Health Consultation

Review of Analysis of Particulate Matter and
Metal Exposures in Air

KCBX
(AKA, "CHICAGO PETROLEUM COKE" sites)

CHICAGO, COOK COUNTY, ILLINOIS

AUGUST 22, 2016

Prepared by the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Division of Community Health Investigations
Central Branch

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SUMMARY

Introduction

The Chicago Petroleum Coke ("petcoke") site is located in an industrial corridor in Chicago, Cook County, Illinois. The "site" consists of two separate properties operated by KCBX Terminals Company (aka "Koch Carbon, LLC", or "KCBX") and previously included the Beemsterboer Slag Company (aka "Beemsterboer"). Historically, large mounds of petcoke have been stored in outdoor piles at each of these facilities. Residents allege that dust from the piles blows into the surrounding community and puts their families at risk. Senator Dick Durbin (D-IL) requested assistance evaluating the potential health impact of windblown dust on residents living near the site.

This health consultation summarizes the results of U.S. Environmental Protection Agency (U.S. EPA) and KCBX perimeter particulate sampling and the potential impact of particulates on residents living near the petcoke storage mounds. This investigation is occurring to characterize risk and determine the need for action to reduce community exposures. U.S. EPA and KCBX collected data on particles and metals in air, but did not include sulfur and organic compounds. This consultation evaluates health impacts from particulates and metals only. Beemsterboer is not addressed because the facility removed all bulk materials from its Chicago location and U.S.EPA eliminated their requirement to conduct air sampling.

Conclusions

ATSDR arrived at three conclusions regarding the Chicago petcoke site:

Conclusion 1

Blown dust from the KCBX facility poses a public health hazard to residents living adjacent to the piles, especially for sensitive individuals. Exposure to particulate matter near KCBX on poor air quality days poses an acute and chronic health threat to sensitive individuals (e.g., children and the elderly) and to those with pre-existing respiratory illnesses (e.g., asthma). Furthermore, peak concentrations of PM_{10} are at harmful levels that may result in serious acute health effects for sensitive individuals and may also affect those who are not considered vulnerable (e.g., healthy adults).

Basis for Decision

ATSDR evaluated 12 months of continuous dust monitoring data. The size of the dust particles measured were 10 micrometers (μm) or less in aerodynamic diameter ("PM_{10}"). Particles this size are considered "respirable" and can get past mucous in the airways and into the lungs. Approximately 8,000 hours of particulate data collected from nine sites around the North and South Terminal petcoke piles at KCBX were evaluated. Since residences are located across the street from the property line, these monitors are surrogates for worst-case community exposures. Hourly average PM_{10} concentrations of up to 985 $\mu g/m^3$ were detected near the piles. Concentrations of dust in this range-hundreds of micrograms per cubic meter-could irritate the respiratory tract, particularly in

sensitive individuals or those with respiratory conditions, such as asthma. It could also result in the worsening of cardiovascular illness in people who have pre-existing heart conditions.

Conclusion 2

Breathing the combined levels of metals in air near KCBX result in a low increased cancer and non-cancer risk. ATSDR concludes that this risk level is similar to that attributable to air sources across Cook County and the State of Illinois.

Basis for Decision

Cancer: Of all metals measured in air, only average concentrations of arsenic and chromium exceeded the ATSDR Cancer Risk Evaluation Guide (CREG). The CREG is equivalent to a risk of one excess cancer per million individuals exposed over a lifetime, which is a very low long term increased risk. The estimated increased cancer risk from arsenic is an additional 4.4 cases in a population of 1,000,000 people downwind of the North Terminal, and an additional 7.6 cases in a population of 1,000,000 downwind of the South Terminal. The estimated cancer risk from chromium is 8.8 per 1,000,000 people at the North Terminal and 10 per 1,000,000 people at the South Terminal. These risks are typical of those posed by arsenic and chromium in urban environments.

The combined upper confidence limit (95% UCL) average of the metals measured in air yielded an increased cancer risk of 1.4 cases in a population of 100,000 people at the North Terminal and an increased risk of 1.9 cases in a population of 100,000 at the South Terminal. These risks are typical of those posed by ambient air pollutants in urban environments, Cook County, and the state of Illinois.

Non-cancer: Concentrations of individual metals averaged for chronic and acute exposure durations did not exceed health based comparison values in air. Evaluating combined risk from all metals did not yield a significantly elevated risk for average concentrations of metals. The calculated non-cancer risk is within the average risk range for Cook County and the state of Illinois.

Conclusion 3

KCBX does adversely impact air quality in the community, and is the predominant source of vanadium, elemental carbon, organic carbon, and particulate matter (PM) measured at the monitor locations.

Basis for Decision

Statistical analyses and graphical presentations of data were used to evaluate air measurements and meteorological data. These assessments allowed us to 1) identify the direction of sources from monitors that contribute to decreased air quality; 2) to evaluate pollutants that are present together at similar fractions of total dust to understand which pollutants various sources may be contributing; and 3) to evaluate trends in the data to help us understand what factors are

influencing concentrations of metals and dust in air. From this information we were able to determine that the KCBX monitors clearly indicate that blown dust from the petcoke mounds are impacting air quality at the monitor locations at the North and South Terminals. There are non-KCBX related regional PM contributions to air quality in the area, but the dust from piles increase the amount of PM at the monitor sites.

Using U.S.EPA's Positive Matrix Factorization method "factors" were identified which identified groups of pollutants that had trends in air suggesting they are from the same source. The KCBX mounds were highly correlated with windblown vanadium, elemental carbon, organic carbon, and PM. Further, trends analyses indicate that the highest concentrations of dust are in the middle of the day (see Appendix C).

Next Steps

The U.S. EPA continues working with KCBX and other local source facilities to reduce emissions and improve air quality in the area and protect the health of the community.

For More Information

More information about this site is available at U.S. EPA's web page, available at: http://www2.epa.gov/petroleum-coke-chicago. More information about the pollutants discussed in this document can be found at ATSDR's Toxic Substances Portal: http://www.atsdr.cdc.gov/substances/index.asp.

PURPOSE AND STATEMENT OF ISSUES

In December 2013, ATSDR received a petition co-signed by Senator Dick Durbin and Representative Robin Kelly regarding the Chicago Petroleum Coke ("petcoke") sites (United States Congress 2013). The petition expressed concern that residents were being exposed to unhealthy amounts of petcoke dust from large mounds of product along the Calumet River in south Chicago, Illinois and requested that ATSDR conduct an evaluation of exposure and health risk in the surrounding community (U.S. Congress 2013). The sites of interest included the KCBX Terminals, Inc., and the Beemsterboer Slag Corporation, which was located between KCBX's North and South Terminals.

BACKGROUND

Site Description and History

KCBX and Beemsterboer are the facilities of interest in this evaluation. KCBX was a storage location for petcoke and coal before it was shipped to end-users. The petcoke received mostly came from refineries processing tar sands oil in the upper Midwest. The stored petcoke was sold to the industrial manufacturing sector (e.g., steel and aluminum manufacturing) as a cheaper alternative to coal. The Beemsterboer facility primarily handled steel slag and resized, stored, and packaged recycled aggregate for use in concrete, asphalt, and rock wool insulation. Beemsterboer's slag aggregate was used as a road base, in construction backfill, deicing agents, and as an agricultural liming product (U.S.EPA 2013a; Beemsterboer, 2014).

In November 2013, the U.S. EPA Air and Radiation Division issued a Section 114 Request for Information that required KCBX and Beemsterboer to conduct air monitoring around their petcoke storage areas, analyze continuous measurements for particulate matter in airborne dust equal or less than 10 microns in diameter ("PM_{10}"), and to speciate filter-based particulate samples for heavy metals (U.S.EPA 2013b,c). In December 2013, Beemsterboer entered into an Interim Agreed Order jointly with the State of Illinois and City of Chicago to remove all bulk materials, including petcoke, from its location in southeast Chicago by the end of February 2014. Beemsterboer requested the elimination of the monitoring requirement in lieu of their agreement with the state of Illinois, and U.S.EPA granted the request unless such time as the company begins handling petcoke again (Beemsterboer 2014).

The KCBX mounds were still present at this location when air monitoring commenced around North and South Terminals in February 2014. Based on the data collected, U.S. EPA issued Notices of Violation (NOV) to KCBX in June 2014 and April 2015 for exceeding the National Ambient Air Quality Standards (NAAQS) for PM_{10} of 150 $\mu g/m^3$ over a 24-hour period (U.S.EPA 2014a; U.S.EPA 2015a). Wipe samples at residences near the facilities identified that the particulate dust from the piles can be found in the surrounding community (U.S.EPA, 2014a, U.S.EPA 2015a). Residents in the community surrounding the KCBX storage facility are concerned that petcoke dust impacts their homes and that exposures to the dust could be harmful to people's health (United States Congress 2013).

On March 13, 2014, the City of Chicago issued Bulk Material Regulations, which required all coke and coal piles to be either removed or enclosed by June 9, 2016. This resulted in the closure of the KCBX North Terminal by June 30, 2015 and the removal of all storage piles from the KCBX South Terminal prior to June 9, 2016. Therefore, all KCBX petcoke piles were removed after the end of the study period (Chicago Department of Health (CDPH) 2016). In December 2014, KCBX announced it would decommission the North Terminal storage of petcoke and consolidate the petcoke piles in an enclosure at the South Terminal location (CDPH 2015). Both Terminals were fully operational during the air monitoring study. Since then, the North Terminal has been shut down and the South Terminal has been converted to a direct transfer facility where petcoke is loaded onto river vessels via a covered conveyor system.

Demographics

This site is along the Calumet River in Chicago, Illinois and the surrounding area is densely populated. The total population within one mile of the North and South Terminals was 35,045 people at the 2010 Census. Of these 15,427 were non-Hispanic white, 7,308 were non-Hispanic blacks, 11,208 were "another race", and 1,102 identified being two or more races. 23,044 were Hispanic or Latino of any race. Sensitive groups include children 6 years of age and younger (3,876), residents 65 years of age or older (3,858), and women of childbearing age (7,141) (U.S. Census 2010).

ENVIRONMENTAL DATA

Data in this evaluation were collected between February 2014 and January 2015. Review of continuous dust data and dust data analyzed for heavy metals are included in this health consultation. Continuous hourly PM_{10} data were collected to quantify ambient concentrations of heavy metals and carbon present in dust particles equal to or smaller than 10 micrograms (µm) in aerodynamic diameter (d_{ae}). For context, a human hair is about 70 µm. PM_{10} is of concern because it is *respirable*-small enough to travel into the lungs. While larger particles are trapped in the mucous lining of the nose, throat, and lungs, respirable particles can travel deep into the lungs and enter the bloodstream. The PM_{10} dust samples were also *speciated*, or analyzed to tell us which metals were present. These two methods are detailed below.

- Continuous monitoring: (URS 2014)

  PM_{10}: The PM_{10} continuous monitors collect ambient particulate matter samples through a size selective inlet that is designed to allow only particles with an aerodynamic diameter <10 µm to pass through to the measurement apparatus. PM_{10} is measured using the MetOne Instruments Model BAM-1020[1] (EPA designated Class III Federal Equivalent Method EQPM-0798-122).
  Weather data: Two 10-meter meteorological towers were installed as part of this program. One was located near the northwest boundary of the North Terminal, and the

[1] *Use of trade names is for identification only and does not imply endorsement by the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry, the Public Health Service, or the U.S. Department of Health and Human Services*

second near the east boundary of the South Terminal. The towers measured wind speed, wind direction, ambient temperature, and barometric pressure.

Continuous measurements for PM_{10} and meteorological data were reported in 1-hour increments, and evaluated in acute (24-hour) and chronic (annual) averaging periods.

- Filter based discrete sampling: (URS 2014)

  The PM_{10} samplers collected ambient particulate matter samples through a size-selective inlet that is designed to allow only particles with an aerodynamic diameter <10 µm to pass through to the filter. PM_{10} was measured using the Thermo Environmental Instruments Model 2025i PartisolPlus sequential sampler (EPA designated Federal Reference Method RFPS-1298-127). Samples were collected for 24-hour periods once every three days at the Northeast location at both the North and South Terminals. The metals reported in the analysis include: arsenic, barium, cadmium, total chromium, copper, iron, lead, manganese, nickel, selenium, silver, vanadium, and zinc.

Overview for identifying contaminants of concern and evaluating risk

Some general observations regarding outdoor air quality are important to understand as a baseline prior to reviewing the data. First, ATSDR notes that outdoor air in populated areas throughout the United States will contain trace amounts of numerous pollutants. The fact that air samples near KCBX contained many different air pollutants is actually not unusual. It is the magnitude of the air pollution that is of greater concern for health risk evaluation purposes. Second, measured air pollution levels in Chicago—as with air pollution anywhere in the United States—will reflect contributions from numerous emission sources. Some of the pollutants found in the air near KCBX are very clearly connected to local industrial sources, but other air pollutants are not. ATSDR has made an effort to provide context on which emission sources likely contributed to the measured air pollution levels in the sections that follow.

Before discussing health risks from exposure to air pollutants, it is important to understand:

1. Which pollutants are present;
2. The magnitude (the range) of concentrations of those pollutants;
3. How often, or the frequency, of which pollutants were detected; and
4. How long (the duration) of exposure to the levels of pollutants detected in air.

The following sections explain our process of evaluating health risks. All data collected in the community are publicly available and were downloaded from U.S. EPA's KCBX/Petcoke website (http://www2.epa.gov/petroleum-coke-chicago/kcbx-fenceline-air-monitoring-data) by ATSDR. The data were then compared to the most conservative (lowest) health based screening levels from ATSDR, U.S.EPA, or other agencies to pinpoint those that are present at levels of potential concern to begin to understand the risk they might pose to area residents. In this document, ATSDR refers to these screening levels as "CVs", or *comparison values*.

Statistical Methods for Evaluating Measured Data

Data were analyzed statistically to describe it over different averaging periods (24 hour, annual) as well as spatially to understand source contributions to pollutants detected in ambient air by the

KCBX monitors. The program "R" was used to evaluate the data for this assessment (http://www.r-project.org/). Polar annulus plots, used to describe concentrations as they relate to wind speed and wind direction, were generated using the *openair* package in R for hourly data from February 18, 2014 through January 31, 2015 (Carslaw and Ropkins 2014, R Core Team 2014). Daily PM_{10} data as well as *speciated* (or individually reported) inorganics/metals data were used to generate polar plots using the *openair* package. These 24-hour averaged data were collected between February 19, 2014 and January 31, 2015.

Means and 95% bootstrap confidence intervals were calculated for the speciated data to help us understand what average concentrations and trends of all the pollutants look like. These averages were used to screen data against health based comparison values to identify contaminants of concern for further analysis. To address measurements that were reported "non-detect" because they were not measured at recordable concentrations, we estimated the non-detected measurements using statistics-specifically "*robust multiplicative lognormal replacement*" for non-detects as implemented in R package *zCompositions* (Palarea-Albaladejo and Martin-Fernandez 2013; 2014). The speciated concentrations of metals and carbon at the North and South Terminals were compared using an "*analysis of similarity*" as implemented in R package *vegan* (Oksanen et al. 2014). Another test to identify significance is looking at pairwise comparisons, which we assessed using 2-sided Wicoxin Rank-Sum test.

HEALTH IMPLICATIONS

Exposure Pathways

In order for residents to be exposed to chemical contaminants, they must come into direct contact with the contaminants through a completed exposure pathway. A completed exposure pathway consists of five main parts:

1. A **Source** of contamination (a chemical release, landfill, etc.),
2. A method of **Environmental Transport** (air, water, soil, sediment, etc.), which allows the chemicals to move from the source area and bring it into contact with people,
3. A **Point of Exposure** is where people come into physical contact with the chemicals,
4. A **Route of Exposure** (ingestion, inhalation, or dermal contact), which is how people come into contact with chemicals, and
5. A **Population at Risk**, i.e., people likely to come into contact with site-related chemicals.

Physical contact with a chemical contaminant alone does not necessarily result in adverse health effects. A chemical's ability to affect a person's health depends on:

- How much of the chemical a person is exposed to (dose)
- How long a person is exposed (duration)
- How often a person is exposed (frequency)
- The toxicity of the chemical (how chemicals can make people sick)

Other factors affecting a chemical's likelihood of causing adverse health effects upon contact include the resident's

- personal habits,
- diet,
- age and sex,
- current health status, and
- past exposures to toxic chemicals (occupational, hobbies, etc.).

Defining Comparison Values

ATSDR develops minimal risk levels (MRLs) based on scientific literature that evaluates exposure to specific pollutants and their associated health effects in human or animal studies. Using the same studies ATSDR develops media-specific comparison values (CVs) using conservative exposure assumptions. As a result, ambient air concentrations lower than their corresponding comparison values are not likely to cause harmful health effects. Because comparison values are often much lower than effect levels, ambient air concentrations greater than comparison values are not necessarily levels of air pollution that would present a possible public health hazard. Rather, chemicals with air concentrations higher than comparison values require further evaluation.

To select the pollutants requiring the most detailed evaluation, ATSDR considered its own health-based comparison values, as well as those published by other agencies. Comparison values were identified for both short-term (acute) and long-term (chronic) exposure durations, and also considered both cancer and non-cancer health effects. In our evaluation, the air sampling results were compared to ATSDR Cancer Risk Evaluation Guides (CREG) and environmental media evaluation guides (EMEGs)/MRLs, and U.S.EPA Regional Screening Levels (RSLs) and Reference Concentrations (RfCs). When ATSDR and U.S.EPA values were not available, we used comparison values from other states who have derived comparison values (like the Air Monitoring Comparison Values (AMCVs) from Texas Department of Environmental Quality (TDEQ)). These CVs are defined, below:

- ***ATSDR CREGs*** are estimates of the concentrations of a carcinogen at which there is an elevated risk for one case of cancer in one million people exposed over a lifetime.
- ***ATSDR inhalation MRLs/EMEGs*** are estimates of the concentrations of pollutants calculated that anyone could be exposed to without experiencing health effects, based on chronic, intermediate, and acute exposures (those occurring longer than 365 days, from between 14-365 days, and 14 days of exposure or less, respectively.)
- ***U.S. EPA RfCs*** are estimates of the concentrations of pollutants calculated that anyone could be exposed to for a lifetime without experiencing health effects. RfCs are for inhalational exposures and based on pollutant specific non-cancer health effects.
- ***U.S. EPA RSLs*** are risk-based numbers that are available for multiple exposure pathways and for chemicals with both carcinogenic and noncarcinogenic effects. The RSLs used in this analysis correspond to either a one excess risk of cancer per million exposed people (10^{-6}) for carcinogens or a Hazard Quotient (HQ) of 1 for non-carcinogens.
- ***TCEQ AMCVs*** are chemical-specific air concentrations set to protect human health and welfare. Exposure to an air concentration at or below the AMCV is not likely to cause health effects in the general public, including sensitive subgroups such as children, the elderly, pregnant women, and people with preexisting health conditions.

In all cases, ATSDR initially considered the lowest—or the most health-protective—comparison value to determine which pollutants require the most detailed evaluation, regardless of which agency published those values. In some cases, ATSDR's comparison values were the most protective; in other cases, the lowest values were published by U.S.EPA or TCEQ. The underlying premise in this approach is that ATSDR used the comparison values to focus on the subset of pollutants having the greatest potential to contribute to adverse health effects, while assuming that the pollutants never found above health-based comparison values do not reach levels of health concern. The pollutants requiring further evaluation are reviewed in the next sub-section.

After compiling all available metals data, ATSDR then selected which subset of chemicals required the most detailed health evaluation. The evaluation of the data occurred in two steps:

- Step 1, Screening: Pollutants were compared to CVs with an averaging time consistent with the averaging time of the pollutant (yielded 3 pollutants for evaluation in Step 2);
- Step 2, Health Implications: Overarching evaluation of measured and modeled data and the cumulative risk assessment data, and incorporating spatial analysis.

Screening

Descriptive statistics were generated for PM_{10}, all metals, and carbon, and the data were compared to health based comparison values specific to the sampling time frames. For example, 24-hour sampling data were compared to acute health-based comparison values, and annually averaged data were compared to chronic health-based comparison values, etc.

Three pollutants - arsenic, cadmium, and chromium - had air concentrations higher than the lowest health-based comparison value for chronic exposure. Only chromium exceeded the acute health based comparison value for hexavalent chromium established by TCEQ on May 14, 2014, but not when the maximum total chromium value is adjusted for hexavalent chromium content. Unfortunately, hexavalent chromium was not directly measured during this investigation, but the ratio of trivalent and hexavalent chromium is available from monitors that did *speciate* (identify the chemical form) chromium at other nearby air monitoring sites. PM_{10} had very high intermittent measured concentrations and was also selected as a contaminant of concern. Tables 6 and 7 in Appendix B displays all metals and screening criteria used to identify arsenic and chromium as contaminants of concern.

For the three metals selected for further evaluation, lifetime cancer risk is the most sensitive health endpoint. U.S. EPA's cancer risk range for arsenic, cadmium, and hexavalent chromium are displayed in Table1 and further discussed below.

Table 1. U.S.EPA cancer risk levels and corresponding metals concentrations, µg/m^3

Risk Level	Arsenic	Cadmium	Hexavalent Chromium
10^{-4} (1 in 10,000)	0.023	0.056	0.0083
10^{-5} (1 in 100,000)	0.0023	0.0056	0.00083
10^{-6} (1 in 1,000,000)	0.00023	0.00056	0.000083

Sources: U.S. EPA, 1998, U.S. EPA, 1995, and U.S. EPA, 1987

Pollutants selected for further evaluation

Arsenic

Most data on human health effects resulting from arsenic inhalation exposure come from occupational studies of workers at smelters and chemical plants. These workers generally have exposure pathways beyond inhalation (dermal or oral exposures) and generally are exposed to other pollutants in addition to arsenic, so evaluating the inhalation pathway alone can be challenging (ATSDR 2007; U.S.EPA 2012). Daily averaged arsenic levels at the North and South Terminal did not exceed TCEQ AMCV acute health based comparison values, however the annual averages at these sites (0.0008 and 0.0012 $\mu g/m^3$, respectively) exceeded ATSDR's CREG of 0.00023 $\mu g/m^3$.

Health effects possible from exposure to arsenic
Chronic (long-term) inhalation exposure to inorganic arsenic of humans is associated with irritation of the skin and mucous membranes and effects in the brain and nervous system. Non-cancer symptoms including cardiovascular (like Reynaud's phenomenon and numbness in fingers), dermal effects (dermatitis and discoloration, like blackfoot disease), and neurological effects have been demonstrated to occur in workers exposed chronically to greater than or equal to 360 $\mu g/m^3$, 78 $\mu g/m^3$, and 310 $\mu g/m^3$, respectively. The most sensitive endpoint in workers exposed for many years is the development of cancer. Long term inhalation exposure (>30 years) has been shown to be strongly associated with lung cancer at levels as low as 50 $\mu g/m^3$ (ATSDR, 2007b).

As shown on Table 1, average concentrations of arsenic around KCBX (0.0008-0.001 $\mu g/m^3$) correspond with the 10^{-5} (0.00001) to 10^{-6} (0.000001) cancer risk range, meaning that if exposed to these concentrations for a lifetime, between 1 in 100,000 and 1 in 1,000,000 people have an increased risk of developing cancer from their exposure. The added risk is very small compared to typical lifetime risks for people living in the United States, which the American Cancer Society (http://www.cancer.org) estimates to be one in two men (0.5) and one in three women (0.33).

The levels of arsenic in air result in a very low increased cancer risk and are unlikely to cause acute or long-term non-cancer health effects. Thus, chronic exposure to the levels of arsenic measured in ambient air is not expected to harm people's health.

Cadmium

Cadmium is a naturally occurring metal found in the earth's crust. Cadmium is also emitted to the air from steel mills, other metal production facilities, and facilities that burn coal and other fuels containing trace amounts of cadmium. Cadmium is present in ambient air as a component of particulate matter. The annual average cadmium concentrations from the air monitoring study did not exceed any CVs, but the maximum upper confidence limit of the mean (95% UCL) of 0.0008 $\mu g/m^3$ at the South Terminal slightly exceeded ATSDR's Cancer Risk Evaluation Guide (CREG) concentration (0.00056 $\mu g/m^3$). The CREG is equivalent to U.S. EPA's 10^{-6} (0.000001) cancer risk level noted on Table 1.

Chronic exposure: Cadmium exposure in air can cause a broad range of impacts to the lining of the airways, lungs, and kidneys with increasing severity with increasing concentrations. Animal studies noted mild neurological effects at 20 $\mu g/m^3$, damage to throat tissue in rats at 22 $\mu g/m^3$, immune response activation in rat alveoli at 98 $\mu g/m^3$, and mortality in 75% of test rats at day 45 in a study of inhalation exposure to 90 $\mu g/m^3$ of cadmium oxide. Similarly, increased mortality was observed in rats exposed to 30 $\mu g/m^3$ of cadmium for 18 months. For cancer in humans, occupational exposure to 100 $\mu g/m^3$ cadmium oxide over 6 months was the lowest cadmium exposure concentration where lung cancer was reported over 6 months to 45 years of cadmium oxide occupational exposure. In rats, the lowest exposure concentration where lung cancer was detected was 30 $\mu g/m^3$ over 18 months (ATSDR, 2012a). The lowest of these values is 25,000 times higher than the highest annual average concentration detected at the South Terminal.

The levels of cadmium in air result in a very low increased cancer risk and are unlikely to cause acute or long-term non-cancer health effects. Thus, chronic exposure to the levels of cadmium measured in ambient air is not expected to harm people's health.

Chromium

Chromium is a naturally occurring metal found in rock and soil. Although other forms exist, two forms of chromium are considered relevant to human health: trivalent chromium (chromium III or CrIII) and hexavalent chromium (chromium VI or CrVI). Chromium is released to the air by many industrial processes, including steel mills and facilities that burn coal containing trace amounts of the element. Trivalent chromium is an essential nutrient in humans that is required to promote the action of insulin, which allows the body to use sugar, protein, and fat (ATSDR 2012b).

Daily averaged chromium levels exceeded the acute health-based comparison value for hexavalent chromium once, on May 14, 2014, at the South Terminal site. The annual averages at the North and South Terminal sites (0.018 and 0.0178 $\mu g/m^3$, respectively) exceeded ATSDR's hexavalent chromium CREG of 0.000083 $\mu g/m^3$. Unfortunately, chromium was not speciated to identify the portion of reported chromium that is trivalent or hexavalent. Hexavalent chromium comprises a small fraction of total chromium in air because it is less chemically stable and often converts to trivalent chromium in the environment. Although U.S.EPA made the conservative assumption in 1996 that 34% of all atmospheric chromium is hexavalent, data of total chromium and hexavalent chromium measured concurrently at sites across the Unites States indicate this ratio is far smaller. Speciated chromium data from sites in Texas indicate that assuming hexavalent chromium is 34% of total atmospheric chromium is extremely conservative (TCEQ 2009). Evaluating data in Texas and California, TCEQ concluded that hexavalent chromium comprises less than 10% of total chromium in ambient air (TCEQ 2009). A U.S.EPA funded study of the fraction of CrVI to total chromium in California and Michigan determined that this ratio was generally between 1.5-3.5% (Battelle 2003). ATSDR's query of the Air Quality System yielded a national average of 1.8% CrVI to total chromium at 14 sites between 2005 and 2013 that reported both total chromium and CrVI (U.S.EPA 2015b).

Health effects possible from exposure to chromium

Chromium exposure via inhalation is mostly associated with respiratory effects. Most of what we know about how it affects animals and humans comes from laboratory and occupational studies where the study animals and workers are exposed to high levels of chromium in air. These health effects include irritation of the lining of the nose, runny nose, and breathing problems such as asthma, cough, shortness of breath, wheezing. Workers have also developed allergies to chromium compounds, which can cause breathing difficulties and skin rashes. However, the concentrations causing respiratory problems in workers are at least 60 times higher than levels normally found in the environment. In workers, inhalation of CrVI has been shown to cause lung cancer (ATSDR 2012b).

Acute exposure: Both CrIII and CrVI inhalation exposure in can cause impacts to the lining of the airways with increasing severity with increasing concentrations. One human case study of five individuals and few animal studies report health outcomes from measured acute exposure to total chromium (including both CrIII and CrVI). In these studies, 50% of rats died when exposed acutely to 29,000 $\mu g/m^3$. In the only other acute exposure study besides those studying lethal doses, rats experienced nasal hemorrhaging when exposed to 1,150 $\mu g/m^3$ of chromium in air. The only case study of humans being exposed acutely was five individuals who had a history of contact dermatitis to chromium. They were dosed via inhaler to 35 $\mu g/m^3$ chromium and experienced an average 20% decreased in lung capacity immediately following their exposure (ATSDR 2012b).

There are no studies of acute CrIII exposure to humans, and only a few case studies of acute exposure of individual workers to CrVI (no measured exposure data were reported, just the resulting health effects). In these studies respiratory irritation (dyspnea, cough, wheezing, sneezing, rhinorrhea, choking sensation), dizziness, and headaches in individuals or small numbers of workers ($n \leq 5$) exposed to high concentrations of CrVI. In addition, acute inhalation exposure of individuals previously sensitized to chromium in air has produced symptoms of asthma and signs of respiratory distress similar to an allergic response (decreased forced expiratory volume, facial erythema, nasopharyngeal pruritus, blocked nasal passages, cough, and wheeze). Since the scientific database is lacking for acute duration studies, there is no acute MRL for CrVI or CrIII (ATSDR 2012b).

Chronic exposure: Chronic or subchronic chromium exposures can cause similar health outcomes to the body as acute exposures, but over a longer time period to lower concentrations. Exposure to CrVI is reported here because CrVI effect levels are lower than those for CrIII. The lowest concentrations of CrVI reported to cause non-cancer health effects reported immune and respiratory effects at 1 and 2 $\mu g/m^3$, respectively (ATSDR 2012b). The immunological effects (a decreased response of peripheral blood mononucleocytes at an average exposure of 1 $\mu g/m^3$) were identified in a study of 20 exposed and 24 unexposed Italian tannery workers exposed on an average of 5.8 years. Respiratory effects were also reported in a study of chrome plating workers in Sweden where respiratory effects from CrVI exposure was measured in 43 workers. The average exposure duration in this study was about 2.5 years. In these workers, signs and symptoms of adverse nasal effects were noted for mean exposure levels of 2-200 $\mu g/m^3$, including mucous membrane dysfunction (at 2 $\mu g/m^3$), lesions and perforation in the nasal

septum (workers exposed to up to 46 µg/m^3), and nasal irritation (2.1-11.0 µg/m^3). No nasal effects were noted in workers exposed to 0.2-1.0 µg/m^3 of CrVI. However, slight decreases in lung function were observed with exposures of 2-20 µg/m^3. In humans, the lowest exposure concentration where lung cancer was detected was 100 µg/m^3 for workers exposed to CrVI (ATSDR, 2012b). Assuming CrVI is present at the upper range (3.5%) of total chromium measured in recent studies, the average concentrations of CrVI adjusted for this percentage KCBX data would equal 0.00063 and 0.00062 µg/m^3. The lowest observed effect levels of 1 and 2 µg/m^3 are well below the annual average concentrations at the North and South Terminals. These values are approximately 1,600 times higher than the highest annual average concentration detected in monitors near KCBX.

Assuming CrVI makes up the upper range (3.5%) of total chromium in recent studies for the purposes of evaluating cancer risk (0.00063 and 0.00062 µg/m^3 in the air near KCBX), average concentrations would represent an additional cancer risk of 7.6 and 7.5 per 1,000,000 residents, respectively. The added risk is very small compared to typical lifetime risks for people living in the United States, which the American Cancer Society (http://www.cancer.org) estimates to be one in two men (0.5) and one in three women (0.33). Table 1 displays concentrations of hexavalent chromium and corresponding cancer risk.

The levels of chromium in air result in a very low increased cancer risk and are unlikely to cause acute or long-term non-cancer health effects. Thus, chronic exposure to the levels of chromium measured in ambient air is not expected to harm people's health.

Particulate Matter

Particulate Matter ("PM") is a term used in air quality that refers to particles of dust suspended in air. PM comes from industrial, manmade, and natural sources. Particles may be emitted directly or formed in the atmosphere by transformations of gaseous emissions such as sulfur oxides (SO_X), nitrogen oxides (NO_X), and volatile organic compounds (U.S.EPA 2009). The chemical and physical properties of PM vary greatly with time, region, meteorology, and source category. PM is measured in different sizes because the size of the dust particles determines how harmful it can be. These sizes are usually discussed as a) "TSP" or Total Suspended Particulate, which is dust of all sizes; b) PM_{10}, which is dust with an aerodynamic diameter (defined by how it moves through the air) of 10 microns in size; and c) $PM_{2.5}$ which is dust with an aerodynamic diameter (defined by how it moves through the air) of 2.5 microns in size. PM_{10} is primarily produced by mechanical processes such as construction activities, road dust re-suspension and wind. $PM_{2.5}$ originates primarily from combustion sources—like wood smoke, motor vehicle exhaust, and emissions from power plants—and certain industrial processes (U.S.EPA 2009). Due to their increasing weight, larger particles do not travel as far as fine particles.

The smaller the particle the more *respirable* it is, and the easier it is for it to lodge deep into the lungs and make it into a person's bloodstream. The risk for various adverse health effects has been shown to increase with exposure to PM. U.S. EPA's regulation of PM has evolved over the years with the increasing knowledge of health effects associated with exposure to PM. The current primary National Ambient Air Quality Standards (NAAQS) for PM_{10} is a 24-hour PM_{10} standard of 150 µg/m^3 that cannot be exceeded more than once per year on average over three

consecutive calendar years (U.S.EPA 2015). Studies on the long-term health effects from exposure to PM_{10} have been inconclusive, and thus, there is no chronic NAAQS for PM_{10}. The World Health Organization's (WHO's) air quality guidelines (AQGs) for PM_{10} are more conservative than the U.S. EPA's NAAQS. WHO has established an annual average AQG of 20 $\mu g/m^3$ and a 24-hour AQG of 50 $\mu g/m^3$ (WHO 2013).

The highest annual average concentration at any of the monitoring sites was 36 $\mu g/m^3$ at the Southeast monitor at the North Terminal. The annual average PM_{10} concentrations for all nine sites, ranging from 25-36 $\mu g/m^3$, exceed the WHO annual AQG of 20 $\mu g/m^3$. In addition to the nine onsite monitors, a regional air monitor also collects continuous measurements of PM_{10} at the Washington High School, which is south southeast of the KCBX facility. Although the school monitor is only 0.65 miles from the South Terminal storage pile and 1.5 miles from the North Terminal storage pile, it is generally upwind from KCBX and represents PM_{10} that is more typical of "background" regional air concentrations (U.S.EPA 2015c).

Health effects from exposure to particulate matter

Particulate matter has been associated with a range of respiratory and cardiovascular health problems. Health effects linked to exposure to ambient particulate matter include: premature death, the exacerbation of asthma as well as respiratory and cardiovascular disease, acute respiratory symptoms, chronic bronchitis, decreased lung function, and increased risk of heart attack (U.S.EPA 2009).

Acute exposure:
Hourly Averages
Hourly data are valuable because they reveal peaks that occur within a given day that may be less apparent when looking at daily averages. The hourly averages at the monitors ranged from a minimum of a few micrograms per cubic meters to nearly 1000 $\mu g/m^3$. Studies report higher rates of hospitalizations, emergency room visits, and doctor's visits for respiratory illnesses or heart disease during poor air quality days with high levels of PM in the air, though nearly all are averaged over 24 hours or longer. One study that evaluated hourly PM_{10} and health outcome data was identified and reported that a change in hourly and daily PM_{10} concentrations of 10 $\mu g/m^3$ was significantly associated with total mortality, and sub-daily (12 hour) exposures were also associated with cardiovascular mortality (Son and Bell, 2013). Asthma symptoms and acute and chronic bronchitis are aggravated by PM as well (U.S.EPA 2009, WHO 2013). Concentrations of PM measured in the KCBX monitors sometimes reach levels that are harmful not only for sensitive individuals such as children, the elderly, and those with pre-existing respiratory and cardiopulmonary disease, but healthy individuals as well. Peak concentrations detected by the monitors could increase symptoms in residents and the number of emergency room visits for breathing problems (e.g., wheeze, cough, shortness of breath, sputum production, chest tightness), as well as lung and heart disease. The hourly data collected at monitors surrounding the KCBX facility show peak PM_{10} concentrations of 440 to 983 $\mu g/m^3$ at the North Terminal sites and 636 to 985 $\mu g/m^3$ at the South Terminal sites (Tables 2 and 3 In Appendix B).

24-Hour Averages

Although the evidence is not as clear for the implications of exposure in PM_{10} as in $PM_{2.5}$ health outcome studies, short-term exposure to PM_{10} has been associated with increases in mortality, cardiovascular, and respiratory effects in areas with mean 24-hour average concentrations as low as 6.1 $\mu g/m^3$, 7.4 $\mu g/m^3$, and 5.6 $\mu g/m^3$, respectively (U.S.EPA 2009). Twenty-four averages at all sites, including the "background" monitor at Washington High School, often exceeded these levels. PM_{10} composition is more variable and includes fine and coarse particles, making the health impacts less clear (WHO 2005). The U.S. EPA's Web site has an Air Quality Index (AQI) online tool known as "AIRNow AQI Calculator", which can be used to estimate potential health effects from known 24-hour levels of PM_{10}, based on how air values compare to the U.S. EPA's National Ambient Air Quality Standards, or NAAQS (U.S.EPA 2015d). Table 5 presents the amount of time that PM levels represent an elevated risk at the nine monitors operated during this investigation. While the majority of sample days were deemed "Good" Air quality days, there were frequent "Moderate" air quality days that may cause respiratory problems for sensitive individuals. At the North Terminal Northeast Monitor (NT-NE) two days were considered "Unhealthy for Sensitive Groups", where there would be an increased likelihood of respiratory symptoms and aggravation of lung disease, such as asthma. In this instance, "sensitive groups" includes people with heart and lung disease, older adults, and children.

Table 5. Number of Daily Observations: Air Quality Index Rankings for KCBX Monitors

AQI Indicator	NT-NW*	NT-NE	NT-SE	NT-SW	ST-NW	ST-N	ST-NE	ST-CE	ST-SW	Washington High School
Good	322	312	294	305	326	320	307	306	314	254
Moderate	**15**	**25**	**45**	**34**	**13**	**19**	**31**	**33**	**25**	**11**
Unhealthy for Sensitive Groups	0	**2**	0	0	0	0	0	0	0	0
Unhealthy	0	0	0	0	0	0	0	0	0	0

**NT-NW: North Terminal northwest monitor; NT-NE: North Terminal northeast monitor; NT-SE: North Terminal southeast monitor; NT-SW: North Terminal southwest monitor*
ST-NW: South Terminal northwest monitor; ST-N: South Terminal north monitor; ST-NE: South Terminal northeast monitor; ST-CE: South Terminal central east monitor; ST-SW: South Terminal southwest monitor

- *"Good" AQI is 0 - 50. Air quality is considered satisfactory, and air pollution poses little or no risk.*
- *"Moderate" AQI is 51 - 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people. For example, people who are unusually sensitive to ozone may experience respiratory symptoms.*
- *"Unhealthy for Sensitive Groups" AQI is 101 - 150. Although general public is not likely to be affected at this AQI range, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.*
- *"Unhealthy" AQI is 151 - 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.*

Daily values frequently exceeded 24-hour concentrations documented to cause negative health outcomes in scientific studies, and exceeded both the WHO AQGs and the U.S.EPA NAAQS for 24-hour PM_{10} concentrations. The WHO 24-hour AQG was exceeded more frequently at the North Terminal monitors (64 days (19% of the time) at one of the four sites) compared to the South Terminal (37 days (11% of the time) at two of the five South Terminal sites). The AQG was exceeded more frequently near the KCBX facility than near Washington High School monitor, where it was exceeded for 15 days out of the sampling year. U.S.EPA has issued two

Notices of Violation to KCBX for exceedances of the 24-hour PM_{10} NAAQS of 150 µg/m^3 for three days since air monitoring began in February 2014: 155 µg/m^3 (4/12/14); 156 µg/m^3 (5/8/14), and 175 µg/m^3 (2/14/15). In all of these instances, the specific monitors that violated the NAAQS were downwind of petcoke operations on the day of the exceedance (U.S.EPA 2014a; U.S.EPA 2015a). Table 3 summarizes the 24-hour PM_{10} exceedances of these values.

Table 3. Number of days exceeding 24-hour Comparison Values

Monitor Name*	Days exceeding 24-hr AQG (50 µg/m^3)	% of days exceeding 24-hr AQG	Days exceeding 24-hr NAAQS (150 µg/m^3)	% of days exceeding 24-hr NAAQS
NT-NW	22	7	0	0
NT-NE	40	12	2	1
NT-SE	64	19	0	0
NT-SW	50	15	0	0
ST-NW	19	6	0	0
ST-N	24	7	0	0
ST-NE	37	11	1	0
ST-CE	37	11	0	0
ST-SW	34	10	0	0
Washington High School	15	6	0	0

NT-NW: North Terminal northwest monitor; NT-NE: North Terminal northeast monitor; NT-SE: North Terminal southeast monitor; NT-SW: North Terminal southwest monitor
ST-NW: South Terminal northwest monitor; ST-N: South Terminal north monitor; ST-NE: South Terminal northeast monitor; ST-CE: South Terminal central east monitor; ST-SW: South Terminal southwest monitor

Tables 4 and 5 in Appendix B summarize the descriptive statistics of all continuous PM_{10} data collected at the North and South Terminals, respectively.

Chronic exposure

There is evidence that long-term exposure to $PM_{2.5}$ can cause an increase in mortality (i.e., all-cause and cardiovascular) with long term average concentrations of 10–32 µg/m^3; for respiratory symptoms and incident asthma, as well as respiratory hospitalizations, at long-term average $PM_{2.5}$ concentrations of 9.7–27 µg/m^3; for developmental outcomes, specifically reductions in birth weight, at long-term average $PM_{2.5}$ concentrations of 11–19.8 µg/m^3; and pre-term birth at concentrations as low as 5.3 µg/m^3 (U.S. EPA 2009, U.S. EPA 2012b). Studies on the long-term health effects from exposure to PM_{10} have been inconclusive, but are likely to present similar impacts to the respiratory and cardiovascular systems. The annual average PM_{10} concentrations for all nine sites, ranging from 25-36 µg/m^3, exceed the WHO AQG guideline of 20 µg/m^3. No annual PM_{10} averages exceeded the annual NAAQS.

In summary, the hourly data show peak PM_{10} concentrations of 440 to 983 µg/m^3 at the North Terminal sites and 636 to 985 µg/m^3 at the South Terminal sites. Daily concentrations of PM_{10} frequently exceeded the WHO 24-hour AQG, and on three occasions exceeded the U.S.EPA NAAQS. Annual average PM_{10} means are lower than the annual average U.S. EPA NAAQS, but are within the risk ranges in several epidemiologic studies.

ATSDR concludes that exposure to particulate matter when there are poor air quality days in area near the KCBX petcoke piles poses an acute and chronic health threat to sensitive

individuals (e.g., children and the elderly) and to those with pre-existing respiratory illnesses (e.g., asthma). Furthermore, peak concentrations of PM_{10} are at harmful levels that may result in serious acute health effects for sensitive individuals and may also affect those who are not considered vulnerable (e.g., healthy adults).

Multi-pollutant Risk Evaluation

To evaluate risk from exposure to multiple pollutants at the same time, non-cancer and cancer health effects were assessed through standard risk assessment screening methodology. Whereas the previous section discussed risks from individual pollutants, this section presents the total hazard calculated for cancer and non-cancer effects from all combined uncensored data. Our averaging approach for long term exposure was presented in the data analysis section. We summed risks from all pollutants and all dates for each sampling location and assumed 1 year of data adequately represents chronic exposure. Acute risks were evaluated in the previous section.

The health based comparison values used in the non-cancer and cancer risk equations that follow were derived by ATSDR, U.S. EPA, California EPA, and TCEQ. In each case chronic exposure has been defined as "continuous exposure over a lifetime". For the purposes of risk assessment, the assumptions are 24 hour/day exposure over a 70 year lifetime. While assuming residents are exposed continuously over 70 years may be an overestimation of risk, we considered this assumption a conservative initial screening of exposure for community members.

Evaluating multi chemical exposures--non-cancer
The likelihood of non-cancer health hazards can be evaluated with the calculation of hazard quotients and hazard indices. A hazard quotient is the ratio of the potential exposure to the substance and the level at which no adverse effects are expected:

$$HQ\ (unitless) = air\ concentration\ (\mu g/m^3) \div health\ based\ non\text{-}cancer\ comparison\ value\ (\mu g/m^3)$$

In short, hazard quotients are calculated by dividing ambient air concentrations of pollutants by the appropriate health based comparison values that represent no increase in health effects (ATSDR, 2005c; TCEQ, 2006; U.S. EPA, 2005). If the HQ calculated is equal to or less than 1, then no adverse health effects are expected as a result of exposure. If the HQ is greater than 1, then further evaluation is warranted. To estimate a total non-cancer hazard posed by more than one pollutant, the HQs are simply summed, yielding a hazard index, or "HI" (ATSDR 2005).

$$HI = HQ_{pollutant\ 1} + HQ_{pollutant\ 2} + HQ_{pollutant\ 3} + HQ_{pollutant\ 4} \ldots\ldots etc.$$

Evaluating multi chemical exposures-cancer
As was done for HQ calculations, excess cancer risk can be calculated using a ratio of measured concentrations in air to air concentrations that represent a 10^{-6} cancer risk (the risk of 1 excess cancer per one million people exposed to the same contaminant concentration over a lifetime), or by multiplying a cancer unit risk factor by the concentration of pollutant measured in air. The calculation yields the relative increase of cancer risk from exposure to individual pollutants, or if summed, the cumulative increased cancer risk to multiple pollutants (ATSDR 2005; TCEQ 2006; U.S.EPA 2005).

Cancer Risk = [air concentration ($\mu g/m^3$) ÷ health based cancer comparison value ($\mu g/m^3$)]10^{-6}*
or
ER = CSF (or IUR) x air concentration ($\mu g/m^3$)

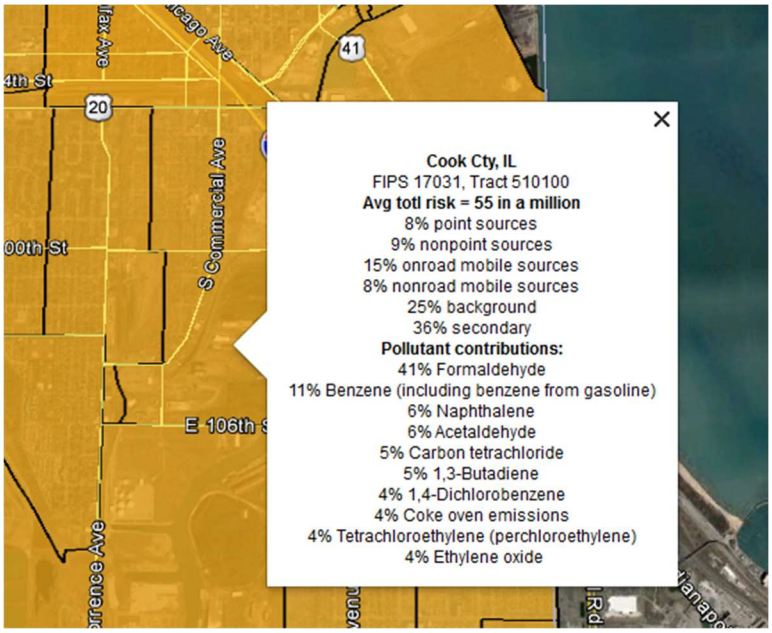
where
ER = estimated risk (unitless)
CSF/IUR = cancer slope factor $(mg/kg/day)^{-1}$ or inhalation unit risk $(\mu g/m^3)^{-1}$

ATSDR and U.S.EPA cancer-based CVs and contaminant concentrations were used to calculate cancer risk for each pollutant at each site in this investigation. The specific values used in our screening analysis assumed constant, 24 hour a day/7 day a week exposure over a 70 year lifetime.

The cancer risks for individual pollutants in the data set were summed to yield cumulative cancer risk by monitoring location, however only three pollutants have cancer risk comparison values: arsenic, cadmium, and chromium. U.S.EPA Risk Assessment Guidance suggests that an exposure point concentration (EPC) be used that is believed to be representative of typical site concentrations to evaluate risk. The most commonly used EPC is the 95% upper confidence limit (UCL) of the mean, which is the 95th percent confidence limit of the average concentration calculated for each pollutant at the site (U.S.EPA 2007). ATSDR calculated cancer and non-cancer risk using the average and UCL of the 95th percent confidence limit of the average for each pollutant in the multi-pollutant risk evaluation.

Cancer Risk Evaluation

Figure 1: NATA Cancer Risk for Census Tract 510100



Source: ***http://www.epa.gov/ttn/atw/nata2005/tables.html***

The U.S. EPA National Air Toxics Assessment (NATA) is an ongoing comprehensive review of cancer and non-cancer risk from the inhalation of air toxics across the United States. NATA provides estimates of the risk to inform both national and more localized efforts to identify and prioritize air toxics and emission source types and locations which are of greatest potential concern in terms of contributing to population risk. This in turn helps air pollution experts focus limited analytical resources on areas and or populations where the potential for health risks are highest. NATA calculates risk from national modeling the emissions of mobile sources (like cars, trucks, buses, and trains) as well as stationary sources (like factories, refineries, and power plants), yielding cancer and

non-cancer risk estimates for census tracts, counties, and states (U.S.EPA 2011).

In Illinois, the NATA estimate of cancer risk from all sources was calculated to be about 4.8 x 10^{-5} (an elevated risk of 4.8 additional cancers per 100,000 people living in the state), and the cancer risk from all sources in Cook County was calculated to be slightly higher, at 6.1 x 10^{-5} (an elevated risk of 6.1 additional cancers per 100,000 people living in the county). For the Census tract where the KCBX facility is located (tract # 510100), cancer risk was calculated to be 5.5 x 10^{-5}, with 36% of the risk attributed to secondary sources (where hazardous air pollutants emitted as one chemical transform into another from chemical reactions in the atmosphere); 25% of the risk attributed to background sources (e.g., natural sources or "long range transport" pollutants (pollutants transported in the atmosphere from other parts of the world), 23% of the risk attributed to mobile sources, and 17% of the risk attributed to stationary sources (like KCBX and other industrial facilities). The maximum long-term cancer risks calculated at the North and South Terminal monitoring stations from metals alone were 1.15 and 1.36 x 10^{-5} (an elevated risk of 1.15 and 1.36 excess cancers per 100,000 people living in the area), respectively, for the mean concentrations of all carcinogenic pollutants evaluated at the North and South Terminal locations. The UCL mean concentration values yielded a slightly higher cancer risk of 1.4 and 1.9 x 10^{-5} (an elevated risk of 1.4 and 1.9 excess cancers per 100,000 people living in the area), respectively, at the North and South Terminal locations (U.S.EPA 2011). See Appendix B for a full list of pollutants and their corresponding risks).

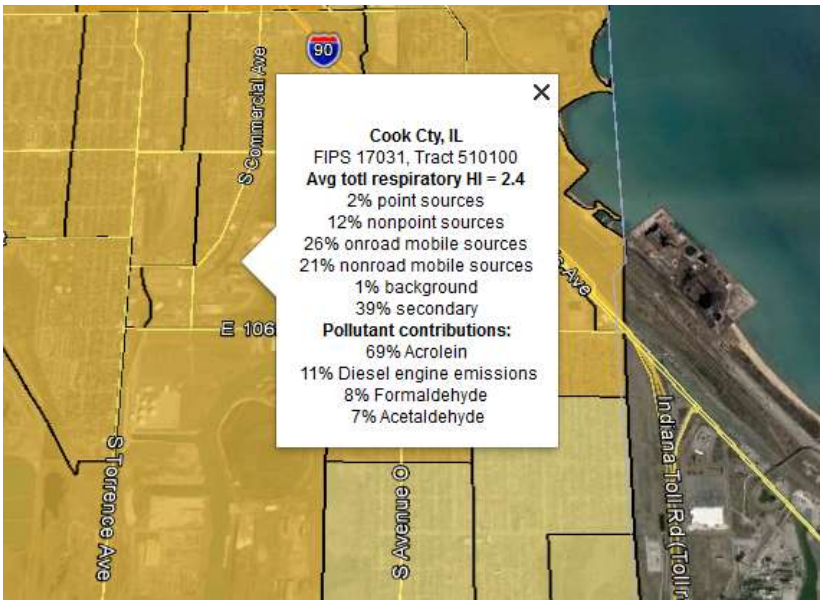
The Report on the Environment, a review of national air monitoring data, determined that 90% of cancer risk from inhalation of outdoor air is contributed to 10 toxic pollutants (U.S. EPA, 2014). Two of those 10 (arsenic and chromium compounds) are heavy metals, while the remaining eight (acetaldehyde, benzene, 1,3-butadiene, carbon tetrachloride, formaldehyde, naphthalene, polycyclic aromatic hydrocarbons (PAHs), and tetrachloroethylene) are volatile organic compounds (VOCs). It is not unusual for cumulative risk in ambient air to pose cancer risks higher than the increased risk of one in one million (10^{-6}) people developing cancer. An evaluation of national air monitoring data determined that concentrations of acetaldehyde, arsenic, benzene, 1,3-butadiene, and carbon tetrachloride individually exceeded 10^{-6} cancer risk at most monitoring sites across the country (McCarthy et al., 2009). Like many metals, these pollutants are generally ubiquitous and found commonly in outdoor air.

Non-cancer Risk Evaluation

Non-cancer hazards by county, state, and across the United States were also reported in the 2011 U.S.EPA NATA document. The NATA evaluation yielded a respiratory hazard index of 2.6 for Cook County, considering all air pollutant sources. This level is above 1.0, which indicates an increased risk for non-cancer hazards. For reference, the state of Illinois had an HI of 1.8.

With 1 being the worst, the Cook County HI ranked 1st out of 103 counties in Illinois, and 179th of 3,223 counties in the United States (U.S.EPA, 2011). For the Census tract where the KCBX facility is located (tract # 510100), non-cancer risk for respiratory health outcomes was calculated with a hazard index of 2.4, with almost half (47%) of the total respiratory risk attributed to mobile sources; 39% of the total respiratory risk attributable to secondary sources (where hazardous air pollutants emitted as one chemical transform into another from chemical reactions in the atmosphere); 17% of the risk attributed to stationary sources (like KCBX and other industrial facilities); and 1% of the risk attributed to background sources (e.g., natural sources or "long range transport" pollutants (pollutants transported in the atmosphere from other parts of the world)).

Figure 2: NATA Respiratory Non-Cancer Risk for Census Tract 510100



Source: ***http://www.epa.gov/ttn/atw/nata2005/tables.html***

The first step in calculating cancer risk is a screening approach combining non-cancer risks for all pollutants regardless of the body system the pollutants are likely to harm (e.g., respiratory tract, neurological, etc.). If this risk exceeds a hazard index (HI) of 1, then a more detailed assessment of "target organ" risk calculations is warranted (U.S. EPA, 1989). The initial screening of combined non-cancer risks calculated from *average* concentrations of metals were not elevated above background. However, at both the North and South Terminals, the non-cancer risk (HI) from metals in ambient air exceeded 1.0 for the 95%UCL mean concentrations of pollutants. At both locations this risk was driven by potential manganese exposure−a pollutant handled in large quantities at a facility directly across the river, east and east-southeast from the North Terminal. The North Terminal had an average non-cancer risk HI of 0.98, with approximately half of the HI (0.43) contributed by manganese exposure risk and a 95%UCL HI of 1.45, also with about half of the HI contributed by manganese (0.67). The South Terminal showed a substantial influence from manganese−the average non-cancer risk HI was 1.07, slightly less than one third of the HI (0.39) contributed by manganese exposure risk, but also showing the influence of other sources. The 95%UCL HI risk at the South Terminal was 1.65, with about a fourth of the HI contributed by manganese (HI=0.39), followed by the contribution of nickel (16% of the HI (0.26)), zinc (11.5% of the HI (0.19)); and chromium (10.3% of the HI (0.17)). Thus, our assessment yielded a slightly elevated non-cancer risk at these sites from combined metals exposure, but only using the upper confidence limit of the mean, and not the measured mean. Note that the NATA HI for Cook County is 2.6, but includes metals and VOCs. A summary of the total cancer and non-cancer risks for all sampling locations are presented in Tables 6 and 7 in Appendix B.

If we were to move on to a target organ risk assessment for these metals, manganese would not

contribute to respiratory non-cancer risks like many of the other pollutants such as nickel and zinc, because it is a neurotoxin and affects brain function. Thus, the overall HI for respiratory effects would be less than 1 for the mean and 95%UCL for respiratory non-cancer effects as well as for neurological effects at both sampling sites.

The combined levels of arsenic, cadmium, and chromium in air near KCBX result in a low increased cancer risk. ATSDR concludes that this cancer risk level is similar to that attributable to air sources across Cook County and the State of Illinois.

SPATIAL ANALYSIS OF MEASURED DATA

Statistical analyses and graphical presentations of data were used to evaluate air measurements and meteorological data. The summary of our assessment is presented here, but a detailed analysis with supporting documentation is provided in Appendix C. Our evaluation allowed us to 1) identify the direction of sources from monitors that contribute to decreased air quality; 2) to evaluate pollutants that are present together at similar fractions of total dust to understand which pollutants various sources may be contributing; and 3) to evaluate trends in the data to help us understand what factors are influencing concentrations of metals and dust in air. From this information we were able to:

Identify the direction of sources from monitors that contribute to decreased air quality:

- The KCBX monitors clearly indicate that windblown dust from the petcoke mounds is impacting air quality at the monitor locations at the North and South Terminals. There are non-KCBX related regional PM contributions to air quality in the area, but the dust from piles increases the amount of PM at the monitor sites.
- Metals analyses of bulk petcoke material collected at the North and South Terminals show that arsenic, cadmium, chromium, and lead are below detection limits in nearly all samples. Presence of these metals at KCBX air monitors suggests the influence of off-site source(s).
- Zinc and manganese were measured at low concentrations in piles at both sites and slightly higher at the South Terminal. Petcoke piles at the two locations may be somewhat different in their actual composition and/or the piles at the South Terminal may be contaminated by dust from other local industries.
- The piles at both locations contained significant and comparable levels of vanadium. Vanadium is not emitted to air by any local industries, suggesting that this metal may be a tracer for windblown petcoke (see http://www2.epa.gov/petroleum-coke-chicago/analysis-pet-coke-samples).

Evaluate pollutants that are present together at similar fractions of total dust to understand which pollutants various sources are contributing to metals and dust detected at the monitors:

- Using U.S.EPA's Positive Matrix Factorization method, five "signals" or "factors" were identified which identified groups of pollutants that had trends in air suggesting they are from the same source. These are, in decreasing order of contribution to local PM: 1) a Vanadium Factor consisting of vanadium, elemental carbon, and organic carbon; 2) a "Mixed Factor" consisting of varying levels of copper, chromium, arsenic, and barium; 3) a Manganese Factor consisting of manganese and iron; 4) a Zinc Factor consisting of lead, cadmium, and zinc; and 5) a Nickel Factor consisting of nickel and chromium.

- From these factors and using TRI data, we believe:
    - ***a.*** The petcoke mounds are the source of the Vanadium Factor pollutants.
    - ***b.*** The Mixed Factor source appears to be from a number of different contributors, where many industries are influencing regional air quality.
    - ***c.*** The Manganese Factor (Mn, Fe) shows a much stronger impact at the North Terminal with elevations when winds are from the southeast. This suggests there may be a source with high manganese concentrations to the southeast of the North Terminal and northeast of the South Terminal.
    - ***d.*** The Zinc Factor appears to emanate from a facility south of the South Terminal.
    - ***e.*** An unidentified source to the southwest of the North Terminal and northwest of the South Terminal is an intermittent contributor of Nickel Factor pollutants.

Evaluate trends in the data to help us understand what factors are influencing concentrations of metals and dust in air:

- Trends analyses indicate that the highest concentrations of dust are in the middle of the day.
- Wind direction and wind speed shows us emissions patterns and support our source factors for Vanadium, Zinc, Nickel, Manganese, and the Mixed Factors.

CONCLUSIONS

Based on our evaluation of data collected around the KCBX petcoke storage piles, blown dust from the piles poses a public health hazard to residents living adjacent to the piles, especially for sensitive individuals. Furthermore:

1. Blown dust from the KCBX facility may pose a short and long term health risk for area residents and irritate pre-existing respiratory conditions in residents living near the petcoke piles.
2. The levels of individual metals measured in air around the petcoke piles on the KCBX property pose a very small long term increased cancer and non-cancer risk. Combined risks for all measured metals were within the range of typical risks in Cook County and the state of Illinois.
3. KCBX does impact air quality in the community, and appears to be the predominant source of vanadium, elemental carbon, organic carbon, and PM at the monitor locations.

RECOMMENDATIONS

ATSDR recommends the following:

1. That the storage enclosures proposed for consolidating petcoke at the South Terminal be built to protect area residents from particulate dust being blown from the piles and into the surrounding neighborhood. Since this study was conducted, the North Terminal was decommissioned and the South Terminal converted to an enclosed direct transfer facility.
2. That U.S.EPA investigate other sources contributing to elevated metals and PM_{10} in ambient air near the KCBX facility to determine whether or not improvements could be made at the facilities to reduce offsite releases, particularly for manganese, nickel, and zinc.
3. That KCBX continue to monitor PM and metals in air to identify the potential acute releases during North Terminal decommissioning and the total reduction of these pollutants when the South Terminal enclosure is operational.

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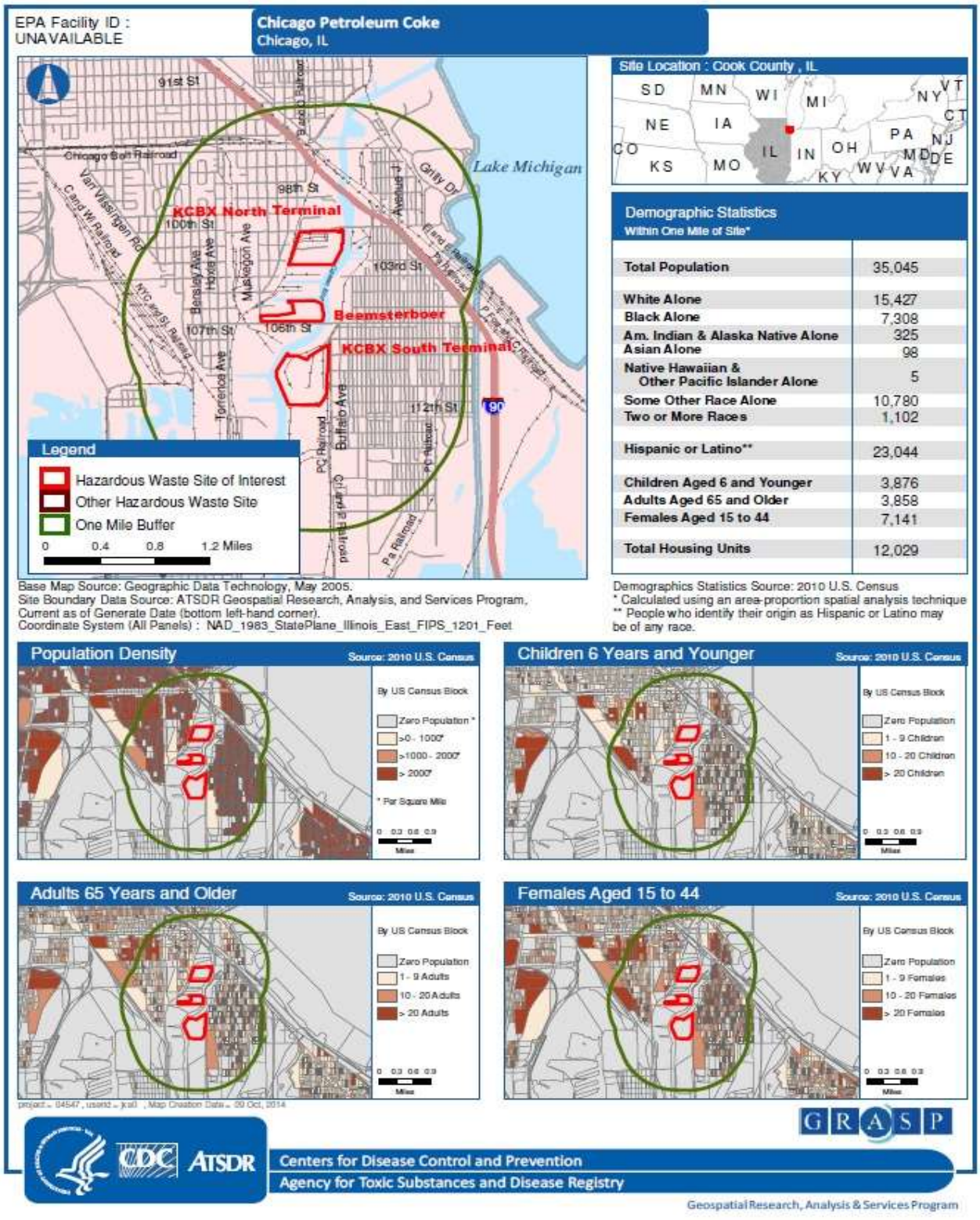
APPENDIX A: Area and Demographic Maps

Figure 1. Area Monitor Locations

Figure 2. Demographic map around the KCBX Storage Facility



APPENDIX B. Data Tables

Table 1. Filter Summary Data Tables (all concentrations in µg/m^3)

North Terminal Filters

Statistics	PM-10	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Selenium	Silver	Vanadium	Zinc
Min	0.2000	0.0001	0.0003	0.0001	0.0010	0.0001	0.0070	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0010
25th Percentile	15.2250	0.0003	0.0105	0.0001	0.0106	0.0060	0.3590	0.0032	0.0240	0.0021	0.0003	0.0001	0.0009	0.0268
50th Percentile	24.7000	0.0004	0.0163	0.0002	0.0130	0.0090	0.5245	0.0072	0.0492	0.0041	0.0003	0.0001	0.0019	0.0608
75th Percentile	33.7250	0.0010	0.0244	0.0004	0.0216	0.0134	1.0294	0.0131	0.1281	0.0078	0.0011	0.0001	0.0046	0.1232
90th percentile	46.1200	0.0020	0.0366	0.0010	0.0276	0.0198	1.5717	0.0224	0.2666	0.0137	0.0020	0.0001	0.0080	0.1948
95th Percentile	52.5700	0.0027	0.0470	0.0010	0.0463	0.0268	1.8936	0.0258	0.4036	0.0226	0.0040	0.0002	0.0136	0.2350
99th Percentile	61.5370	0.0040	0.1446	0.0019	0.0754	0.0516	2.9220	0.0544	1.4881	0.1198	0.0060	0.0028	0.0159	0.6970
Max	117.3000	0.0064	0.4255	0.0040	0.0970	0.1466	3.9640	0.0740	1.7185	0.1520	0.0080	0.0040	0.0380	0.7360
Average	**26.7327**	**0.0008**	**0.0235**	**0.0003**	**0.0178**	**0.0121**	**0.7717**	**0.0101**	**0.1281**	**0.0085**	**0.0010**	**0.0001**	**0.0036**	**0.1005**
N=	112	112	112	112	112	112	112	112	112	112	112	112	112	112

South Terminal Filters

Statistics	PM-10	Arsenic	Barium	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Nickel	Selenium	Silver	Vanadium	Zinc
Min	7.4000	0.0001	0.0019	0.0001	0.0001	0.0018	0.1262	0.0008	0.0036	0.0003	0.0001	0.0001	0.0002	0.0036
25th Percentile	17.6750	0.0003	0.0078	0.0001	0.0110	0.0050	0.3738	0.0044	0.0256	0.0026	0.0003	0.0001	0.0010	0.0370
50th Percentile	27.0500	0.0004	0.0126	0.0002	0.0132	0.0084	0.6824	0.0109	0.0473	0.0060	0.0003	0.0001	0.0021	0.0888
75th Percentile	37.2250	0.0012	0.0226	0.0007	0.0199	0.0141	1.2102	0.0213	0.0995	0.0115	0.0013	0.0001	0.0050	0.2115
90th percentile	46.3800	0.0026	0.0352	0.0014	0.0292	0.0223	1.8839	0.0403	0.2076	0.0175	0.0020	0.0002	0.0088	0.5911
95th Percentile	60.4000	0.0030	0.0447	0.0021	0.0333	0.0307	2.5758	0.0592	0.2759	0.0333	0.0050	0.0004	0.0146	0.9822
99th Percentile	112.2400	0.0155	0.1722	0.0039	0.0915	0.0377	4.0516	0.0810	0.4293	0.0986	0.0080	0.0029	0.0230	1.8245
Max	132.8000	0.0169	1.0843	0.0050	0.1880	0.4381	4.8850	0.0890	0.9777	0.2890	0.0080	0.0040	0.0500	3.4620
Average	**30.4735**	**0.0012**	**0.0278**	**0.0006**	**0.0180**	**0.0146**	**0.9455**	**0.0168**	**0.0865**	**0.0120**	**0.0011**	**0.0002**	**0.0041**	**0.2394**
N=	108	108	108	108	108	108	108	108	108	108	108	108	108	108

Table 2. North Terminal Continuous Monitor PM_{10} Hourly Descriptive Statistics

Hourly Avg Statistics	NT-NW (µg/m³ §)	NT-NE (µg/m³)	NT-SE (µg/m³)	NT-SW (µg/m³)
Number of days	7879	8012	7952	8005
Minimum detect	0	0	1	0
25th Percentile	13	14	17	15
50th Percentile	21	22	26	25
75th Percentile	32	36	41	39
90th Percentile	48	57	68	62
95th Percentile	63	77	97	84
99th Percentile	121	166	189	168
Maximum detect	440	898	983	723
Average detection	**27**	**30**	**36**	**33**

NT-NW: North Terminal northwest monitor; NT-NE: North Terminal northeast monitor; NT-SE: North Terminal southeast monitor; NT-SW: North Terminal southwest monitor
§ µg/m³ micrograms of pollutant per cubic meter of air

Table 3. South Terminal Continuous Monitor PM_{10} Hourly Descriptive Statistics*

Hourly Avg Statistics	ST-NW (µg/m³ §)	ST-N (µg/m³)	ST-NE (µg/m³)	ST-CE (µg/m³)	ST-SW (µg/m³)	Washington High School Reference Monitor (µg/m³)
Number of days	8002	7972	7977	8003	7981	6328
Minimum detect	0	0	0	0	0	2
25th Percentile	12	13	14	13	13	11
50th Percentile	20	21	22	21	21	22
75th Percentile	31	32	35	34	33	38
90th Percentile	46	48	56	57	53	60
95th Percentile	59	65	82.2	83	73	78
99th Percentile	113.99	126.58	181	178.98	140	128
Maximum detect	689	930	985	690	636	296
Average detection	**25**	**27**	**31**	**30**	**29**	**29**

ST-NW: South Terminal northwest monitor; ST-N: South Terminal north monitor; ST-NE: South Terminal northeast monitor; ST-CE: South Terminal central east monitor; ST-SW: South Terminal southwest monitor
§ µg/m³ micrograms of pollutant per cubic meter of air

Table 4. North Terminal Daily (24-hr average) Descriptive Statistics for Continuous PM_{10}

Daily Avg Statistics	NT-NW (µg/m³ §)	NT-NE (µg/m³)	NT-SE (µg/m³)	NT-SW (µg/m³)
Number of days	337	339	339	339
Minimum detect	5	4	7	5
25th Percentile	17	18	22	20
50th Percentile	24	26	30	29
75th Percentile	31	36	44	41
90th Percentile	42	52	60	55
95th Percentile	53	62	75	67
99th Percentile	92	117	126	108
Maximum detect	148	156	146	132
Average detection	**27**	**30**	**36**	**33**

NT-NW: North Terminal northwest monitor; NT-NE: North Terminal northeast monitor; NT-SE: North Terminal southeast monitor; NT-SW: North Terminal southwest monitor
§ µg/m³ micrograms of pollutant per cubic meter of air

Table 5. South Terminal Daily (24-hr average) Descriptive Statistics for Continuous PM_{10}*

Daily Avg Statistics	ST-NW (µg/m³ §)	ST-N (µg/m³)	ST-NE (µg/m³)	ST-CE (µg/m³)	ST-SW (µg/m³)	Washington High School Reference Monitor (µg/m³)
Number of days	339	339	339	339	339	265
Minimum detect	5	4	4	5	5	7
25th Percentile	16	17	18	17	17	19
50th Percentile	22	24	26	26	25	26
75th Percentile	31	33	37	35	34	37
90th Percentile	43	44	53	53	50	45
95th Percentile	51	56	69	72	60	53
99th Percentile	82	81	115	93	98	70
Maximum detect	93	111	156	121	114	83
Average detection	**25**	**27**	**31**	**30**	**29**	**29**

ST-NW: South Terminal northwest monitor; ST-N: South Terminal north monitor; ST-NE: South Terminal northeast monitor; ST-CE: South Terminal central east monitor; ST-SW: South Terminal southwest monitor
§ µg/m³ micrograms of pollutant per cubic meter of air

Table 6. Calculations for Cancer and non-Cancer Risk at the North Terminal: Filter-based 24-hour metals data

Statistics-North Terminal	Max µg/m³ β	Average µg/m³	95% UCL µg/m³	Acute CV µg/m³	Cancer CV µg/m³	Chronic CV µg/m³	Acute Risk?	Average Non-cancer Risk (HQ)§	95% UCL Non-cancer risk (HQ)	Ca Risk*	95% UCL Ca Risk
Arsenic	0.0064	0.0008	***0.0010***€	9.9[a]	0.00023[d]	0.015[e]	No	0.0520	0.0667	3.39E-06	**4.35E-06**
Barium	0.4255	0.0235	0.0381	5[a]		0.5[f]	No	0.0469	0.0762		
Cadmium	0.0040	0.0003	0.0005	0.03[b]	0.00056[d]	0.01[b]	No	0.0339	0.0459	6.06E-07	**8.20E-07**
Chromium	0.0034	***0.0006***¶	***0.0007***	0.1[a]	0.000083[d]	0.005[b]	No	0.1240	0.1460	7.47E-06	**8.80E-06**
Copper	0.1466	0.0121	0.0173	10[a]		1[a]	No	0.0121	0.0173		
Iron	3.9640	0.7717	0.9180				N/A				
Lead	0.0740	0.0101	0.0128	0.15[c]		0.15[c]	No	0.0673	0.0853		
Manganese	1.7185	0.1281	0.2020	2[a]		0.3[b]	No	0.4271	0.6773		
Nickel	0.1520	0.0085	0.0152	1.1[a]		0.09[b]	No	0.0950	0.1689		
Selenium	0.0080	0.0010	0.0013	2[a]		0.2[a,g]	No	0.0050	0.0065		
Silver	0.0040	0.0001	0.0003				N/A				
Vanadium	0.0380	0.0036	0.0048	0.5[a]		0.05[a]	No	0.0712	0.0966		
Zinc	0.7360	0.1005	0.1330	20[a]		2[a]	No	0.0503	0.0665		
							Total Risk¥	***0.98***	***1.45***	1.15E-05	1.40E-05

β Units of measured data are micrograms per cubic meter air (µg/m³).

§ Hazard Quotient is equal to the relative contribution of each metal to total risk for respiratory health outcomes posed for all metals evaluated. HQs are added together to yield a Hazard Index (HI). An HI of <1 indicates no increased risk for non-cancer health outcomes; an HI >1 indicates that the combined ratios of pollutants are higher than their respective non-cancer health based comparison values and could potentially present a greater risk of adverse health outcomes.

** Cancer risk is represented as the risk of 1 excess cancer case per 10,000,000 people (10^{-7}); 1 excess cancer case per 1,000,000 people (10^{-6}); or 1 excess cancer case per 100,000 people (10^{-5}).*

¶ Adjusted Chromium value reflects an assumption of 3.5% hexavalent chromium in the total chromium detected.

¥ Total risk is a Hazard Index for non-cancer affects and the additive cancer risk for carcinogens evaluated in the sampling.

*€ **Bolded** and Highlighted cells indicate an exceedance of a health based comparison value.*

Comparison Values used for screening are as follows:

a TCEQ short-term or long-term Air Monitoring Comparison Value (AMCV)

b ATSDR acute or chronic Environmental Media Evaluation Guide (EMEG)

c U.S. EPA National Ambient Air Quality Standards (NAAQS)

d ATSDR Cancer Risk Evaluation Guide (CREG)

e California EPA Reference Exposure Limit (REL)

f U.S. EPA Health Effects Assessment Summary Table (HEAST) value

g U.S. EPA Reference Concentration (RfC)

Table 7. Calculations for Cancer and non-Cancer Risk at the South Terminal: Filter-based 24-hour metals data

Statistics-South Terminal	Max µg/m³ β	Average µg/m³	95% UCL µg/m³	Acute CV µg/m³	Cancer CV µg/m³	Chronic CV µg/m³	Acute Risk?	Chronic Non-cancer Risk (HQ)§	95% UCL Non-cancer risk (HQ)	Ca Risk*	95% UCL Ca Risk
Arsenic	0.0169	***0.0012***€	***0.0018***	9.9[a]	0.00023[d]	0.015[e]	No	0.0767	0.1167	5.00E-06	7.61E-06
Barium	1.0843	0.0278	0.0767	5[a]		0.5[f]	No	0.0555	0.1534		
Cadmium	0.0050	0.00056	***0.0008***	0.03[b]	0.00056[d]	0.01[b]	No	0.0562	0.0758	1.00E-06	1.35E-06
Chromium	0.007¶	***0.0006***	***0.0008***	0.1[a]	0.000083[d]	0.005[b]	No	0.1260	0.1666	7.59E-06	1.00E-05
Copper	0.4381	0.0146	0.0350	10[a]		1[a]	No	0.0146	0.0350		
Iron	4.8850	0.9455	1.1300				N/A				
Lead	0.0890	0.0168	0.0209	0.15[c]		0.15[c]	No	0.1121	0.1393		
Manganese	0.9777	0.0865	0.1170	2[a]		0.3[d]	No	0.2285	0.3900		
Nickel	0.2890	0.0120	0.0232	1.1[a]		0.09[b]	No	0.1334	0.2578		
Selenium	0.0080	0.0011	0.0015	2[a]		0.2[a,g]	No	0.0056	0.0076		
Silver	0.0040	0.0002	0.0003				N/A				
Vanadium	0.0500	0.0041	0.0060	0.5[a]		0.05[a]	No	0.0828	0.1200		
Zinc	3.4620	0.2394	0.3700	20[a]		2[a]	No	0.1197	0.1850		
							Total Risk¥	**1.07**	**1.65**	1.36E-05	1.90E-05

β Units of measured data are micrograms per cubic meter air (µg/m³).

§ Hazard Quotient is equal to the relative contribution of each metal to total risk for respiratory health outcomes posed for all metals evaluated. HQs are added together to yield a Hazard Index (HI). An HI of <1 indicates no increased risk for non-cancer health outcomes; an HI >1 indicates that the combined ratios of pollutants are higher than their respective non-cancer health based comparison values and could potentially present a greater risk of adverse health outcomes.

** Cancer risk is represented as the risk of 1 excess cancer case per 10,000,000 people (10^{-7}); 1 excess cancer case per 1,000,000 people (10^{-6}); or 1 excess cancer case per 100,000 people (10^{-5}).*

¶ Adjusted Chromium value reflects an assumption of 3.5% hexavalent chromium in the total chromium detected.

¥ Total risk is a Hazard Index for non-cancer affects and the additive cancer risk for carcinogens evaluated in the sampling.

*€ **Bolded** and Highlighted cells indicate an exceedance of a health based comparison value.*

Comparison Values used for screening are as follows:

a TCEQ short-term or long-term Air Monitoring Comparison Value (AMCV)

b ATSDR acute or chronic Environmental Media Evaluation Guide (EMEG)

c U.S. EPA National Ambient Air Quality Standards (NAAQS)

d ATSDR Cancer Risk Evaluation Guide (CREG)

e California EPA Reference Exposure Limit (REL)

f U.S. EPA Health Effects Assessment Summary Table (HEAST) value

g U.S. EPA Reference Concentration (RfC)

Appendix C: Spatial Analysis of Measured Data

SPATIAL ANALYSIS OF MEASURED DATA

Filter-based samples

EPA's Positive Matrix Factorization (PMF) program was used to analyze the speciated metals and elemental carbon and organic carbon data (USEPA, 2014b). PMF can be used to identify individual sources contributing to the air quality at air monitoring stations. PMF was executed using PM_{10}, lead, copper, chromium, cadmium, zinc, arsenic, nickel, selenium, vanadium, iron, manganese, barium, elemental carbon, and organic carbon data from both the North and South Terminals. Other species were excluded due to the low percentage of data above the detection limits. Data from July 4, 2014 were excluded due to the clear influence of fireworks on general air quality, which are not site-related. "Factors" are identified when using this approach that represent individual source profiles that are contributing specific pollutants to air at a given monitor. These factors include the identification of pollutants that consistently occur together at similar ratios, which indicate that they are from the same source. Five factors were selected from the PMF analysis. The number of factors was selected based on a combination of model error characteristics, correlation plots generated with *openair*, and physical significance of the generated factors. The factors were named for the species that were found in each one at the highest relative abundance. The Zinc Factor contained a high percentage of the total zinc (78.17%), cadmium (57.99%), and lead (55.74%). The Mixed Factor contained a mixture of several species at similar relative abundances. The Nickel Factor contained a high percentage of the total nickel (92.30%) and chromium (38.48%). The Manganese Factor contained a high percentage of the total manganese (74.89%) and iron (54.72%). The Vanadium Factor contained a high percentage of the total vanadium (86.36%), elemental carbon (83.39%), PM_{10} (48.45%) and organic carbon (46.24%). Figures 3 and 4 below illustrate polar plots of the five factors at the North Terminal and South Terminal monitoring sites. These plots show the direction ***from which*** the pollutant is blowing.

The polar plots for the Vanadium Factor are the most consistent, both in the factor composition and the dominant wind speed/direction, with a fugitive dust source from the petcoke piles. These factors show increased contributions when winds are from the southwest (the direction of the petcoke piles) at both the North and South Terminals. Bulk analysis of the petcoke (see http://www2.epa.gov/petroleum-coke-chicago/analysis-pet-coke-samples) shows that vanadium is present at relatively high concentrations in the petcoke material (relative to the vanadium content expected to be present in background particulate matter). Bulk petcoke material also has high concentrations of both elemental carbon (EC) and organic carbon (OC). The composition of the Vanadium Factor, with the majority of the measured vanadium as well as high concentrations of EC, OC, and PM is consistent with fugitive dust from the petcoke piles. Some other factors may show behavior that could indicate the petcoke pile as a source from one terminal but not the other. For example, the Nickel Factor for the North Terminal is elevated when winds are from the southwest (over the petcoke pile) but at the South Terminal the same factor is elevated when winds are from the northwest (not over the petcoke pile). This suggests that there may be a source with a high relative nickel concentration that is between the two terminals.

Figure 3: Polar Plots of PMF Factors – North Terminal

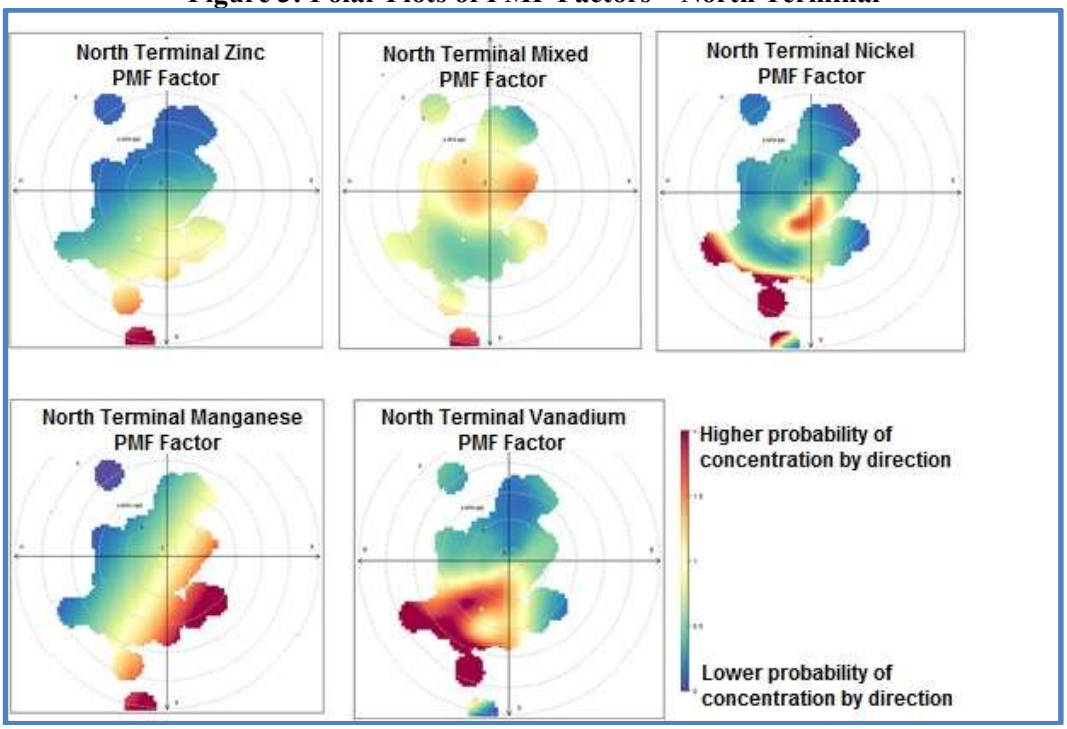
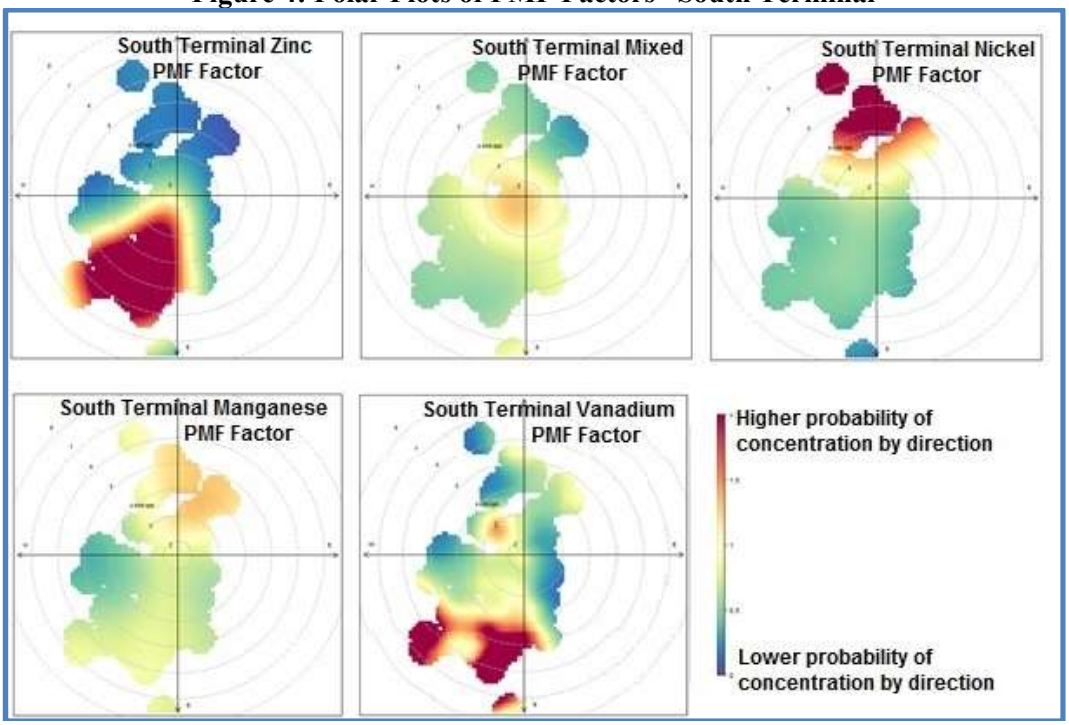


Figure 4: Polar Plots of PMF Factors –South Terminal



Similarly, the Zinc Factor from the South Terminal shows elevated concentrations with winds from the southwest while the North Terminal does not show the same elevation. This suggests that there may be a source with high zinc concentrations to the southwest of the South Terminal. The Manganese Factor shows a much stronger impact at the North Terminal with elevations when winds are from the southeast. This suggests there may be a source with high manganese

concentrations to the southeast of the North Terminal (and potentially northeast of the South Terminal).

In summary, when reviewing the source factors of these clustered pollutants, it appears that:

1. the petcoke mounds are the source of the Vanadium Factor pollutants;
2. a facility south of the South Terminal is the source of the Zinc Factor;
3. an unidentified source to the southwest of the North Terminal and northwest of the South Terminal is an intermittent contributor of Nickel Factor pollutants;
4. the Manganese Factor (Mn, Fe) source is likely a facility across the river from the North Terminal; and
5. the Mixed Factor source appears to be from a number of different contributors, where many industries are influencing regional air quality.

Polar plots of the measured concentrations of individual species provide a similar picture to that from the PMF factors. Species that are primarily contained in one factor show polar plots quite similar to the polar plot for the corresponding factor. Species that are spread among multiple factors have polar plots that do not match the PMF factors as well. Individual polar plots of each species are available for both terminals but are not provided here.

Continuous PM Analysis

Hourly BAM data were available for four sites at the North Terminal and five sites at the South Terminal. The nine BAM sites form rings around the outer perimeter of the two petcoke piles. The North Terminal monitors are located at the northwest, northeast, southeast, and southwest corners of the petcoke pile. The South Terminal monitors are located at the northwest, northeast, and southwest corners with two additional monitors along the north and east sides of the petcoke pile. BAM data were also available (U.S. EPA, 2015c) from Washington High School, approximately 0.6 miles southeast of the South Terminal.

Time of Day and-Wind Direction Effects on PM_{10}

Polar annulus plots of hourly BAM data were generated for each BAM location and are shown on Figure 5. These plots show the mean concentration by wind direction and time of day and are shown below overlaid on a map of the area. Similar to a polar plot, the polar annulus shows the direction ***from which*** the pollutant is blowing; the inner part of the annulus represents the earliest time (i.e. midnight) and the outer part of the circle is the latest time.

The polar annulus for the Washington High School site is shown separately as that site is located approximately 0.6 miles southeast of the South Terminal (See Figure 6 One consistent feature in all of the polar annulus plots is that the maximum PM concentrations at all sites occur during the middle of the day. At the North Terminal, the areas of highest concentration are generally consistent with the petcoke pile as a source of PM. The southern BAM monitors at the North Terminal also suggest that there may be another source with PM impacts to the south of the North Terminal. This could be the South Terminal or some other facility. The southeast monitor at the North Terminal also suggests that there may be a source of PM to the east of the North TerminalAt the South Terminal, there is again an indication that the petcoke pile contributes to elevated PM concentrations. This relationship appears to be weakest at the southwest monitor. Again, the southern monitors suggest that there may be an additional source with PM impacts to

the south of the South Terminal. At Washington High School, the major PM source appears to be to the southwest while the South Terminal is to the northwest.

Figure 5: BAM Hourly PM_{10} Polar Annulus Plots – KCBX Terminals

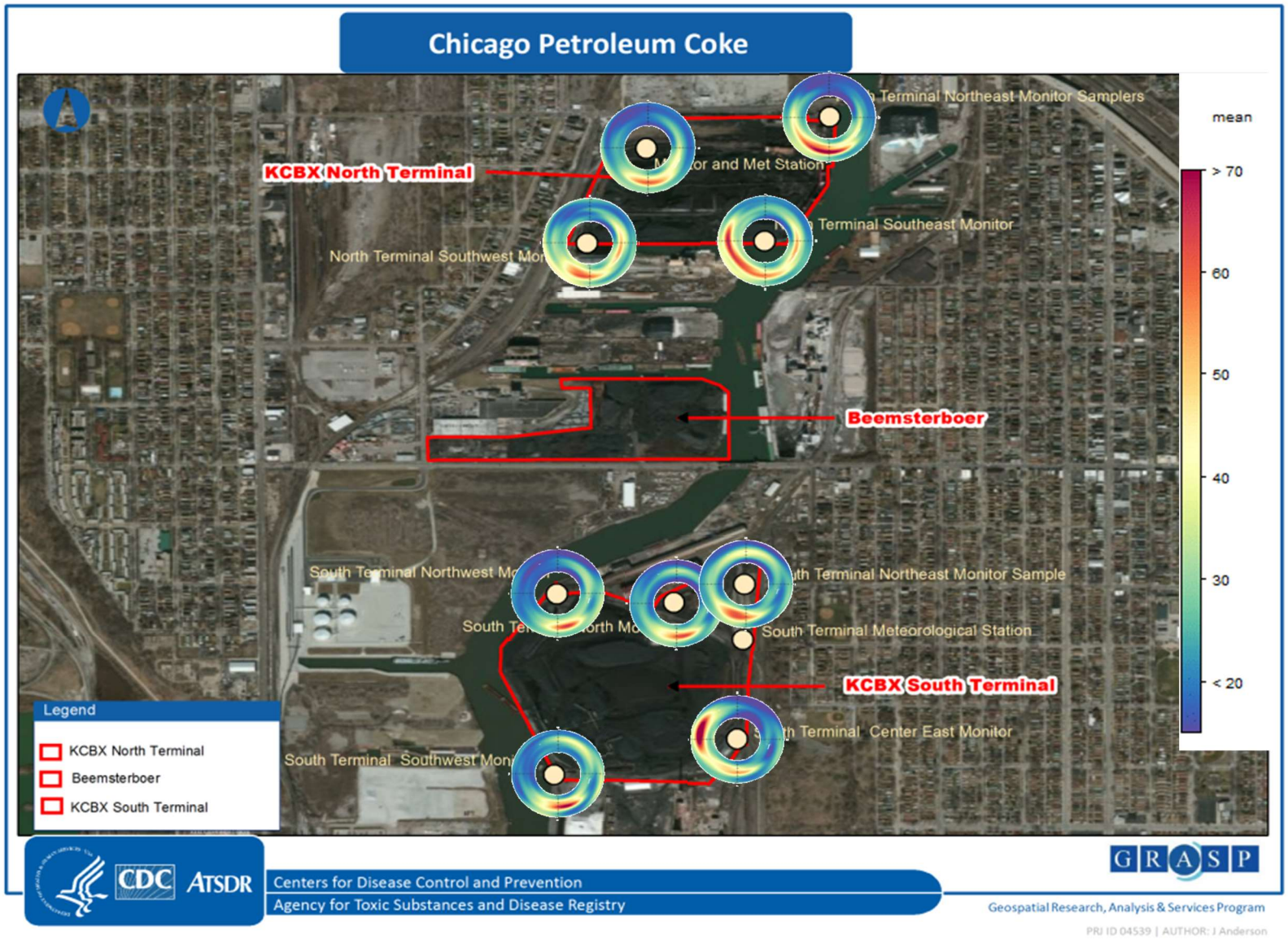
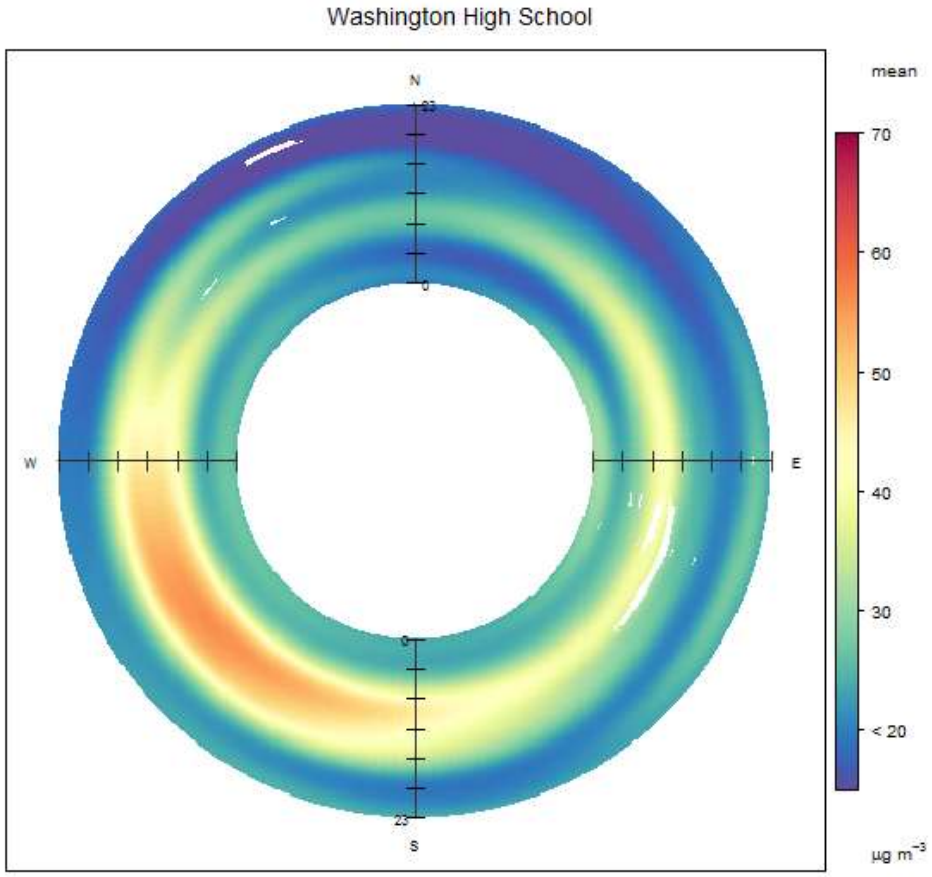


Figure 6: Washington High School Hourly PM_{10} Polar Annulus



Wind Speed and-Wind Direction Effects on PM_{10}

In addition to the polar annulus plots, which relate PM concentrations to wind direction and time of day, polar plots, which relate PM to wind direction and wind speed were also generated (Figure 7). Fugitive dust sources are expected to contribute more PM when wind speeds are elevated and polar plots are a useful tool to investigate the relationship between PM and wind speed. Polar plots for the nine monitors ringing the petcoke piles are shown below on a map of the area. A separate polar plot is provided for Washington High School (Figure 8). All of the polar plots show that the highest PM concentrations occur when wind speeds are high (the red area is not at the origin but rather on the edges of the polar plot). This is consistent with a fugitive dust source as a major source of PM around the petcoke piles. The plots also show that, in all cases, there is a region of elevated PM concentration when winds blow over the pile and to the monitor. Some monitoring locations show additional regions with high concentrations, but all of them show some impact from the petcoke piles. Concentrations at the Washington High School site are generally lower than the locations on the perimeter of the piles. The polar plot shows some elevation at high wind speeds when winds are from the northwest (the direction of the South Terminal) as well as when winds are from the southwest.

Figure 7: BAM PM_{10} Polar Plots – KCBX Terminals

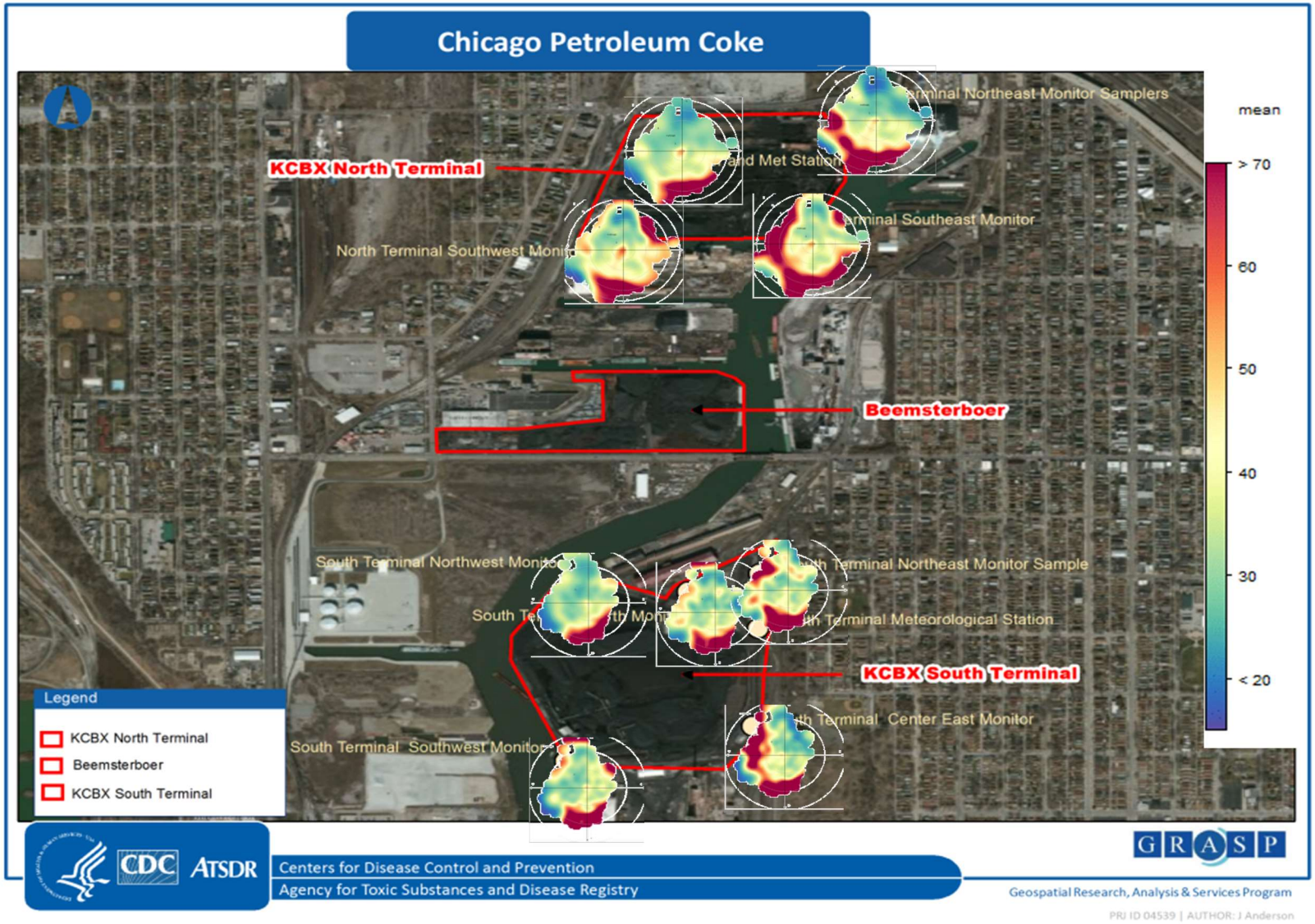


Figure 8: Hourly PM_{10} Polar Plot - Washington High School