Air Toxic Emissions and Associated Health Risks in Cook County, Illinois, 1999-2014

BY

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THESIS

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LIST OF ABBREVIATIONS

AERMOD AMS/ EPA Regulatory Model

AMS Advanced Monitoring Systems

ATSDR Agency for Toxic Substances and Disease Registry

ARB Air Resources Board

ASPEN Assessment System for Population Exposure Nationwide

AT Averaging time

BW Body Weight

CAA Clean Air Act

CalEPA California Environmental Protection Agency

CAPs Criteria Air Pollutants

CAS Chemical Abstracts Service

CF Conversion factor

CMAQ Community Multiscale Air Quality Model

EC Exposure Concentration

ED Exposure Duration

EF Exposure Factor

EIS Emissions Inventory System

EPA Environmental Protection Agency

EtO Ethylene Oxide

GIS Geographic Information Systems

HAPs Hazardous Air Pollutants

HI Hazard Index

LIST OF ABBREVIATIONS (continued)

HQ Hazard Quotient

IARC International Agency for Research on Cancer

IR Inhalation Rate

IRIS Integrated Risk Information System

LOAEL Lowest Observed Adverse Effect Level

MOVES Motor Vehicle Emission Simulator

NATA National Air Toxics Assessment

NCP National Contingency Plan

NEI National Emissions Inventory

NOAEL No Observed Adverse Effect Level

NOx Nitrogen Oxides

NRC National Research Council

OEHHA Office of Environmental Health Hazard Assessment

PM Particulate Matter

RfC Reference Concentration

RMLs Regional Removal Management Levels

TPY Tons Per Year

UF Uncertainty Factor

URE Unit Risk Estimate

USEPA United States Environmental Protection Agency

WOE Weight of Evidence

SUMMARY

The Clean Air Act of 1990 listed 187 air toxics that USEPA is required to control to protect public health. To uncover the spatial and temporal trends in air toxic emissions and identify higher contributing emission sources and chemicals to the total inhalation in Illinois, we assessed USEPA's National Emissions Inventory (NEI) data, which includes estimates of annual emissions, by sources, of air pollutants in each state of the U.S. on county level. In addition, we analyzed the data of USEPA's National Air Toxics Assessment (NATA), which estimates inhalation cancer risk and non-cancer risks across the U.S. on census tract level. The risk assessment results were compared to the Regional Removal Management Levels (RMLs) of the USEPA, "A 10^{-4} risk level corresponds to the upper-end of USEPA's generally acceptable risk range of 10^{-6} to 10^{-4}"as indicated in the National Contingency Plan (NCP). In addition, due to the prominence of diesel PM as agent that is "likely to be human carcinogen" and lack of diesel PM cancer and noncancer risk estimates under NATA, we calculated diesel PM cancer and non-cancer risks using California EPA-developed toxicity values. We assessed spatial distribution of diesel PM and select air toxics (those which contribute most to cancer and non-cancer risks) in Cook County, IL to support inhalation exposure and health risk mitigation efforts and guide environmental justice and health disparities research and policy.

To unveil the temporal and spatial trends in air toxic emissions, and to identify top-contributing chemicals to the total load of toxic air emissions in Illinois and Cook County, IL, USEPA's National Emissions Inventory (NEI) data from 1999 to 2014 were analyzed. In addition, USEPA's National Air Toxics Assessment (NATA) data was analyzed to assess the spatial distribution of ambient air concentrations, exposure concentrations, and health risks of air toxics in Illinois and Cook County, IL from 1999 to 2014. By delineating the geographic areas with higher air toxic emissions, exposure concentrations, associated inhalation cancer and non-cancer risks, potential environmental justice areas are identified. Temporal and spatial patterns of the diesel PM inhalation cancer risk in Cook County from 1999 to 2014 were also analyzed. Top-contributing chemicals to the inhalation cancer risk estimates and non-cancer risk estimates in Cook County, IL followed with the spatial distribution of the chemicals were also identified. The determination of specific air pollutants contributing most to air toxic emissions and inhalation cancer risks allowed identification of specific emission source categories for air pollution source control and management strategies along with future exposure and risk alleviation and public health prevention efforts.

Based on our findings, there is an increase in on-road emissions (from 19.2% in 2011 to 26.7% in 2014) and non-road emissions (from 21.0% in 2011 to 24.9% in 2014) in Illinois. However, the overall air toxic pollutant emissions decreased from 1999-2014 by 40%. The top three Illinois Counties in contributions of air pollution sources to total air toxic emissions in tons per year (TPY) were Cook (26.42%), followed by DuPage (5.87%) and Lake (4.55%) Counties while the non-point emission contributed most to total air emissions in Illinois in 2014. Cook County, Illinois is consistently the county that contributes the most to the total air emissions in Illinois in 1999, 2002, 2005, 2011 and 2014 with the following percentage of contributions: 28.4%, 24.8%, 25.3%, 24.0%, and 26.4%, which is much higher than the second highest contributing county (around 5%) for each year. Although the percentile contribution of other higher contributing counties were extremely less than Cook County, IL, those higher contributing Illinois counties are concentrated in the counties near Cook County, IL, which are more urbanized counties in Illinois. According to the NEI data, toluene was found to be the

highest contributing chemical in total air emission and on-road emission from 1999 to 2014. Other top chemical-specific total emissions in Illinois in 2014 are ethylene glycol, xylenes, and diesel PM. In the point emission category, the primary air toxics in Cook County, IL were hexane, carbon disulfide, hydrochloric acid, and toluene. Ethylene glycol, methanol, toluene, benzene, hexane, and xylenes were the significant contributing chemicals of non-point/ area emissions in Cook County, IL.

In terms of spatial distribution of NATA datasets, all the total inhalation cancer risk areas in Cook County, IL were in the acceptable range (10^{-6}-10^{-4}) but the inhalation cancer risk of those higher areas were close to the edge of being above the acceptable range. The inhalation cancer risk estimates of ethylene oxide, the largest contributed chemical to the total inhalation cancer risk in Cook County, IL, shows similar pattern to the highlighted area in total inhalation cancer risk estimates which are Lyons (southwest side of Cook County) and O'Hare Airport. Ethylene oxide is commonly used to make other chemicals that are used in making a range of products, including antifreeze, textiles, plastics, detergents and adhesives. Ethylene oxide is also used to sterilize equipment and plastic devices that cannot be sterilized by steam, such as medical equipment. Except one chemical plant in Lyons, Illinois out of the 17 facilities that were listed in NATA for the contribution of ethylene oxide cancer risk, all the other facilities were institutional (i.e. school, hospital, prison, etc.). Most of the facilities were general medical and surgical hospitals. Benzene and formaldehyde are the other two highest contributors to the total inhalation cancer risk. The emission from benzene and formaldehyde usually come from mobile vehicles and this matches the spatial pattern of the two chemicals. The spatial distribution of these two chemicals align with each other and the highlight the more urbanized area in Cook County such as downtown Chicago, O'Hare airport, and Midway airport.

Diesel PM is an important air toxic and it was the top three highest chemical that contributes to the total inhalation cancer risk in Cook County, Illinois, hence, we decided to also examine diesel PM cancer risk, separately, in Cook County. Unlike ethylene oxide and formaldehyde or other chemicals, USEPA did not develop the Unit Risk Estimates (URE), for diesel PM, which were essential for cancer risk estimates. Diesel PM related parameters developed by the Air Resources Board (ARB) and the Office of Environmental Health Hazard Assessment (OEHHA) from the Diesel Guidelines in California were used following the NATA-method equation to determine the diesel PM inhalation cancer risk in Cook County, IL. In terms of spatial and temporal analysis of diesel PM inhalation cancer risk from NATA, downtown Chicago steadily remain the most condensed area from 1999 to 2014. As diesel PM usually come from mobile vehicle, the spatial distribution also highlights the highways. It is a serious concern that most of the cancer risk estimates of diesel PM in Cook County, IL from 1999 to 2014 were above the acceptable range (10^{-6}- 10^{-4}). The diesel PM non-cancer risk in Cook County, IL 2014 were in the acceptable range (Hazard Index (HI) less than 1) and the concentrated area of it also matches the cancer risk estimates maps.

Although the health effect of non-cancer risk contributing chemicals were not as severe as cancer risk contributing chemicals, we think it is important to also look at the spatial distribution of the top three contributing non-cancer risk chemicals in Cook County, IL, in 2014, in order to have a more comprehensive understanding of risks, including both cancer risk and non-cancer risk, for Cook County, Illinois. The top three chemicals contributing to the inhalation non-cancer risk was acrolein, formaldehyde, and diesel PM. Acrolein also comes from the burning of fuels such as gasoline or oil. The distribution of the area with higher acrolein and formaldehyde non-cancer risk matches the cancer risk map of formaldehyde and benzene, which highlights more urbanized areas in Cook County, IL like downtown Chicago, O'Hare airport and Midway airport. All the top contributors in inhalation non-cancer risk were in the safe range (Hazard Index (HI) less than 1).

Future studies are warranted to investigate the more detailed emission of ethylene oxide and diesel PM in Cook County, Illinois as soon as possible. Since ethylene oxide is already classified as a known human carcinogen and the contribution of it meets the pattern of total inhalation cancer risk. Most of the inhalation risk of diesel PM cancer risk estimates in Cook County, IL from 1999 to 2014, respectively, were above the acceptable range. This is a significant sign that it is urgent for USEPA to file the important parameters of diesel PM and model the cancer risk of diesel PM nationally. Furthermore, create and execute the risk management strategies of diesel PM are also highly recommended.

I. INTRODUCTION

A. Air Toxic Definition

Air toxics, also known as hazardous or toxic air pollutants (HAP), are defined as air pollutants known to cause cancer and other health effects by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 2018d).

The Clean Air Act Amendments of 1999 listed 187 Hazardous Air Pollutants (HAPs) that USEPA is required to control to protect public health (U.S. Environmental Protection Agency, 2017a).

B. National Emissions Inventory Development by USEPA for Air Toxics

The National Emissions Inventory (NEI) developed by the USEPA is a detail and extensive estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources in order to provide the EPA, federal, state, local and tribal decision makers, and the national and international public the best and most complete estimates of CAP and HAP emissions. NEI data are built by using the Emissions Inventory System (EIS) for State, Local, and Tribal air agencies data collection and then blend the data with other data sources. This data are released every three years based on data provided by State, Local, and Tribal air agencies for sources in their jurisdictions and supplemented by data developed by the USEPA. The NEI data include estimates of annual emissions, by sources, of air pollutants in each area. (State and County) of the U.S. (U.S. Environmental Protection Agency,2017b; 2018b).

1. NEI Point/ Major Sources

Before 2005 NATA, USEPA classified stationary sources as “major” and “area” (or “area and other” sources according to the 1990 Clean Air Act (CAA). Major sources are defined as sources that have the potential to emit 10 tons per year of a HAP or at least 25 tons per year of any combination of HAPs.

Beginning with 2005 NATA, stationary sources were grouped into either the “point” or non-point” category, based solely on how the emissions are inventoried by USEPA. Since then, “point” sources include emissions estimates for larger sources (facility level) that are located at a fixed location. Emission sources categorized as point source within the NEI data include large industrial facilities and electric power plants, airports, and smaller industrial, non-industrial and commercial facilities. A tiny number of portable sources like asphalt or rock crushing operations are included as well.

2. <u>NEI Non-Point/ Area Sources</u>

Before 2005 NATA, “area” emissions are classified as stationary point sources with inventoried locations that do not meet the definition of “major” under the 1990 Clean Air Act.

After 2005 NATA, “non-point” emissions include emissions estimates for sources which individually are too small in magnitude to report as point sources. For example, gas station, dry cleaners, residential heating, commercial combustion, asphalt paving, and commercial and consumer solvent use.

3. <u>NEI On-Road Sources</u>

National Emissions Inventory (NEI) On-Road sources include emissions from on-road vehicles that use gasoline, diesel, and other fuels. Both light duty and heavy duty vehicle emissions from operation on roads, highway ramps, and during idling are included in the NEI On-Road sources.

The USEPA uses the Motor Vehicle Emission Simulator (MOVES) model to compute On-Road source emissions in all states across the US except California based on model inputs provided by State, Local, and Tribal air agencies. A specific model is used in California to estimate On-Road emissions.

4. NEI Non-Road Sources

National Emissions Inventory (NEI) Non-Road sources include off-road mobile sources that use gasoline, diesel, and other fuels examples include construction equipment, lawn and garden equipment, aircraft ground support equipment, locomotives, and commercial marine vessels.

5. NEI Event Sources

Wildfires and prescribed burns, fires that are reported in a day-specific format, are included in NEI Event sources. In general, the USEPA calculates these emissions using a satellite detection approach combined with fire models and activity data provide by State, Local, and Tribal air agencies or forestry agencies. This source was not provided in the NEI before the 2008 NEI.

6. NEI Biogenic Sources

Emissions that come from natural sources are classified as Biogenic sources. In the NEI data, only emissions from vegetation and soils are included, but other relevant sources include volcanic emissions, lightning oxides of nitrogen (NOx), and sea salt. This source was included since 2011 NEI.

C. National Air Toxic Assessment for 2014 by USEPA

1. Air Quality Modeling

National Air Toxic Assessment (NATA) is a screening tool that provides a “snapshot” of outdoor air quality as it relates to air toxics. NATA uses NEI emission data for each single year as inputs to air quality models. An air quality model is a set of mathematical equations that uses emissions, meteorological and other information to simulate the behavior and movement of air toxics in the atmosphere. Air quality models estimate outdoor concentrations of air toxics at specific locations. Different approaches were utilized by the USEPA to model and estimate the ambient concentration of air toxics. For 1996, 1999, 2002, and 2005 NATA, the USEPA used the Assessment System for Population Exposure Nationwide (ASPEN) to model ambient concentrations. The ASPEN model includes rate of pollutant release, location of and height from which the pollutants are released, wind speeds and directions from the meteorological stations nearest to release, breakdown of the pollutants in the atmosphere after release, settling of pollutant out of atmosphere, and transformation of one pollutant into another. Other than ASPEN model, Community Multiscale Air Quality Model (CMAQ) were first employed in 2005 to model the secondary formations of acrolein, acetaldehyde, formaldehyde, and the decay of 1,3-butadiene to acrolein. Since then, CMAQ has become more fully integrated as a hybrid modeling system for HAPS and diesel particulate matters (PM). In 2011, CMAQ is the main source used to model ambient concentration. Although the number of modeling HAPS for CMAQ has improved from 2011 to 2014, AMS/ EPA Regulatory Model (AERMOD) is used as the main dispersion model in 2014. The 2014 NATA modeling approach for the HAPs in the development and application of a hybrid approach blending a chemical transport model (CMAQ) with a dispersion model (AERMOD) to estimate ambient concentrations of about 50 of the more prevalent and higher risk HAP (U.S. Environmental Protection Agency, 2018a; 2018c).

AMS/ EPA Regulatory Model (AERMOD) is USEPA's preferred model in 2014 because of the ability of it to model near-surface air turbulence in both simple and complex terrain. This ability makes AERMOD able to simulate how pollutants move and disperse in the atmosphere.

AERMOD estimates pollutant concentrations from surface and the elevated point, area, line and volume sources at many discrete points (U.S. Environmental Protection Agency, 2018a; 2018c). Other than air quality models, NATA also estimates inhalation cancer risk and non-cancer risks for air toxics. It is helpful for identifying pollutants, emission subcategories and categories, and locations for which further study may be warranted for air quality control and management, exposure and health risk mitigation, public health improvement, and environmental justice and health disparities analyses.

2. Human Exposure Assessment

Exposure assessment is one of the vital steps of the four-step process risk assessment. Thus, it is required to understand the risk assessment process in order to effectively develop exposure assessment. Risk assessment is a method and science that characterize the potential health effects of human exposure to chemical, physical and biological agents (National Research Council, 1983; California Environmental Protection Agency Office of Environmental Health Hazard Assessment, n.d.a; U.S. Environmental Protection Agency, 2019a).

The four-step process of risk assessment collects scientific information to assess the health effects related to human exposure are as follows: 1) hazard identification, 2) exposure assessment, 3) dose-response assessment, and 4) risk characterization (National Research Council, 1983; California Environmental Protection Agency Office of Environmental Health Hazard Assessment, n.d.a; U.S. Environmental Protection Agency, 2019a).

According to the Guidelines For Human Exposure Assessment from U.S. (U.S. Environmental Protection Agency, 2019a): "Exposure assessment is the process of estimating or measuring the magnitude, frequency and duration of exposure to an agent and the size and characteristics of the population exposed." The following three elements of exposure assessment:

1) Identification of exposure pathways and population, 2) Dose of exposure; 3) Duration of exposure (U.S. Environmental Protection Agency, 2018a).

3. Inhalation Cancer Risk Assessment

Referred to NATA, certain exposure assumptions were made in order to convert the results of cancer dose-response assessments for a given chemical to a Unit Risk Estimates (URE). The value can be then multiplied by the 70-year-average EC to obtain a lifetime cancer risk estimate for each individual. Since NATA is focusing on long-term exposure, the toxicity values used in NATA are referred to the available results of chronic dose-response studies. In addition, each toxicity value used in NATA is best described as an estimate within a range of possible values appropriate for screening level risk assessments. The true cancer risks are believed to be lower than those estimated in the assessment (U.S. Environmental Protection Agency, 2018a).

United States Environmental Protection Agency (U.S. Environmental Protection Agency, 2018a) evaluated the following three broad categories of toxicological data in order to make a weight-of-Evidence (WOE) determination: 1) human data (primarily epidemiological); 2) animal data (i.e. results of long-term experimental animal bioassays) and 3) supporting data, which includes a variety of short-term tests for genotoxicity and other properties, metabolic studies and pharmacokinetic and structure activity relationships. The weight-of-evidence (WOE) descriptors from the USEPA provide estimates of the level of certainty regarding carcinogenic potential of a chemical. The detailed weight of evidences descriptors are listed in the below:

- Carcinogenic to humans
- Likely to be carcinogenic to humans
- Suggestive evidence of carcinogenic potential

- Inadequate information to assess carcinogenic potential
- Not likely to be carcinogenic to humans

A series of monographs with the classification of carcinogenicity were published by the International Agency for Research on Cancer (IARC) after their research on cancer. The classification as follows were used when USEPA weight-of-evidence (WOE) determinations were not available for a substance or are out of date:

- Group 1: Carcinogenic to humans;
- Group 2A: Probably carcinogenic to humans;
- Group 2B: Possibly carcinogenic to humans;
- Group 3: Not classifiable as to human carcinogenicity; and
- Group 4: Probably not carcinogenic to humans.

4. Non-Cancer Risk Assessment

Hazard identification procedures for noncancer effects have not been described as comprehensively as those carcinogens in USEPA guidance because of the wide variety of endpoints. However, USEPA published guidelines for several specific types of chronic non-cancer effects such as developmental toxicity, mutagenicity, reproductive toxicity, and neurotoxicity at Products and Publications Relating to Risk Assessment Produced by the Office of the Science Advisor (EPA 2015) and a framework for using studies of these and other effects in inhalation risk assessment (EPA 1994) (U.S. Environmental Protection Agency, 2018a).

Regarding to the toxicity value of non-cancer effects, the Reference Concentration (RfC) is used as an estimate of continuous inhalation exposures. The RfC value is calculated by dividing the no-observed-adverse-effect level (NOAEL), lowest-observed-adverse-effect level (LOAEL), or benchmark concentration with uncertainty factors (UF) applied reflecting the limitations of the used data (U.S. Environmental Protection Agency, 2018a).

Different from linear dose-response assessment for carcinogens, non-cancer risks are generally not showed as a probability that an individual will experience an adverse effect. Hence, the potential for non-cancer effects in human is quantified by hazard quotient (HQ), the ratio of the inhalation exposure concentration (EC) to the RfC, given that when the HQs are above 1, the adverse effect potential increases. In contrast, when the HQ are less than 1, there are not likely to have adverse health effects to human that are associated with the air toxic (U.S. Environmental Protection Agency, 2018a).

D. <u>Health Effects of Air Toxics</u>

Referring to USEPA, air toxics, also known as hazardous air pollutants, are the pollutants that are known to cause cancer or other serious health effects. The severity and type of the health effects associated with exposure to air toxic depends on the following factors, the exposure settings, the magnitude and duration of exposure, and the unique sensitivities and behaviors of the individual who was exposed. Differ from HAPs, other chemicals can cause non-cancer adverse health effects (i.e. cardiovascular, respiratory, and neuro-logical effects) (Lopez et al., 2002; Ekenga et al., 2019)

Table I displays the carcinogenic and non-carcinogenic toxicity values or benchmarks (i.e., Unit Risk Estimate (URE) for inhalation exposure to carcinogens and Reference Concentration (RfC) for inhalation exposure to non-carcinogens) related to the estimation of human health risk through inhalation exposure to hazardous air pollutants (U.S. Environmental Protection Agency, 2020) and diesel PM. Although diesel PM is not a HAP and USEPA have not yet developed a unit risk estimate for it (U.S. Environmental Protection Agency, 2018a), it is a prominent likely carcinogenic to humans. Despite the undeveloped unit risk estimate from USEPA, the Office of

Environmental Health Hazard Assessment (OEHHA) in California have developed the Diesel Guidelines with the assistance of the Air Resources Board (ARB). Hence, the benchmark value for diesel PM listed in table I and utilized in this study are rely on the value from OEHHA. The higher the Unit Risk Estimate (URE) for an air toxic is, the higher its cancer risk estimate is. The lower the Reference Concentration (RfC) is, the higher its non-cancer health risk estimate is.

E. Cook County, Illinois, Population Demography in 1999 – 2014

Illinois is the fifth largest populated state in the U.S. and Cook County has remained the county with largest population in Illinois. Table II. Displays the population of Cook County, Illinois in 2010 and 2014. The population of Cook County, Illinois reported by U.S. Census Bureau was 5,246,456 people, a 0.9% increase from the 2010 report of 5,200,950.

According to the U.S. Census Bureau report, "Native Hawaiian and Other Pacific Islander alone" were the largest population increased with 38.94% comparing 2014 to 2010, followed by "Two or more races" and "Asian alone" with an increase of 25.37% and 12.38%. In addition, "Black or African American alone" are showing the highest decreasing percentage of 2.66% followed by "Some other race alone". In spite of the changes between the years, the primary race in Cook County are consistently Whites (56%), followed by Black or African Americans (approximately 24%). While comparing the population by Hispanic or Latino origin, there was a 4.77% increase in Hispanic or Latino between 2010 and 2014. However, none Hispanics or Latinos are still the major group of the population in Cook County.

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
1	1,2-Propyleneimine (2-Methyl Aziridine)	75-55-8		IRIS[a]		
2	1,3-Propanesultone	1120-71-4	6.90E-04	IRIS/Cal EPA[b]		
3	2,2,4-Trimethylpentane	540-84-1	-	-	-	-
4	2,4-D, Salts And Esters	94-75-7	-	-	-	-
5	2,4-Toluene Diamine	95-80-7	1.10E-03	IRIS/Cal EPA		
6	2,4-Toluene Diisocyanate	584-84-9	1.10E-05	IRIS/Cal EPA	8.00E-06	Cal EPA
7	3,3'-Dimethyl Benzidine	119-93-7		IRIS		
8	4,4'-Methylenedianiline	101-77-9	4.60E-04	IRIS/Cal EPA		
9	4-Nitrobiphenyl	92933		IRIS		
10	4-Nitrophenol	100-02-7	-	-	-	-
11	Acetaldehyde	75-0-70	2.20E-06	IRIS	9.00E-03	IRIS
12	Acetamide	60-35-5	2.20E-05	Cal EPA	6.00E-02	IRIS
13	Acetonitrile	75-05-8			6.00E-02	IRIS
14	Acetophenone	98-86-2				
15	Acetylaminofluorene, 2-	53-96-3	1.30E-03	Cal EPA		
16	Acrolein	107-02-8			2.00E-05	IRIS
17	Acrylamide	79-06-1	1.00E-04	IRIS	6.00E-03	IRIS
18	Acrylic Acid	79-10-7			1.00E-03	IRIS
19	Acrylonitrile	107-13-1	6.80E-05	IRIS	2.00E-03	IRIS
20	Allyl Chloride	107-05-1	6.00E-06	Cal EPA	1.00E-03	IRIS
21	Aminobiphenyl, 4-	92-67-1	6.00E-03	Cal EPA		
22	Aniline	62-53-3	1.60E-06	Cal EPA	1.00E-03	IRIS
23	Antimony Compounds	7440-36-0	-	-	-	-
24	Arsenic Compounds (Inorganic Including Arsine)	107-02-8	4.3x10-3 (IN)[c]	IRIS	1.5E-5 (IN) 5.0E-5 (arsine)	Cal EPA/IRIS

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
25	Benzene	71-43-2	7.80E-06	IRIS	3.00E-02	IRIS
26	Benzidine	92-87-5	6.70E-02	IRIS		
27	Benzotrichloride	98-07-7				
28	Benzyl Chloride	100-44-7	4.90E-05	Cal EPA	1.00E-03	PPRTV[d]
29	Beryllium Compounds	107-02-8	2.4x10-3	IRIS	2.00E-05	IRIS
30	Biphenyl	92-52-4		IRIS		
31	Bis(2-Ethylhexyl) Phthalate	117-81-7	2.40E-06	Cal EPA		
32	Bis(Chloromethyl) Ether		NA		NA	
33	Bromoform	75-25-2	1.10E-06	IRIS		
34	Bromomethane	74-83-9			5.00E-03	IRIS
35	Butadiene, 1,3-	106-99-0	3.00E-05	IRIS	2.00E-03	IRIS
36	Cadmium Compounds	0	1.8x10-3	IRIS	1.00E-05	ATSDR[e]
37	Calcium Cyanamide	156-62-7	-	-	-	-
38	Captan	133-06-2	6.60E-07	Cal EPA		
39	Carbaryl	63-25-2				
40	Carbon Disulfide	75-15-0			7.00E-01	IRIS
41	Carbon Tetrachloride	56-23-5	6.00E-06	IRIS	1.00E-01	IRIS
42	Carbonyl Sulfide	463-58-1			1.00E-01	PPRTV
43	Catechol	120-80-9		IRIS		
44	Chloramben	133-90-4				
45	Chlordane	12789-03-6	1.00E-04	IRIS	7.00E-04	IRIS
46	Chlorine	7782-50-5			1.50E-04	ATSDR
47	Chloroacetaldehyde, 2-	107-20-0				
48	Chloroacetic Acid	79-11-8				
49	Chlorobenzene	108-90-7			5.00E-02	PPRTV
50	Chlorobenzilate	510-15-6	3.10E-05	Cal EPA		

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
51	Chloroform	67-66-3	2.30E-05	IRIS	9.80E-02	ATSDR
52	Chloromethane	74-87-3			9.00E-02	IRIS
53	Chloromethyl Methyl Ether	107-30-2	6.90E-04	Cal EPA		
54	Chloroprene	126-99-8	3.4x10-4	IRIS	2.00E-02	IRIS
55	Chromium (VI)	18540-29-9	8.40E-02	G[f]	1.00E-04	IRIS
56	Cobalt Compounds	0	9.0x10-3	PPRTV	6.00E-06	PPRTV
57	Coke Oven Emissions	8007-45-2	6.20E-04	IRIS		
58	Cresols/Cresylic Acid	1319-77-3		IRIS	6.00E-01	Cal EPA
59	Cumene	98-82-8			4.00E-01	IRIS
60	Cyanide Compounds	74-90-8		IRIS	3.00E-03	IRIS
61	Dibenzofuran	132-64-9				
62	Dibromo-3-Chloropropane, 1,2-	96-12-8	6.00E-03	PPRTV	2.00E-04	IRIS
63	Dibutyl Phthalate	84-74-2		IRIS		
64	Dichlorobenzene, 1,4-	106-46-7	1.10E-05	Cal EPA	8.00E-01	IRIS
65	Dichlorobenzidine, 3,3'-	91-94-1	3.40E-04	Cal EPA		
66	Dichloroethane, 1,1-	75-34-3	1.60E-06	Cal EPA		
67	Dichloroethane, 1,2-	107-06-2	2.60E-05	IRIS	7.00E-03	PPRTV
68	Dichloroethyl Ether	111-44-4	3.3x10-4	IRIS		
69	Dichloropropane, 1,2-	78-87-5	3.70E-06	PPRTV	4.00E-03	IRIS
70	Dichloropropene, 1,3-	542-75-6	4.00E-06	IRIS	2.00E-02	IRIS
71	Dichlorvos	62-73-7	8.30E-05	Cal EPA	5.00E-04	IRIS
72	Diethanolamine	111-42-2			2.00E-04	PPRTV
73	Dimethylaminoazobenzene, 4-		NA		NA	
74	Diethyl Sulfate	64-67-5		IRIS		
75	Dimethoxybenzidine, 3,3'-	119-90-4				
76	Dimethyl Carbamoyl Chloride	79-44-7	3.7E-03	Cal EPA		

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
77	Dimethyl Formamide	68-12-2			3.00E-02	IRIS
78	Dimethyl Phthalate	131-11-3		IRIS		
79	Dimethyl Sulfate	77-78-1		IRIS		
80	Dimethylaniline, N,N-	121-69-7				
81	Dimethylhydrazine, 1,1-	57-14-7			2.00E-06	PPRTV Screening Level
82	Dinitro-O-Cresol, 4,6-	534-52-1				
83	Dinitrophenol, 2,4-	51-28-5				
84	Dinitrotoluene, 2,4-	121-14-2	8.90E-05	Cal EPA		
85	Dioxane, 1,4-	123-91-1	5.00E-06	IRIS	3.00E-02	IRIS
86	Diphenylhydrazine, 1,2-	122-66-7	2.20E-04	IRIS		
87	Diesel Exhaust Particulate		3.0 E-04	Cal OEHHA[g]	5.00E-03	Cal OEHHA
88	Epichlorohydrin	106-89-8	1.20E-06	IRIS	1.00E-03	IRIS
89	Epoxybutane, 1,2-	106-88-7			2.00E-02	IRIS
90	Ethyl Acrylate	140-88-5			8.00E-03	PPRTV
91	Ethyl Carbamate	51-79-6	2.9xE-04	IRIS/Cal EPA		
92	Ethyl Chloride (Chloroethane)	75-00-3			1.00E+01	IRIS
93	Ethylbenzene	100-41-4	2.50E-06	Cal EPA	1.00E+00	IRIS
94	Ethylene Dibromide (Dibromoethane)	106-93-4	6.0E-04	IRIS	9.00E-03	IRIS
95	Ethylene Glycol	107-21-1			4.00E-01	Cal EPA
96	Ethylene Oxide	75-21-8	3.00E-03	IRIS	3.00E-02	Cal EPA
97	Ethylene Thiourea	96-45-7	1.30E-05	Cal EPA		
98	Ethyleneimine	151-56-4	1.90E-02	Cal EPA		
99	Formaldehyde	50-00-0	1.30E-05	IRIS	9.80E-03	ATSDR

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
100	Glycol Ethers	0			2-Methoxyethanol: 2.0E-22-Ethoxyethanol: 2.0E-12- Buthoxyethanol: 2.0E-2	IRIS
101	Heptachlor	76-44-8	1.30E-03	IRIS		
102	Hexachlorobenzene	118-74-1	4.60E-04	IRIS		
103	Hexachlorobutadiene	87-68-3	2.20E-05	IRIS		
104	Hexachlorocyclyhexane, 1,2,3,4,5,6-		NA		NA	
105	Hexachlorocyclopentadiene	77-47-4			2.00E-04	IRIS
106	Hexachloroethane	67-72-1	1.10E-05	Cal EPA	3.00E-02	IRIS
107	Hexamethylphosphoramide	680-31-9				
108	Hexane	110-54-3			7.00E-01	IRIS
109	Hydrazine	302-01-2	4.90E-03	IRIS	3.00E-05	PPRTV
110	Hydrogen Chloride	7647-01-0			2.00E-02	IRIS
111	Hydrogen Fluoride	7664-39-3			1.40E-02	Cal EPA
112	Hydroquinone	123-31-9				
113	Hexamethylene Diisocyanate		NA		NA	
114	Isophorone	78-59-1			2.00E+00	Cal EPA
115	Lead Compounds					
	~Lead Phosphate	7446-27-7	1.20E-05	Cal EPA		
	~Lead Acetate	301-04-2	1.20E-05	Cal EPA		
	~Lead And Compounds	7439-92-1				
	~Lead Subacetate	1335-32-6	1.20E-05	Cal EPA		
116	Maleic Anhydride	108-31-6			7.00E-04	Cal EPA
117	Manganese Compounds	0		IRIS	5.00E-05	IRIS

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference	RfCi (mg/m^3)	Reference
118	Mercury Compounds					
	~Mercuric Chloride (And Other Mercury Salts)	7487-94-7			3.00E-04	G
	~Mercury (Elemental)	7439-97-6			3.00E-04	IRIS
	~Methyl Mercury	22967-92-6				
	~Phenylmercuric Acetate	62-38-4				
119	Methanol	67-56-1			2.00E+01	IRIS
120	Methoxychlor	72-43-5				
121	Methyl Chloroform (1,1,1-Trichloroethane)	71-55-6		IRIS	5.00E+00	IRIS
122	Methyl Hydrazine	60-34-4	1.0x10-3	PPRTV	2.0x10-5	PPRTV
123	Methyl Iodide (Iodomethane)	74-88-4	-	-	-	-
124	Methyl Isobutyl Ketone (4-Methyl-2-Pentanone)	108-10-1			3.00E+00	IRIS
125	Methyl Isocyanate	624-83-9			1.00E-03	Cal EPA
126	Methyl Methacrylate	80-62-6			7.00E-01	IRIS
127	Methyl Tert-Butyl Ether (MTBE)	1634-04-4	2.60E-07	Cal EPA	3.00E+00	IRIS
128	Methylene Chloride	75-09-2	1.00E-08	IRIS	6.00E-01	IRIS
129	Methylene Diphenyl Diisocyanate (MDI)	101-68-8		IRIS	6.0x10-4	IRIS
130	Methylene-Bis(2-Chloroaniline), 4,4'-	101-14-4	4.30E-04	Cal EPA		
131	Naphthalene	91-20-3	3.40E-05	Cal EPA	3.00E-03	IRIS
132	Nickel Compounds	0	Ni refinery dust: 2.4E-4 Ni subsulfide: 4.8E-4 Ni carbonyl: 2.6E-4	Cal EPA	Ni refinery dust, Ni subsulfide, and Ni carbonyl: 1.4E-5	Cal EPA
133	Nitrobenzene	98-95-3	4.00E-05	IRIS	9.00E-03	IRIS
134	Nitropropane, 2-	79-46-9	5.80E-04	PPRTV Screening Level	2.00E-02	IRIS

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR (ug/m^3)$^{-1}$	Reference		
135	Nitrosodimethylamine, N-	62-75-9	1.40E-02	IRIS	4.00E-05	PPRTV Screening Level
136	Nitrosomorpholine [N-]	59-89-2	1.90E-03	Cal EPA		
137	Nitroso-N-Methylurea, N-	684-93-5	3.40E-02	Cal EPA		
138	O-Toluidine	95-53-4	5.10E-05	IRIS/Cal EPA		
139	Parathion	56-38-2				
140	PAHPOM		NA		NA	
141	Pentachloronitrobenzene	82-68-8				
142	Pentachlorophenol	87-86-5	5.10E-06	Cal EPA		
143	Phenol	108-95-2			2.00E-01	Cal EPA
144	Phenylenediamine, P-	106-50-3				
145	Phosgene	75-44-5			3.00E-04	IRIS
146	Phosphine	7803-51-2			3.00E-04	IRIS
147	Phosphorus, White	7723-14-0				
148	Phthalic Anhydride	85-44-9			2.00E-02	Cal EPA
149	Polychlorinated Biphenyls (Pcbs)					
	~Aroclor 1016	12674-11-2	2.00E-05	G		
	~Aroclor 1221	11104-28-2	5.70E-04	G		
	~Aroclor 1232	11141-16-5	5.70E-04	G		
	~Aroclor 1242	53469-21-9	5.70E-04	G		
	~Aroclor 1248	12672-29-6	5.70E-04	G		
	~Aroclor 1254	11097-69-1	5.70E-04	G		
	~Aroclor 1260	11096-82-5	5.70E-04	G		
	~Aroclor 5460	11126-42-4				

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference		
	~Heptachlorobiphenyl, 2,3,3',4,4',5,5'- (Pcb 189)	39635-31-9	1.10E-03	TEF applied[h]	1.30E-03	TEF applied
	~Hexachlorobiphenyl, 2,3',4,4',5,5'- (Pcb 167)	52663-72-6	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Hexachlorobiphenyl, 2,3,3',4,4',5'- (Pcb 157)	69782-90-7	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Hexachlorobiphenyl, 2,3,3',4,4',5- (Pcb 156)	38380-08-4	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Hexachlorobiphenyl, 3,3',4,4',5,5'- (Pcb 169)	32774-16-6	1.10E+00	TEF applied	1.30E-06	TEF applied
	~Pentachlorobiphenyl, 2',3,4,4',5- (Pcb 123)	65510-44-3	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Pentachlorobiphenyl, 2,3',4,4',5- (Pcb 118)	31508-00-6	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Pentachlorobiphenyl, 2,3,3',4,4'- (Pcb 105)	32598-14-4	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Pentachlorobiphenyl, 2,3,4,4',5- (Pcb 114)	74472-37-0	1.10E-03	TEF applied	1.30E-03	TEF applied
	~Pentachlorobiphenyl, 3,3',4,4',5- (Pcb 126)	57465-28-8	3.80E+00	TEF applied	4.00E-07	TEF applied
	~Polychlorinated Biphenyls (High Risk)	1336-36-3	5.70E-04	IRIS		
	~Polychlorinated Biphenyls (Low Risk)	1336-36-3	1.00E-04	IRIS		
	~Polychlorinated Biphenyls (Lowest Risk)	1336-36-3	2.00E-05	IRIS		
	~Tetrachlorobiphenyl, 3,3',4,4'- (Pcb 77)	32598-13-3	3.80E-03	TEF applied	4.00E-04	TEF applied
	~Tetrachlorobiphenyl, 3,4,4',5- (Pcb 81)	70362-50-4	1.10E-02	TEF applied	1.30E-04	TEF applied
150	Propionaldehyde	123-38-6			8.00E-03	IRIS
151	Propoxur (Baygon)	114-26-1	-	-	-	-
152	Propylene Oxide	75-56-9	3.70E-06	IRIS	3.00E-02	IRIS
153	Quinoline	91-22-5				
154	Quinone	106-51-4	-	-	-	-
155	Selenium Compounds	7782-49-2		IRIS	2.00E-02	Cal EPA
156	Styrene	100-42-5			1.00E+00	IRIS
157	Styrene Oxide	96-09-3	4.60E-05	IRIS/Cal EPA		
158	Tetrachloroethane, 1,1,2,2-	79-34-5	5.80E-05	Cal EPA		
159	Tetrachloroethylene	127-18-4	2.60E-07	IRIS	4.00E-02	IRIS
160	Titanium Tetrachloride	7550-45-0			1.00E-04	ATSDR
161	Toluene	108-88-3			5.00E+00	IRIS
162	Toxaphene	8001-35-2	3.20E-04	IRIS		
163	Trichlorobenzene, 1,2,4-	120-82-1			2.00E-03	PPRTV

TABLE I. TOXICOLOGICAL PARAMETERS FOR HAZARDOUS AIR POLLUTANTS AND DIESEL EXHAUST PARTICULATE (continued)

	Air Toxics	CAS No.	Cancer		Non-Cancer	
			IUR $(ug/m^3)^{-1}$	Reference		
164	Trichloroethane, 1,1,2-	79-00-5	1.60E-05	IRIS	2.00E-04	PPRTV Screening Level
165	Trichloroethylene	79-01-6	4.10E-06	IRIS	2.00E-03	IRIS
166	Trichlorophenol, 2,4,5-	95-95-4				
167	Trichlorophenol, 2,4,6-	88-06-2	3.10E-06	IRIS		
168	Triethylamine	121-44-8			7.00E-03	IRIS
169	Trifluralin	1582-09-8				
170	Vinyl Acetate	108-05-4			2.00E-01	IRIS
171	Vinyl Bromide	593-60-2	3.20E-05	HEAST[i]	3.00E-03	IRIS
172	Vinyl Chloride	75-01-4	4.40E-06	IRIS	1.00E-01	IRIS
173	Vinylidene Chloride (1,1-Dichloroethylene)	75-35-4		IRIS	2.00E-01	IRIS
174	Xylenes	1330-20-7			1.00E-01	IRIS

[a]IRIS: EPA's Integrated Risk Information System;

[b]Cal EPA: The California Environmental Protection Agency Office of Environmental Health Hazard Assessment;

[c]IN: Inorganic;

[d] PPRTV: The Provisional Peer Reviewed Toxicity Values;

[e]ATSDR: The Agency for Toxic Substances and Disease Registry minimal risk levels (MRLs);

[f] G:Special considerations, these cases are which the standard equations do not apply and/or external adjustments to the SLs are recommended;

[g]Cal OEHHA: California's Office of Environmental Health Hazard Assessment;

[h]TEF applied: Toxicity Equivilence Factors (TEF) applied;

[i]HEAST: The EPA Superfund program's Health Effects Assessment Summary Table

TABLE II. POLULATION DEMOGRAPHICS IN COOK COUNTY, ILLINOIS IN 2010 AND 2014 (U.S. CENSUS BUREAU, N.D.B; N.D.C)

	Census 2010		Census 2014		2010-2014 Change	
	Count	**%**	**Count**	**%**	**Change**	**%**
Total population	5,200,950	100	5,246,456	100	45,506	0.87
Population by Race						
American Indian and Alaska Native alone	13,614	0.26	13816	0.26	202	1.48
Asian alone	327,243	6.29	367760	7.01	40,517	12.38
Black or African American alone	1,286,124	24.73	1251913	23.86	-34,211	-2.66
Native Hawaiian and Other Pacific Islander alone	1,207	0.02	1677	0.03	470	38.94
Some other race alone	544,290	10.47	529965	10.10	-14,325	-2.63
White alone	2,934,502	56.42	2963512	56.49	29,010	0.99
Two or more races	93,970	1.81	117813	2.25	23,843	25.37
Population by Hispanic or Latino Origin (of any race)						
Hispanic or Latino (of any race)	1251133	24.06	1,310,801	24.98	59,668	4.77
Not Hispanic or Latino	3949817	75.94	3,935,655	75.02	-14,162	-0.36

F. <u>Purpose of This Study</u>

The goal of this study is to uncover the temporal and spatial trends in air toxic emissions and identify the top contributing chemicals to the total load of toxic air emissions in Illinois and Cook County by utilizing the National Emissions Inventory data released from USEPA. In addition, to assess the spatial distribution of air emissions and health risks of air toxics in Illinois and Cook County by employing the National Air Toxics Assessment (NATA) data from the USEPA. Calculate diesel PM cancer and non-cancer risks using California EPA-developed toxicity values and assess spatial distribution of diesel PM risks in Cook County to gain understanding of its role in mobile source-driven exposures and risks for cancer and non-cancer effects and characterize the spatial distribution of cancer and respiratory non-cancer risks of select air toxics and diesel PM in Illinois and Cook County in support of inhalation exposure and health risk mitigation efforts and guiding environmental justice and health disparities research and policy.

The objectives are: (1) to identify specific chemicals and associated emission source categories in Illinois and Cook County for air pollution source control and management strategies along with future exposure and risk alleviation; and public health prevention efforts.

II. BACKGROUND

The National Emissions Inventory (NEI) is a detailed and comprehensive dataset of air emissions information in the United State. This dataset is primarily based on data provided by State, Local, and Tribal air agencies for sources in their jurisdictions and supplemented by data developed by the USEPA. It provides information on criteria pollutants, criteria precursors, and hazardous air pollutants in stationary and mobile sources (U.S. Environmental Protection Agency, 2017b). National Air Toxics Assessment (NATA) database assembles National Emissions Inventory (NEI) data for the modeling of air quality and characterization of the potential public inhalation health risks in each year. NATA was primarily developed to inform national and localized efforts to characterize air pollution sources, emission sources and health risks (U.S. Environmental Protection Agency,2018a; 2018d).

Four main emission source categories, point/ major, non-point/ area, on-road, non-road, were included in the NEI as well as in NATA. On-road emission was concluded as the greatest contributor of all four emission source categories in total cancer risk in several U.S. studies in California (Morello-Frosh et al., 2000), and South Carolina (Wilson et al., 2015).

In addition, previous studies have mentioned the uneven spatial distribution of cancer risk and its associations between poverty, educational, race and ethnicity, and exposure to carcinogenic air toxics (Linder et al., 2008; Young et al.,2012; James et al., 2012; Jia and Foran, 2013; Wilson et al., 2015; Grineski et al., 2017; Ekenga et al.,2019). Previous studies also displayed negative academic performing on children who exposed to air pollutions (Pastor et al., 2004; Zweig et al., 2009; Mohai et al., 2011; Legot et al., 2012; Scharber et al., 2013; Gaffron and Niemeier, 2015; Stingone et al., 2016; 2017).

Although many studies concluded the uneven spatial distribution of local area with further health effects association of air pollutants. Little is known about the spatial and temporal distribution of air toxics in Illinois and Cook County. In addition, the information of higher contributing air toxics, inhalation cancer risk, and other health effects were also not investigated. Besides, more and more studies have seen negative impacts of diesel particulate matter, and USEPA has not yet filed the important parameter of diesel PM for risk assessment. Hence, the goal of this study is to 1) unveil the spatial and temporal trends of hazardous air toxic and identify the top contributing chemicals in Illinois and Cook County, 2) and delineate the spatial and temporal pattern of the excess cancer risk and non-cancer risk estimates of higher contributing chemicals and diesel PM.

III. METHOD

A. National Emissions Inventory Data

1. Data Organization

The NEI data with its technical support document for the following years, 1999,2002, 2005, 2011, and 2014 were downloaded from USEPA website respectively for the state of Illinois and all counties within the state of Illinois. The data we utilized are at the county level, which is the smallest publicly available geographic unit for NEI data. The following four source categories of air pollution: Point/ Major; Non-Point/Area; On-Road; Non-Road, were the air emission sources included in this study because these are the four source categories that were consistently included in NEI from 1999 to 2014.

The emission source grouping follows NATA classification. As the definition of emission source categories and the classification of the inclusive subgroups in varies from year to year, the subgroups of each air emission source were arranged by comparing and matching the groups in the released data file as shown in Table III. Most of the data from previous years, 1999 to 2005, were only available until emission source category level, hence, subgroups included in each source categories from these years were based on the technical support document of the same year. Two new groups in 2014, "Agricultural Livestock" in Non-Point emission and "Heavy Duty- Hoteling" in On-Road emission, were the only subgroups that were excluded in this study. All the other subgroups in each emission source categories in Table III were summed up. The "Refueling" were count as the On-Road emission in 2011 and 2014 files for further analysis because there are no "Refueling" in Non-Road emission in each data file from 2011 and 2014. For Point/Major emissions, 1999 is the only year that includes "Airport" and 2002 is the only year that includes "Railyard" due to the available data file. Since 2005, "Airport" and "Railyard" were excluded in Point/ Major emission. "Industrial" was not found in Non-Point Emissions or any other source category in the available 2014 data file. Construction was not existed in the Non-Road emission of the 1999 file. Besides, "Agricultural" was not included in the Non-Point emission in 1999, 2002 and 2005.

2. <u>Data Analysis</u>

All NEI data analysis follow NATA broad group to classify the four included emission categories, Point/ Major, Non-Point/ Area, On-Road, and Non-Road. Microsoft Excel Version 2003 were utilized to identify total air emissions, emissions and percentile of total emissions contributed by each county in the state of Illinois, emission and percentile of total emissions contributed by each air emission source categories, and emission and percentile of total emissions contributed by each air toxic chemicals in the state of Illinois and the counties in the state of Illinois. In this analysis, we examined the redefined four air pollution source categories in the previous section, which is Point/ Major; Non-Point/ Area; On-Road; and Non-Road.

Prior to spatial analysis and data visualization, the percentile distribution that best characterized the total air emission data in the state of Illinois were determined using Microsoft Excel Version 2003. The percentiles in the maps that best demonstrate our data are as follows: 0-25^{th}, 25^{th}-50^{th}, 50-75^{th}, 75-90^{th},90^{th} -98^{th}, 98^{th}-99.5^{th}, 99.5^{th}-100^{th} percentiles.

3. <u>Spatial Data Analysis and Data Visualization</u>

Arc Geographic Information System software (ArcGIS Desktop 10.7.1) was used for spatial analysis and the visualization of the NEI air emissions data from USEPA in order to identify the areas with higher air toxic emissions across all counties in Illinois from the year 1999, 2002, 2005, 2011, and 2014. There are 102 counties in Illinois as showed in Figure 1 and Table IV.

TABLE III. MATCHING SUBGROUPS OF RELEASED 1999-2014 NEI EMISSION DATA BY NATA SOURCE CATEGORIES

Emission Source Category	**1999**	**2002**	**2005**	**2011**	**2014**
Point Sources	Y (Includes Airports)	Y (Excludes Airports, Includes Raiyard)	Y (Excludes Airports and Railroads)	Y (Excludes airports and railyards)	Y (Excludes airports and railyards)
Non-Point Sources					
1. NP-industrial	Y	Y	Y	Y	Y (Not found in the 2014 emissions data)
2.NP- Commercial Cooking	Y	Y	Y	Y	Y
3.NP-OilGas	Y	Y	Y	Y	Y
4.NP-SolventsCoatings	Y	Y	Y	Y	Y
5.NP-SotrageTransfer_BulkTerminals_GasStage1	Y	Y	Y	Y	Y
6.NP-MiscellaneousNonindustrial	Y	Y	Y	Y	Y
7. NP-FuelCombustion_not_RWC	Y	Y	Y	Y	Y
8. NP-Residential WoodCombutsionRWC	Y	Y	Y	Y	Y
9. NP-WasteDisposal	Y	Y	Y	Y	Y
10. NP-AgriculturalLivestock	N	N	N	N	Y (2014NEW)
On-Road Sources					
1. OR-LD_Gas					
-- Light duty-Off network gasoline	Y	Y	Y	Y	Y
-- Light duty-On network gasoline	Y	Y	Y	Y	Y
2. OR-HD_Gas					
-- Heavy duty-Off network gasoline	Y	Y	Y	Y	Y
-- Heavy duty-On network gasoline	Y	Y	Y	Y	Y
3. OR-LD_Diesel					
-- Light duty-Off network diesel	Y	Y	Y	Y	Y
-- Light duty-On network diesel	Y	Y	Y	Y	Y
4. OR-LD_Diesel					
-- Light duty-Off network diesel	Y	Y	Y	Y	Y
-- Light duty-On network diesel	Y	Y	Y	Y	Y
5. OR-Refueling	BOTH OR and NR	BOTH OR and NR	BOTH OR and NR	Y	Y
6. OR- HeavyDuty-Hoteling	N	N	N	N	Y (2014NEW)
Non-Road Sources					
1. NR-Airport (PT)	N	Y	Y	Y	Y
2. NR-Railyard (PT)	Y	N (in PT)	Y	Y	Y
3.NR-CMV_C1C2_ports	Y	Y	Y	Y	Y
4.NR-CMV_C3_ports	Y	Y	Y	Y	Y

TABLE III. MATCHING SUBGROUPS OF RELEASED 1999-2014 NEI EMISSION DATA BY NATA SOURCE CATEGORIES (continued)

Emission Source Category	**1999**	**2002**	**2005**	**2011**	**2014**
5.NR-CMV_C1C2C3_underway	Y	Y	Y	Y	Y
6. NR-Locomotives	Y	Y	Y	Y	Y
7. NR-Recreational-inc-PleasureCraft	Y	Y	Y	Y	Y
8. NR-Construction	N (in NP)	Y	Y	Y	Y
9. NR- CommercialLawnGarden	Y	Y	Y	Y	Y
10.NR-ResidentialLawnGarden	Y	Y	Y	Y	Y
11.NR-Agrivulture	N (in NP)	N	Y (in NP)	Y	Y
12.NR-CommercialEquipment	Y	Y	Y	Y	Y
13.NR-AllOther	Y	Y	Y	Y	Y
14. NR- refueling	BOTH OR and NR	BOTH OR and NR	BOTH OR and NR	N (In OR)	N (In OR)

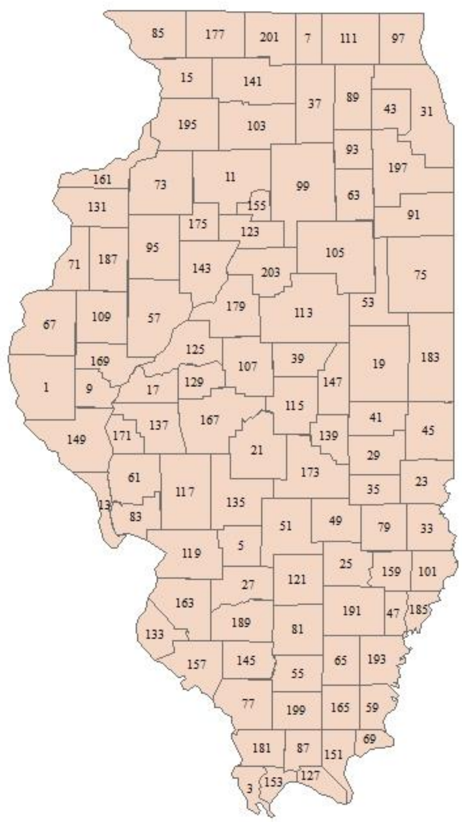

Figure1. Map of 102 counties in Illinois

TABLE IV. LISTED STATE AND COUNTY CODES OF 102 COUNTIES IN ILLINOIS (CENSUS BUREAU, N.D.A)

State Code	County Code	CountyName	County Code	CountyName	County Code	CountyName	County Code	CountyName
17	1	Adam	53	Ford	105	Livingston	157	Randolph
17	3	Alexander	55	Franklin	107	Logan	159	Richland
17	5	Bond	57	Fulton	109	McDonough	161	Rock Island
17	7	Boone	59	Gallatin	111	McHenry	163	St. Clair
17	9	Brown	61	Greene	113	McLean	165	Saline
17	11	Bureau	63	Grundy	115	Macon	167	Sangamon
17	13	Calhoun	65	Hamilton	117	Macoupin	169	Schuyler
17	15	Carroll	67	Hancock	119	Madison	171	Scott
17	17	Cass	69	Hardin	121	Marion	173	Shelby
17	19	Champaign	71	Henderson	123	Marshall	175	Stark
17	21	Christian	73	Henry	125	Mason	177	Stephenson
17	23	Clark	75	Iroquois	127	Massac	179	Tazewell
17	25	Clay	77	Jackson	129	Menard	181	Union
17	27	Clinton	79	Jasper	131	Mercer	183	Vermilion
17	29	Coles	81	Jefferson	133	Monroe	185	Wabash
17	31	Cook	83	Jersey	135	Montgomery	187	Warren
17	33	Crawford	85	Jo Daviess	137	Morgan	189	Washington
17	35	Cumberland	87	Johnson	139	Moultrie	191	Wayne
17	37	DeKalb	89	Kane	141	Ogle	193	White
17	39	DeWitt	91	Kankakee	143	Peoria	195	Whiteside
17	41	Douglas	93	Kendall	145	Perry	197	Will
17	43	DuPage	95	Knox	147	Piatt	199	Williamson
17	45	Edgar	97	Lake	149	Pike	201	Winnebago
17	47	Edwards	99	La Salle	151	Pope	203	Woodford
17	49	Effingham	101	Lawrence	153	Pulaski		
17	51	Fayette	103	Lee	155	Putnam		

B. National Air Toxics Assessment Data

1. Data Organization

The NATA data for the following years, 1999, 2002, 2005, 2011, and 2014 are downloaded from USEPA website respectively for the state of Illinois and all counties within the state of Illinois in order to identify the census tracts with the highest inhalation cancer risk estimates in Cook County. The smallest publicly available geographic unit of NATA data are at census tract level, hence, this allows us to do spatial assessment and visualization of inhalation cancer risk estimates in Cook County.

Similar to NEI, because of the classification of NATA subgroups in each air emission source categories changes from year to year and we also found that some of the available NATA risk data were not aligned with the description in the technical support document, we compared and arranged the NATA cancer risk groupings for the four emission source category under NATA classification as displayed in Table V. Cancer risk from the two new groups in 2014, “Agricultural Livestock” in Non-Point emission and “Heavy Duty- Hoteling” in On-Road emission, were also excluded. Although the 2005 NATA technical support file mentioned “Airport” was excluded, it was included in the “Point Cancer Risk” in the released data. Hence, we decided the Total Point Cancer Risk in this study includes cancer risk in “Point”, “Railyard”, and “Airport”. The cancer risk of “Construction” and “Agricultural” in 1999 was grouped in the Non-Point emission in the available data. The 2011 NATA technical support document mentioned “Locomotives” is included in Non-Road emission but the available 2011 NATA cancer risk file excluded it. All the other subgroups were summed up by each source category as shown in Table V.

2. <u>Data Analysis</u>

National Air Toxics Assessment (NATA) inhalation cancer risk estimate data in Cook County from USEPA were collected for each air emission source with the same subgroups we mentioned in NEI data section: Point/Major, Non-Point/Area, On-Road, Non-Road, and total cancer risk for the following years, 1999, 2002, 2005, 2011, and 2014.

TABLE V. MATCHING SUBGROUPS OF RELEASED 1999-2014 NATA CANCER RISK DATA BY NATA SOURCE CATEGORIES

Emission Source Category	**1999**	**2002**	**2005**	**2011**	**2014**
Total Point Cancer Risk= Point +Railyard +Airport					
1. Point Cancer Risk	**Y (Includes Airport and Railyard)**	**Y (Includes Airport and Railyard)**	**Y (Includes Airport and Railyard)**	**Y (Includes Railyard)**	**Y**
2. RailyardCancer Risk	**N (Included in point)**	**N (Included in point)**	**N (Included in point)**	**N (Included in point)**	**Y**
3. Airport_Cancer Risk	**N (Included in point)**	**N (Included in point)**	**N (Included in point)**	**Y**	**Y**
Total Non-Point Cancer Risk					
1.NP-industrial Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
2.NP-Commercial Cooking Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
3. NP-OilGas Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
4. NP-Solvents Coatings Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
5. NP-Storage Transfer Bulk Terminals GasStage1 Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
6. NP-Miscellaneous Nonindustrial Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
7. NP-FuelCombustion not RWC Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
8. NP-Residential Wood Combustion RWC Cancer Risk	**Y**	**Y**	**Y**	**Y**	**Y**
9. NP-Waste Disposal Cancer Risk	Y	Y	Y	Y	Y
10. NP-Agriculture Livestock Cancer Risk	N	N	N	N	Y (2014 New)
Total On-Road Cancer Risk					
1. OR-Light Duty-Off Network-Gas Cancer Risk	Y	Y	Y	Y	Y
2. OR-Light Duty-Off Network-Diesel Cancer Risk	Y	Y	Y	Y	Y
3. OR-Heavy Duty-Off Network-Gas Cancer Risk	Y	Y	Y	Y	Y
4. OR-Heavy Duty-Off Network-Diesel Cancer Risk	Y	Y	Y	Y	Y
5. OR-Light Duty-On Network-Gas Cancer Risk	Y	Y	Y	Y	Y
6. OR-Light Duty-On Network-Diesel Cancer Risk	Y	Y	Y	Y	Y
7. OR-Heavy Duty-On Network-Gas Cancer Risk	Y	Y	Y	Y	Y
8. OR-Heavy Duty-On Network-Diesel Cancer Risk	Y	Y	Y	Y	Y
9. OR-Refueling Cancer Risk	Y (BOTH OR and NR)	Y (BOTH OR and NR)	Y (BOTH OR and NR)	Y	Y
10. OR-HeavyDuty-Hoteling Cancer Risk	N	N	N	N	Y (2014 New)
Total Non-Road Cancer Risk					
1. NR-Recreational-inc-PleasureCraft Cancer Risk	Y	Y	Y	Y	Y
2. NR-Construction Cancer Risk	N (in NP)	Y	Y	Y	Y

TABLE V. MATCHING SUBGROUPS OF RELEASED 1999-2014 NATA CANCER RISK DATA BY NATA SOURCE CATEGORIES (continued)

Emission Source Category	**1999**	**2002**	**2005**	**2011**	**2014**
3. NR-Commercial Lawn Garden Cancer Risk	Y	Y	Y	Y	Y
4. NR-Residential Lawn Garden Cancer Risk	Y	Y	Y	Y	Y
5. NR-Agriculture Cancer Risk	N (in NP)	Y	Y	Y	Y
6. NR-Commercial Equipment Cancer Risk	Y	Y	Y	Y	Y
7. NR-All Other Cancer Risk	Y	Y	Y	Y	Y
8. NR-CMV C1C2 ports Cancer Risk	Y	Y	Y	Y	Y
9. NR-CMV C3 ports Cancer Risk	Y	Y	Y	Y	Y
10. NR-CMV C1C2C3 underway Cancer Risk	Y	Y	Y	Y	Y
11. NR-Locomotives Cancer Risk	Y (BOTH OR and NR)	Y (BOTH OR and NR)	Y (BOTH OR and NR)	N	Y
12.NR-Refueling	Y	Y	Y	N	N

Prior to spatial analysis and data visualization, the percentile distribution that best characterized the total inhalation cancer risk estimate data in the state of Illinois were determined using Microsoft Excel Version 2003. The percentiles in the maps of the total inhalation cancer risk estimates, chemical specific inhalation cancer risk and non-cancer risk, in Cook County that best demonstrate our data are as follows: 0-5th, 5th-25th, 25th-50th, 50-75th, 75-90th,90th -95th, 95th-98th, 98th-100th percentiles of each dataset.

Due to the prominent importance of diesel PM as an air toxic, we also examine diesel PM cancer risk estimates in Cook county. United States Environmental Protection Agency (EPA) did make estimates for emissions of diesel PM, however, unlike other chemicals, they did not estimate the cancer risk of it. Because of the prominence that diesel PM is an air toxic, we decided to also examine diesel PM cancer risk in Cook County. Unlike ethylene oxide and formaldehyde or other chemicals, USEPA did not develop the Unit Risk Estimates (URE) for diesel PM. The Diesel Guidelines in California developed by the Air Resources Board (ARB) and the Office of Environmental Health Hazard Assessment (OEHHA) were intended to assist California local Air Pollution Control and Air Quality Management Districts (Districts) and sources of diesel PM emissions in making consistent risk management decision. Because of the lack information of diesel PM URE in USEPA, we determined the diesel PM inhalation cancer risk in Cook County by using the parameters from the Diesel Guidelines in California with the NATA-method equation listed in NATA technical supporting document.

a. **NATA-Method Cancer Risk Estimate:**

$$Risk = EC \times URE$$ [Equation 1.]

Where:

Risk = estimated incremental lifetime cancer risk for an individual due to exposure to a specific air toxic, unitless (expressed as a probability)

EC = estimate of long-term inhalation exposure concentration for a specific air toxic, in units of μg/m^3

URE = the corresponding inhalation unit risk estimate for that air toxic, in units of 1/(μg/m^3)

b. NATA-Method Non-Cancer Risk:

$$HQ = \frac{EC}{RfC}$$ [Equation 2.]

Where:

HQ = the hazard quotient for an individual air toxic, unitless

EC = estimate of long-term inhalation exposure concentration for a specific air toxic, in units of μg/m^3

RfC = the corresponding reference concentration for that air toxic, in units of μg/m^3

c. Full-Method Cancer Risk Estimate:

$$Risk = \frac{EC \times IR \times EF \times ED \times CF}{BW \times AT \times CSF-inh}$$ [Equation 3.]

Where:

EC = estimate of long-term inhalation exposure concentration for a specific air toxic, in units of μg/m3

IR =Inhalation rate

EF: Exposure frequency in units of days/year

ED: Exposure duration in units of year

CF: Conversion factor- 10^{-3}mg/μg

BW: Body weight (kg)*AT:* Averaging time (days)

CSF-inh: Cancer slope factor

The percentiles in the diesel PM cancer risk maps that best demonstrate our data are as follows: 0-5th, 5th-25th, 25th-50th, 50-75th, 75-90th,90th-95th, 95th-98th, and 98th-100th percentile. According to the methodology in the Regional Removal Management Levels (RMLs) User's Guide from USEPA, "A 10^{-4} risk level corresponds to the upper-end of USEPA's generally acceptable risk range of 10^{-6} to 10^{-4}" as discussed in the National Contingency Plan (NCP). Although the NCP gives no analogous recommended range for non-carcinogenic risks, Hazard Index (HI), the sum of the ratios of the exposure levels to the Reference Concentration (RfC), is often used for non-carcinogenic risk assessments. If the hazard index is less than 1, no adverse effects are expected. While the hazard index is above 1 does not mean that effects will occurred but the level of concern has increased and further assessment may be warranted.

TABLE VI. PARAMETERS USED IN CALCULATION OF ESTIMATED NATA-METHOD AND FULL-METHOD CANCER/ NON-CANCER RISK OF DIESEL PM

Parameters	Value	Reference
URE	3.0 E-4 $(\mu g/m^3)^{-1}$	U.S. CA OEHHA/ARB 2016
RfC	5 $\mu g/m^3$	U.S. CA OEHHA/ARB 2016
CSF	1.1 E+0 $(mg/kg\text{-}day)^{-1}$	U.S. CA OEHHA/ARB 2016
IR	Adult: Average 95th Percentile 21-71 years old recommended long-term exposure:20.66 m^3/day Child: Average 95th Percentile birth-6 years old recommended long-term exposure: 9.56 m^3/day	USEPA Exposure Handbook Table 6-1, 2011
EF	350 days/year	USEPA Default Exposure Factors 2014
ED	Adult: 26 years Child: 6 years	USEPA Default Exposure Factors 2014
BW	Adult: 80 kg Child: 15 kg	USEPA Default Exposure Factors 2014
AT	365 days/ year	USEPA Default Exposure Factors 2014

3. Spatial Data Analysis and Data Visualization

Similar to NEI data, Arc Geographic Information System software (ArcGIS Desktop 10.7.1) was used for spatial analysis and the visualization of the NATA data in Cook County from USEPA in order to identify the areas with higher inhalation cancer risk estimates and respiratory non-carcinogen risk estimates across Cook County in 2014. In addition, spatial distribution of the diesel PM inhalation cancer risk across Cook County in 1999, 2002, 2005, 2011, and 2014 were also visually displayed.

IV. RESULTS

A. Emissions Delineation in Illinois and Cook County, Illinois

1. Temporal Air Emissions Assessment for the State of Illinois from 1999 To 2014

a. NEI Air Emissions Delineation of Counties Across Illinois

There are 102 counties in Illinois and the population of Illinois is the fifth largest across the United States. The total emission is a summation of the four following air emission categories in each year: Point/ Major, Non-Point/ Area, On-Road, and Non-Road. The subgroups include in each source categories evolved and updated over years. In this study, we tried to match all the subgroups from different year as much as possible as demonstrated in Table III and V. The classification of “construction” was in Non-Point source in 1999 NEI instead of Non-Road source since 2002 NEI. “Airport” was switched from Point source to Non-Road source since 2002. Besides, “Railroad (railyard)” started to be exclude in Point source and categorized as Non-Road source since 2005. While agricultural burning was categorized as Non-Point sources in 1999, 2002, and 2005, it started to be classified into the Fire group since 2011 NEI. Although there might be some changes in the name of each subgroups, the total of inclusive subgroups in the four air emission source categories are mostly the same (U.S. Environmental Protection Agency, 2004; 2008; 2011a; 2011c; 2015a; 2015b; 2017b, 2018a; 2018b;Ted Palma, Office of Air Quality Planning and Standards, Health and Environmental Impacts Division, U.S. Environmental Protection Agency, June 8, 2020, personal communication).

TABLE VII. DESCRIPTIVE STATISTICS OF NEI TOTAL EMISSIONS (TPY) ACROSS ILLINOIS, 1999-2014

	1999	**2002**	**2005**	**2011**	**2014**
Minimum	58	62	50	54	72
Mean	1686	1566	1322	1118	1013
Median	600	628	421	543	407
Max	48910	39652	34155	27363	27284
SD	5066	4123	3586	2798	2805
95th Percentile	5623	4700	3914	2756	2663

TABLE VIII. DESCRIPTIVE STATISTICS OF POINT/MAJOR AIR EMISSIONS (TPY) ACROSS ILLINOIS, 1999-2014

	1999	**2002**	**2005**	**2011**	**2014**
Minimum	0	0	0	0	0
Mean	584	336	315	128	122
Median	94	46	25	25	18
Max	7357	3995	4221	1814	1972
SD	1268	785	776	272	294
95th Percentile	3168	1786	1921	477	469

TABLE IX. DESCRIPTIVE STATISTICS OF NON-POINT/AREA AIR EMISSIONS (TPY) ACROSS ILLINOIS, 1999-2014

	1999	**2002**	**2005**	**2011**	**2014**
Minimum	15	20	14	24	18
Mean	353	577	429	540	369
Median	113	230	127	276	120
Max	13312	18921	16555	14315	13121
SD	1344	1906	1674	1440	1333
95th Percentile	894	1746	1489	1036	898

TABLE X. DESCRIPTIVE STATISTICS OF ON-ROAD AIR EMISSIONS (TPY) ACROSS ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	21	19	16	8	2
Mean	507	417	357	215	271
Median	150	153	119	72	82
Max	21526	10918	9845	6563	8260
SD	2147	1134	1022	682	857
95th Percentile	1344	1179	987	678	789

TABLE XI. DESCRIPTIVE STATISTICS OF NON-ROAD AIR EMISSIONS (TPY) ACROSS ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	11	12	11	12	23
Mean	241	236	221	234	252
Median	73	69	68	99	135
Max	6715	6040	5232	5049	4510
SD	758	679	591	552	489
95th Percentile	559	792	721	702	773

Table VII shows the descriptive statistics of NEI total air emissions across counties in Illinois. As shown in the table, the maximum NEI total emissions (in tons per year) of each year have decreased through the years from 1999 to 2014. The mean of the NEI total emissions in each year also shows a steady declining trend.

The descriptive statistics of 1999 to 2014 NEI air emissions across Illinois in the four emission source categories are also estimated as shown in Table VIII (Point/ Major), Table IX (Non-Point/ Area), Table X (On-Road), and Table XI (Non-Road) in order to have a more clear picture of the change of each emissions source categories in Illinois over the years.

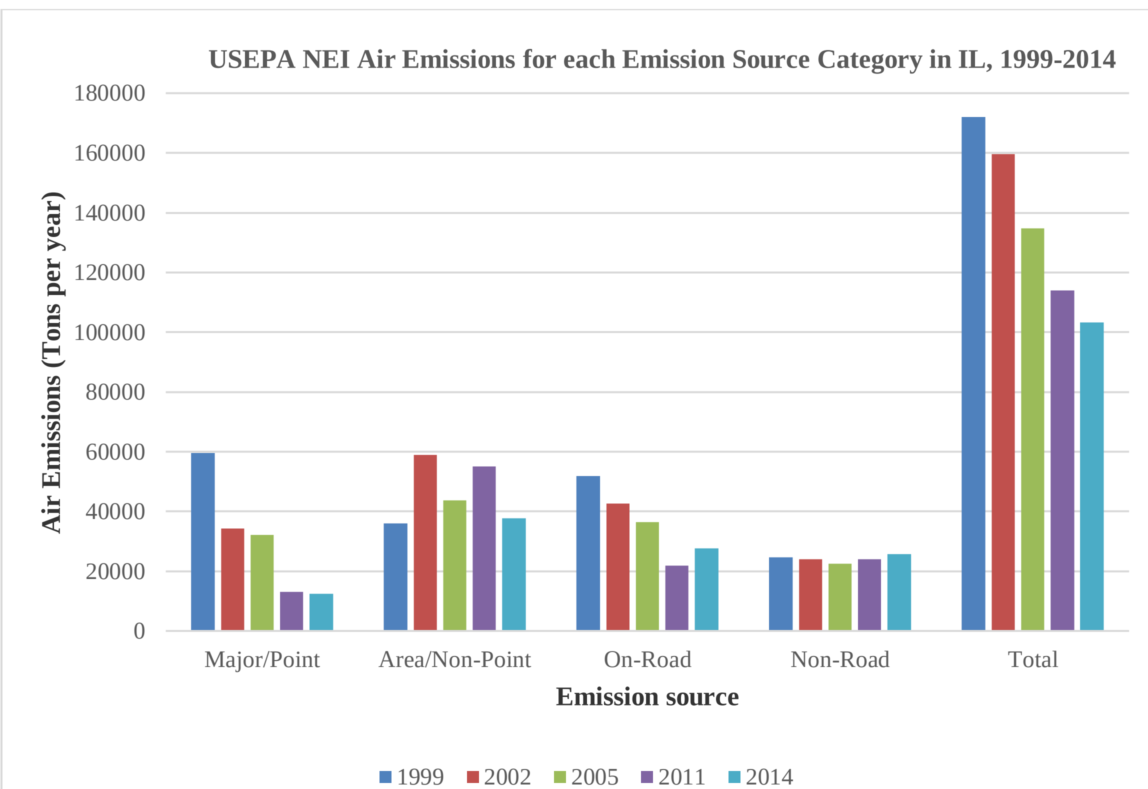

Figure 2. USEPA NEI air emissions for each emission source category in IL, 1999-2014

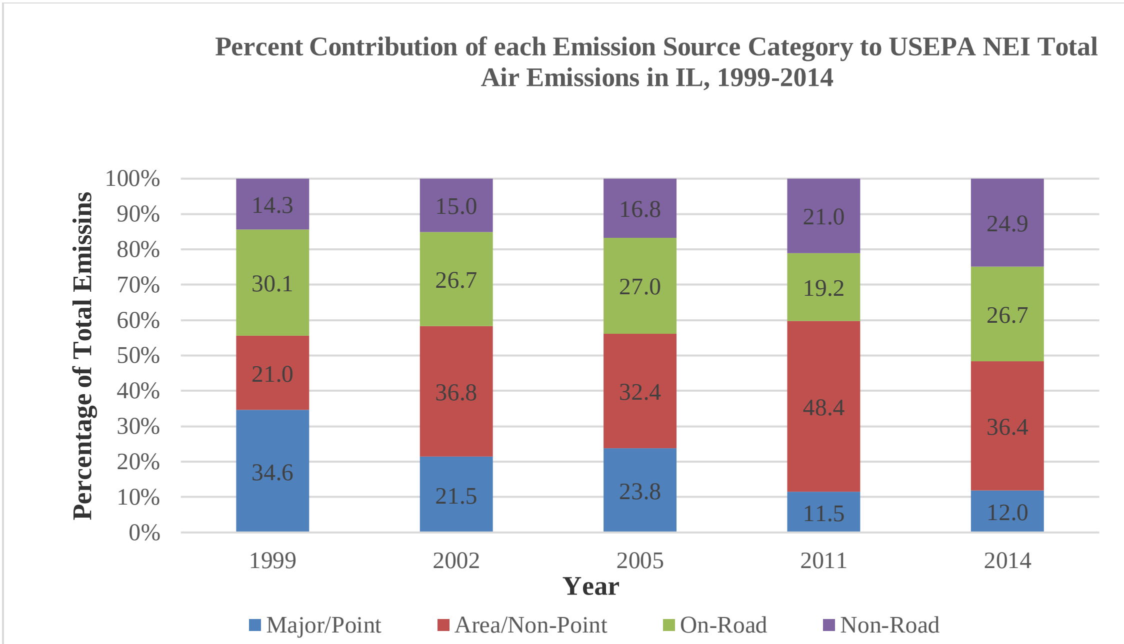

Figure 3. Percent contribution of each emission source category to USEPA NEI total air emissions in IL, 1999-2014

Table VIII shows that the mean and maximum point emissions decreased from 1999 to 2014. The change in Non-Point emission (Table IX) fluttered from 1999 to 2014. There is a steady decline in the mean of On-Road emission (Table X) but the maximum On-Road emission went up in 2014. Unlike the other three emission source categories, Non-Road emission (Table XI) did not show dramatic change over the years.

The NEI data were plotted into Figure 2 and 3 to have a better understanding of the temporal trend of the four emission source categories in Illinois. It is easy to observe the decreasing trend of the total air emissions (40%) from 1999 to 2014 in Figure 2. However, this does not mean that all four source categories decreased through the years. The point emission also declined over the years by 79% but the non-point emission fluttered from one year to next with no significant reduction. The on-road emission steadily decreased until 2011 and increased by 26% in 2014. There were not much change in non-road emission from 1999 to 2014.

Figure 3 demonstrates the percentage contribution of each source categories to total air emission in Illinois of each year. Although there was decreases in the percentage contribution of both point/ major emissions (34.6% in 1999 to 12.0% in 2014) and on-road emissions (30.1% in 1999 to 26.7% in 2014), a steady increase occurred in the percentage contribution of non-road emissions (14.3% in 1999 to 24.9% in 2014). The percentage contribution of on-road emissions declined until 2011 and rose in 2014. In addition, it is also recognized by Figure 3 that the main contributed emission source changed over the years. In 1999, the main contributed emission source was point/major emission and the main contributed emission source since 2002 was non-point/ area emission.

b. <u>Spatial Air Emissions Assessment for the State of Illinois from 1999 to 2014</u>

To assess spatial distribution of air emissions in countries across the state of Illinois, the NEI data were mapped using ArcGIS Desktop 10.7.1 as displayed in the following figures, Figures 4, 5, 6, 7, 8 for the year of 1999, 2002, 2005, 2011 and 2014, respectively. In 1999, Cook and DuPage Counties are the two counties with the highest total air emissions in Illinois with the contribution of 48910 (tpy) and 11394 (tpy). Following with Lake County, the third highest total air emissions contribution in Illinois with the contribution of 7606 (tpy). Since 2002, Cook County is consistently the only county with the highest total air emissions in Illinois. Table XII, XIII, XIV, XV and XVI also respectively demonstrated the top 20 counties contributing to NEI total air emissions in Illinois and the percentage contribution of each source category to total emissions in each county for the year 1999, 2002, 2005, 2011, and 2014. As shown in Figure 4, 5, 6, 7, 8 and Table XII, XIII, XIV, XV, VI Cook County has remained the highest total emission contributed county to the state of Illinois over the years. Besides, counties near Cook County, DuPage County, Lake County, and Will County, are also higher contributors to the total air emissions to Illinois.

c. <u>Chemicals Contributing to Total Air Emission in Illinois over the Years</u>

1) <u>Top 20 Air Toxics Contributing to Total Emission Across Illinois</u>

National Emissions Inventory (NEI) data for each year were also analyzed to identify the contributing chemicals to the total air emissions in Illinois. Table XVII, XVIII, XIX, XX, and XXI displays the top 20 chemicals contributing to total air emission and each air emission source categories in tons per year (Tpy) for the following year 1999, 2002, 2005, 2011, and 2014, separately.

Toluene was the air toxic that consistently contributes the most to the total emission and the on-road emission in each year in Illinois, however, the emission amount of it decreased over the years. In addition to toluene, xylenes are also the air toxic that consistently contributes the most to the on-road emission throughout the years. Since 2011, diesel PM replaced toluene and became the air toxic that contributes the most to the non-road emission. Since 2011, diesel PM had become the top five contributors to the total emission. Hydrochloric acid and hexane were the top two contributors to the point emissions from 1999 to 2011, in 2014, hydrochloric acid was replaced by carbon disulfide. The order of the top contributing air toxic in non-point emission slightly changes from year to year but the composition of it were primarily by the following chemicals: toluene, methanol, hexane, xylenes, benzene, and ethylene glycol.

Toluene is mainly used in the gasoline to improve octane rating and for producing benzene. Toluene is also been used as a solvent in coatings, paints, cleaning agents. In addition, the production of polymers for making nylon, plastic bottles, polyurethanes, cosmetic nail products (U.S. Environmental Protection Agency, 2012; Agency for Toxic Substances and Disease Registry, 2017). Xylenes are usually produced from petroleum in chemical industries. It is also used as solvent and in printing, leather industries. Besides, it is also used as a cleaning agent (Agency for Toxic Substances and Disease Registry, 2011c). Benzene is widely use in U.S. industries for making plastics, nylon and synthetic fibers and resins. It is also used to make rubbers, dyes, detergents, and pesticides. In addition, benzene is a natural part of crude oil, gasoline and cigarette smoke (Agency for Toxic Substances and Disease Registry, 2011a) Ethylene glycol is used to make antifreeze and de-icing solutions for cars, airplanes, and boats (Agency for Toxic Substances and Disease Registry, 2011b).

2. Air Emissions Assessment for Cook County, Illinois, 1999-2014

a. NEI Air Emissions Delineation in Cook County, Illinois

Cook County is the county that contributes the most air emissions in the state of Illinois. Table XXII demonstrates the descriptive statistics of total air emissions in Cook County for the following years: 1999, 2002, 2005, 2011, and 2014. The total emission was summed up by point emission, non-point emission, on-road emission, and non-road emission from each year, respectively. The mean of the total emission decreased from year to year. The median of the total emission in Cook County remained almost the same. The maximum of the total emission in Cook County decreased from 1999 to 2005. However, it fluttered between 2005 to 2014.

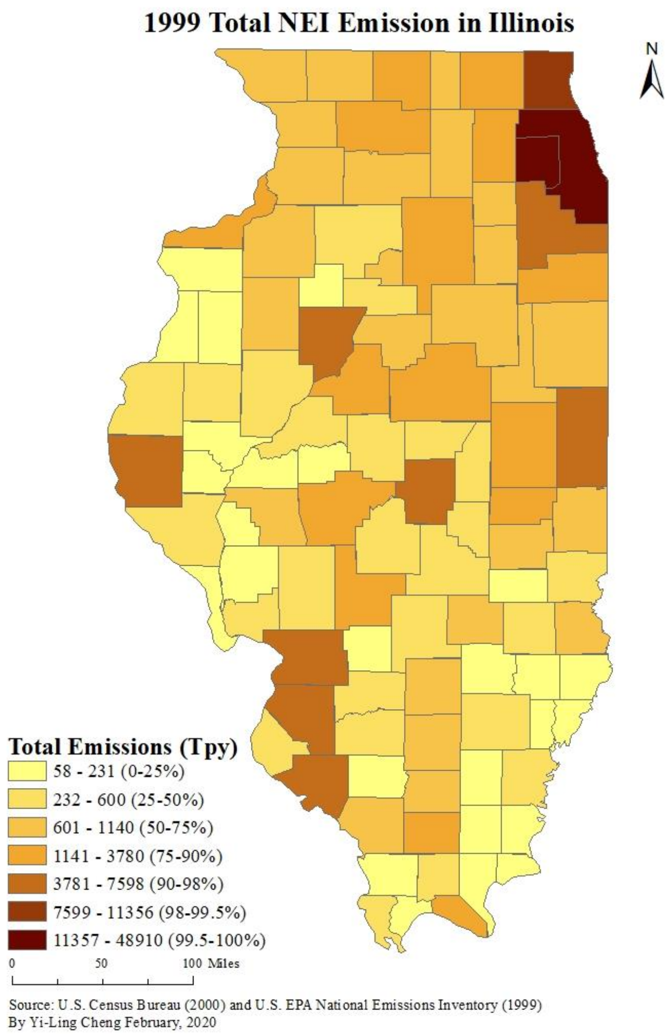

Figure 4. USEPA NEI total emissions in IL, 1999

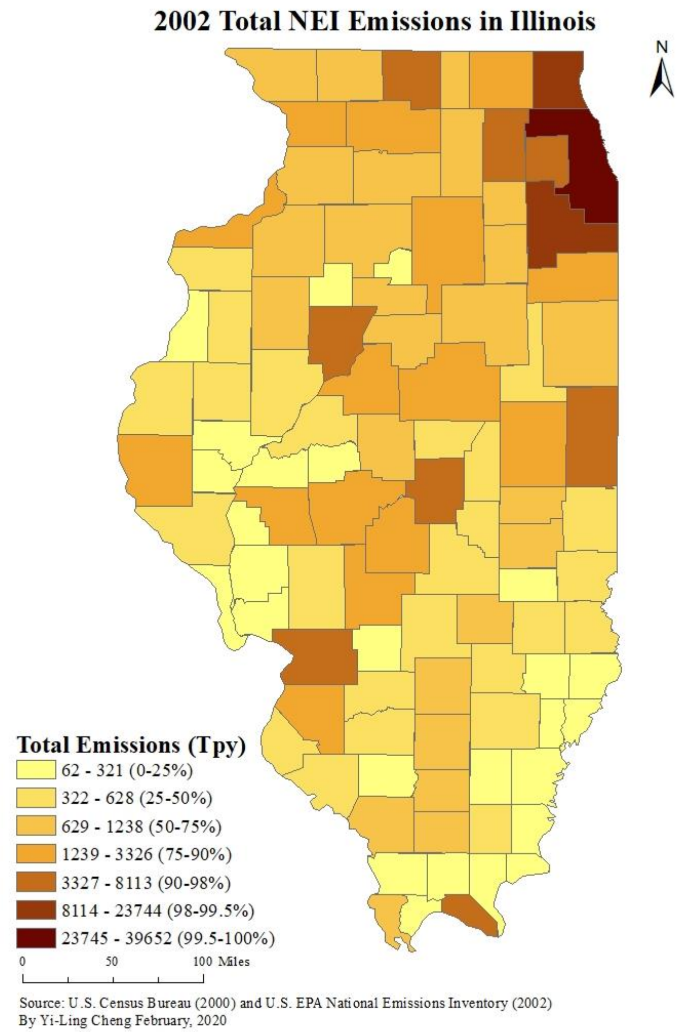

Figure 5. USEPA NEI total emissions in IL, 2002

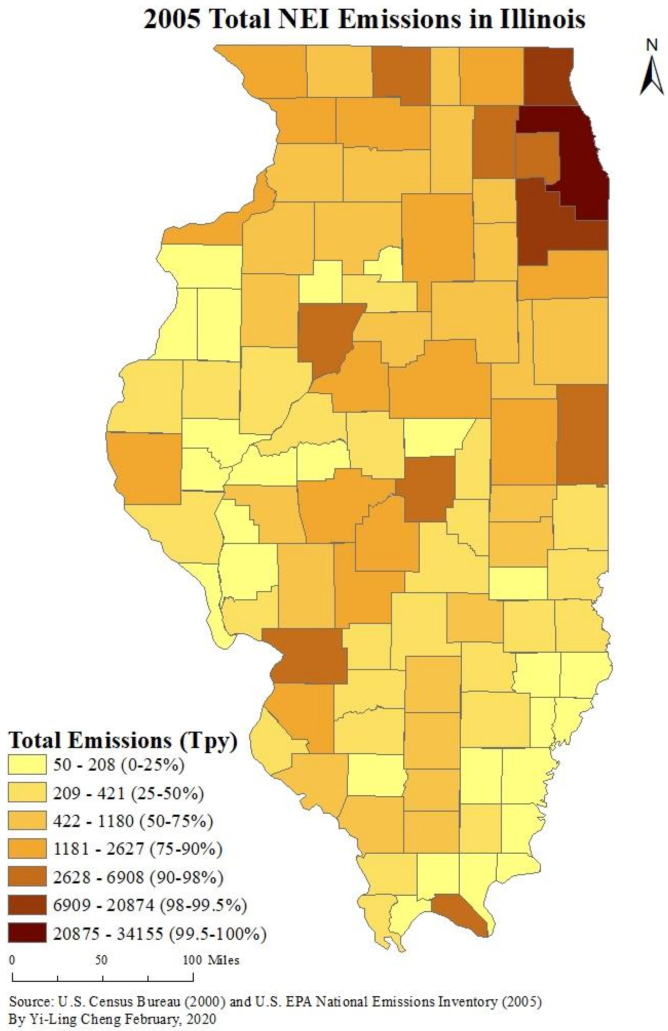

Figure 6. USEPA NEI total emissions in IL, 2005

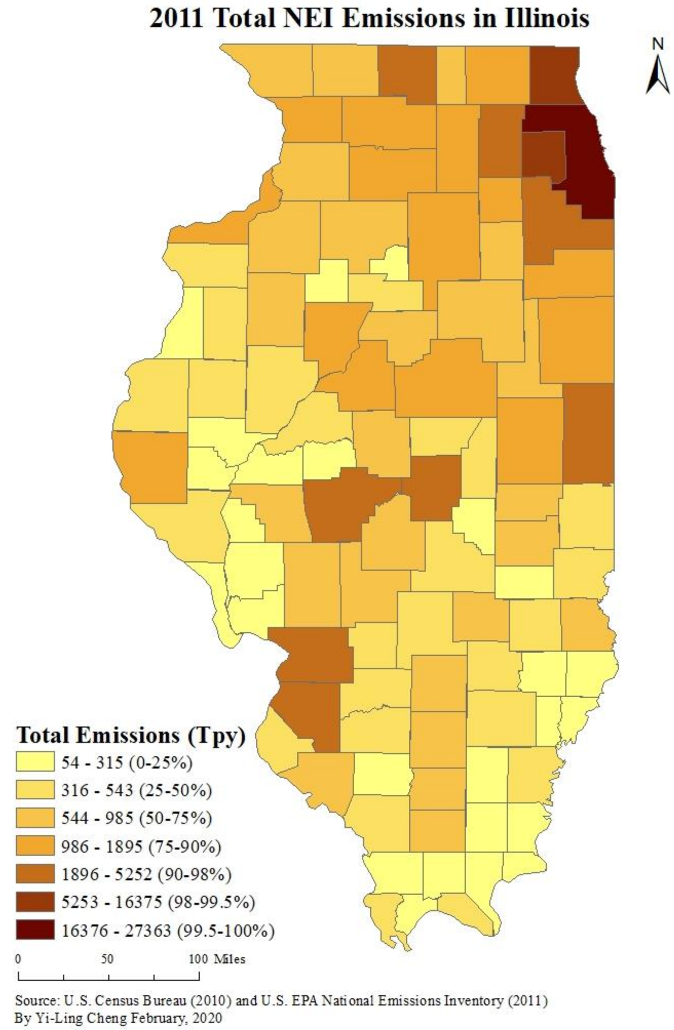

Figure 7. USEPA NEI total emissions in IL,2011

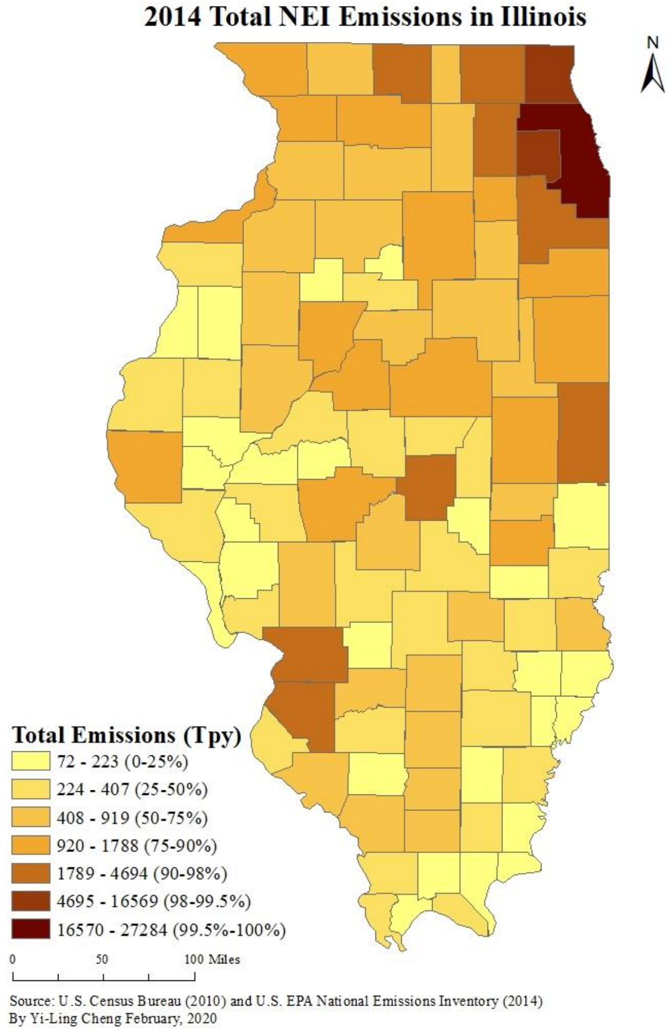

Figure 8. USEPA NEI total emissions in IL, 2014

TABLE XII. TOP 20 COUNTIES CONTRIBUTING TO NEI 1999 TOTAL AIR EMISSIONS IN ILLINOIS AND PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN EACH COUNTY

	County	Major/ Point Emissions (tpy)	% of Point Sources to Total Emissions	Area/ Non-Point Emissions (tpy)	%of Non-Point Sources to Total Emissions	On-Road Emissions (tpy)	% of On-Road Sources to Total Emissions	Non-Road Emissions (tpy)	% of Non-road Sources to Total Emissions	Total Air Emissions (tpy)	% of Total Air Emissions per county
1	Cook	7357	15.04	13312	27.22	21526	44.01	6715	13.73	48910	28.448
2	DuPage	3974	34.88	2552	22.40	3223	28.29	1644	14.43	11394	6.627
3	Lake	661	8.69	1730	22.75	1726	22.69	3489	45.87	7606	4.424
4	Adams	6483	90.07	242	3.36	315	4.38	157	2.19	7197	4.186
5	Will	2961	49.84	1260	21.21	968	16.30	751	12.65	5940	3.455
6	Madison	3179	56.29	704	12.46	1357	24.03	407	7.22	5647	3.285
7	Randolph	4792	92.89	114	2.20	144	2.80	109	2.11	5159	3.001
8	Vermilion	3567	80.98	302	6.85	402	9.13	134	3.04	4405	2.562
9	St. Clair	1543	38.18	764	18.90	1409	34.87	326	8.06	4041	2.350
10	Macon	2791	72.48	347	9.01	577	14.99	135	3.51	3851	2.240
11	Peoria	2020	52.97	533	13.97	953	25.00	308	8.06	3813	2.218
12	Sangamon	1492	42.85	566	16.24	1108	31.80	318	9.12	3483	2.026
13	Winnebago	478	14.46	898	27.19	1416	42.86	512	15.49	3303	1.921
14	Rock Island	1213	45.27	443	16.55	754	28.16	268	10.02	2679	1.558
15	Kane	313	13.27	1134	48.18	349	14.80	559	23.75	2355	1.370
16	Montgomery	1903	82.77	100	4.35	222	9.67	74	3.21	2299	1.337
17	McLean	482	24.24	405	20.37	880	44.24	222	11.15	1990	1.157
18	Kankakee	890	44.74	405	20.36	482	24.26	212	10.64	1988	1.157
19	LaSalle	679	34.82	429	22.01	606	31.11	235	12.06	1949	1.133
20	Tazewell	609	31.58	441	22.90	685	35.52	193	10.01	1928	1.122

TABLE XIII. TOP 20 COUNTIES CONTRIBUTING TO 2002 NEI TOTAL AIR EMISSIONS IN ILLINOIS AND PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN EACH COUNTY

	County	Major/ Point Emissions (tpy)	% of Point Sources to Total Emissions	Area/ Non-Point Emissions (tpy)	%of Non-Point Sources to Total Emissions	On-Road Emissions (tpy)	% of On-Road Sources to Total Emissions	Non-Road Emissions (tpy)	% of Non-road Sources to Total Emissions	Total Air Emissions (tpy)	% of Total Air Emissions per county
1	Cook	3774	9.52	18921	47.72	10918	27.54	6040	15.23	39652	24.83
2	Lake	376	4.62	2943	36.10	1915	23.49	2917	35.79	8151	5.10
3	Will	3995	49.17	1881	23.15	1399	17.22	850	10.46	8125	5.09
4	DuPage	335	4.45	2889	38.36	2769	36.75	1539	20.43	7532	4.72
5	Vermilion	3765	77.01	580	11.86	426	8.70	119	2.43	4889	3.06
6	Winnebago	407	8.60	2528	53.34	1434	30.25	370	7.81	4740	2.97
7	Massac	3364	85.00	459	11.61	106	2.68	28	0.72	3957	2.48
8	Kane	187	4.85	1775	45.96	1100	28.49	800	20.71	3863	2.42
9	Peoria	1788	46.96	773	20.30	921	24.19	325	8.55	3808	2.38
10	Macon	2155	63.26	568	16.68	538	15.79	145	4.27	3406	2.13
11	Madison	877	26.12	921	27.41	1182	35.19	379	11.28	3359	2.10
12	St. Clair	673	22.23	943	31.13	1122	37.05	291	9.59	3030	1.90
13	Sangamon	350	13.48	834	32.16	1078	41.53	333	12.83	2595	1.62
14	McHenry	46	1.93	1185	49.40	686	28.60	481	20.06	2398	1.50
15	Montgomery	1756	73.84	295	12.41	256	10.76	71	2.99	2378	1.49
16	La Salle	807	35.54	520	22.91	700	30.81	244	10.74	2272	1.42
17	Champaign	171	7.77	896	40.62	914	41.42	224	10.18	2206	1.38
18	McLean	322	15.90	510	25.17	969	47.82	225	11.12	2026	1.27
19	Adams	780	39.43	796	40.22	264	13.33	139	7.02	1978	1.24
20	Rock Island	416	21.15	574	29.19	727	36.99	249	12.68	1966	1.23

TABLE XIV. TOP 20 COUNTIES CONTRIBUTING TO 2005 NEI TOTAL AIR EMISSIONS IN ILLINOIS AND PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN EACH COUNTY

	County	Major/ Point Emissions (tpy)	% of Point Sources to Total Emissions	Area/ Non-Point Emissions (tpy)	%of Non-Point Sources to Total Emissions	On-Road Emissions (tpy)	% of On-Road Sources to Total Emissions	Non-Road Emissions (tpy)	% of Non-road Sources to Total Emissions	Total Air Emissions (tpy)	% of Total Air Emissions per county
1	Cook	2523	7.39	16555	48.47	9845	28.83	5232	15.32	34155	25.33
2	Will	4221	53.73	1631	20.76	1265	16.11	739	9.41	7856	5.83
3	Lake	268	3.87	2353	34.03	1756	25.39	2538	36.71	6915	5.13
4	DuPage	259	3.93	2600	39.40	2463	37.32	1277	19.34	6599	4.89
5	Macon	3827	79.47	431	8.95	430	8.94	127	2.64	4815	3.57
6	Winnebago	109	2.78	2079	52.97	1393	35.49	344	8.76	3925	2.91
7	Vermilion	2861	77.45	342	9.26	368	9.97	123	3.32	3694	2.74
8	Peoria	1935	54.03	600	16.77	755	21.08	291	8.11	3580	2.66
9	Massac	3238	92.51	155	4.44	81	2.32	25	0.73	3500	2.60
10	Kane	68	2.11	1519	46.85	987	30.46	667	20.58	3242	2.40
11	Madison	786	29.78	779	29.50	731	27.70	343	13.01	2639	1.96
12	St. Clair	429	17.07	848	33.73	984	39.15	253	10.05	2514	1.86
13	Sangamon	410	18.07	619	27.27	912	40.18	329	14.48	2269	1.68
14	Montgomery	1657	80.51	131	6.35	194	9.45	76	3.69	2058	1.53
15	McHenry	21	1.05	927	45.39	666	32.60	428	20.96	2042	1.51
16	Christian	1661	82.56	130	6.44	137	6.80	85	4.20	2012	1.49
17	McLean	347	19.80	390	22.24	813	46.39	203	11.58	1753	1.30
18	Ogle	727	41.90	205	11.84	293	16.89	510	29.37	1735	1.29
19	La Salle	373	22.35	460	27.59	559	33.52	276	16.54	1669	1.24
20	Adams	702	43.47	558	34.52	209	12.94	147	9.07	1615	1.20

TABLE XV. TOP 20 COUNTIES CONTRIBUTING TO 2011 NEI TOTAL AIR EMISSIONS IN ILLINOIS AND PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN EACH COUNTY

	County	Major/ Point Emissions (tpy)	% of Point Sources to Total Emissions	Area/ Non-Point Emissions (tpy)	%of Non-Point Sources to Total Emissions	On-Road Emissions (tpy)	% of On-Road Sources to Total Emissions	Non-Road Emissions (tpy)	% of Non-road Sources to Total Emissions	Total Air Emissions (tpy)	% of Total Air Emissions per county
1	Cook	1437	5.25	14315	52.31	6563	23.98	5049	1.06	27363	24.01
2	DuPage	129	2.30	2627	46.87	1657	29.57	1192	0.32	5604	4.92
3	Lake	143	2.73	2024	38.44	1072	20.36	2026	0.28	5266	4.62
4	Will	501	10.99	2053	45.07	1153	25.31	849	0.70	4556	4.00
5	Kane	83	2.74	1549	50.96	705	23.20	702	0.10	3039	2.67
6	Vermilion	1814	65.44	606	21.87	162	5.86	189	0.64	2772	2.43
7	Madison	405	16.52	1011	41.30	680	27.76	353	0.08	2449	2.15
8	Macon	1162	55.48	582	27.82	197	9.42	152	1.12	2094	1.84
9	Sangamon	351	16.91	931	44.86	450	21.68	344	0.22	2076	1.82
10	St. Clair	103	5.17	992	49.68	639	32.00	263	1.52	1998	1.75
11	Winnebago	52	2.76	1028	54.21	528	27.82	288	0.73	1896	1.66
12	McHenry	45	2.39	987	52.44	402	21.37	448	0.33	1882	1.65
13	McLean	197	10.49	1030	54.76	398	21.18	255	0.30	1880	1.65
14	La Salle	335	19.01	803	45.55	299	16.98	325	0.44	1763	1.55
15	Champaign	24	1.39	1037	59.85	392	22.63	279	0.80	1732	1.52
16	Peoria	181	11.45	739	46.87	356	22.57	301	24.01	1577	1.38
17	Ogle	429	27.49	446	28.61	153	9.80	532	0.72	1559	1.37
18	Tazewell	367	24.30	649	42.97	271	17.98	223	0.24	1509	1.32
19	Iroquois	420	31.56	579	43.47	118	8.89	214	0.31	1331	1.17
20	Kankakee	188	14.49	615	47.38	206	15.90	289	0.94	1298	1.14

TABLE XVI. TOP 20 COUNTIES CONTRIBUTING TO 2014 NEI TOTAL AIR EMISSIONS IN ILLINOIS AND PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN EACH COUNTY

	County	Major/ Point Emissions (tpy)	% of Point Sources to Total Emissions	Area/ Non-Point Emissions (tpy)	%of Non-Point Sources to Total Emissions	On-Road Emissions (tpy)	% of On-Road Sources to Total Emissions	Non-Road Emissions (tpy)	% of Non-road Sources to Total Emissions	Total Air Emissions (tpy)	% of Total Air Emissions per county
1	Cook	1393	5.11	4510	48.09	8260	30.27	13121	16.53	27284	26.418
2	DuPage	126	2.07	1331	42.60	2025	33.39	2585	21.94	6067	5.874
3	Lake	127	2.69	1312	39.36	1410	30.01	1849	27.94	4697	4.548
4	Will	558	12.35	892	38.57	1325	29.33	1742	19.75	4518	4.374
5	Kane	74	2.35	744	43.42	963	30.60	1367	23.62	3147	3.048
6	Vermilion	1972	73.64	193	11.01	218	8.13	295	7.23	2678	2.593
7	Madison	449	18.92	429	32.90	714	30.11	781	18.07	2372	2.297
8	Macon	1400	62.45	169	16.74	298	13.29	375	7.53	2242	2.171
9	Winnebago	69	3.30	327	43.17	793	37.89	903	15.64	2092	2.026
10	McHenry	43	2.17	480	40.92	644	32.61	808	24.30	1975	1.912
11	St. Clair	81	4.47	305	40.68	686	37.98	735	16.88	1806	1.749
12	Sangamon	66	4.04	408	34.96	586	35.97	570	25.02	1629	1.577
13	McLean	315	19.38	273	33.13	500	30.71	539	16.77	1627	1.575
14	Peoria	138	8.97	349	35.86	503	32.55	554	22.63	1544	1.495
15	Tazewell	416	27.46	265	28.69	399	26.34	435	17.52	1515	1.467
16	La Salle	312	21.58	381	27.47	356	24.63	397	26.32	1446	1.401
17	Champaign	19	1.40	279	43.31	490	35.23	602	20.07	1391	1.347
18	Rock Island	92	7.08	345	34.96	407	31.35	454	26.62	1298	1.257
19	Ogle	230	19.58	559	17.76	179	15.18	209	47.48	1177	1.139
20	Adams	469	40.98	247	21.45	183	15.99	245	21.58	1144	1.108

The descriptive statistics of air emissions from each source categories are shown in Table XXIII, XXIV, XXV, and XXVI. The mean of the point emission, non-point emission, and on-road emission declined over the years while the mean of the non-road emission fluttered between 2005 to 2014. The maximum of the point emission and on-road emission rose from 2011 to 2014. The maximum of the non-point consistently increased from 1999 to 2011 and decreased in 2014. The non-road steadily decreased from 1999 to 2014.

Figure 9 and 10 show the temporal air emissions by emission source categories and the percentage contribution of air emissions by each source category to total emission in Cook County. The temporal total air emission in Cook County decreased by 33% from 1999 to 2011 and remained the same for 2014.The point emission and on-road Emission have the similar pattern as the point emission and on-road emission in Illinois where the point emission decreased significantly (i.e., 81% decrease from 1999 to 2014) and on-road emission dropped greatly in 2002 (50%) and consistently decreased in the following years with an anomaly 26% increase in 2014.

The change in point emission from 1999 to 2002 is not as extreme as the Illinois point emission showed but the change of on-road emission from 1999 to 2002 was more dramatically than the Illinois on-road emission. The non-point emission in Cook County had different trend from the Illinois, it consistently went down after 2002 (decreased by 31% from 2002 to 2014). The non-road emission in Cook County slightly declined from year to year. The contribution of each source category to total air emission displayed different trend from Illinois. The most contributed sources were always non-point/area emission and on-road emission from 1999 to 2014. The contribution of point/area emission to total air emission steadily decreased over the years from 15.0% in 1999 and 5.1% in 2014. The contribution of both non-point/area and non-road emission to the total air emission in Cook County increased until 2011 and decreased in 2014.

The contribution of on-road emission total emission in Cook County is the only source category that had similar pattern to the Illinois, which is slightly decreased from year to year until 2011 and raised in 2014. The main contributor to the total emissions in Cook County has also shifted over the years. It was on-road source emissions in 1999 but non-point source emissions in 2014.

b. Chemicals Contributing to Total Air Emission in Cook County, Illinois over the Years

Table XXVII – XXXI show the top 20 contributing air toxics to the total air emissions and each emission source categories in Cook County for the year 1999 to 2014. Toluene was the highest contributor to the total emission from 1999 to 2011. In 2014, the highest contributor to the total emission was ethylene glycol but toluene is still higher contributor as it is the second highest contributor of 2014. Toluene is also the higher contributor in all four emission categories, respectively, in all the inclusive years. Other heavily contributed chemicals in point/major emission are xylenes, glycol ethers, hexanes, and hydrogen fluoride. Xylenes usually used in paints and coatings, or as a blend in gasoline (U.S. Environmental Protection Agency, 2003a). Glycol ethers are used as solvents for resins, lacquers, paints, varnishes, gum, perfume, dyes, inks, as a constituent of paints and pastes, cleaning compounds, liquid soaps, cosmetics, and hydraulic fluids (U.S. Environmental Protection Agency, 2000). Hydrogen fluoride emission are primarily from industrial operations like aluminum and fluorocarbon production, and uranium processing (Theissen, 1988).

TABLE XVII. TOP 20 AIR TOXICS CONTRIBUTING TO 1999 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hydrochloric acid	26180.00	Toluene	5679.00	Toluene	17380.00	Toluene	6770.00	Toluene	34510.00
2	Toluene	4686.00	Methanol	4050.00	Xylenes	9860.00	Xylenes	5987.00	Hydrochloric acid	27160.00
3	Hexane	4263.00	Hexane	3510.00	2,2,4-Trimethylpentane	6826.00	2,2,4-Trimethylpentane	3171.00	Xylenes	21840.00
4	Xylenes	2884.00	Xylenes	3162.00	Benzene	6039.00	Formaldehyde - Primary	2251.00	Hexane	10608.00
5	Methyl ethyl ketone	2549.00	Methyl chloroform	2693.00	Formaldehyde - Primary	3148.00	Benzene	2235.00	2,2,4-Trimethylpentane	10600.00
6	Styrene	1992.00	Methyl ethyl ketone	2486.00	Ethyl Benzene	2576.00	Ethyl Benzene	1307.00	Benzene	9810.00
7	Carbon Disulfide	1769.40	Methylene Chloride	1640.00	Hexane	1912.00	Acetaldehyde - Primary	1004.00	Formaldehyde - Primary	7320.00
8	Formaldehyde - Primary	1553.00	Methyl bromide	1365.00	Acetaldehyde - Primary	1856.00	Hexane	923.00	Methanol	5510.00
9	Methanol	1460.00	Benzene	1120.00	1,3-Butadiene	840.00	1,3-Butadiene	382.00	Methyl ethyl ketone	5036.00
10	Hydrofluoric acid	1459.00	Perchloroethylene	1098.30	Styrene	540.90	Propionaldehyde - Primary	206.00	Ethyl Benzene	4959.00
11	Glycol Ethers	1413.70	Hydrochloric acid	983.00	Methyl Tert-Butyl-Ether	288.00	Acrolein - Primary	110.20	Styrene	3000.00
12	Methylene Chloride	1119.00	1,3-Dichloropropene	969.90	Polycyclic Organic Matter	175.90	Styrene	98.20	Acetaldehyde - Primary	2907.00
13	Maleic anhydride	757.00	Glycol Ethers	736.70	Propionaldehyde - Primary	161.50	Methyl Tert-Butyl-Ether	96.20	Methyl chloroform	2823.00
14	Methyl isobutyl ketone	755.80	Ethyl Benzene	645.70	Naphthalene	156.30	Polycyclic Organic Matter	61.08	Methylene Chloride	2752.00
15	Trichloroethylene	582.00	Trichloroethylene	616.20	Acrolein - Primary	149.60	Naphthalene	46.12	Glycol Ethers	2156.00
16	Lead Compounds	444.00	Cyanides	589.30	7-PAH	1.27	Lead Compounds	19.72	Carbon Disulfide	1781.30
17	Ethyl Benzene	424.70	Methyl isobutyl ketone	524.00	Chromium Compounds: Total	0.52	Nickel Compounds	1.03	Hydrofluoric acid	1518.00
18	Benzene	418.10	1,4-Dichlorobenzene	473.50	Nickel Compounds	0.40	7-PAH	0.68	1,3-Butadiene	1485.00
19	2,2,4-Trimethylpentane	414.30	Polycyclic Organic Matter	467.70	Chromium Compounds: Hexavalent	0.21	Manganese Compounds	0.06	Methyl bromide	1395.00
20	Chlorine	341.60	Chlorobenzene	437.40	Manganese Compounds	0.18	Chromium Compounds: Total	0.05	Methyl isobutyl ketone	1280.00

TABLE XVIII. TOP 20 AIR TOXICS CONTRIBUTING TO 2002 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hydrochloric Acid	14714.62	Benzene	11901.01	Toluene	14196.29	Toluene	7066.26	Toluene	30904.68
2	Hexane	4143.65	Methanol	7283.16	Xylenes (Mixture of o, m, and p Isomers)	8038.80	Xylenes (Mixture of o, m, and p Isomers)	5746.39	Benzene	19770.63
3	Toluene	2595.23	Toluene	7042.66	2,2,4-Trimethylpentane	5446.56	2,2,4-Trimethylpentane	3258.17	Xylenes (Mixture of o, m, and p Isomers)	18650.81
4	Hydrogen Fluoride	2309.18	Methyl Ethyl Ketone	5254.52	Benzene	5413.90	Benzene	2162.87	Hydrochloric Acid	15241.91
5	Carbon Disulfide	1424.22	Xylenes (Mixture of o, m, and p Isomers)	3712.49	Formaldehyde	2543.29	Formaldehyde	1957.96	2,2,4-Trimethylpentane	8890.71
6	Methanol	1200.70	Ethylene Glycol	2827.62	Ethyl Benzene	2100.81	Ethyl Benzene	1159.40	Methanol	8483.86
7	Xylenes (Mixture of o, m, and p Isomers)	1151.33	Methyl Isobutyl Ketone	2806.29	Hexane	1577.28	Hexane	973.38	Hexane	7867.95
8	Glycol Ethers	1071.15	Methyl Chloroform	2692.53	Acetaldehyde	1497.68	Acetaldehyde	896.12	Methyl Ethyl Ketone	5262.35
9	Styrene	926.02	Tetrachloroethylene	2577.74	1,3-Butadiene	662.54	1,3-Butadiene	348.13	Formaldehyde	5261.86
10	Methyl Isobutyl Ketone	597.76	2,4-Dichlorophenoxy Acetic Acid	1684.70	Styrene	444.78	Propionaldehyde	195.87	Ethyl Benzene	3684.03
11	Trichloroethylene	425.99	Methyl Bromide	1342.90	Methyl Tert-Butyl Ether	242.99	Styrene	91.55	Methyl Isobutyl Ketone	3404.05
12	Formaldehyde	373.74	Glycol Ethers	1250.19	Propionaldehyde	135.89	Acrolein	69.65	Ethylene Glycol	2883.41
13	Methylene Chloride	341.96	1,4-Dichlorobenzene	1227.25	Naphthalene	123.48	Naphthalene	63.40	Tetrachloroethylene	2718.10
14	Phenol	296.02	Methylene Chloride	1186.76	Acrolein	121.85	Lead	15.85	Methyl Chloroform	2716.14
15	Benzene	284.47	Hexane	1173.52	Acenaphthylene	4.75	Phenanthrene	5.10	Acetaldehyde	2625.41
16	Chlorine	267.59	Hydrochloric Acid	527.29	Phenanthrene	3.08	Acenaphthylene	3.87	Hydrogen Fluoride	2341.88
17	o-Xylene	210.45	Trichloroethylene	464.21	Fluorene	1.88	Fluorene	2.44	Glycol Ethers	2321.34
18	Ethyl Benzene	203.13	Chlorobenzene	430.73	Pyrene	1.56	Pyrene	1.46	2,4-Dichlorophenoxy Acetic Acid	1684.71
19	Acetaldehyde	188.54	Naphthalene	368.04	Fluoranthene	1.12	Acenaphthene	1.41	Styrene	1608.77
20	Tetrachloroethylene	140.35	Formaldehyde	367.72	Anthracene	1.09	Fluoranthene	1.25	Methylene Chloride	1528.72

TABLE XIX. TOP 20 AIR TOXICS CONTRIBUTING TO 2005 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hydrochloric Acid	14552.4	Methanol	7318.9	Toluene	11800.3	Toluene	6725.4	Toluene	26708.4
2	Hexane	5727.2	Toluene	6790.9	m-Xylene	4906.6	m-Xylene	3714.8	Hydrochloric Acid	15250.5
3	Hydrogen Fluoride	2352.4	Xylenes (Mixture of o, m, and p Isomers)	3712.6	2,2,4-Trimethylpentane	4557.2	2,2,4-Trimethylpentane	3013.8	Hexane	9248.0
4	Carbon Disulfide	1666.9	Ethylene Glycol	2831.8	Benzene	4385.4	Benzene	2008.0	Methanol	8773.2
5	Methanol	1419.0	Methyl Isobutyl Ketone	2753.3	Formaldehyde	2479.6	Formaldehyde	1968.6	m-Xylene	8635.7
6	Toluene	1391.8	Methyl Chloroform	2691.5	o-Xylene	1775.6	o-Xylene	1323.7	2,2,4-Trimethylpentane	7863.5
7	Styrene	837.5	Tetrachloroethylene	2527.5	Ethyl Benzene	1755.1	Ethyl Benzene	1041.3	Benzene	7838.6
8	Xylenes (Mixture of o, m, and p Isomers)	607.3	2,4-Dichlorophenoxy Acetic Acid	1684.7	Acetaldehyde	1696.3	Hexane	894.6	Formaldehyde	5269.7
9	Glycol Ethers	469.3	Benzene	1345.8	Hexane	1384.9	Acetaldehyde	886.4	Xylenes (Mixture of o, m, and p Isomers)	4345.1
10	Phenol	319.3	Methyl Bromide	1334.8	1,3-Butadiene	695.9	1,3-Butadiene	344.4	o-Xylene	3214.9
11	Acetaldehyde	317.3	Hexane	1241.4	Styrene	364.2	Propionaldehyde	186.6	Ethyl Benzene	3167.0
12	Methylene Chloride	275.1	Glycol Ethers	1236.7	Naphthalene	334.5	Acrolein	107.8	Acetaldehyde	3115.2
13	Methyl Isobutyl Ketone	261.4	1,4-Dichlorobenzene	1226.8	Acrolein	115.9	Acenaphthylene	88.7	Methyl Isobutyl Ketone	3014.6
14	Chlorine	246.2	Methylene Chloride	1202.4	Propionaldehyde	111.2	Styrene	88.3	Ethylene Glycol	2860.4
15	Formaldehyde	180.2	Hydrochloric Acid	698.0	Methyl Tert-Butyl Ether	31.6	Naphthalene	80.7	Methyl Chloroform	2720.2
16	Trichloroethylene	171.4	Formaldehyde	641.3	Acenaphthylene	3.7	Methanol	35.3	Tetrachloroethylene	2586.0
17	Ethyl Benzene	115.4	Trichloroethylene	461.8	Phenanthrene	2.4	Xylenes (Mixture of o, m, and p Isomers)	25.1	Hydrogen Fluoride	2401.3
18	Maleic Anhydride	110.9	Chlorobenzene	430.2	Fluorene	1.5	Lead	16.8	Glycol Ethers	1706.0
19	Benzene	99.5	Naphthalene	367.2	Pyrene	1.2	Phenol	14.2	2,4-Dichlorophenoxy Acetic Acid	1684.7
20	Naphthalene	97.2	Chloroform	306.1	Fluoranthene	0.9	1-Methylnaphthalene	6.1	Carbon Disulfide	1683.7

TABLE XX. TOP 20 AIR TOXICS CONTRIBUTING TO 2011 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hexane	2591.9	Toluene	17638.9	Toluene	5711.0	Diesel PM	7590.6	Toluene	29243.4
2	Hydrochloric Acid	2205.0	2,4-Dichlorophenoxy Acetic Acid	13907.8	Diesel PM	4828.8	Toluene	5093.4	2,4-Dichlorophenoxy Acetic Acid	13907.8
3	Carbon Disulfide	1770.7	Methanol	7288.2	Xylenes (mixed Isomers)	3870.9	Xylenes (mixed Isomers)	3550.2	Diesel PM	12419.4
4	Hydrogen Fluoride	966.2	Hexane	4933.7	Benzene	1748.4	2,2,4-Trimethylpentane	2326.6	Hexane	9444.5
5	Toluene	800.0	Ethylene Glycol	2568.3	Formaldehyde	1492.5	Benzene	1403.0	Sum of Xylenes	8616.6
6	Methanol	660.3	Trifluralin	2167.4	Hexane	1270.9	Formaldehyde	1350.1	Xylenes (mixed Isomers)	8081.4
7	Styrene	513.3	Benzene	1336.5	2,2,4-Trimethylpentane	1246.9	Ethyl Benzene	720.3	Methanol	7967.8
8	Formaldehyde	464.3	Methyl Isobutyl Ketone	792.1	Ethyl Benzene	1062.8	Hexane	647.9	Benzene	4615.5
9	Glycol Ethers	426.6	Sum of Xylenes	755.4	Acetaldehyde	993.6	Acetaldehyde	632.6	Formaldehyde	3845.8
10	Xylenes (mixed Isomers)	418.0	Formaldehyde	538.8	1,3-Butadiene	269.2	1,3-Butadiene	213.8	2,2,4-Trimethylpentane	3762.5
11	Phenol	399.9	Acetaldehyde	321.9	Naphthalene	186.2	Propionaldehyde	135.9	Ethylene Glycol	2622.2
12	Tetrachloroethylene	141.6	m-Xylene	261.2	Acrolein	101.2	Acrolein	72.4	Hydrochloric Acid	2367.2
13	Trichloroethylene	130.7	Xylenes (mixed Isomers)	242.3	Propionaldehyde	77.7	Styrene	63.0	Trifluralin	2167.4
14	Benzene	127.6	Sum of Cyanides	215.7	Styrene	51.5	Naphthalene	48.7	Acetaldehyde	2064.5
15	Acetaldehyde	116.5	Hydrogen Cyanide	215.7	Phenanthrene (PAH_000E0)	18.4	Methanol	19.3	Ethyl Benzene	2044.6
16	Methylene Chloride	115.0	Styrene	213.6	Acenaphthylene (PAH_880E5)	12.1	Phenol	7.8	Carbon Disulfide	1772.4
17	Maleic Anhydride	92.4	Tetrachloroethylene	194.3	Pyrene (PAH_000E0)	9.3	Lead	7.1	Hydrogen Fluoride	967.7
18	Chlorine	79.4	2,2,4-Trimethylpentane	185.0	Fluorene (PAH_880E5)	8.7	m-Xylene	5.4	Methyl Isobutyl Ketone	858.0
19	Ethyl Benzene	78.7	Ethyl Benzene	182.7	Fluoranthene (PAH_880E5)	7.5	Phenanthrene (PAH_000E0)	3.8	Styrene	841.4
20	Cyanide	73.8	Hydrochloric Acid	162.2	Acenaphthene (PAH_880E5)	4.3	Acenaphthylene (PAH_880E5)	3.0	1,3-Butadiene	555.4

TABLE XXI. TOP 20 AIR TOXICS CONTRIBUTING TO 2014 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hexane	2887.3	Ethylene Glycol	15492.3	Toluene	8112.5	Diesel-PM	6035.3	Toluene	17978.8
2	Carbon Disulfide	1953.5	Methanol	6127.7	Xylenes (Mixed Isomers)	5409.3	2,2,4-Trimethylpentane	4770.7	Ethylene Glycol	15516.8
3	Hydrochloric Acid	1755.2	Toluene	4270.9	Diesel-PM	3527.3	Toluene	4652.9	Xylenes (Mixed Isomers)	10487.0
4	Toluene	942.6	Benzene	1366.3	Benzene	2277.6	Xylenes (Mixed Isomers)	3506.0	Diesel-PM	9562.6
5	Hydrogen Fluoride	803.3	Hexane	1346.8	Hexane	1853.5	Formaldehyde	1987.5	Hexane	6762.2
6	Formaldehyde	505.8	Xylenes (Mixed Isomers)	1210.0	2,2,4-Trimethylpentane	1753.6	Benzene	1381.0	2,2,4-Trimethylpentane	6698.6
7	Methanol	490.1	2,4-Dichlorophenoxy Acetic Acid	867.9	Ethyl Benzene	1478.3	Ethyl Benzene	1003.4	Methanol	6634.2
8	Xylenes (Mixed Isomers)	361.6	Formaldehyde	720.7	Formaldehyde	1269.8	Acetaldehyde	754.7	Benzene	5175.1
9	Styrene	336.7	Methyl Chloroform	578.8	Acetaldehyde	1127.5	Hexane	674.6	Formaldehyde	4483.7
10	Glycol Ethers	300.8	Naphthalene	497.9	1,3-Butadiene	359.7	1,3-Butadiene	246.8	Ethyl Benzene	2791.3
11	Phenol	220.1	Glycol Ethers	457.4	Naphthalene	184.3	Acrolein	162.9	Acetaldehyde	2422.0
12	Benzene	150.2	Acetaldehyde	429.1	Acrolein	89.7	Propionaldehyde	156.9	Hydrochloric Acid	1969.7
13	Tetrachloroethylene	116.0	Hydrogen Cyanide	425.4	Propionaldehyde	76.1	Styrene	137.5	Carbon Disulfide	1954.7
14	Methylene Chloride	116.0	Diethylene Glycol Monobutyl Ether	363.6	Styrene	65.0	Naphthalene	129.0	Naphthalene	879.8
15	Acetaldehyde	110.6	Trichloroethylene	329.7	Phenanthrene	19.4	Phenanthrene	18.2	2,4-Dichlorophenoxy Acetic Acid	867.9
16	Trichloroethylene	95.0	Tetrachloroethylene	322.7	Acenaphthylene	14.0	Methanol	16.4	Hydrogen Fluoride	804.8
17	Methyl Isobutyl Ketone	92.0	Trifluralin	314.2	Pyrene	8.9	Acenaphthylene	12.1	Styrene	778.4
18	Maleic Anhydride	87.7	m-Xylene	262.9	Fluorene	8.5	Fluorene	8.4	Glycol Ethers	758.2
19	Phthalic Anhydride	83.8	Styrene	239.2	Fluoranthene	7.3	Lead	6.9	1,3-Butadiene	725.7
20	Ethyl Benzene	81.6	Ethyl Benzene	227.9	Acenaphthene	4.1	Phenol	6.6	Methyl Chloroform	579.6

TABLE XXII. DESCRIPTIVE STATISTICS OF NEI TOTAL EMISSIONS (TPY) IN COOK COUNTY, ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	0.0	0.0	0.0	0.0	0.0
Mean	273.4	233.2	203.3	199.9	176.0
Median	0.1	0.5	0.4	0.6	0.4
Max	12000.0	8738.6	7537.1	9572.2	6317.7
SD	1174.2	910.2	739.3	913.8	739.1
95th Percentile	1232.5	1303.4	1159.4	959.8	994.3

TABLE XXIII. DESCRIPTIVE STATISTICS OF NEI MAJOR/ POINT EMISSIONS (TPY) IN COOK COUNTY, ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	0.0	0.0	0.0	0.0	0.0
Mean	41.3	34.3	15.0	12.0	12.2
Median	0.0	0.2	0.0	0.1	0.1
Max	994.0	673.3	448.8	213.3	296.2
SD	150.8	108.9	60.2	36.8	38.0
95th Percentile	260.3	234.1	89.7	103.1	92.1

TABLE XXIV. DESCRIPTIVE STATISTICS OF NEI AREA/ NON-POINT EMISSIONS (TPY) IN COOK COUNTY, ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	0.0	0.0	0.0	0.0	0.0
Mean	74.7	129.6	98.5	96.8	84.6
Median	0.0	0.3	0.2	0.0	0.0
Max	2160.0	3375.7	3404.4	7015.0	6309.7
SD	275.2	474.4	404.9	641.0	556.5
95th Percentile	415.8	962.8	535.8	88.4	145.8

TABLE XXV. DESCRIPTIVE STATISTICS OF NEI ON-ROAD EMISSIONS (TPY) IN COOK COUNTY, ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	0.0	0.0	0.0	0.0	0.0
Mean	120.0	303.3	58.6	51.4	53.3
Median	0.0	0.3	0.0	0.0	0.0
Max	7260.0	3574.2	3120.4	1553.5	2396.3
SD	692.2	729.7	301.3	225.1	262.0
95th Percentile	232.7	1583.1	279.2	321.1	358.5

TABLE XXVI. DESCRIPTIVE STATISTICS OF NEI NON-ROAD EMISSIONS (TPY) IN COOK COUNTY, ILLINOIS, 1999-2014

	1999	2002	2005	2011	2014
Minimum	0.0	0.0	0.0	0.0	0.0
Mean	37.4	35.5	31.1	39.7	29.1
Median	0.0	0.0	0.0	0.0	0.0
Max	1730.0	1637.7	1282.7	1266.1	957.6
SD	200.1	192.1	150.3	174.2	132.2
95th Percentile	61.8	76.8	167.2	176.3	133.1

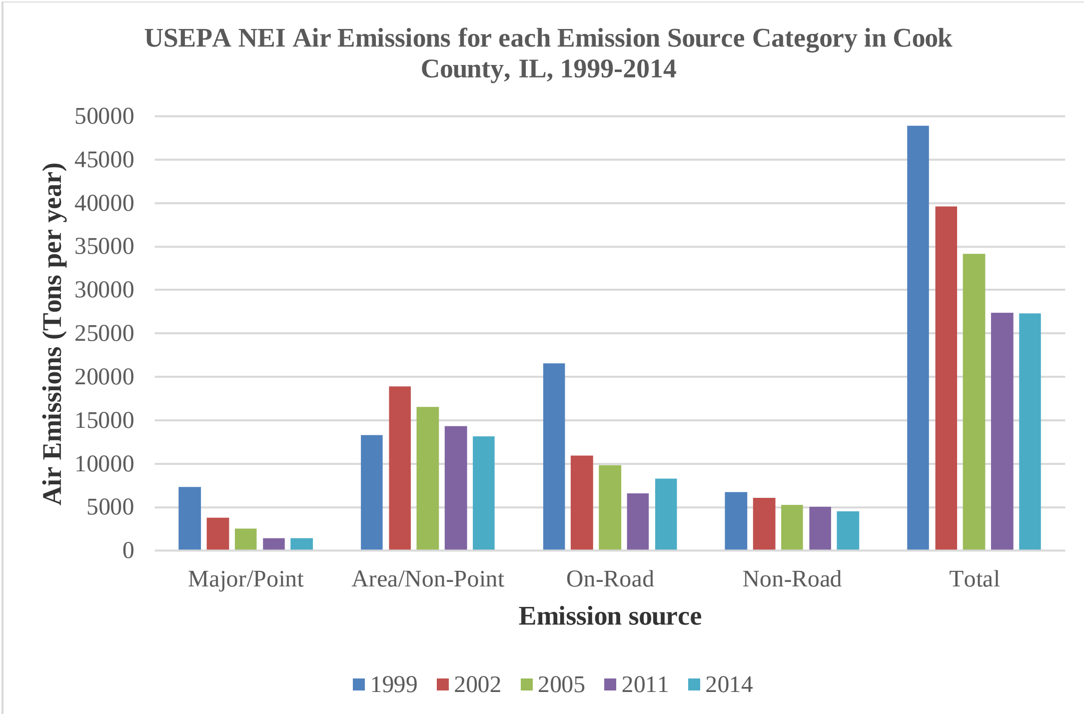

Figure 9. USEPA NEI air emissions for each emission source category in Cook County, IL, 1999-2014

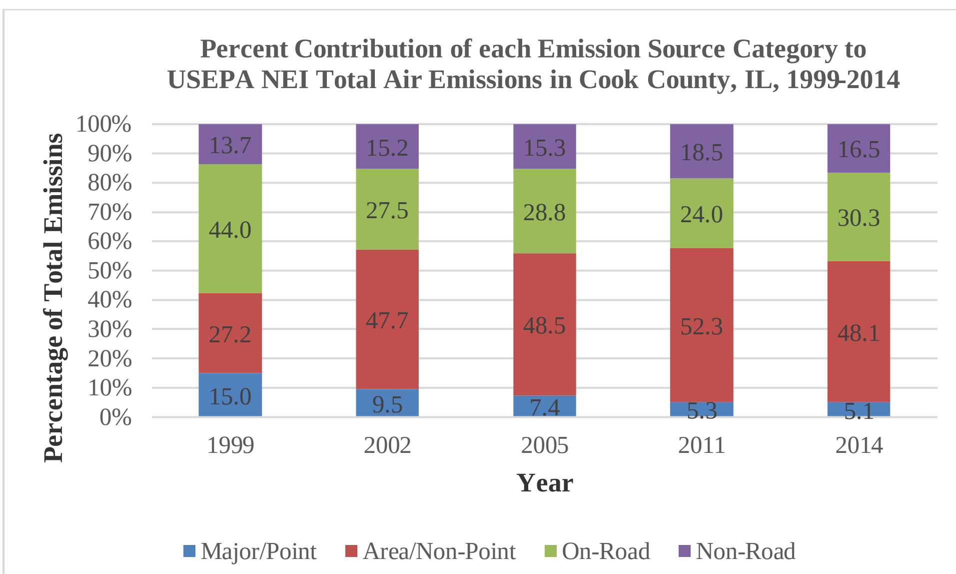

Figure 10. Percent contribution of each emission source category to USEPA NEI total air emissions in Cook County, IL, 1999-2014

In terms of non-point/area emission, toluene and methanol, are the two that consistently contribute the most in the inclusive years except 2011. Toluene emission in non-point/area source are mostly from the use of it as a solvent in coatings, paints, cleaning agents as well as the production of polymers for making nylon, plastic bottles, polyurethanes, cosmetic nail products smaller (U.S. Environmental Protection Agency, 2012; Agency for Toxic Substances and Disease Registry, 2017) but in a much smaller magnitude while comparing to point/ major source. Methanol is a common use chemical product in construction or housing industries. It is also included in paints and adhesives (U.S. Environmental Protection Agency, 2013). In terms of on-road emission, toluene was the top contributor in all years, followed with xylene. Since 2011, diesel PM has become a highly contributor in on-road emission. In terms of non-road emission, toluene and xylene are the steadily contributor since 1999, started from 2011, diesel PM become the most significant contributor to the non-road emission.

B. Cancer Risk Assessment According to Air Toxic Exposure in Cook County, Illinois, 1999-2014

1. Spatial Distribution of Total Cancer Risks Across Census Tracts in Cook County, Illinois

National Air Toxics Assessment (NATA) data for Cook County, from USEPA at census tract level were mapped using ArcGIS Desktop 10.7.1 and spatial distribution of the inhalation cumulative excess cancer risk of all carcinogenic air toxics 2014 is displayed in Figure 11. Although none of the excess cancer risk in all area within Cook County, which excludes the cancer risk contribution from diesel PM, are having risk greater than 1 x 10^{-4}, which means all of the excess cancer risks in Cook County are within the acceptable range, there are some areas highlighted in the darkest color in the map that are close to the acceptable threshold for cancer risk. To be more specific, the following areas are three main locations with highest excess cancer risk in Cook County: Chicago's O'Hare Airport, downtown Chicago, and Lyons. Lyons is in the southwestern township in Cook County where many manufacturing, warehouses, pharmaceutical located.

2. **<u>Percentage Contribution of Cancer Risks Per Emissions Source Categories Across Census Tracts in Cook County, Illinois</u>**

Table XXXII demonstrates the percentage contribution of NATA excess inhalation cancer risk per emission source categories in Cook County for 1999, 2002, 2005, 2011, and 2014. All point excess inhalation cancer risk shown here includes those from airport and railyards except 2005, the separate inhalation cancer risk from airport source was not found in the released data file. The overall largest contributor of all years is from the other sources. However, to be more specific, the consist of the other sources are slightly different in each year. For NATA 1999 and 2002, only background source is included in the other sources. For NATA 2005, background sources and secondary sources are included. For NATA 2011 and 2014, the other sources consist background, secondary, fire sources, and biogenics. The two new subgroups in 2014, heavy duty hoteling in on-road, and agricultural livestock in non-point, are excluded. Since the emission sources in the "other" category varies from year to year and was not comparable, the greatest contributor of NATA excess inhalation cancer risk in Cook County excluding the "other" source group was the "on-road" emission.

TABLE XXVII TOP 20 AIR TOXICS CONTRIBUTING TO 1999 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN COOK, COUNTY, IL

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Toluene	994.00	Toluene	2160.00	Toluene	7260.00	Xylenes	1730.00	Toluene	12000.00
2	Xylenes	847.00	Methanol	1710.00	Xylenes	4120.00	Toluene	1590.00	Xylenes	7770.00
3	Methyl ethyl ketone	756.00	Hexane	1460.00	2,2,4-Trimethylpentane	2940.00	2,2,4-Trimethylpentane	801.00	2,2,4-Trimethylpentane	3820.00
4	Glycol Ethers	727.00	Methyl chloroform	1170.00	Benzene	2340.00	Formaldehyde - Primary	698.00	Benzene	3290.00
5	Maleic anhydride	673.00	Xylenes	1070.00	Formaldehyde - Primary	1330.00	Benzene	675.00	Hexane	2740.00
6	Hydrochloric acid	654.00	Methyl ethyl ketone	908.00	Ethyl Benzene	1080.00	Ethyl Benzene	369.00	Formaldehyde - Primary	2260.00
7	Methylene Chloride	533.00	Methyl bromide	584.00	Acetaldehyde - Primary	918.00	Acetaldehyde - Primary	293.00	Methanol	1830.00
8	Trichloroethylene	355.00	Methylene Chloride	465.00	Hexane	766.00	Hexane	260.00	Ethyl Benzene	1800.00
9	Methyl isobutyl ketone	324.00	Perchloroethylene	430.00	1,3-Butadiene	342.00	1,3-Butadiene	133.00	Methyl ethyl ketone	1660.00
10	Hexane	257.00	1,3-Dichloropropene	415.00	Styrene	227.00	Propionaldehyde - Primary	58.10	Acetaldehyde - Primary	1210.00
11	Phthalic anhydride	157.00	Glycol Ethers	312.00	Polycyclic Organic Matter	75.40	Acrolein - Primary	53.20	Methyl chloroform	1210.00
12	Methanol	111.00	Trichloroethylene	297.00	Naphthalene	67.10	Styrene	29.70	Glycol Ethers	1040.00
13	Cumene	109.00	Ethyl Benzene	264.00	Propionaldehyde - Primary	65.90	Polycyclic Organic Matter	23.40	Methylene Chloride	997.00
14	Formaldehyde - Primary	94.30	Hydrochloric acid	228.00	Acrolein - Primary	62.60	Naphthalene	19.80	Hydrochloric acid	882.00
15	Benzene	87.90	Cyanides	207.00	7-PAH	0.51	Lead Compounds	4.01	Maleic anhydride	673.00
16	Perchloroethylene	85.30	1,4-Dichlorobenzene	202.00	Chromium Compounds: Total	0.22	Nickel Compounds	0.22	Trichloroethylene	652.00
17	Ethyl Benzene	83.00	Methyl isobutyl ketone	188.00	Nickel Compounds	0.17	7-PAH	0.19	Methyl bromide	584.00
18	Hydrofluoric acid	82.90	Chlorobenzene	187.00	Chromium Compounds: Hexavalent	0.09	Manganese Compounds	0.01	Perchloroethylene	515.00
19	Polycyclic Organic Matter	80.40	Benzene	184.00	Manganese Compounds	0.08	Chromium Compounds: Total	0.01	Methyl isobutyl ketone	512.00
20	Naphthalene	78.30	Polycyclic Organic Matter	153.00	Methanol	0.00	Cadmium Compounds	0.01	1,3-Butadiene	505.00

TABLE XXVIII TOP 20 AIR TOXICS CONTRIBUTING TO 2002 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN COOK, COUNTY, IL

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Toluene	673.28	Methanol	3375.66	Toluene	3574.20	Xylenes (Mixture of o, m, and p Isomers)	1637.66	Toluene	8738.58
2	Glycol Ethers	544.49	Toluene	2976.00	Xylenes (Mixture of o, m, and p Isomers)	2033.75	Toluene	1515.10	Xylenes (Mixture of o, m, and p Isomers)	5556.56
3	Hydrogen Fluoride	418.40	Methyl Ethyl Ketone	2419.21	2,2,4-Trimethylpentane	1432.82	2,2,4-Trimethylpentane	810.59	Methanol	3404.01
4	Hexane	402.81	Xylenes (Mixture of o, m, and p Isomers)	1520.21	Benzene	1295.00	Benzene	617.64	Methyl Ethyl Ketone	2419.62
5	Xylenes (Mixture of o, m, and p Isomers)	364.94	Methyl Isobutyl Ketone	1232.65	Formaldehyde	757.22	Formaldehyde	464.31	Benzene	2288.67
6	Methyl Isobutyl Ketone	251.12	Tetrachloroethylene	1150.08	Ethyl Benzene	531.70	Ethyl Benzene	307.28	2,2,4-Trimethylpentane	2278.97
7	Trichloroethylene	213.31	Methyl Chloroform	1137.10	Acetaldehyde	511.83	Hexane	266.87	Methyl Isobutyl Ketone	1483.77
8	Styrene	191.10	Ethylene Glycol	1094.92	Hexane	374.22	Acetaldehyde	207.94	Hexane	1424.79
9	Hydrochloric Acid	182.03	Methyl Bromide	566.58	1,3-Butadiene	174.23	1,3-Butadiene	101.19	Formaldehyde	1414.91
10	Benzene	74.15	1,4-Dichlorobenzene	523.38	Styrene	115.54	Propionaldehyde	47.05	Tetrachloroethylene	1167.21
11	Phenol	64.63	Glycol Ethers	521.57	Propionaldehyde	40.40	Styrene	23.34	Methyl Chloroform	1137.26
12	o-Xylene	59.75	Hexane	380.89	Acrolein	36.27	Naphthalene	16.47	Ethylene Glycol	1104.57
13	Methylene Chloride	51.79	Benzene	301.88	Naphthalene	36.13	Acrolein	16.27	Glycol Ethers	1066.06
14	Ethyl Benzene	43.25	Methylene Chloride	265.00	Acenaphthylene	1.40	Lead	2.58	Ethyl Benzene	943.40
15	Formaldehyde	40.57	Trichloroethylene	207.56	Phenanthrene	0.91	Phenol	1.15	Acetaldehyde	736.29
16	Naphthalene	38.50	Chlorobenzene	183.50	Fluorene	0.56	Phenanthrene	1.01	Methyl Bromide	566.78
17	Methanol	28.35	Formaldehyde	152.80	Pyrene	0.46	Acenaphthylene	0.86	1,4-Dichlorobenzene	523.44
18	Maleic Anhydride	24.78	Naphthalene	128.74	Fluoranthene	0.33	Fluorene	0.52	Trichloroethylene	420.87
19	Phthalic Anhydride	23.11	Chloroform	121.19	Anthracene	0.32	Pyrene	0.35	Hydrogen Fluoride	420.84
20	Tetrachloroethylene	17.13	Hydrogen Cyanide	111.57	Acenaphthene	0.27	Fluoranthene	0.30	Styrene	369.00

TABLE XXIX TOP 20 AIR TOXICS CONTRIBUTING TO 2005 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN COOK, COUNTY, IL

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hydrochloric Acid	448.773	Methanol	3404.375	Toluene	3120.403	Toluene	1282.675	Toluene	7537.125
2	Hydrogen Fluoride	379.161	Toluene	2902.986	m-Xylene	1306.052	m-Xylene	1007.150	Methanol	3427.811
3	Xylenes (Mixture of o, m, and p Isomers)	313.841	Xylenes (Mixture of o, m, and p Isomers)	1538.406	2,2,4-Trimethylpentane	1263.220	2,2,4-Trimethylpentane	692.373	m-Xylene	2314.377
4	Glycol Ethers	255.537	Methyl Isobutyl Ketone	1220.736	Benzene	1087.484	Benzene	550.911	2,2,4-Trimethylpentane	2027.428
5	Toluene	231.062	Methyl Chloroform	1133.887	Formaldehyde	766.272	Formaldehyde	436.492	Benzene	1950.417
6	Methylene Chloride	167.992	Tetrachloroethylene	1120.743	Acetaldehyde	574.910	o-Xylene	359.201	Xylenes (Mixture of o, m, and p Isomers)	1855.727
7	Hexane	124.018	Ethylene Glycol	1088.824	o-Xylene	469.655	Ethyl Benzene	256.967	Methyl Isobutyl Ketone	1324.283
8	Styrene	106.271	Methyl Bromide	566.583	Ethyl Benzene	465.224	Hexane	230.341	Formaldehyde	1301.972
9	Methyl Isobutyl Ketone	103.547	Glycol Ethers	542.482	Hexane	331.906	Acetaldehyde	207.726	Tetrachloroethylene	1173.153
10	Trichloroethylene	63.964	1,4-Dichlorobenzene	523.380	1,3-Butadiene	181.418	1,3-Butadiene	91.856	Methyl Chloroform	1133.914
11	Ethyl Benzene	55.974	Hexane	419.823	Naphthalene	105.858	Propionaldehyde	40.837	Hexane	1106.088
12	Tetrachloroethylene	52.410	Benzene	303.412	Styrene	100.047	Styrene	20.174	Ethylene Glycol	1091.597
13	Naphthalene	32.373	Methylene Chloride	268.486	Acrolein	34.537	Naphthalene	17.695	Ethyl Benzene	859.045
14	Phenol	30.427	Trichloroethylene	213.615	Propionaldehyde	34.135	Acrolein	17.157	o-Xylene	847.816
15	Phthalic Anhydride	25.761	Chlorobenzene	183.394	Acenaphthylene	1.158	Acenaphthylene	4.303	Acetaldehyde	820.926
16	Maleic Anhydride	24.602	Naphthalene	135.338	Phenanthrene	0.751	Methanol	3.578	Glycol Ethers	798.019
17	Methanol	19.858	Chloroform	121.273	Fluorene	0.459	Xylenes (Mixture of o, m, and p Isomers)	3.479	Methyl Bromide	568.532
18	Acetaldehyde	15.175	Hydrochloric Acid	119.065	Pyrene	0.381	1-Methylnaphthalene	1.625	Hydrochloric Acid	567.838
19	Methyl Chloride	10.625	Hydrogen Cyanide	111.567	Fluoranthene	0.273	Lead	1.618	1,4-Dichlorobenzene	523.380
20	Formaldehyde	8.690	Formaldehyde	90.517	Anthracene	0.266	Phenol	1.439	Methylene Chloride	436.478

TABLE XXX. TOP 20 AIR TOXICS CONTRIBUTING TO 2011 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN COOK, COUNTY, IL

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hexane	2591.9	Toluene	17638.9	Toluene	5711.0	Diesel PM	7590.6	Toluene	29243.4
2	Hydrochloric Acid	2205.0	2,4-Dichlorophenoxy Acetic Acid	13907.8	Diesel PM	4828.8	Toluene	5093.4	2,4-Dichlorophenoxy Acetic Acid	13907.8
3	Carbon Disulfide	1770.7	Methanol	7288.2	Xylenes (mixed Isomers)	3870.9	Xylenes (mixed Isomers)	3550.2	Diesel PM	12419.4
4	Hydrogen Fluoride	966.2	Hexane	4933.7	Benzene	1748.4	2,2,4-Trimethylpentane	2326.6	Hexane	9444.5
5	Toluene	800.0	Ethylene Glycol	2568.3	Formaldehyde	1492.5	Benzene	1403.0	Xylenes (mixed Isomers)	8081.4
6	Methanol	660.3	Trifluralin	2167.4	Hexane	1270.9	Formaldehyde	1350.1	Methanol	7967.8
7	Styrene	513.3	Benzene	1336.5	2,2,4-Trimethylpentane	1246.9	Ethyl Benzene	720.3	Benzene	4615.5
8	Formaldehyde	464.3	Methyl Isobutyl Ketone	792.1	Ethyl Benzene	1062.8	Hexane	647.9	Formaldehyde	3845.8
9	Glycol Ethers	426.6	Formaldehyde	538.8	Acetaldehyde	993.6	Acetaldehyde	632.6	2,2,4-Trimethylpentane	3762.5
10	Xylenes (mixed Isomers)	418.0	Acetaldehyde	321.9	1,3-Butadiene	269.2	1,3-Butadiene	213.8	Ethylene Glycol	2622.2
11	Phenol	399.9	m-Xylene	261.2	Naphthalene	186.2	Propionaldehyde	135.9	Hydrochloric Acid	2367.2
12	Tetrachloroethylene	141.6	Xylenes (mixed Isomers)	242.3	Acrolein	101.2	Acrolein	72.4	Trifluralin	2167.4
13	Trichloroethylene	130.7	Hydrogen Cyanide	215.7	Propionaldehyde	77.7	Styrene	63.0	Acetaldehyde	2064.5
14	Benzene	127.6	Styrene	213.6	Styrene	51.5	Naphthalene	48.7	Ethyl Benzene	2044.6
15	Acetaldehyde	116.5	Tetrachloroethylene	194.3	Phenanthrene (PAH_000E0)	18.4	Methanol	19.3	Carbon Disulfide	1772.4
16	Methylene Chloride	115.0	2,2,4-Trimethylpentane	185.0	Acenaphthylene (PAH_880E5)	12.1	Phenol	7.8	Hydrogen Fluoride	967.7
17	Maleic Anhydride	92.4	Ethyl Benzene	182.7	Pyrene (PAH_000E0)	9.3	Lead	7.1	Methyl Isobutyl Ketone	858.0
18	Chlorine	79.4	Hydrochloric Acid	162.2	Fluorene (PAH_880E5)	8.7	m-Xylene	5.4	Styrene	841.4
19	Ethyl Benzene	78.7	Phenol	144.3	Fluoranthene (PAH_880E5)	7.5	Phenanthrene (PAH_000E0)	3.8	1,3-Butadiene	555.4
20	Cyanide	73.8	o-Xylene	135.7	Acenaphthene (PAH_880E5)	4.3	Acenaphthylene (PAH_880E5)	3.0	Phenol	552.0

TABLE XXXI. TOP 20 AIR TOXICS CONTRIBUTING TO 2014 NEI TOTAL AIR EMISSIONS (TPY) AND EACH SOURCE CATEGORY IN COOK COUNTY, ILLINOIS

	Major/ Point Emissions		Area/ Non-Point Emissions		On-Road Emissions		Non-Road Emissions		Total Emissions	
1	Hexane	296.2	Ethylene Glycol	6309.7	Toluene	2396.3	Diesel PM	957.6	Ethylene Glycol	6317.7
2	Glycol Ethers	158.2	Methanol	2436.6	Xylenes (Mixed Isomers)	1606.4	Toluene	847.7	Toluene	4888.6
3	Hydrogen Fluoride	126.0	Toluene	1548.5	Diesel PM	1094.8	2,2,4-Trimethylpentane	671.6	Xylenes (Mixed Isomers)	2731.0
4	Xylenes (Mixed Isomers)	102.6	Hexane	511.9	Benzene	662.4	Xylenes (Mixed Isomers)	598.6	Methanol	2512.1
5	Hydrochloric Acid	98.0	Xylenes (Mixed Isomers)	423.4	Hexane	559.0	Formaldehyde	455.3	Diesel PM	2052.4
6	Toluene	96.1	Methyl Chloroform	204.3	2,2,4-Trimethylpentane	514.9	Benzene	304.0	Hexane	1487.6
7	Tetrachloroethylene	90.0	Glycol Ethers	191.4	Ethyl Benzene	438.9	Ethyl Benzene	164.7	2,2,4-Trimethylpentane	1247.0
8	Methanol	62.6	Tetrachloroethylene	157.9	Formaldehyde	382.9	Acetaldehyde	162.5	Benzene	1083.5
9	Trichloroethylene	45.3	Naphthalene	140.6	Acetaldehyde	348.0	Hexane	120.6	Formaldehyde	956.1
10	Phenol	43.3	Diethylene Glycol Monobutyl Ether	128.3	1,3-Butadiene	108.3	1,3-Butadiene	62.4	Ethyl Benzene	701.8
11	Methylene Chloride	36.3	Trichloroethylene	116.4	Naphthalene	55.2	Acrolein	41.8	Acetaldehyde	566.7
12	Ethyl Benzene	30.5	m-Xylene	105.6	Acrolein	27.1	Propionaldehyde	31.3	Glycol Ethers	349.6
13	Styrene	28.2	Benzene	100.0	Propionaldehyde	22.5	Styrene	31.1	Tetrachloroethylene	247.9
14	Methyl Isobutyl Ketone	27.4	Hydrogen Cyanide	96.6	Styrene	19.4	Naphthalene	24.4	Naphthalene	237.4
15	Maleic Anhydride	26.4	Formaldehyde	96.3	Phenanthrene	5.9	Methanol	12.8	Methyl Chloroform	204.4
16	Phthalic Anhydride	23.8	Diethylene Glycol Monomethyl Ether	74.5	Acenaphthylene	4.2	Phenol	5.2	1,3-Butadiene	178.8
17	Formaldehyde	21.5	Ethyl Benzene	67.7	Pyrene	2.8	m-Xylene	3.8	Trichloroethylene	161.6
18	Naphthalene	17.2	2,2,4-Trimethylpentane	59.9	Fluorene	2.6	Phenanthrene	3.0	Hydrochloric Acid	144.3
19	Benzene	17.1	Acetaldehyde	53.5	Fluoranthene	2.2	Acenaphthylene	2.0	Diethylene Glycol Monobutyl Ether	128.3
20	Ethylene Glycol	8.0	o-Xylene	50.6	Acenaphthene	1.2	o-Xylene	1.8	Hydrogen Fluoride	126.6

TABLE XXXII. PERCENTAGE CONTRIBUTION OF NATA EXCESS INHALATION CANCER RISK PER EMISSION SOURCE CATEGORIES IN COOK COUNTY, ILLINOIS, 1999-2014

	Point/Major (%)	Non-Point/Area (%)	On-Road (%)	Non-Road (%)	Other (%)
1999	5.5	21.0	27.6	5.9	40.0
2002	17.4	16.1	21.8	6.9	37.8
2005	6.4	14.4	15.7	6.5	56.9
2011	6.0	4.3	26.2	11.4	52.0
2014	19.0	8.9	22.1	7.5	42.4

3. Top Contributing Chemicals to Inhalation Excess Cancer Risk

Table XXXIII shows the top 20 contributing chemicals to inhalation excess cancer risk in Cook County from 1999-2014. Benzene steadily stayed in the top two contribution of the inhalation cancer risk for each year. Formaldehyde is also the higher contributing chemical since 2005. The inhalation cancer risk of both benzene and formaldehyde did not change much throughout the years. Based on data analysis from NATA 1999, 2002, 2005, 2011 and 2014, both benzene and formaldehyde in Cook County are emitted from on-road sources. Benzene emission in the on-road emission source are primarily from the mobile vehicles exhaust and fuel evaporation, coal or oil burning (U.S. Environmental Protection Agency, 2009b). Formaldehyde emission in the on-road source is also commonly found in cars and trucks. Ethylene Oxide was the highest contributor to the inhalation excess cancer risk of 2014. Ethylene oxide is used to make other chemicals that are used in making a range of products, including antifreeze, textiles, plastics, detergents and adhesives. Ethylene oxide also is used to sterilize equipment and plastic devices that cannot be sterilized by steam, such as medical equipment (U.S. Environmental Protection Agency, 2016). The result of ethylene oxide was to our surprise as it was never the top 5 highest contributing chemicals in any of the other inclusive years. Based on the 2014 analysis, ethylene oxide primarily emitted from point source, which are large stationary facilities, to be more specific, the contributing facilities reported in NATA 2014 were mainly medical industry except one chemical product manufacturing facility and one school. The top three contributed chemical were then mapped utilizing ArcGIS 10.7.1.

4. Spatial Distribution of Ethylene Oxide in Cook County, Illinois, 2014

Figure 12 shows the spatial distribution of ethylene oxide in Cook County in2014. The distribution of the ethylene oxide inhalation cancer risk aligns with the total inhalation cancer risk of Cook County in 2014. At first, we were expecting there were industrial facilities near those area with higher ethylene oxide inhalation cancer risk. However, except one chemical plant in Lyons, Illinois out of the 17 facilities that were listed in NATA for the contribution of ethylene oxide cancer risk, all the other facilities were institutional (i.e. school, hospital, prison, etc.). Most of the facilities were general medical and surgical hospitals.

Although all the cancer risk estimates are in the acceptable range (10^{-6} – 10^{-4}), since ethylene oxide is already group as a carcinogen to human under WOE Characterization (U.S. Environmental Protection Agency, 2016), it is urgent to investigate and regulate the ethylene oxide emissions of those higher contributing facilities. In addition, the concentrated areas in the ethylene oxide cancer risk estimate map (Figure 12) shows similar patterns to the overall cancer risk estimate in Cook County this provides the evidence for the critical role that the facilities emitting ethylene oxide into the atmosphere play in cancer risk estimates locally.

5. Spatial Distribution of Formaldehyde in Cook County, Illinois, 2014

Figure 13 displays the spatial distribution of formaldehyde in Cook County in 2014. Formaldehyde usually come from mobile vehicles and this matches those highlighted area, downtown Chicago, O’Hare airport, and Midway airport. In addition, formaldehyde is emitted by combustion processes in industrial sources such as power plants, incineration; manufacture of resins, as a disinfectant and fixative, or as a preservative in consumer products. Although three highlighted areas are having higher cancer risk estimates, all the formaldehyde cancer risk estimates within Cook County are in the acceptable range (10^{-6}-10^{-4}).

6. Spatial Distribution of Benzene in Cook County, Illinois, 2014

Figure 14 shows the spatial distribution of benzene in Cook County in 2014. Benzene also comes from mobile vehicles and the spatial distribution shows similar pattern to formaldehyde map in Figure 13. Besides, benzene is emitted industrial operations involving burning coal and oil, waste and storage operations, and evaporation from gasoline service stations. However, all the benzene cancer risk estimates in Cook County are in the acceptable range (10^{-6}-10^{-4}).

7. Spatial Distribution of Diesel PM in Cook County, Illinois, 1999-2014

As diesel PM is an important air toxic and it was the top four highest chemical that contributes to the air emission in Cook County in 2014. Hence, we decided to also examine diesel PM cancer risk in Cook County. Figure 15-19 demonstrate the spatial distribution of diesel PM in Cook County from 1999 to 2014. The diesel PM cancer risk estimates in Cook County, Illinois were decreasing over the years. However, most of the diesel PM were above the acceptable range per USEPA guideline (10^{-6}-10^{-4}).The areas in Cook County, Illinois that are higher contributed to the diesel PM Inhalation Cancer Risk was in more urban areas such as downtown Chicago. In earlier years from 1999 to 2014, the spatial distribution of diesel PM also highlights the major highways in the region (e.g., I-90, I-94, I-55, I-290). The health of people living in those area should be concerned. Diesel exhaust is currently classified as likely to be carcinogen to human under WOE Characterization according to USEPA. The OEHHA in California report that diesel exhaust and many substances contained in it (including arsenic, benzene, formaldehyde and nickel) have the potential to contribute to mutations in cells that can lead to cancer and long-term exposure to diesel exhaust particles had posed the highest cancer risk of any toxic air contaminant evaluated by them (California Environmental Protection Agency Office of Environmental Health Hazard Assessment, n.d.b).

C. Non-Cancer Risk Assessment According to Air Toxic Exposure in Cook County, Illinois, 2014

1. Top Contributing Chemicals to Inhalation Non-Cancer Risk

Although the concern of non-cancer risk is usually not as urgent as cancer risk, NATA still provides non-cancer risk estimates for respiratory, neurological, liver, kidney, and immunological. We think it is important to also look at the respiratory non-cancer risk in order to have a better understanding of the whole picture of the inhalation risks, including both cancer risk and non-cancer risk, for Cook County, 2014. The top three chemicals contributing to the inhalation non-cancer risk was acrolein, formaldehyde, and diesel PM as shown in Table XXXIV.

2. Spatial Distribution of Diesel PM in Cook County, Illinois, 2014

The spatial distribution of diesel PM non-cancer risk was displayed in Figure 20. All the non-cancer risk estimates in Cook County contributed by diesel PM were in acceptable range. Areas with highest contribution of diesel PM non-cancer risk are condensed in those urban area especially downtown Chicago.

In addition to the potential of mutations that could lead to cancer, other health effects related to diesel exhaust are irritations to eye, nose, throat and lungs. Besides, it can also cause coughs, headaches, light-headedness and nausea (California Environmental Protection Agency Office of Environmental Health Hazard Assessment, 2001).

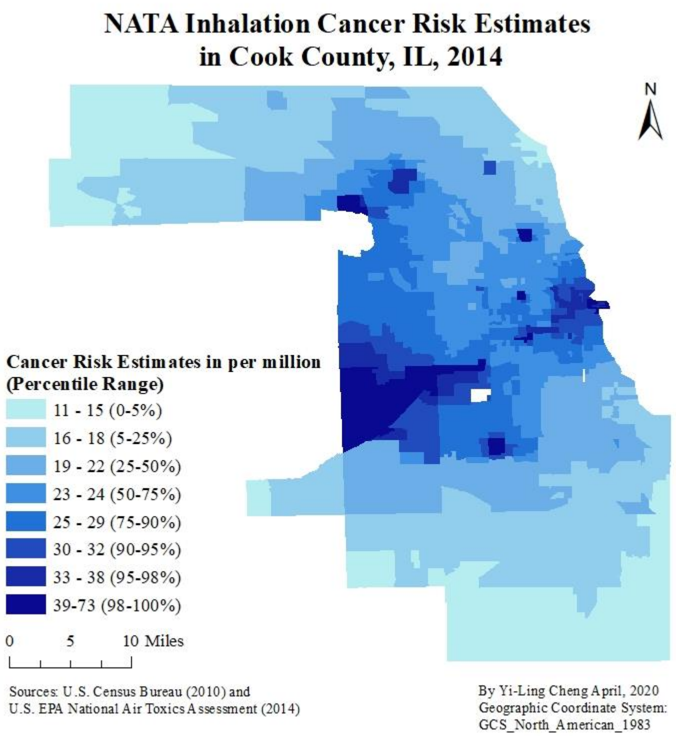

Figure 11. Spatial distribution of USEPA NATA total inhalation cancer risks in Cook County, IL, 2014

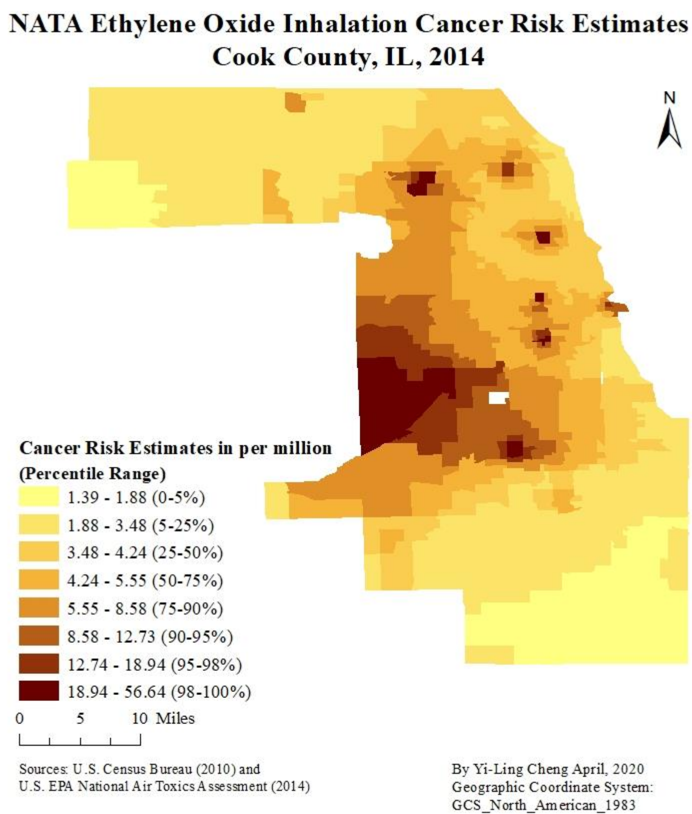

Figure 12. Spatial distribution of USEPA NATA ethylene oxide inhalation cancer risks in Cook County, IL, 2014

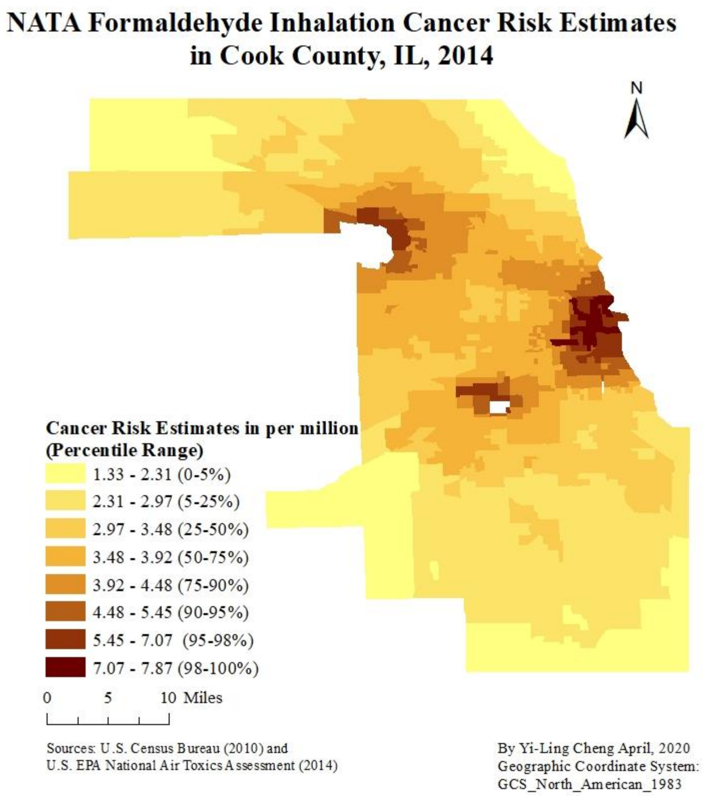

Figure 13. Spatial distribution of USEPA NATA formaldehyde inhalation cancer risks in Cook County, IL, 2014

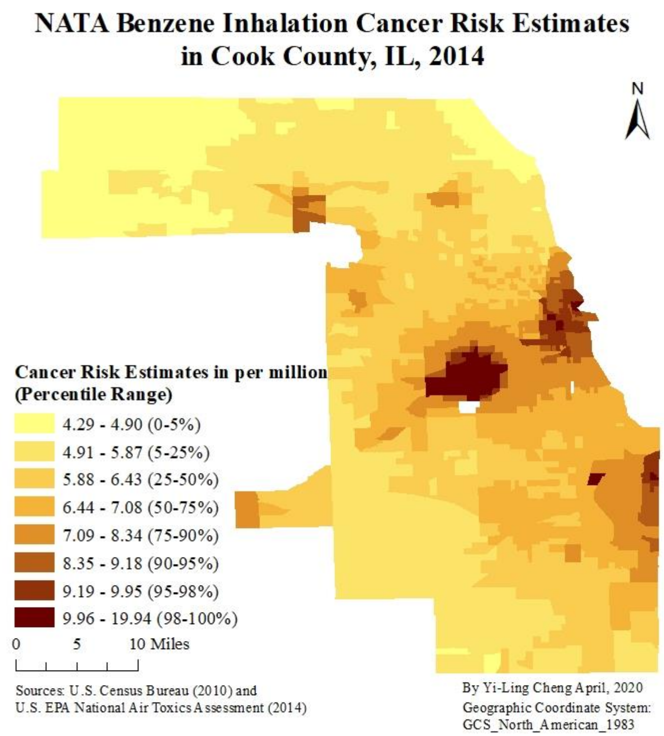

Figure 14. Spatial distribution of USEPA NATA benzene inhalation cancer risks in Cook County, IL, 2014

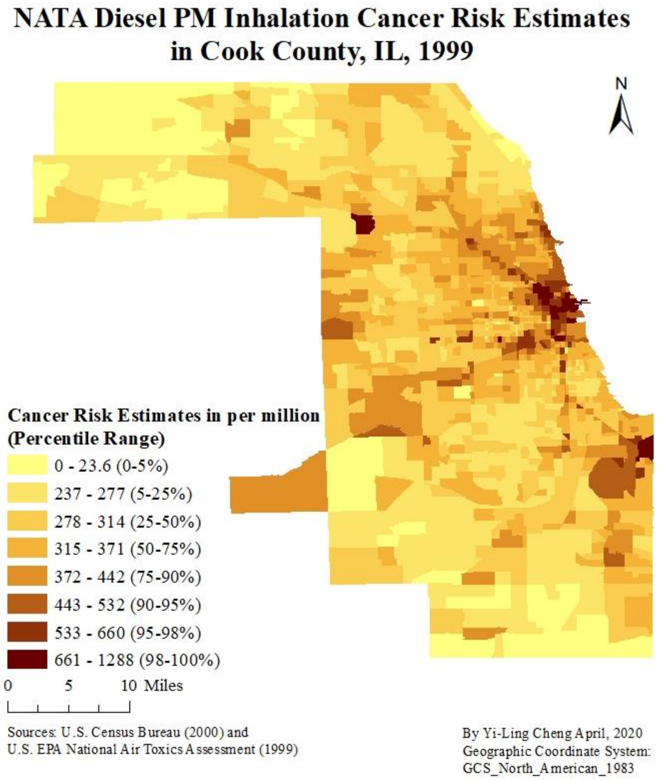

Figure 15. Spatial distribution of USEPA NATA diesel PM inhalation cancer risks in Cook County, IL, 1999

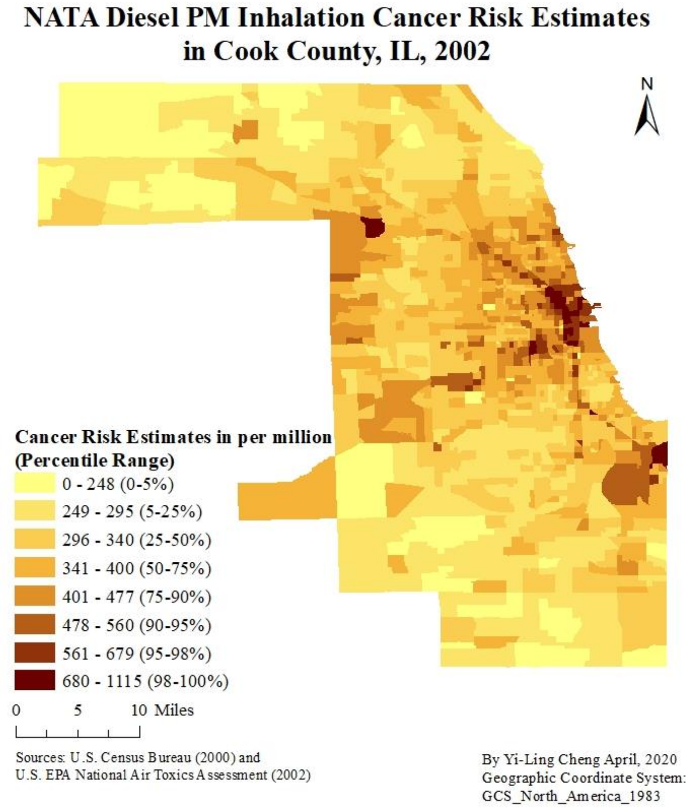

Figure 16. Spatial distribution of USEPA NATA diesel PM inhalation cancer risks in Cook County, IL, 2002

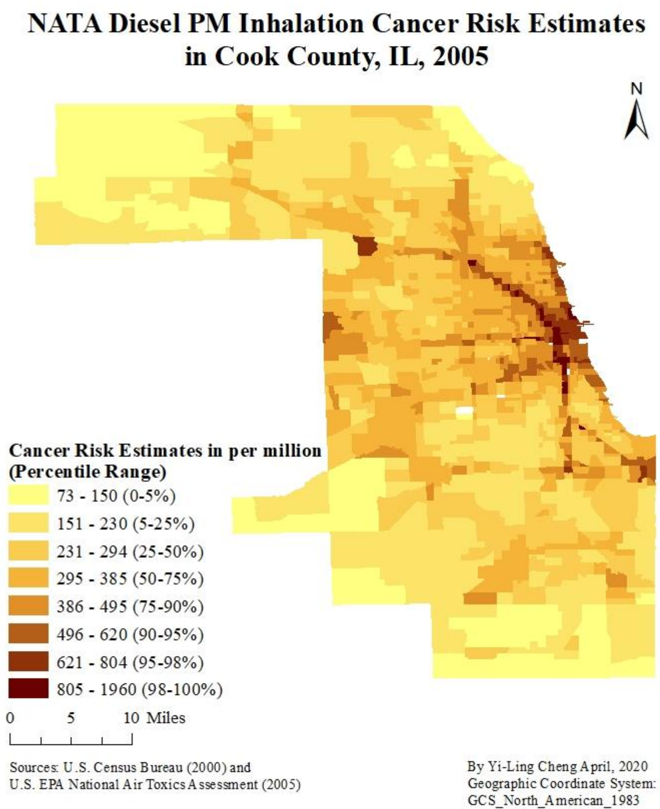

Figure 17. Spatial distribution of USEPA NATA diesel PM inhalation cancer risks in Cook County, IL, 2005

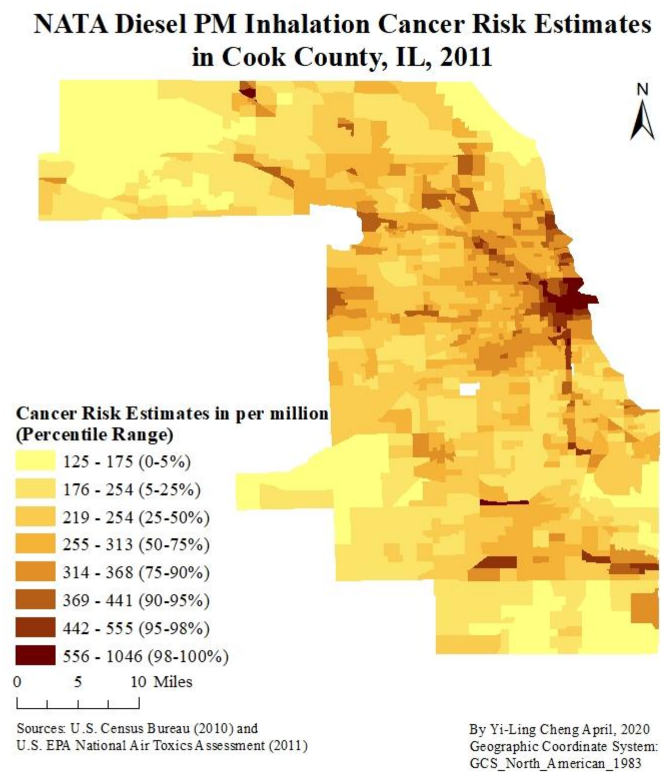

Figure 18. Spatial distribution USEPA NATA diesel PM inhalation cancer risks in Cook County, IL, 2011

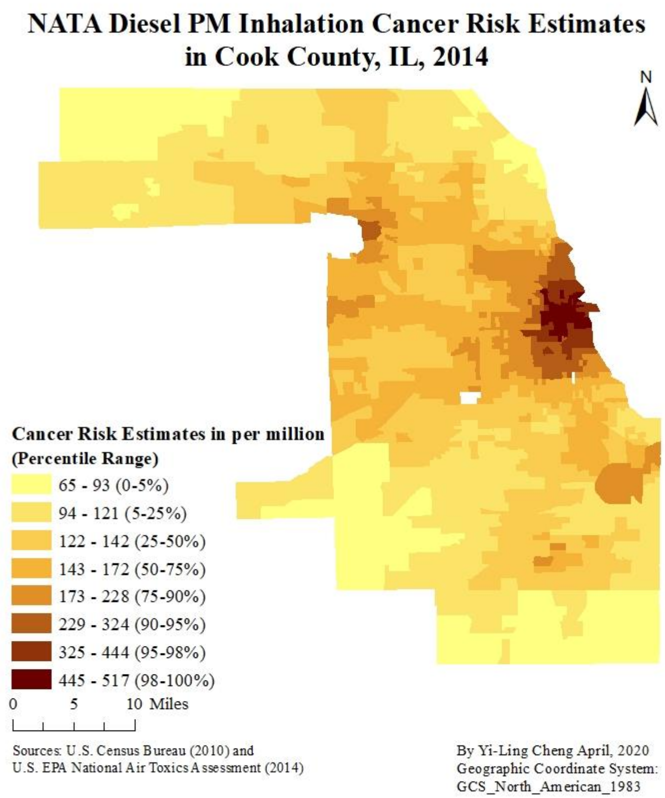

Figure 19. Spatial distribution of USEPA NATA diesel PM inhalation cancer risks in Cook County, IL, 2014

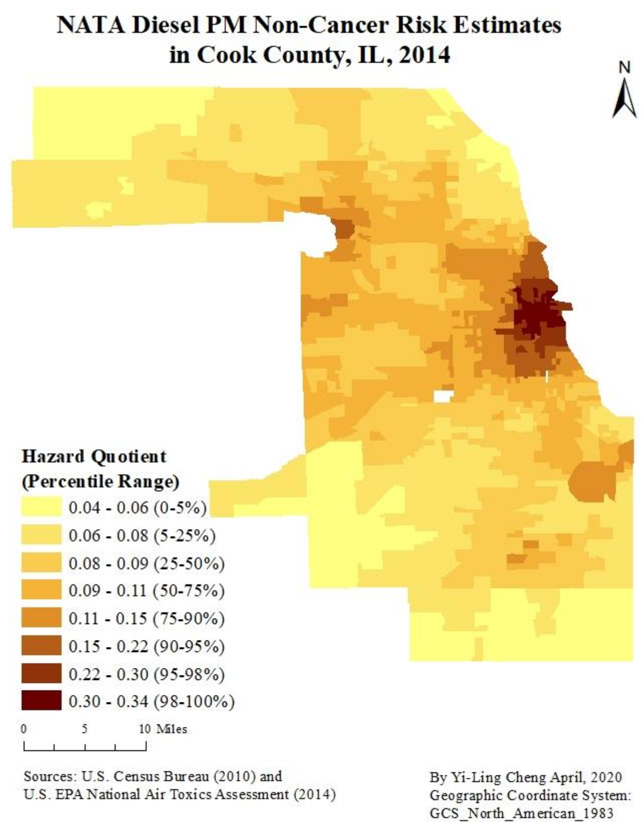

Figure 20. Spatial distribution of USEPA NATA diesel PM inhalation non-cancer risks in Cook County, IL, 2014

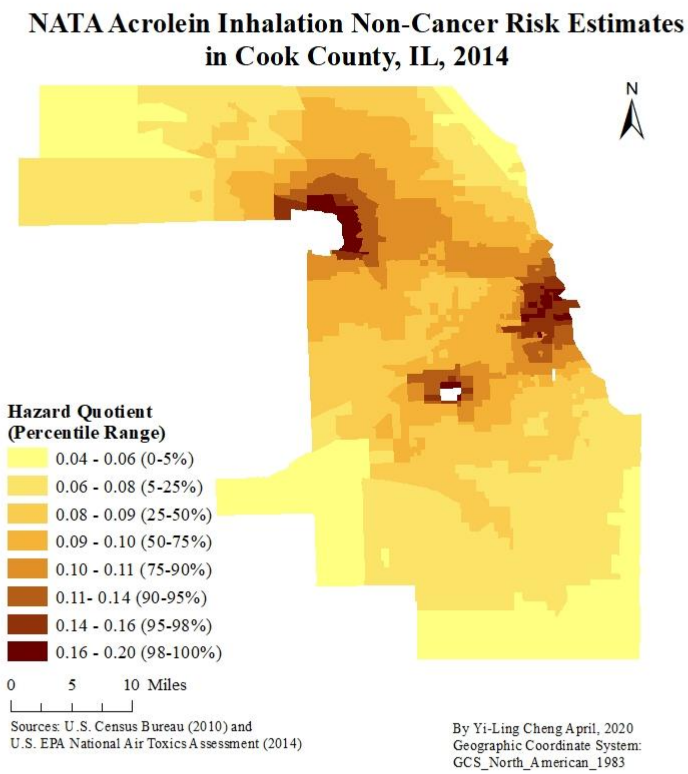

Figure 21. Spatial distribution of USEPA NATA acrolein inhalation non-cancer risks in Cook County, IL, 2014

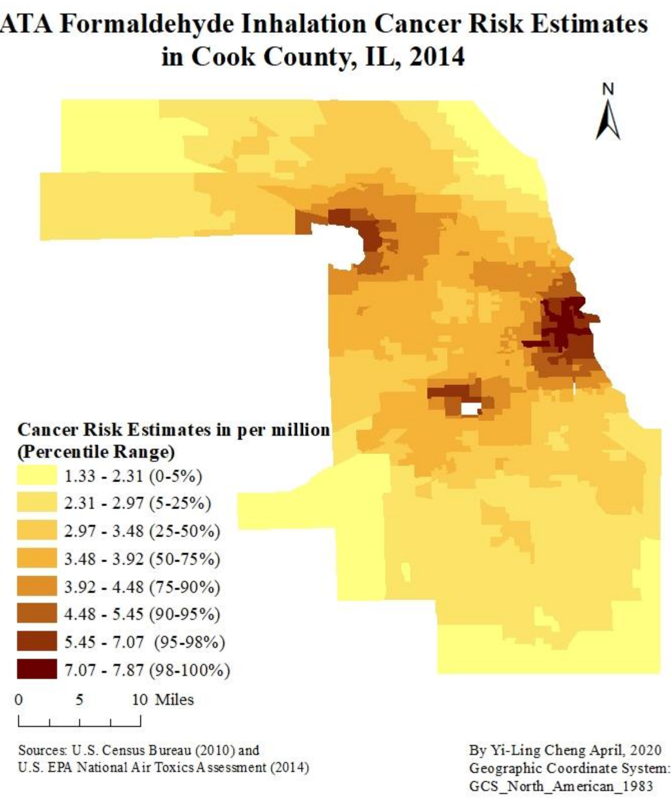

Figure 22. Spatial distribution of USEPA NATA formaldehyde inhalation non-cancer risks in Cook County, IL, 2014

TABLE XXXIII. TOP 20 CONTRIBUTED CHEMICALS IN NATA INHALATION CANCER RISK IN COOK COUNTY, IL 1999-2014

	NATA 1999		NATA 2002		NATA 2005		NATA 2011		NATA2014	
	Chemical	**Contribution to Cancer Risk**	**Chemical**	**Contribution to Cancer Risk**	**Chemical**	**Contribution to Cancer Risk**	**Chemical**	**Contribution to Cancer Risk**	**Chemical**	**Contribution to Cancer Risk**
1	Benzene	1.62E-05	Benzene	9.3E-06	Formaldehyde	2.4E-05	Benzene	6.2E-06	Ethylene Oxide	5.5E-06
2	Ethylene dibromide	7.75E-06	Naphthalene	3.0E-06	Benzene	7.3E-06	Formaldehyde	4.4E-06	Benzene	5.0E-06
3	Butadiene	7.04E-06	Acetaldehyde	2.8E-06	Naphthalene	4.4E-06	1,3-Butadiene	2.6E-06	Formaldehyde	3.5E-06
4	Acetaldehyde	5.56E-06	Arsenic Compounds	2.8E-06	Acetaldehyde	3.5E-06	Naphthalene	2.0E-06	Naphthalene	3.1E-06
5	1,1,2,2-Tetrachloroethane	4.38E-06	1,3-Butadiene	2.6E-06	1,4-Dichlorobenzene	3.5E-06	Ethylbenzene	9.7E-07	1,3-Butadiene	1.8E-06
6	Naphthalene	4.17E-06	1,4-Dichlorobenzene	2.6E-06	Tetrachloroethylene	3.2E-06	Chromium VI	8.9E-07	Chromium VI	7.0E-07
7	Carbon tetrachloride	3.17E-06	Tetrachloroethylene	2.3E-06	1,3-Butadiene	2.9E-06	Acetaldehyde	5.8E-07	Ethylbenzene	7.0E-07
8	Cadmium Comp	2.82E-06	Coke Oven Emissions	1.7E-06	Carbon Tetrachloride	2.9E-06	Arsenic Compounds	3.3E-07	Acetaldehyde	4.4E-07
9	Chromium VI	2.49E-06	Chromium Compounds	1.4E-06	Ethylene Oxide	2.0E-06	Trichloroethylene	2.7E-07	Trichloroethylene	3.7E-07
10	Bis(2-ethylhexyl) phthalate	2.23E-06	Pahpom	8.7E-07	Chromium Compounds	1.8E-06	Pahpom	2.2E-07	Arsenic Compounds	2.4E-07
11	Tetrachloroethylene	1.86E-06	Ethylene Oxide	5.4E-07	Acrylonitrile	9.2E-07	Nickel Compounds	1.7E-07	Nickel Compounds	1.6E-07
12	Ethylene_oxide	1.41E-06	Trichloroethylene	2.4E-07	Arsenic Compounds	9.0E-07	Ethylene Oxide	1.7E-07	Pahpom	1.2E-07
13	Ethylene dichloride	1.25E-06	Cadmium Compounds	2.2E-07	Pahpom	6.9E-07	Coke Oven Emissions	1.3E-07	Cadmium Compounds	9.2E-08
14	P-Dichlorobenzene	9.91E-07	Nickel Compounds	1.8E-07	Ethylbenzene	6.4E-07	Cadmium Compounds	5.9E-08	Coke Oven Emissions	7.1E-08
15	POM	8.66E-07	1,3-Dichloropropene	1.6E-07	Coke Oven Emissions	5.9E-07	Acrylonitrile	4.9E-08	Acrylonitrile	3.8E-08
16	Vinyl chloride	7.25E-07	Methylene Chloride	7.2E-08	Trichloroethylene	4.3E-07	Beryllium Compounds	3.4E-08	Tetrachloroethylene	2.5E-08
17	1,3-Dichloropropene	7.22E-07	Acrylonitrile	3.6E-08	Cadmium Compounds	2.6E-07	Tetrachloroethylene	2.3E-08	Beryllium Compounds	1.6E-08
18	Trichloroethylene	6.25E-07	Beryllium Compounds	3.3E-08	Nickel Compounds	2.4E-07	Ethylene Dichloride	1.4E-08	Ethylene Dichloride	1.0E-08
19	Coke Oven Emissions	5.94E-07	1,1,2,2-Tetrachloroethane	1.2E-08	Ethylene Dibromide	2.0E-07	Benzyl Chloride	8.0E-09	Ethylene Dibromide	5.4E-09
20	Propylene dichloride	4.94E-07	Ethylene Dichloride	9.4E-09	1,1,2,2-Tetrachloroethane	1.7E-07	Ethylene Dibromide	7.5E-09	Benzyl Chloride	3.7E-09

TABLE XXXIV. TOP 20 CONTRIBUTED CHEMICALS IN 2014 NATA RESPIRATORY NON-CANCER RISK, COOK COUNTY, IL

	Pollutant Name	Total Respiratory HI
1	Acrolein	0.12045
2	Formaldehyde	0.11463
3	Diesel PM	0.10428
4	Acetaldehyde	0.09930
5	Naphthalene	0.03149
6	Maleic Anhydride	0.01197
7	Ethylene Glycol	0.00717
8	Chlorine	0.00647
9	Methyl Bromide (Bromomethane)	0.00561
10	Hydrochloric Acid (Hydrogen Chloride [Gas Only])	0.00471
11	Nickel Compounds	0.00384
12	Propionaldehyde	0.00308
13	2,4-Toluene Diisocyanate	0.00074
14	Chromium Vi (Hexavalent)	0.00059
15	4,4'-Methylenediphenyl Diisocyanate (Mdi)	0.00041
16	Beryllium Compounds	0.00034
17	Methylene Chloride	0.00033
18	Acrylonitrile	0.00028
19	Acrylic Acid	0.00026
20	Phthalic Anhydride	0.00023

3. <u>Spatial Distribution of Acrolein in Cook County, Illinois, 2014</u>

The spatial distribution of diesel PM non-cancer risk was displayed in Figure 21. All of the acrolein non-cancer risk estimates in Cook County were in acceptable range (i.e., Hazard Quotient <1). Acrolein is mostly emitted into the atmosphere from mobile sources (both on-road and non-road mobile vehicles) (i.e., 75% of emitted acrolein into air).

In addition, it is byproduct of the incomplete combustion of organic material as well as the oxidation of atmospheric chemicals such as 1,3-butadiene, a primary component of motor vehicle exhaust. The remainder of acrolein emissions into air (i.e., 25%) originate from agriculture, industrial processes, tobacco smoke and forest fires (Seaman et al., 2007). The distribution of the area with higher non-cancer risk in Figure 21 matches the cancer risk map of formaldehyde (Figure 13) and benzene (Figure 14), which highlights more urbanized areas in Cook County.

Although there are neither health effect as harmful as cancer nor reproductive diseases or development diseases caused by acrolein exposure. The chronic effects from acrolein exposure are general respiratory congestion, and irritation in eye, nose and throat (U.S. Environmental Protection Agency, 2009a).

4. **Spatial Distribution of Formaldehyde in Cook County, Illinois, 2014**

The spatial distribution of diesel PM non-cancer risk was displayed in Figure 22. All formaldehyde non-cancer risk estimates in Cook County were in acceptable range.

Formaldehyde are mainly from mobile vehicles. This map also highlights those areas which are more urbanized as the formaldehyde cancer risk map (Figure 13), benzene cancer risk map (Figure 14) and acrolein non-cancer risk map showed.

Except for cancer risks, exposed to formaldehyde will also cause some other health effects like nasal and eye irritation, neurological effects, and increased risk of asthma (Agency for Toxic Substances and Disease Registry, 2015)

V. DISCUSSION

In this study, we evaluate air toxics emissions utilizing National Emissions Inventory (NEI) data for Illinois and Cook County, Illinois, inhalation cancer risk estimates and non-cancer risk estimates using National Air Toxics Assessment (NATA) data for Cook County for the year 1999, 2002, 2005, 2011, and 2014.

Different emission sources categories for Illinois and Cook County were assessed by using NEI dataset from the USEPA. Although the total emissions in Illinois and Cook County over the years has decreased, it does not mean that all emissions from different source categories decreased. Based on our findings, there is an increase in on-road emissions (from 6563Tpy in 2011 to 8260Tpy in 2014 in Illinois. The top three Illinois Counties in contributions of air pollution sources to total air toxic emissions in tons per year (TPY) were Cook (26.42%), followed by DuPage (5.87%) and Lake (4.55%) Counties while the on-road emission contributed most to total air emissions in Illinois in 2014. According to Apelberg et al., 2005, on-road sources were the greatest contributor to cancer risk among census tracts in Maryland. Our result shows the same that on-road is the highest contributor to cancer risk in Cook County after excluding contributing proportion by the "other source emissions" category, as in Apelberg's study, they only analyzed the contribution of the four main emission categories, major, area, on-road and non-road. In addition, this finding is also consistent with the research conducted in California and in South Carolina, which concluded that on-road source was the primary source to cancer risk (Wilson et al., 2015; Morello-Frosh et al., 2000).

Cook County is consistently the county that contributes the most to the total air emissions in Illinois in 1999, 2002, 2005, 2011 and 2014. Other higher contributing counties near Cook County are all more urbanized counties in Illinois. Previous studies have concluded the associations between poverty, educational, race and ethnicity, and exposure to carcinogenic air toxics (Apelberg et al.,2005; Linder et al., 2008; Young et al.,2012; James et al., 2012; Jia and Foran, 2013; Wilson et al., 2015; Grineski et al., 2017; Ekenga et al., 2019). This illustrates the importance of understanding the primary emissions source categories and cancer and non-cancer risk drivers for targeted and effective public health improvement program that reduces burden on socio-economically disadvantaged subpopulations. However, our analysis focused on Cook County only since it has the highest and the most diverse population in IL and it contributes significantly more to the total air toxic emissions in IL. It will be important to perform similar analysis for other counties in IL so that a state-wide air pollution reduction and exposure/risk mitigation program can be developed in an informed manner.

In terms of top chemicals contributing to NATA cancer risk, formaldehyde was also one of the greater contributor of cumulative cancer risk in a Portland study (Tam et al., 2004). On the other hands, acrolein was the only non-carcinogenic HAP with hazard ratios exceeded safe range (HQ >1.0) in the Portland study (Tam et al., 2004). Acrolein was also the most contributed non-cancer risk chemical in Cook County, 2014.

In addition, studies in California (Pastor et al., 2004; Gaffron and Niemeier, 2015; Zweig et al., 2009), Louisiana (Legot et al., 2012; Scharber et al., 2013), Michigan (Mohai et al., 2011), New York (Stingone et al., 2016; 2017) that revealed air pollution exposures have negative academic effects on schoolchildren. Although USEPA has not filed the cancer risk estimates parameter of diesel PM, our assessment shows that the diesel PM inhalation cancer risk in Cook County were above the acceptable range since 1999.

A risk assessment report for the Sterigenics Facility in Willowbrook, Illinois was published August, 2019 (U.S. Environmental Protection Agency, 2019b). The report was conducted to assess the human health risks posted by ethylene oxide (EtO) emission from the Sterigenics facility in Willowbrook, IL. This assessment reported that, for residential areas, the estimated cancer risks from lifetime exposure while the facility was operating ranged from less than 100 in 1 million (i.e., 10^{-4}) to 1,000 in a million (10^{-3}) in areas closest to the facility, which is above the USEPA's acceptable range (U.S. Environmental Protection Agency, 2019b). The Agency for Toxic Substances and Disease Registry (ATSDR) assessed the human health risks posed by Ethylene oxide (EtO) air emissions from the Sterigenics facility in Willowbrook, IL (Agency for Toxic Substances and Disease Registry, 2018). Based on measured and modeled EtO concentrations generated by the USEPA, and the proximity to residences and other commercial structures to the source, ATSDR concluded that cancer risks higher than 1 in 10,000 people may exist for some community members and workers exposed to airborne EtO in this community. They further stated that "If these measured and estimated concentrations represent chronic exposures (with higher exposures likely for workers of the facility), EtO emissions from the Sterigenics Corporation poses a public health hazard." Agency for Toxic Substances and Disease Registry (ATSDR) estimated lifetime cancer risk of 6.4×10^{-3} for residents and of 2.1x10-3 for occupational workers (Agency for Toxic Substances and Disease Registry, 2018), which were both above the acceptable range per USEPA guideline as well. Ethylene Oxide (EtO) was the highest contributing air toxic in Cook County in our study. Although the cancer risk estimates of it in our study were all in the acceptable range (10^{-6}- 10^{-4}), the highlighted areas were closed to the edge to be above the acceptable cancer risk value. The facilities identified in our study were also mainly from Sterigenics and the highlighted area in southwest of Cook County was right near Willowbrook, IL. It is critical to investigate if any EtO emission in Cook County were affected by Willowbrook, Illinois.

The primary limitations of this study are the evolving emission source classifications of the NEI data, NATA data over the years and the ability to access the historical NATA and NEI dataset publicly and in detailed. As the classification definition and the data arrangement differs every year, we found it difficult to match all the inclusive groups from year to year by reviewing all the available database and technical supporting documents. Potential problems cause by the change of emission grouping were also mentioned in a latest article by Declet-Barreto et al., (2020). In the article, Declet-Barreto mentioned on January 25, 2018, the United States Environmental Protection Agency (USEPA) withdrew a 1995 policy that mandates the use of maximum achievable control technology (MACT) to regulate emissions from major sources of hazardous air pollutants (HAPs), and their result shows that the change is estimated to emit an additional 35,0303 tpy of HAPs nationally, which nearly triples the total air toxics that qualifying sources emitted in 2014 (12,800 tpy), if all qualifying major sources were reclassified to area sources. Future studies are warranted to investigate the more detailed emission of ethylene oxide and diesel PM in Cook County. Since ethylene oxide is already classified as a known human carcinogen and the contribution of it meets the pattern of the total inhalation cancer risk in Cook Cook County. Most of the inhalation risk of diesel PM cancer risk estimates in Cook County from 1999 to 2014, respectively, were above the acceptable range. This is a significant sign that it is urgent for USEPA to file the important parameters of diesel PM and model the cancer risk of diesel PM nationally. We recommend that the USEPA performs cancer risk estimates for diesel PM and updates the total cancer risk estimates for each census tract across the nation since all of our estimates for Cook County are above the USEPA's acceptable range across all years studied (1999 to 2014).

Further socio-economic research that aims to uncover the variables that explain the variability in cancer and non-cancer risk estimates for air toxics are highly recommended in order to advance our understanding of environmental and health inequities and disparities in Cook County.

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