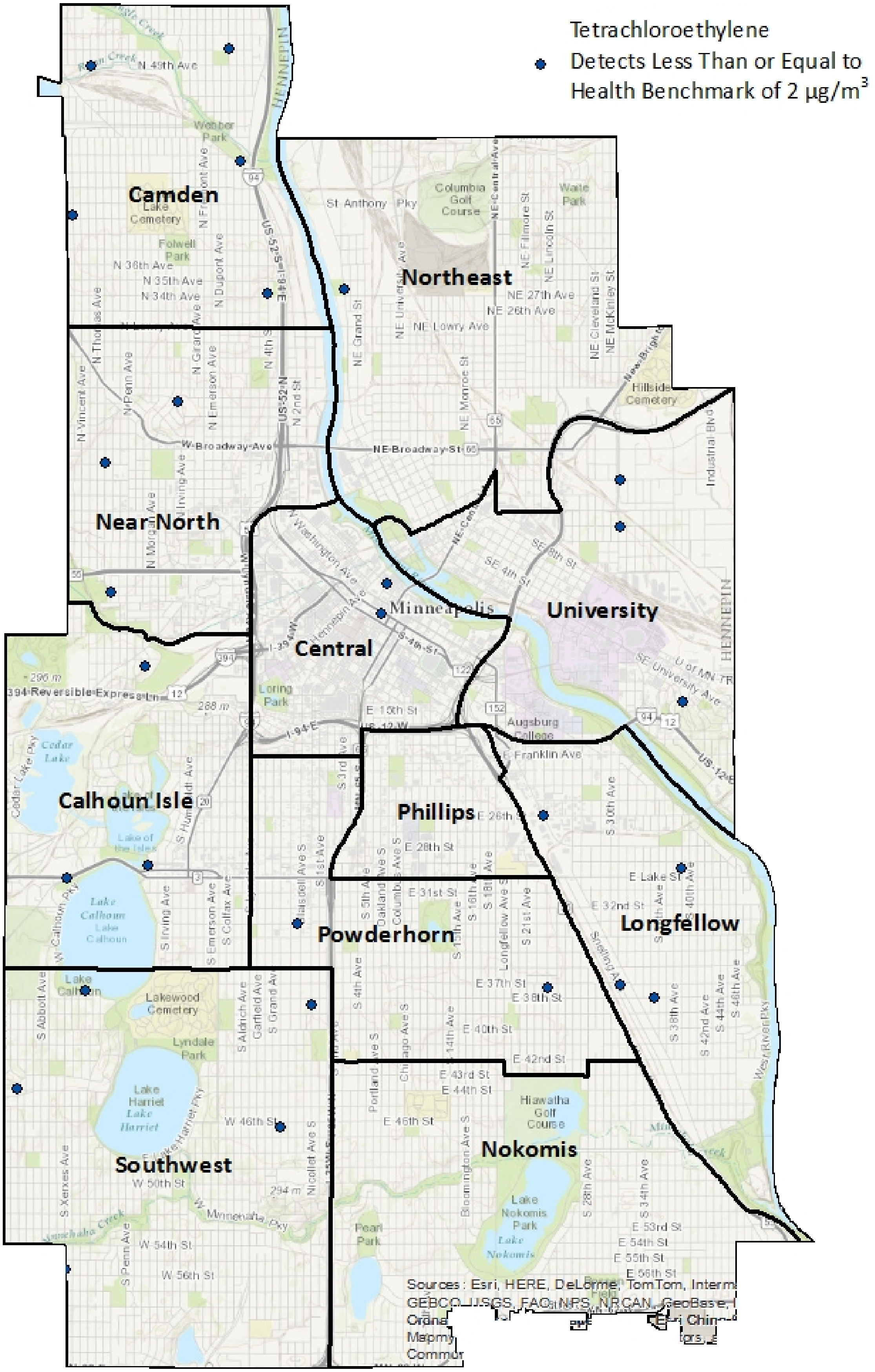
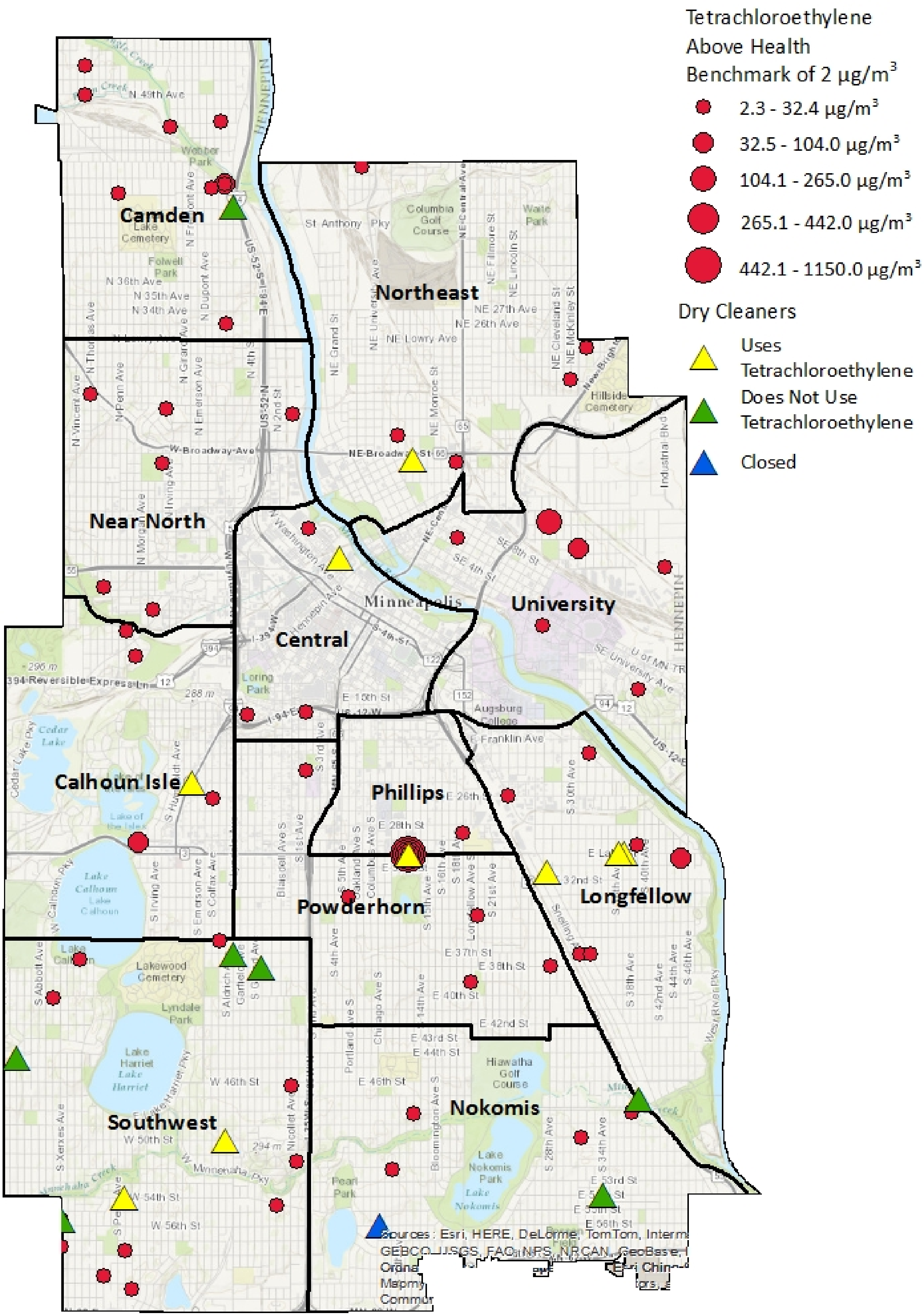


Figure 16 - Tetrachloroethylene Results above Health Benchmark



The site with the highest levels of tetrachloroethylene, located on the border of the Phillips and Powderhorn communities, was the one dry cleaner, which uses tetrachloroethylene, where sampling took place for the study. Since the study ended, that dry cleaner is no longer in operation. We would assume similarly high levels of tetrachloroethylene at the other eight dry cleaning facilities in Minneapolis that use tetrachloroethylene.

Table 10 - Averages of Tetrachloroethylene Results by Sampling Date ($\mu g/m^3$)

Community	Nov 2013	Feb 2014	May 2014	Aug 2014	Nov 2014	Feb 2015	May 2015	Aug 2015	Total
Calhoun Isle	0.0	0.3	0.1	0.0	14.2	0.1	0.0	1.4	2.1
Camden	0.0	0.0	0.1	1.6	1.0	2.2	0.0	1.1	**0.8**
Central	1.4	0.0	1.3	0.3	7.2	0.2	0.0	0.0	**1.2**
Longfellow	0.0	0.0	0.9	0.8	5.6	0.2	0.0	0.2	**1.1**
Near North	0.0	0.0	0.0	1.2	2.1	1.0	0.0	0.1	**0.6**
Nokomis	0.0	0.0	0.7	0.6	2.6	0.0	0.0	0.0	**0.5**
Northeast	0.0	0.0	0.6	0.0	2.0	0.0	0.0	0.0	**0.3**
Phillips	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	**0.1**
Powderhorn*	0.0	0.0	0.0	0.0	4.2	0.8	0.0	0.0	**0.9**
Southwest	0.0	0.0	0.3	0.4	3.3	0.3	0.0	0.7	**0.8**
University	0.0	0.0	0.2	0.1	18.9	0.0	0.0	0.0	2.8
Total	**0.1**	**0.0**	**0.4**	**0.6**	**5.7**	**0.5**	**0.0**	**0.4**	**1.1**

Table 11 - Averages, Maximums, and Minimums of Tetrachloroethylene Results ($\mu g/m^3$)

Community	Average	Max	Min	Number of Samples
Calhoun Isle	2.1	65.8	0.0	67
Camden	0.8	38.3	0.0	130
Central	1.2	16.5	0.0	41
Longfellow	1.1	64.3	0.0	119
Near North	0.6	8.9	0.0	83
Nokomis	0.5	15.4	0.0	78
Northeast	0.3	8.1	0.0	89
Phillips	0.1	4.0	0.0	32
Powderhorn	0.9	16.6	0.0	41*
Southwest	0.8	10.0	0.0	95
University	2.8	151.0	0.0	96
Total	**1.1**	151.0	**0.0**	**871***

*Twenty-nine Tetrachloroethylene results were not included in this table.

Figure 17 - All Tetrachloroethylene Results by Community

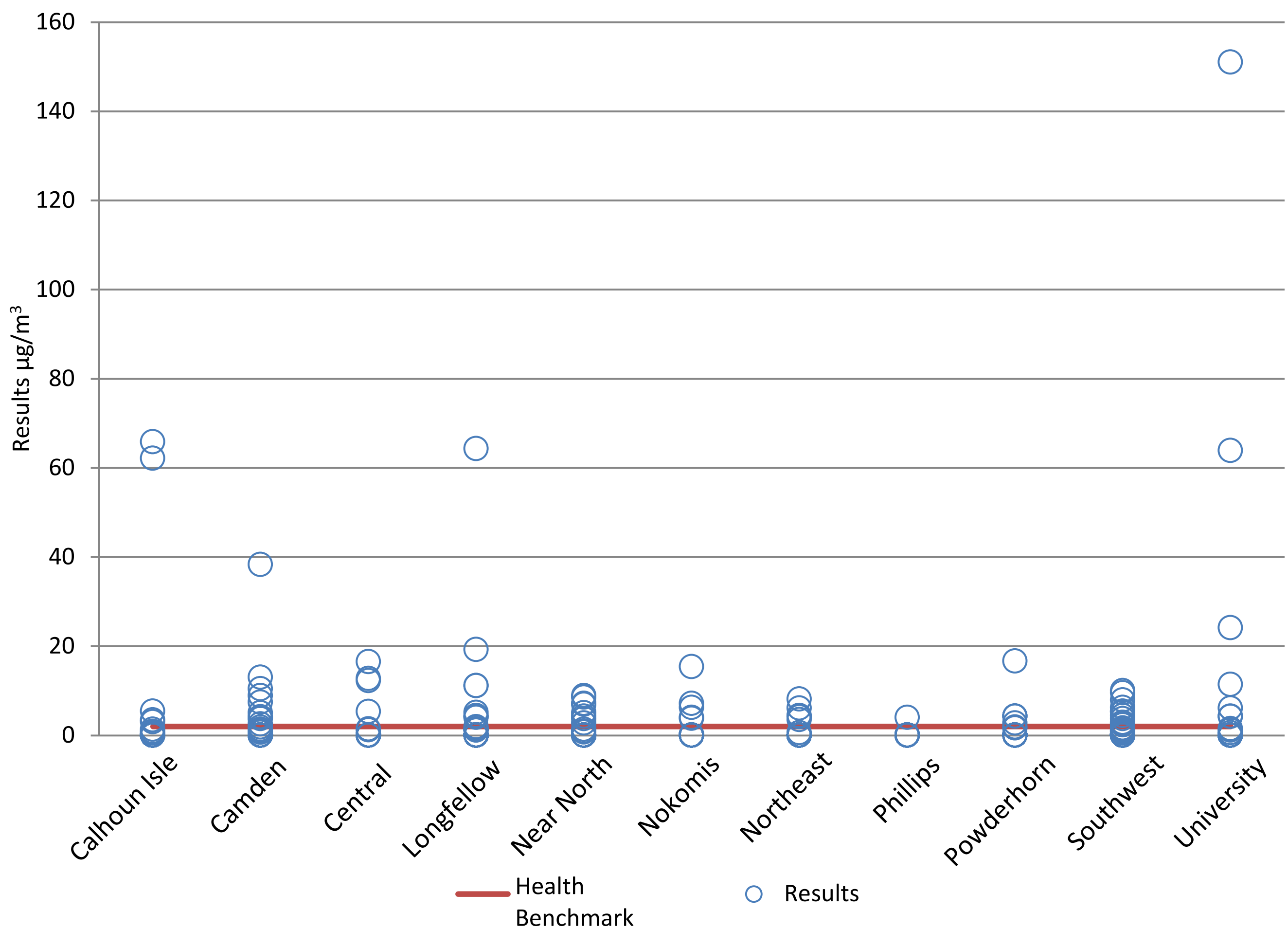


Figure 18 - Tetrachloroethylene Results under 20 µg/m³ by Community

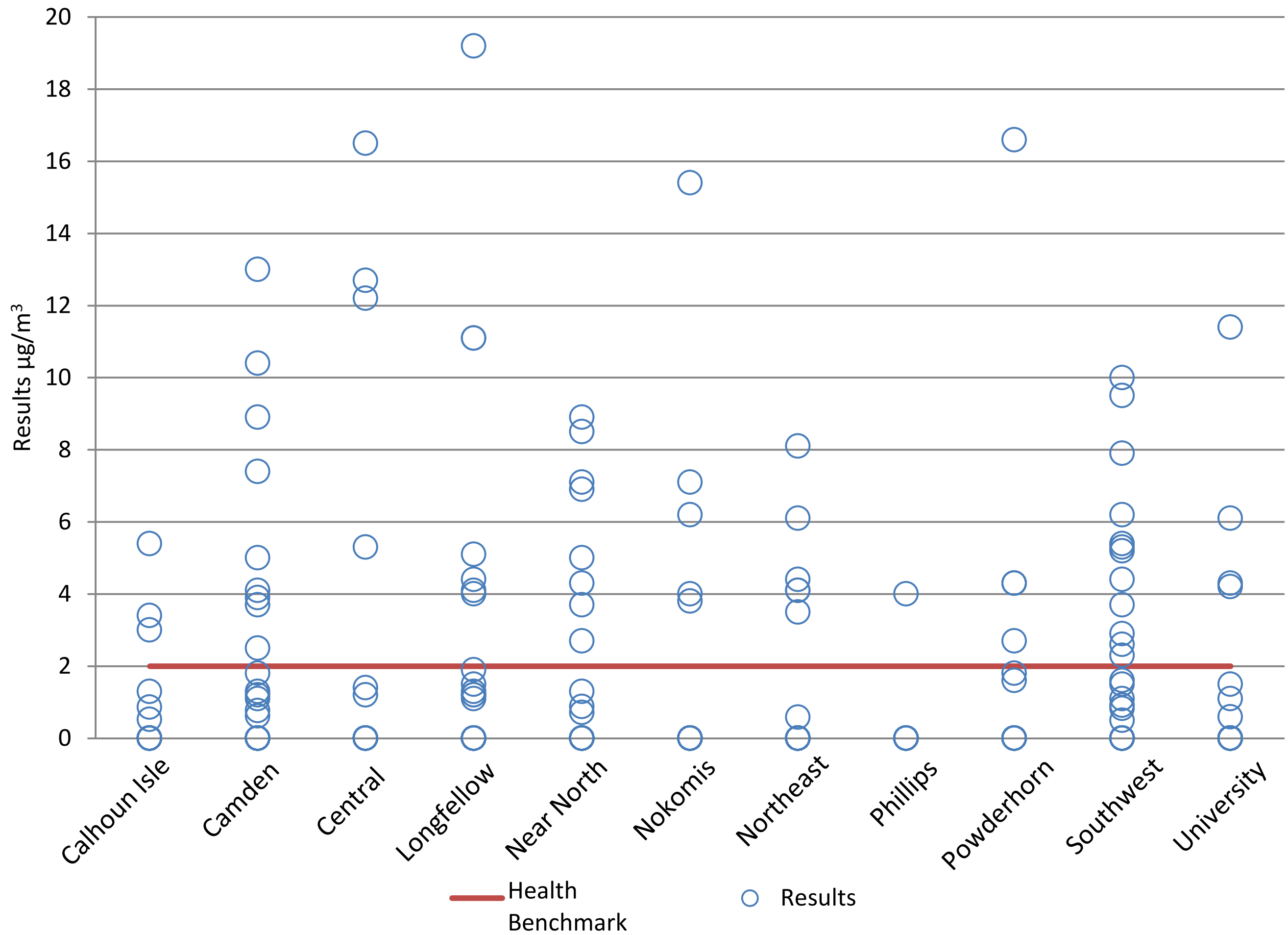
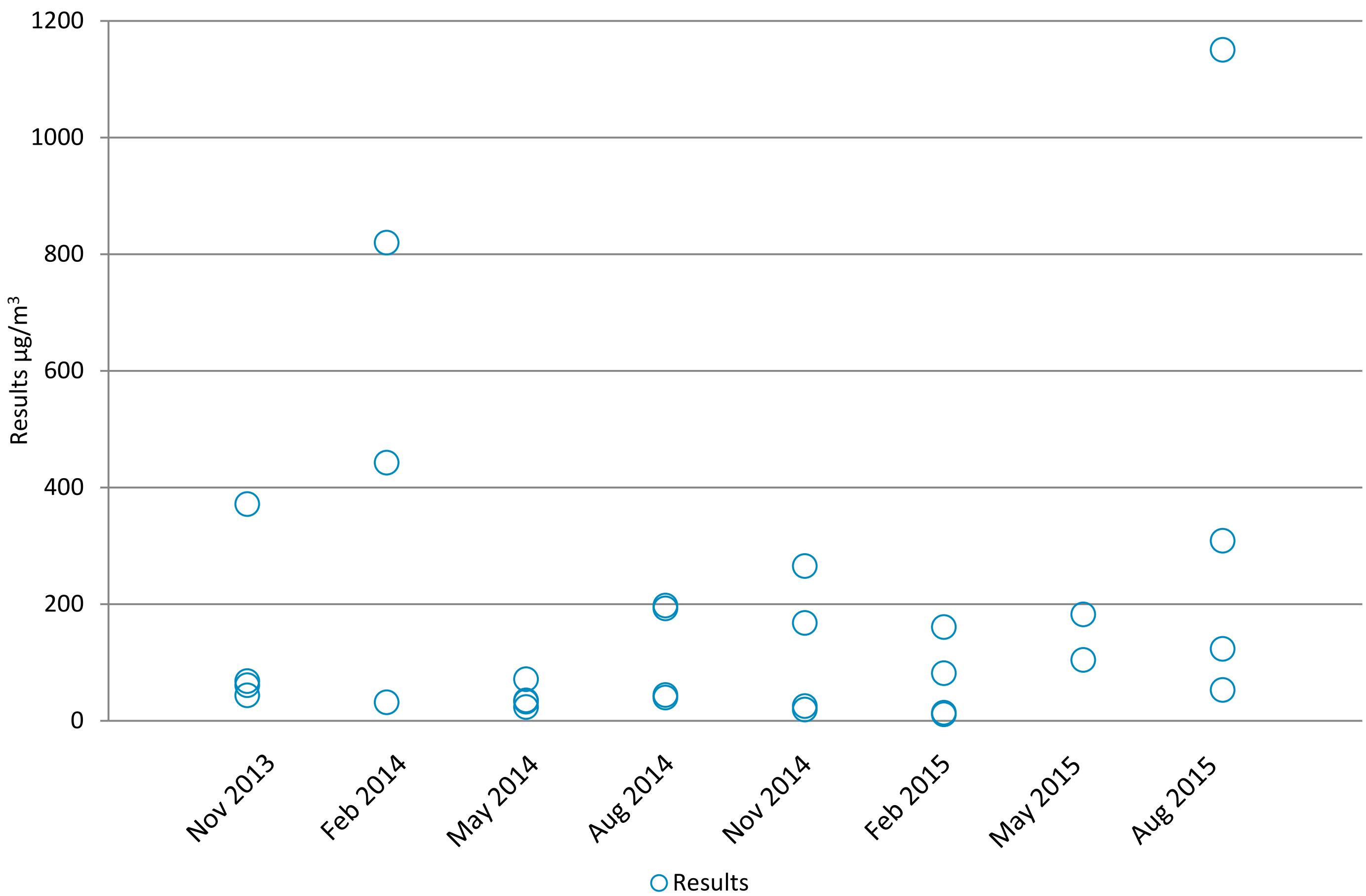


Table 12 - Averages, Maximums, and Minimums of Tetrachloroethylene Results at Dry Cleaning Facility in Powderhorn ($\mu g/m^3$)

Date	Average	Max	Min	Number of Samples
Nov 2013	135.5	371.0	43.2	4
Feb 2014	430.8	819.0	31.4	3
May 2014	40.2	70.9	22.9	4
Aug 2014	118.1	197.0	39.6	4
Nov 2014	118.9	265.0	18.8	4
Feb 2015	66.3	160.0	10.6	4
May 2015	143.0	182.0	104.0	2
Aug 2015	408.4	1150.0	52.4	4
Total	**176.8**	**1150.0**	**10.6**	**29**

Figure 19 - Tetrachloroethylene Results at Dry Cleaning Facility in Powderhorn



Trichloroethylene

Trichloroethylene was detected at locations across the entire City. Of the 900 samples collected, trichloroethylene was detected a total of 67 times. Of those detects, 14 were above and 53 were at or below the health benchmark of 2 $\mu g/m^3$ (with six of the 53 within 10% of the health benchmark). The average level of trichloroethylene across all communities and across all sampling events is 0.3 $\mu g/m^3$.

Figure 20 shows the locations where trichloroethylene was detected with results less than or equal to the health benchmark. Figure 21 shows the locations where trichloroethylene was detected above the health benchmark. Table 13 shows the average trichloroethylene levels for each community by sampling event. Table 14 shows the average, maximum, and minimum result for each community across all sampling events, as well as the total number of samples from each community. Any result (average, maximum, or minimum) above the health benchmark is highlighted in red. Figure 22 shows all results for trichloroethylene by community compared to the health benchmark with non-detects replaced by zeros. Figure 23 shows a close up of the cluster of results found below 10 $\mu g/m^3$.

Figure 20 - Trichloroethylene Results Less Than or Equal to Health Risk Value

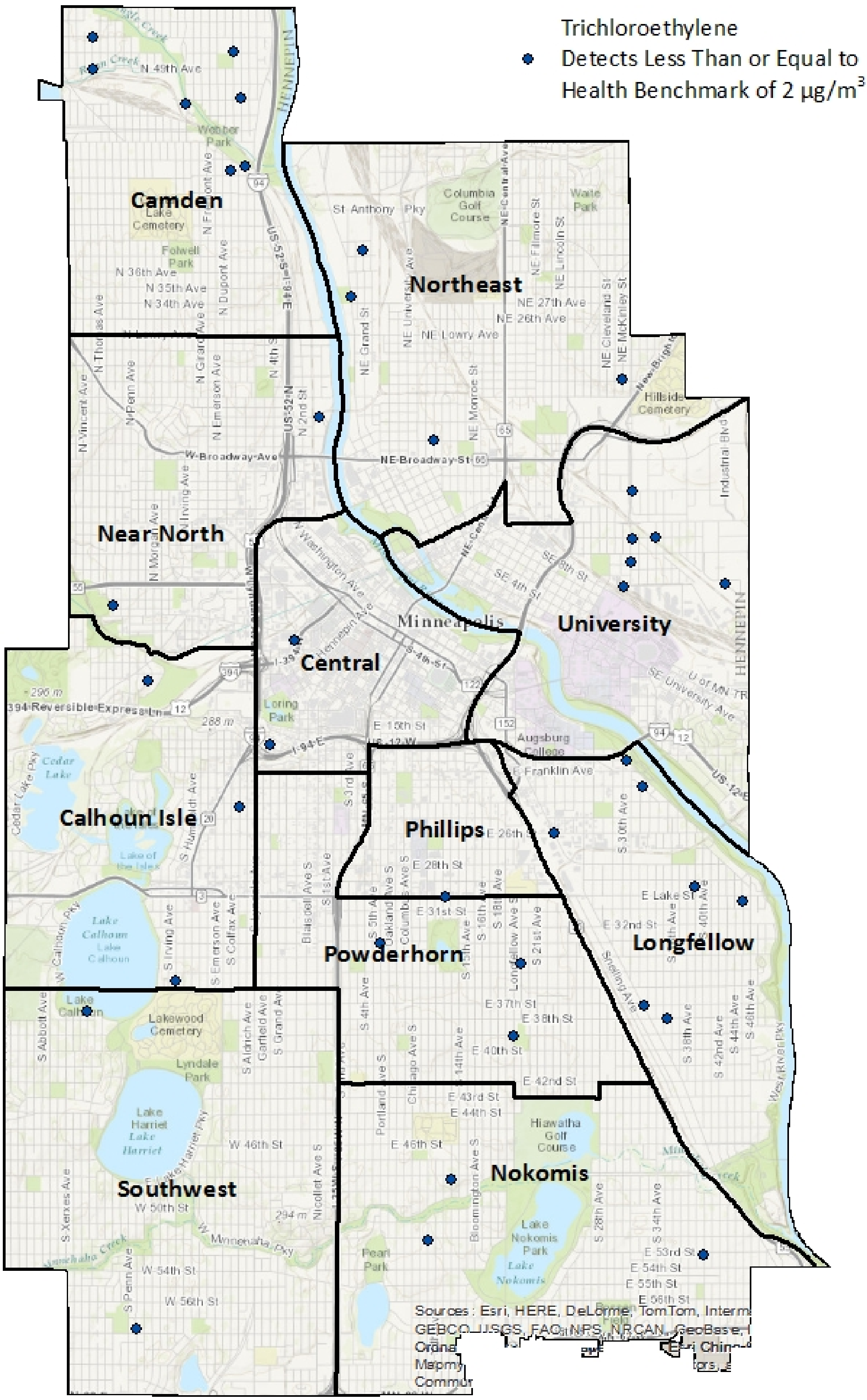


Figure 21 - Trichloroethylene Results above Health Benchmark

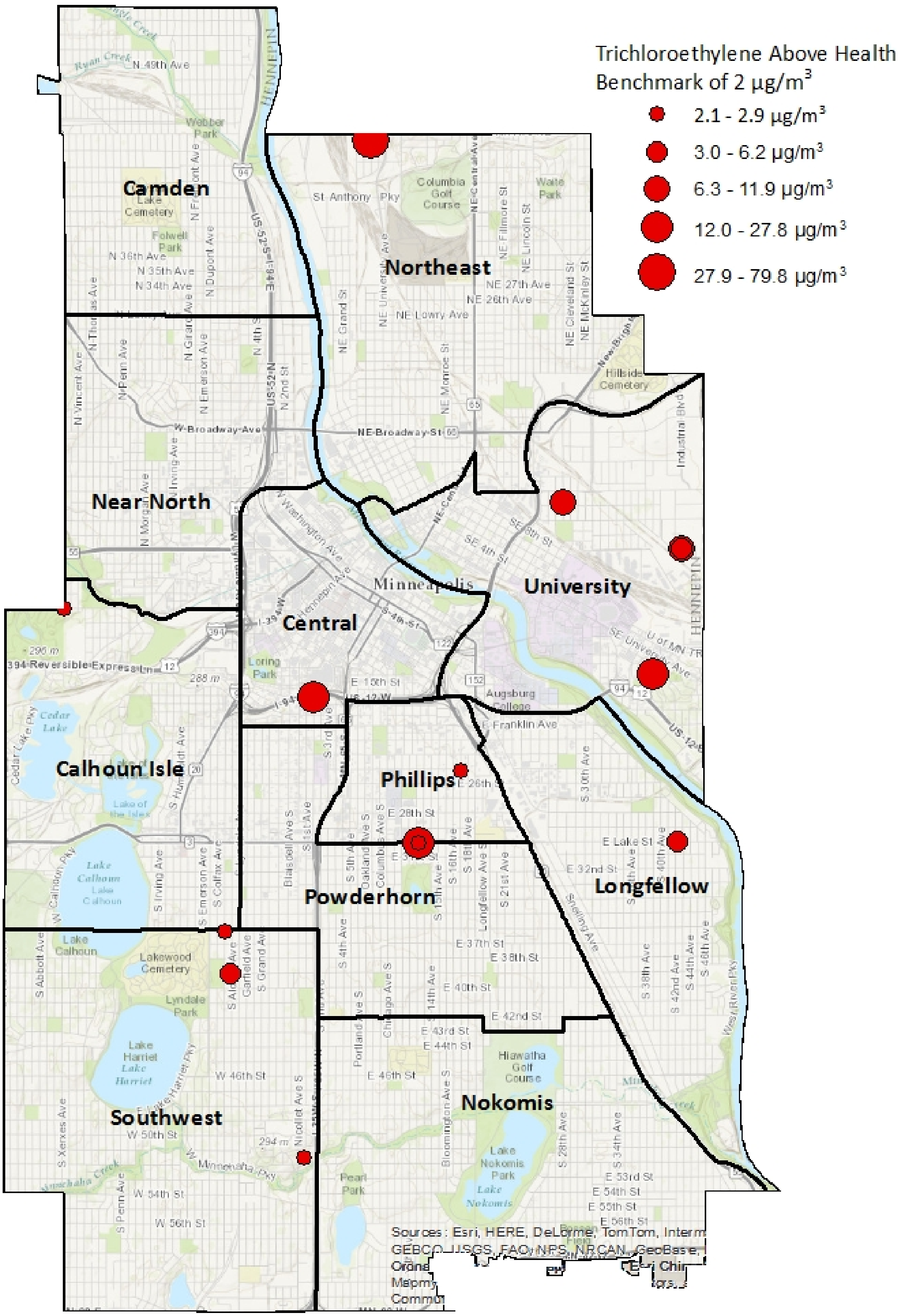


Table 13 - Averages of Trichloroethylene Results by Sampling Date (µg/m^3)

Community	Nov 2013	Feb 2014	May 2014	Aug 2014	Nov 2014	Feb 2015	May 2015	Aug 2015	Total
Calhoun Isle	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.2	**0.1**
Camden	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	**0.1**
Central	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	**0.5**
Longfellow	0.2	0.1	0.1	0.2	0.0	0.0	0.4	0.1	**0.1**
Near North	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	**0.0**
Nokomis	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	**0.1**
Northeast	6.7	0.2	0.1	0.0	0.0	0.0	0.0	0.1	**0.9**
Phillips	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
Powderhorn	3.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	**0.4**
Southwest	0.1	0.0	0.3	0.3	0.0	0.0	0.0	0.4	**0.1**
University	4.2	0.0	0.2	0.0	0.9	0.0	0.0	0.7	**0.7**
Total	**1.6**	**0.1**	**0.1**	**0.1**	**0.2**	**0.0**	**0.1**	**0.2**	**0.3**

Table 14 - Averages, Maximums, and Minimums of Trichloroethylene Results (µg/m^3)

Community	Average	Max	Min	Number of Samples
Calhoun Isle	0.1	2.9	0.0	67
Camden	0.1	1.6	0.0	130
Central	0.5	19.8	0.0	41
Longfellow	0.1	5.9	0.0	119
Near North	0.0	1.9	0.0	83
Nokomis	0.1	1.3	0.0	78
Northeast	0.9	79.8	0.0	89
Phillips	0.1	2.1	0.0	33
Powderhorn	0.4	21.2	0.0	69
Southwest	0.1	4.8	0.0	95
University	0.7	27.8	0.0	96
Total	**0.3**	79.8	**0.0**	**900**

Figure 22 - All Trichloroethylene Results by Community

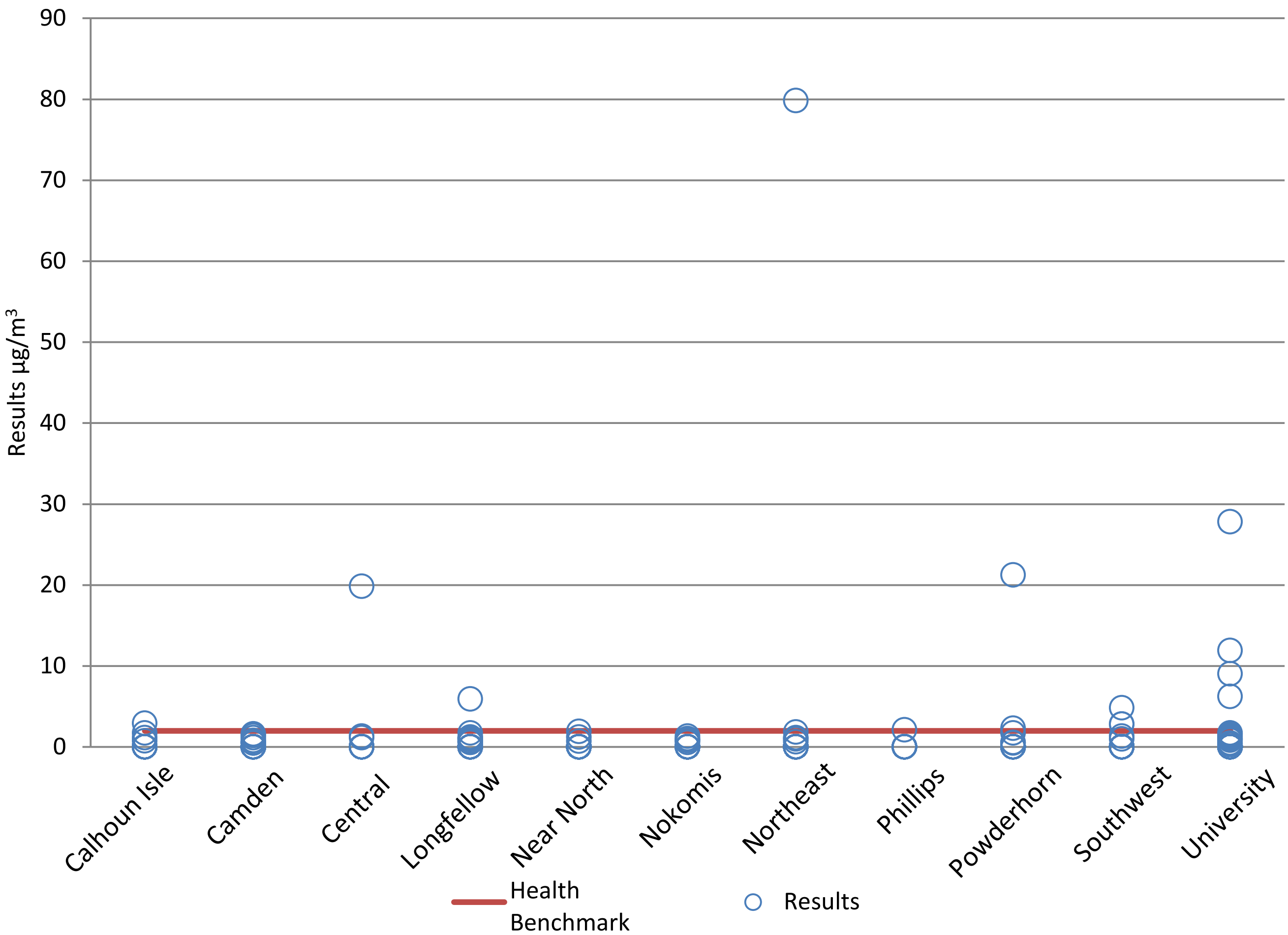
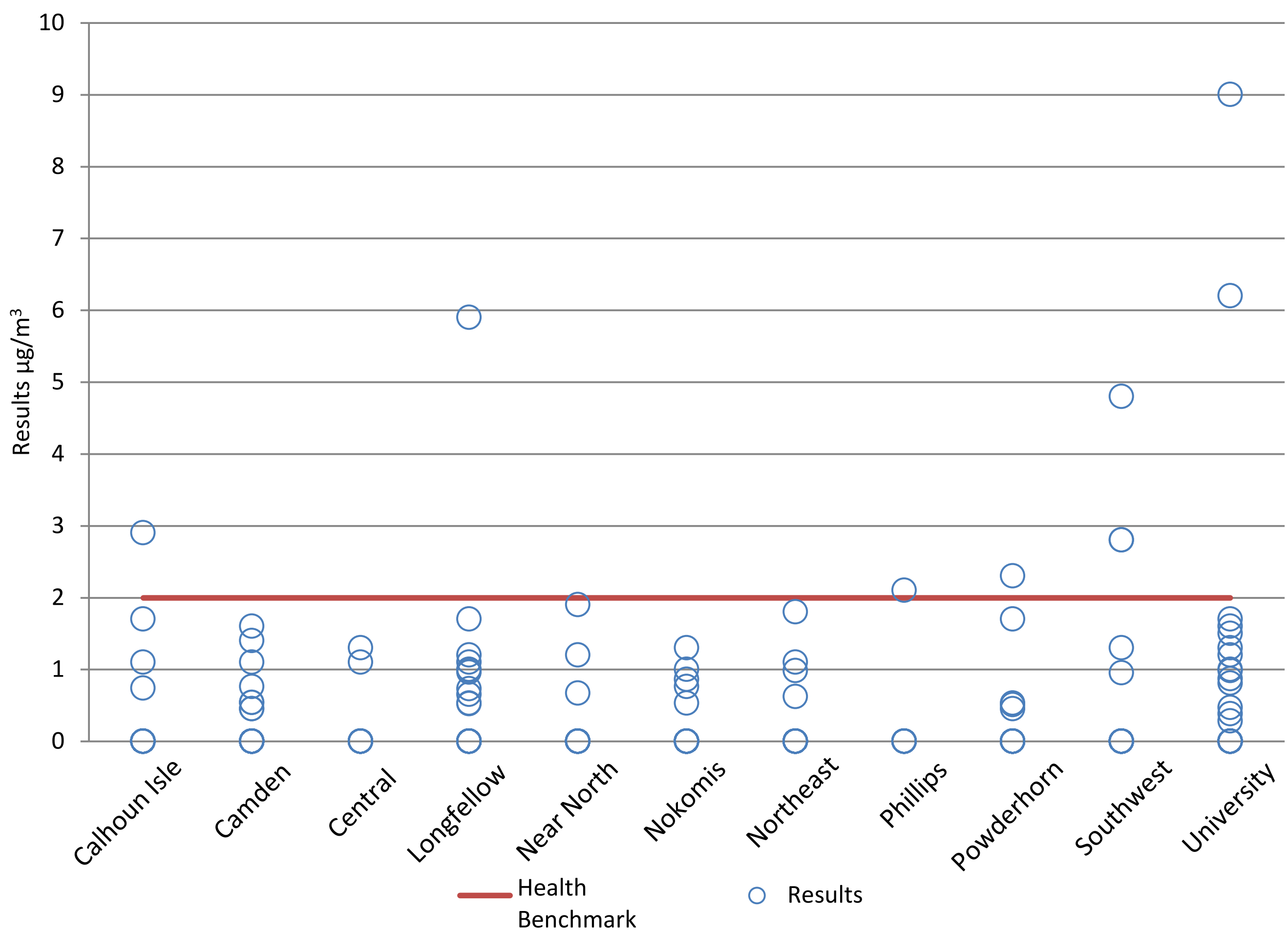


Figure 23 - Trichloroethylene Results under 10 µg/m^3 by Community



Formaldehyde

Formaldehyde was detected at all sample locations. Of the 114 sampled collected for formaldehyde, 93 were detect results and all of the detect results were above the health benchmark of 2 µg/m^3. Because the formaldehyde samples were located in an attempt to determine differences away from the road-way, community comparisons are not available. In general, the results were similar with no outliers, indicating a consistent level of formaldehyde across Minneapolis that is higher than the health benchmark. The average of all 93 detects was 3.6 µg/m^3, the maximum was 8.5 µg/m^3, and the minimum detect was 2.4 µg/m^3.

Limitations

Limitations to the study included the use of residents as data collectors. We could not have sampled on this level, deploying over 100 Summa canisters at the same time, without the use of volunteers, yet we acknowledge the possible introduction of human error with the use of multiple data collectors. The chance of error was addressed in part by excluding any samples which did not contain enough air for an accurate analysis.

Results would be more detailed if we could sample with real-time data collection. Our funding for this study allowed us to sample over four seasons for two years. Further recommendations would be to study over four seasons, for one year, using real-time data collection.

The study is also limited by the number of canisters. While this study uses more sampling locations than many other similar studies, in Minneapolis or elsewhere in the U.S., more locations provide for an even finer resolution of data for conducting spatial analysis. Even with over 100 locations, it is difficult to make conclusions regarding data and particular locations over such a relatively large geographic area.

Conclusions

The results show areas and specific VOCs of potential concern in Minneapolis. Each of the five VOCs selected for detailed consideration has a unique set of conclusions based on the data.

Benzene and Formaldehyde

Data on annual average air toxics levels recorded at MPCA monitoring stations are available through 2014 (MPCA, 2016b). Because half of our sampling events took place in 2014, we compared the annual average from the MPCA for 2014 to our overall averages. When the MPCA releases the averages for 2015, we will add those into our comparison. The results for benzene and formaldehyde are consistent with data found in MPCA air toxics sampling. Benzene and formaldehyde are the two pollutants consistently measured above their health benchmarks by the MPCA (MPCA, 2003). In 2014, across all monitors in Minneapolis, MPCA recorded an annual average level for benzene of 0.70 $\mu g/m^3$, matching our overall average of 0.70 $\mu g/m^3$. In 2014, across all monitors in Minneapolis, MPCA recorded an annual average level for formaldehyde of 2.4 $\mu g/m^3$, slightly below, but in in line with, our overall average of 3.6 $\mu g/m^3$.

Benzene had 78 results over the lower end of its health benchmark of 1.3 $\mu g/m^3$. There were also eight times where a community's average for a particular sampling event was over the health benchmark. While the average for one sampling event isn't an appropriate indicator of a long-term, chronic exposure level, it is still potentially concerning. While formaldehyde wasn't sampled across Minneapolis in the way that the other analytes were, every detect result for formaldehyde was above its health benchmark of 2 $\mu g/m^3$. Of greatest potential concern is the overall average across all sampling events for formaldehyde of 3.6 $\mu g/m^3$, which is above its health benchmark. Formaldehyde was the only analyte with an overall average above its health benchmark, although there were limited sampling locations.

These results are likely associated with traffic use in Minneapolis. The main source of benzene and formaldehyde emissions in Minneapolis is from mobile sources. The mobile sources are both on-road and non-road, which includes construction equipment. The results confirm that, in addition to fine particulates, benzene and formaldehyde are health concerns related to intensive traffic use in Minneapolis. Benzene is a fuel additive and formaldehyde is a byproduct of combustion. Benzene and formaldehyde are health impacts of traffic and these pollutants may impact health at a further distance from road ways then fine particulates.

Naphthalene

Naphthalene was noted in this study because there were eight results over its health benchmark of 9 $\mu g/m^3$, although overall it was found in relatively small numbers of samples and all averages were below the health benchmark. Naphthalene is not reported in the MPCA air toxics data explorer. Combustion is the largest emission source of naphthalene and there may be increases in areas with older vehicles without properly functioning catalytic converters as well as in areas with diesel vehicles (Jia, 2010). It is likely that the few results over the health benchmark were due to particular vehicular traffic in the area. More sampling, modeling, and study would need to be done to understand a distribution of naphthalene and its sources throughout the city.

Tetrachloroethylene

Tetrachloroethylene results are concerning for both levels across the city and at dry cleaning facilities. In the MPCA air toxics data, there were only two monitors reporting annual averages for tetrachloroethylene in 2014. In 2014, across those two monitors in Minneapolis, MPCA recorded an annual average level for tetrachloroethylene of 0.19 µg/m^3, slightly below, but consistent with, our overall average of 1.2 µg/m^3. This lower level may be due to fewer locations and the higher monitor location above breathing height as tetrachloroethylene is heavier than air (OSHA, 2005).

The ambient atmospheric level of tetrachloroethylene is typically <1 µg/m^3 (ATSDR, 1997). There were times when the average levels were well above this, during the November 2014 sampling event in particular. The results for tetrachloroethylene were uniformly higher across all communities in November 2014, although the exact reason is unknown. During that time there were no recorded weather events, such as a temperature inversion, and the Air Quality Index (AQI) was good, which also indicated no weather event that would have resulted in higher pollutant concentrations. Other analytes measured in this study did not spike in November 2014. It is possible there were high emissions from one or more facility using tetrachloroethylene in Minneapolis during that time. There were also 100 times when an individual result was above the health benchmark for tetrachloroethylene, which indicates that tetrachloroethylene is found at levels above the ambient atmospheric level throughout the City and not just close to dry cleaning facilities.

The average levels of tetrachloroethylene from the dry cleaning facility are well above the health benchmark and are potentially concerning. All results from samples taken at the dry cleaning facility are above the health benchmark. These samples were collected on the roof of the dry cleaning facility, not inside, indicating that high levels of tetrachloroethylene are found in emissions of dry cleaning facilities. The overall average tetrachloroethylene level outside the dry cleaning facility was 176.8 µg/m^3. This is potentially concerning, in particular for residents who live near dry cleaning facilities in Minneapolis. The levels of tetrachloroethylene found at or near neighboring homes are likely above the health benchmark. Future study of tetrachloroethylene will involve targeted sampling around dry cleaning facilities throughout the City.

Trichloroethylene

Trichloroethylene will take further study to identify more specific sources and reasons for their distribution within the study. In the MPCA air toxics data, only one monitor reported an annual average for tetrachloroethylene in 2014. In 2014, the recorded level for tetrachloroethylene was 0.13 µg/m^3, slightly below, but consistent with, our overall average of 0.3 µg/m^3. There were times, in particular November 2013, when some community averages were above the health benchmark. Similar to the high tetrachloroethylene events in November 2014, it is possible these localized high averages may be the result of high emissions from a facility or facilities using trichloroethylene. Trichloroethylene will take further study to identify more specific sources and reasons for their distribution within the study, in particular the time-localized high averages. Future study could include targeted sampling around facilities using trichloroethylene and documentation of emissions to determine unusually high averages.

Next Steps

The City of Minneapolis is hoping to further understand the results of this study by working in partnership with Virginia Tech to develop a land-use regression model (LUR). LUR is a statistical-empirical approach to model the spatial patterns of air quality. LUR is a useful tool for estimating concentrations at locations where measurements are not available. A requirement for using LUR is a dense network of air quality measurements, which we have as a result of the study. We also plan to do additional focused sampling at and around dry cleaning facilities in order to determine the extent to which tetrachloroethylene is being emitted and the distance at which the chemical reaches into the surrounding neighborhoods. The LUR should be finished in the spring of 2017. Additional sampling around dry cleaning facilities will begin in spring of 2017.

As MDH updates their health benchmarks, we will continue to review and compare our data. MDH keeps guidance values up-to-date and prioritizes which guidance values should be re-evaluated. If an HRV or RAA is updated, we will review our data based on the new health benchmark. MDH also adds new chemicals, selecting them for review based on requests from other programs within MDH, from other state agencies, and from the public through the Contaminants of Emerging Concern program (MDH, 2016b). The Air Quality Study showed some VOCs above their EPA, ATSDR, or CDC defined health benchmark. At the time of this study, these VOCs didn't have a health benchmark defined by MDH. We will continue to watch for these, and other, new VOCs to be added to the MDH health benchmark list.

The Health Department will also continue to provide incentives through the Green Business Cost Share Program to businesses that change to cleaner practices and reduce the pollutants found in this study. To date, this approach has led to the reduction of 21.39 tons of pollution annually by working with small businesses like dry cleaners, auto body shop, and larger manufacturers. At the time of this report, partners at Clean Air Minnesota are evaluating ways to more quickly get dry cleaners to switch away from tetrachloroethylene. These efforts are a direct result of this study's findings.

Appendices

Appendix A: Volunteer Forms

Can ID#_______

Acknowledgment, Waiver, & Consent to Participate in the City of Minneapolis - Air Quality in Minneapolis: A Neighborhood Approach Study

I, ____ (PRINT NAME), as the owner or legal adult resident responsible for the property located at ____, in the City of Minneapolis, hereby GIVE MY CONSENT TO AND PERMISSION FOR the placement of a Summa canister on my property in accord with the Minneapolis Air Quality Study as described in the informational material provided to me.

Furthermore, I understand that I may revoke my consent to participate in this study <u>at any time</u> by telephoning the City of Minneapolis's Environmental Services at *(612) 673-2319* or by writing to: *Minneapolis Environmental Services; Air Quality Study; Room 414 Public Service Center; 250 South 4th Street; Minneapolis, MN 55415*. I understand that I am responsible for placing, opening, and closing the Summa canister on my property in the manner described to me; locked in a non-invasive and non-destructive manner at a location on the exterior of my property or in my yard; and that in order to most effectively assist and contribute to this scientific study, to the best of my ability, I will assume the Summa canister is not tampered with, moved, or displaced during the course of the 72-hour study. I understand that I am responsible for returning the Summa canister by May 22nd, 2015 (unless alternate arrangements are made). I understand that my address may be included on a map of the study, but my name and personal information will not be made public. Finally, I understand that that there will be no fees or payments made by or to any party to this study but that my participation will be greatly appreciated by the City of Minneapolis and all of its citizens and visitors and that my cooperation will contribute to the scientific knowledge and study of our local environment.

DATED: ____________________ ____________________________________

(Signature)

I can be contacted at the following telephone numbers (optional):

THANK YOU! – ANY QUESTIONS REGARDING THE PROGRAM MAY BE DIRECTED TO
PATRICK HANLON: ***(612) 673-2319 or patrick.hanlon@minneapolismn.gov***
JIM DOTEN: ***(612) 673-3595 or jim.doten@minneapolismn.gov***
JENNI LANSING: ***(612) 673-3023 or jenni.lansing@minneapolismn.gov***

Minneapolis Air Quality Study - Emissions Activity Form

This form is provided to gain a better understanding of emissions around the location of the air monitoring canister. Please fill-in information to the best of your ability.

Name ___________________ **Location** (Address): ___________________________**Can ID** _____

Time canister was opened (5/11/15) _______ **Time canister was closed (5/14/15)** _________

Description of Activity (Circle all that apply)

•Gas powered lawn equip.	•Painting	•Idling engine
•Cigarette smoke	•Burning	•Diesel engine
•Airplane	•Roofing	•Road work

•Industrial operation (Describe the industry type or name)

Other Activity ____

Odor Descriptor – Please use the chart on the back to describe any odors that you detected

____

____

Date and Time emissions and/or odors were noticed:

Activity__________	**Activity**__________	**Activity**__________
Start____________	**Start**____________	**Start**____________
End_____________	**End**_____________	**End**_____________

Intensity of the odors (circle 1=least intense to 5=most intense)

1 2 3 4 5

Additional Comments-

____

____

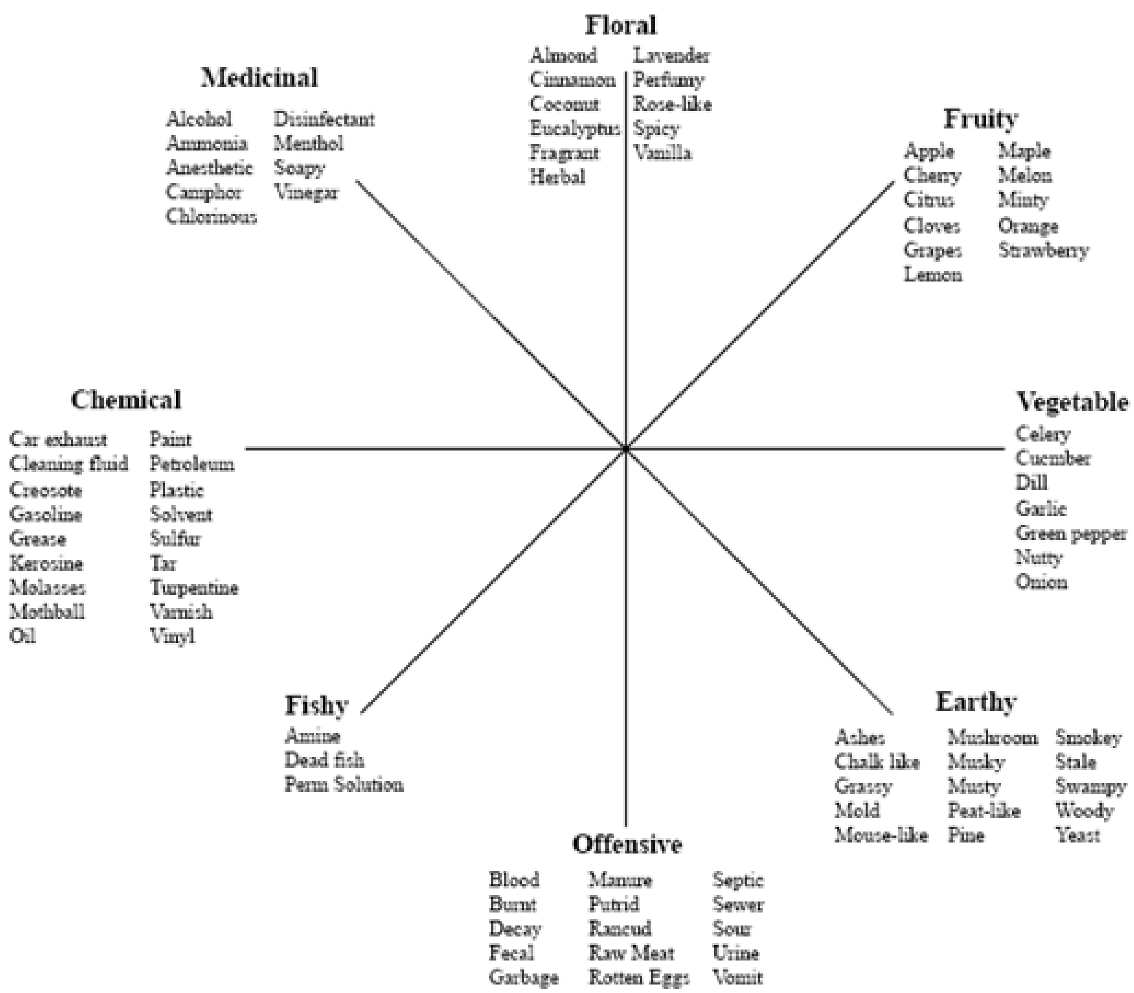
Minneapolis Air Quality Study - Emissions Activity Form Instructions

This form is provided to gain a better understanding of emissions around the location of the air monitoring canister. Please fill-in information to the best of your ability.

- Please complete the form **if** you notice any emissions or detect any odors during the span of the sampling dates (odors may or may not be associated with emissions activities noted).

- Below is an 'Odor Descriptors' chart to use as a guide if you notice any odors.

- **Please return this form with your canister when you return it by May 22nd, 2015.**



St. Croix Sensory, Inc. • P.O. Box 313, 3549 Lake Elmo Ave. N. • Lake Elmo, MN 55042 U.S.A. • Tel:800-879-9231 • Fax:651-439-1065
Email:stcroix@fivesenses.com • Web:www.fivesenses.com

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