Health Consultation

PUBLIC COMMENT VERSION

Health Evaluation of Ethylene Oxide Concentrations in

Outdoor Air Near

Medline Industries and Vantage Specialty Chemicals

LAKE COUNTY, ILLINOIS

June 21, 2024
PUBLIC COMMENT PERIOD ENDS: August 5, 2024

Prepared by the

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Office of Community Health Hazard Assessment
Central Section
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

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

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members.

This health consultation is released for a 45-day public comment period. ATSDR will address all public comments and revise or append the document as appropriate. The health consultation will then be reissued as a final document. The final document will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

Please address comments regarding this report to:
Agency for Toxic Substances and Disease Registry
Attn: Records Center
4770 Buford Highway NE, MS S106-5
Atlanta, Georgia 30341

Email comments will also be accepted at:
atsdrrecordscenter@cdc.gov

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: https://www.atsdr.cdc.gov

HEALTH CONSULTATION

Health Evaluation of Ethylene Oxide Concentrations in Outdoor Air Near Medline Industries and Vantage Specialty Chemicals LAKE COUNTY, ILLINOIS

Prepared by the:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
Office of Community Health and Hazard Assessment
Atlanta, Georgia 30333

Contents

Figure List

Table List

1. Summary

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia, is a federal public health agency within the U.S. Department of Health and Human Services (DHHS). ATSDR's purpose is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent people from coming into contact with harmful toxic substances. This health consultation presents the findings of ATSDR's health evaluation of ethylene oxide (EtO) air monitoring data measured in Lake County, Illinois.

On March 26, 2019, the Lake County Health Department and Community Health Center (LCHD) requested that ATSDR assess whether EtO concentrations in outdoor (ambient) air around Medline Industries (Medline), a medical sterilization facility in Waukegan, Illinois, and Vantage Specialty Chemicals (Vantage), a chemical manufacturing plant in Gurnee, Illinois, pose a public health hazard to the Lake County community. Both facilities are in Lake County, about 3 miles from one another.

The LCHD, Village of Gurnee, City of Waukegan, and the Illinois Environmental Protection Agency (IEPA) conducted air sampling (monitoring) for EtO near the Medline and Vantage facilities during three short-term "phases" of sampling (meaning sampling started and stopped three times) from June 2019 to May 2020. The LCHD EtO outdoor air sampling data set included five air sampling locations within about 1 mile from Medline (M1–M5) and five sampling locations less than 1 mile from Vantage (V1–V5) as well as two air sampling locations meant to characterize background concentrations of EtO (R1 and R2).

Vantage installed a new dry bed absorption device in April 2019 and began an enhanced leak detection and repair (LDAR) program in May 2019 before sampling began. During sampling, Vantage removed a cooling tower in November 2019 which was likely a source of fugitive emissions. The latest air permit for Vantage did not come into effect until December of 2019. The EtO air concentrations measured near the Vantage plant from June 2019 to December 2019 were collected when pollution controls at Vantage may not have been fully operational. Also, the Medline facility shut down temporarily and then reopened in March 2020 with a new permanent total enclosure (PTE) emissions control system. After Medline re-opened, the Medline facility conducted monthly 24-hour outdoor air sampling at two community and two fenceline air sampling locations beginning as soon as the PTE was operational in March of 2020 in compliance with Illinois state law. Air sampling is currently ongoing at Medline as of the publication of this document.

ATSDR evaluated air sampling that took place during three different periods of operation at Medline:

- Pre-closure operation period:
    - LCHD sampling June 6–July 3, 2019 and
    - October 26–December 12, 2019
- Temporary closure period:
    - LCHD sampling December 13, 2019–January 21, 2020
- PTE operation period:
    - LCHD sampling April 4–May 1, 2020
    - Medline air sampling March 27, 2020–September 28, 2023

This ATSDR health consultation evaluated LCHD's air sampling data from 2019 to 2020 and Medline's monthly air sampling data from 2020 through 2023 to evaluate health hazards from breathing EtO in outdoor air near the Medline and Vantage facilities. ATSDR evaluated the EtO air concentrations to estimate EtO exposure and the associated cancer and noncancer risks to residents and off-site workers (people that work near but not at Medline or Vantage) within 1 mile of the facilities. We evaluated how outdoor concentrations of EtO varied with operational changes at Medline as well as how concentrations changed over time with differences in weather and distance from both facilities. ATSDR also analyzed the Illinois Ambient Air Monitoring Network EtO air sampling data for two Cook County air sampling locations (Northbrook and Schiller Park) to assess background EtO concentrations as no known EtO sources were near these sites.

In September 2020, U.S. Environmental Protection Agency (EPA) informed ATSDR of two issues that have prevented U.S. EPA from putting an exact number on background EtO concentrations [U.S. EPA 2021] The first issue is the uncertainty of measuring EtO concentrations near the method detection limit (MDL). The second issue is from positive sampling bias from canister growth of EtO [U.S. EPA OAR 2021, U.S. EPA ORD 2021]. Positive sampling bias is the artificially high measurement and reporting of EtO concentrations in some outdoor air samples. To address positive bias in LCHD air sampling, ATSDR used a generalized additive model (GAM) to estimate the effects of canister type and holding time at the two outdoor air sampling stations in Cook County, Illinois. The GAM was used to adjust the measured LCHD EtO air concentrations for the effects of canister type, holding time, and seasonal pattern. Medline monthly sampling was collected in types of canisters less prone to bias, so adjustment was only done for holding time and seasonal pattern. The GAM reduces bias from the canister effect in EtO concentration measurements and associated cancer risk, but it does not remove all uncertainty from measurements.

To determine whether exposure to the elevated EtO concentrations in the outdoor air near Vantage and Medline could adversely affect public health, ATSDR evaluated the cancer and noncancer risks to residents and off-site workers (people that work near but not at Medline or Vantage) within 1 mile of the facilities during operation and closure periods. To calculate an upper bound lifetime excess cancer risk estimate from chronic exposure to EtO air concentrations for many years, ATSDR used protective upper bound estimates of exposure point concentrations (EPC), reasonable maximum exposure (RME) scenarios, and the U.S. EPA's inhalation unit risk (IUR) estimate at each sampling location. Whenever possible, ATSDR accounts for limitations by using protective, reasonable upper bound exposure estimates as the basis for determining whether harmful health effects are possible.

The ATSDR calculated lifetime excess cancer risk estimates for residents and workers breathing EtO for many years are estimates of excess cancer risk that may contribute to a small increase in cancer risk *in addition to* the already existing observed lifetime risk of cancer from all causes. The lifetime risk of cancer from all risk factors during a lifetime is based on the incidence of cancer cases diagnosed and reported to state cancer registries across the United States. In the United States, 1 out of every 2 men and 1 out of every 3 women are at risk for developing cancer during their lifetime. The lifetime risk that a woman in the United States will develop breast cancer during her lifetime is 1 out of every 8 women. This means a woman has about 1 chance in 8 of developing breast cancer.

ATSDR considers any lifetime excess cancer risk estimate of more than 1 excess cancer case in 10,000 persons exposed as a potential increased cancer risk and as such requires a recommendation to minimize exposure to protect public health. An ATSDR lifetime excess cancer risk estimate greater than 1 cancer case in 10,000 persons exposed does not necessarily mean any given individual will develop cancer due to exposure.

ATSDR cannot determine an individual's risk of developing cancer. An individual's lifetime risk of developing cancer depends on many factors other than exposure to EtO. The calculated lifetime excess cancer risk estimates from EtO exposure are not actual cancer cases, do not represent the actual cases of cancer in Lake County communities, and are not estimates of an individual's cancer risk. The lifetime excess cancer risk estimates are a tool for making public health conclusions and recommendations. The lifetime excess cancer risk estimates are designed to be protective of health, as they use reasonable upper bound exposure estimates and are likely an overestimate of the potential risk.

After evaluating available data, ATSDR reached the following five conclusions:

Conclusion 1 1. Health effect: cancer 2. Facility: Vantage 3. Sampling time: June 2019–May 2020	**Breathing air for many years with adjusted EtO concentrations measured from June 2019 to May 2020, when pollution controls may not have been fully operational, may increase the risk of certain types of cancer for residents living within 0.6 miles of Vantage and people who work within ¼ mile of Vantage's northern or eastern property boundary.**
Basis for Conclusion 1	▪ EtO is classified as carcinogenic to humans from breathing EtO in the air over many years [U.S. EPA 2016]. The best evidence of which cancers might be associated with breathing EtO comes from studies of workers exposed to high levels over a long period of time. Evidence from human epidemiological studies is strong but less than conclusive in associating specific cancers with EtO exposure [U.S. EPA 2016]. ▪ Studies of a large cohort of workers observed a dose-response in the incidence of female breast cancer and breast cancer mortality in women [Steenland et al. 2003; Steenland, Stayner, and Deddens 2004]. A study from the same cohort also found increased mortality in male workers from certain lymphoid cancers (non-Hodgkin lymphoma [also known as non-Hodgkin's lymphoma or NHL], myeloma, and lymphocytic leukemia as a group) [Steenland, Stayner, and Deddens 2004; U.S. EPA 2016; IARC 2012]. ▪ For residents and workers breathing EtO over many years, ATSDR calculated the upper bound population-based estimates of lifetime excess cancer risk designed to be protective of health, as they use reasonable upper bound exposure estimates and are likely an overestimate of the potential risk. This calculated lifetime excess risk of cancer from EtO exposure may contribute a small increased risk in addition to the already existing lifetime risk of cancer from all causes. ▪ ATSDR estimated lifetime excess cancer risks at five LCHD sampling locations near Vantage (V1 through V5) based on RME assumptions and the 95% upper confidence limit (UCL) of GAM-adjusted EtO concentrations measured long-term during three non-continuous phases of sampling from June 2019 to May 2020. These air samples

	were collected after Vantage installed a new dry bed absorption system in April 2019 to better control EtO emissions. The pollution controls may not have been fully operational until the air permit for Vantage came into effect in December 2019. ▪ The calculated upper bound lifetime excess cancer risk estimates for people who live near sampling locations within 0.6 miles of Vantage ranged from 3 to 20 in 10,000 people (Table 4 and Figure 3). ATSDR considers these estimated lifetime excess cancer risks from long-term breathing of EtO concentrations measured in the air to be an elevated cancer risk. ▪ The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close they live or work to the facility. ▪ Lifetime excess cancer risks calculated using average or typical assumptions rather than upper bound assumptions about exposure ranged from 0.3 to 0.8 in 10,000 for adults living near Vantage. ▪ Estimated upper bound lifetime excess cancer risks for people who work but do not live near Vantage were elevated at air sampling location V2, 0.2 miles to the east of Vantage, but not at other air sampling locations including a sample location closer to the facility (i.e., V3, 0.05 miles south of Vantage.) This indicates people who work in the predominant wind direction from Vantage (northeast of Vantage) may have elevated cancer risk but people who work south of the facility may not. ▪ Adjusted EtO concentrations at four of five sampling locations (V1, V2, V3, and V5) were statistically higher than adjusted EtO concentrations measured at the background sampling locations (R1 and R2) (Section 5.1.1, Appendix D2, Appendix E2). ▪ The farthest air sampling from the facility is 0.6 miles away. ATSDR does not know precisely how far from the facility people living nearby may be at elevated risk because EtO concentrations were elevated at four of five air sampling locations. EtO concentrations would be expected to decrease with distance within a given direction from the facility. ▪ In early November 2019, EtO concentrations at several sampling locations near Vantage were higher than EtO concentrations measured during the rest of the sampling period (Section 5.1.1, Appendix D1), which may have been due to the removal of a cooling tower that month. Additionally, although Vantage had emissions controls installed prior to the beginning of sampling, the new permit did not come into effect until December of 2019. These facts add uncertainty in the long-term estimates of lifetime cancer risk. ▪ Long-term air sampling was not available to assess EtO concentrations and associated lifetime cancer risk prior to June 2019.
Conclusion 2 1. Health effect: cancer 2. Facility: Medline 3. Sampling time: March 2020–September 2023 4. Operating period: Operating, PTE	**ATSDR cannot exclude the possibility that breathing air for many years with EtO levels measured within 0.7 miles of the Medline plant between March 2020 and September 2023 could increase the risk of certain types of cancer for residents. However, any potential increase in risk would likely be small over a person's lifetime. Air sampling locations adjacent to the Medline plant show a downward trend in EtO concentrations during this period, which suggests that the EtO controls on the plant have become**

	increasingly effective. The most recent observed EtO levels adjacent to Medline are low enough to not pose an excess lifetime cancer risk for off-site workers.
Basis for Conclusion 2	▪ ATSDR calculated lifetime excess cancer risk estimates based on RME assumptions and the 95% UCL of GAM-adjusted EtO concentrations measured in Medline's monthly sampling from March 2020 to September 2023 at four air sampling locations within 0.6 miles of Medline. These air samples were collected after Medline installed the PTE emissions control system in March 2020 to better control EtO emissions. ▪ The estimated lifetime excess cancer risk from long-term breathing of EtO in the air for people who live in the apartments 0.1 miles southwest of Medline was 5 in 10,000, and it was 6 in 10,000 for people who live in the neighborhood about 0.5 miles northeast of Medline. ATSDR considers these estimated lifetime excess cancer risks from long-term breathing EtO concentrations measured in the air to be an elevated cancer risk (Table 3 and Figure 3). ▪ Lifetime excess cancer risk estimates calculated using average or typical assumptions rather than upper bound assumptions about EtO exposure were 0.6 and 0.8 in 10,000 for adults living near Medline. ▪ Concentrations have trended downward at the two fenceline sampling locations (F1 and F2) as have emissions from Medline (Section 5.1.2, Section 5.3.2, Appendix F2). This downward trend in EtO concentrations was not observed at the community sampling locations (CF1 and C1, later replaced by C2). ▪ The estimated lifetime excess cancer risk from EtO exposure for people who work immediately northeast of the facility is 0.8 in 10,000 assuming more recent (2023) EtO concentrations are more representative of what people working near Medline will breathe in the future than concentrations measured earlier in the March 2020–September 2023 sampling period. ▪ Statistical testing concluded adjusted EtO concentrations from all four air sampling locations including two fenceline air sampling locations (F1 and F2), one location northeast of Medline (C1, later replaced by C2), and the sampling location near the apartment complex (CF1) were elevated compared to background EtO concentrations measured at the Northbrook and Schiller Park air sampling locations in Cook County, Illinois (Section 5.1.2, Appendix D5, Figure D6, Appendix E2). ▪ ATSDR is uncertain precisely how far the elevated lifetime cancer risk may extend from Medline in any given direction. EtO concentrations were highest at the fenceline sampling locations (F1 and F2), decreased at the nearest community monitor (CF1), and decreased still more at the farthest community sampling location (C1 and C2) (Section 5.1.2, Section 5.3.2, Appendix F2). The farthest air sampling location was 0.7 miles from the facility. EtO concentrations would be expected to continue decreasing with distance within a given direction from the facility. ▪ The lifetime excess cancer risk estimates are based on breathing EtO over many years. There is not a health hazard of increased lifetime

	cancer risk from breathing EtO from Medline for people living or working near Medline for time periods less than 1 year. ▪ The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close you live or work to the facility.
Conclusion 3 1. Health effect: cancer 2. Facility: Medline 3. Sampling time: June–December 2019 4. Operating period: Operating, pre-closure	**ATSDR concludes breathing EtO for many years prior to December 2019 could have harmed the health of people who lived within 0.6 miles of Medline. Based on EtO concentrations measured from June–December 2019, before the installation of new emission controls, long-term exposure to EtO near Medline may have increased the risk of certain types of cancers.**
Basis for Conclusion 3	▪ ATSDR estimated lifetime cancer risk at five LCHD air sampling locations near Medline (M1 through M5) based on RME assumptions and the GAM-adjusted EtO concentrations measured from June 2019 to December 2019. These air samples were collected before Medline installed the PTE emissions control system in March 2020 to better control EtO emissions. ▪ Estimated lifetime cancer risk during the pre-closure operational period for the nearest residential area (near monitor M3) was 40 in 10,000, and it was 5 in 10,000 near a neighborhood northeast of the facility (near monitor M1). ATSDR considers these estimated lifetime excess cancer risks from long-term breathing EtO concentrations measured in the air to be an elevated cancer risk (Table 5 and Figure 3). ▪ Estimated lifetime excess cancer risks calculated using the average or typical assumptions rather than upper bound assumptions about exposure for adults who live near Medline were 0.3 in 10,000 at M1 and 1 in 10,000 at M3. ▪ Statistical tests showed adjusted EtO concentrations at the three closest sampling locations within 0.6 miles of Medline, including two residential areas (M3 and M1) and a local park (M4), were higher than background EtO concentrations at R1 and R2 (Section 5.1.2, Appendix D5, Appendix E2). The EtO air sampling data were collected from June–December 2019 during the pre-closure operational time period before new PTE emissions controls were installed in March 2020. ▪ Long-term air sampling was not collected prior to June 2019 to assess exposure to EtO concentrations and associated lifetime excess cancer risks before June 2019. ▪ The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close you live or work to the facility.

Conclusion 4 1. Health effect: noncancer 2. Facility: Medline and Vantage 3. Sampling time: June 2019–September 2023 4. Operating period: Operating, PTE	**ATSDR concludes that breathing EtO in the air near Medline and Vantage is not expected to result in noncancer health effects. This conclusion applies to the measured EtO concentrations at all sampling locations during all phases of facility operations.**
Basis for Conclusion 4	▪ The highest measured EtO air concentrations near Medline and Vantage were well below the noncancer health guidelines and significantly below the lowest concentrations that have been reported to result in noncancer health effects in scientific studies of acute (less than 2 weeks), intermediate (2 weeks to 1 year), and chronic (greater than 1 year) exposure to EtO. This conclusion applies to EtO concentrations measured during all operating periods at Medline and post installation of new controls at Vantage. ▪ People who live, work, go to school, or traveled near these Medline or Vantage facilities are not expected to have noncancer health effects from exposure to EtO concentrations that were detected in the community.
Conclusion 5 1. Health effect: cancer 2. Background EtO Sampling time: June 2019–May 2020	**EtO concentrations measured in Lake County away from Medline and Vantage and near Medline when the facility was closed were similar to background levels observed across the United States. Lifetime excess cancer risk estimates from EtO exposure for people living or working in other parts of Lake County removed from Medline or Vantage is similar to EtO-related cancer risk for people living or working in other areas without a known EtO source.**
Basis for Conclusion 5	▪ Estimates of background EtO concentrations are challenging due to measurement uncertainty from sources including EtO concentration increases in canisters and compounds that may mimic EtO during chemical analysis [US EPA ORD 2021]. ATSDR's use of the GAM limits the impact of positive bias due to the canister effect. ▪ ATSDR lifetime excess cancer risk estimates are designed to be protective of health, as they use reasonable upper bound exposure estimates as the basis for determining whether harmful health effects are possible. ▪ ATSDR estimated lifetime excess cancer risk based on RME assumptions and the 95% UCL of GAM-adjusted EtO air concentrations measured during the LCHD study at background sampling locations (R1 and R2) from June 2019 to May 2020 and at five sampling locations (M1 through M5) when Medline was temporarily closed from December 13, 2019 to January 21, 2020. ▪ Estimated residential lifetime excess cancer risk at R1 and R2 for the entire LCHD sampling period was 3 in 10,000 at both background sampling locations (Table 4). ▪ When Medline temporarily closed, the residential upper bound lifetime excess cancer risks ranged from 2 to 4 in 10,000 at each sampling location (Table 5).

Conclusion 5 3. Health effect: cancer 4. Background EtO Sampling time: June 2019–May 2020	**EtO concentrations measured in Lake County away from Medline and Vantage and near Medline when the facility was closed were similar to background levels observed across the United States. Lifetime excess cancer risk estimates from EtO exposure for people living or working in other parts of Lake County removed from Medline or Vantage is similar to EtO-related cancer risk for people living or working in other areas without a known EtO source.**
Basis for Conclusion 5	▪ Estimates of background EtO concentrations are challenging due to measurement uncertainty from sources including EtO concentration increases in canisters and compounds that may mimic EtO during chemical analysis [US EPA ORD 2021]. ATSDR's use of the GAM limits the impact of positive bias due to the canister effect. ▪ ATSDR lifetime excess cancer risk estimates are designed to be protective of health, as they use reasonable upper bound exposure estimates as the basis for determining whether harmful health effects are possible. ▪ ATSDR estimated lifetime excess cancer risk based on RME assumptions and the 95% UCL of GAM-adjusted EtO air concentrations measured during the LCHD study at background sampling locations (R1 and R2) from June 2019 to May 2020 and at five sampling locations (M1 through M5) when Medline was temporarily closed from December 13, 2019 to January 21, 2020. ▪ Estimated residential lifetime excess cancer risk at R1 and R2 for the entire LCHD sampling period was 3 in 10,000 at both background sampling locations (Table 4). ▪ When Medline temporarily closed, the residential upper bound lifetime excess cancer risks ranged from 2 to 4 in 10,000 at each sampling location (Table 5). ▪ ATSDR considers these estimated upper bound residential excess cancer risks from long-term breathing of background EtO concentrations measured in the air to be an elevated cancer risk. ▪ The most reliable estimate of residential excess cancer risk is up to 3 in 10,000 based on all the available background EtO concentration data collected during the LCHD study from June 2019 to May 2020. Lifetime excess cancer risk is also reported for R1 and R2 during Medline's three operating periods for comparability. These cancer risks tend to be more variable because they are based on fewer samples to estimate risk. They ranged from 2 to 7 in 10,000. ▪ Excess cancer risks calculated using average or typical assumptions rather than upper bound assumptions about exposure for adults were 0.3 and 0.4 in 10,000 at R1 and R2, respectively.
Next Steps	Following ATDR's public health assessment evaluation of available information and EtO air concentrations: **ATSDR recommends** that Illinois EPA and the two facilities investigate potential sources of EtO emissions that may affect outdoor EtO air concentrations at the closest residential areas and adjacent businesses. Further, ATSDR recommends that additional air sampling is conducted at Vantage to better characterize long-term EtO exposure. **ATSDR recommends** that U.S. EPA continue to work to:

	• Improve analytical methods with lower *detection limits* so that EtO can be accurately measured at lower concentrations. • Better understand EtO concentrations in background outdoor air and sources of EtO in outdoor air in order to accurately estimate exposure to EtO. **ATSDR is committed** to continued support of local, state, and federal health and environmental agencies. When requested, ATSDR can evaluate additional EtO air sampling data. **ATSDR recommends** local residents with health concerns related to EtO exposure talk with their doctor. In addition to advice from their doctor, individual community members can contact experts in environmental medicine using the information below. **Great Lakes Center for Reproductive and Children's Environmental Health at the University of Illinois at Chicago Website:** https://childrensenviro.uic.edu/ **Phone:** 866-967-7337 **Email:** ChildrensEnviro@uic.edu
	Clinicians interested in learning more about EtO exposure and health may also access ATSDR resources on EtO for clinicians through our website at the links below. Community members who wish to speak to their doctors about their exposure may recommend these resources for their doctors. ATSDR Clinician Brief: Ethylene Oxide | ATSDR (cdc.gov) Clinician Overview of Ethylene Oxide | ATSDR (cdc.gov)
For More Information	If you have questions about this document or ATSDR's work on EtO, call our toll-free number at 1-800-CDC-INFO, and ask for information on the Medline and Vantage EtO health consultation in Lake County, Illinois.

2. Background

2.1 Statement of Issues and Purpose

On March 26, 2019, the Lake County Health Department (LCHD) requested that the Agency for Toxic Substances and Disease Registry (ATSDR) evaluate measurements of ethylene oxide (EtO) concentrations in outdoor (ambient) air around two facilities in Lake County, Illinois: the Medline Industries (Medline) medical sterilization facility in Waukegan, Illinois, and the Vantage Specialty Chemicals (Vantage) chemical manufacturing plant in Gurnee, Illinois. LCHD requested that ATSDR use EtO air sampling results to assess whether EtO concentrations pose a public health hazard to the Lake County community. Between June 6, 2019 and May 1, 2020, outdoor EtO air sampling was conducted in the communities near Medline and Vantage at 12 air sampling locations through an agreement funded by the City of Waukegan, Illinois, Village of Gurnee, LCHD, and the Illinois Environmental Protection Agency (IEPA). Air sampling was not continuous and took place during three short-term phases of sampling over a total duration of about 5 months. A separate monthly EtO air sampling effort, funded by Medline Industries in compliance with Illinois state law, began in March 2020 following Medline re-opening with a new permanent total enclosure (PTE) emissions control system; this sampling is currently ongoing. ATSDR received Medline monthly sampling data through September 2023 from IEPA. Medline is taking 24-hour EtO air samples monthly at two fenceline sampling locations and two community sampling locations. The purposes of this health consultation document are:

- To estimate exposure to EtO in outdoor air for people who live (residential) and/or work (off-site worker) near Medline or Vantage.
- To estimate lifetime excess cancer risk and noncancer health effects from the EtO exposure.
- To understand background levels of EtO in ambient (outdoor) air in order to accurately evaluate EtO and lifetime cancer risk estimates and distinguish the industrial contribution to total exposure.

In September 2020, U.S. Environmental Protection Agency (EPA) informed ATSDR of two issues that have prevented U.S. EPA from putting an exact number on background EtO concentrations measured using the U.S. EPA analytical method TO-15 for analysis of volatile organic compounds including EtO [U.S. EPA 2021a; McClenny and Holdren 1999]. The first issue is the uncertainty of measuring EtO concentrations near the method detection limit (MDL). ATSDR uses a health protective statistical approach and exposure assumptions in our calculations of EtO exposure to ensure our conclusions protect public health even when there are measurements of contaminants near or below the MDL.

The second issue is positive bias (artificially high EtO concentrations) in EtO concentrations collected and analyzed in some air sampling canisters using U.S. EPA method TO-15, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. U.S. EPA released two memoranda in May 2021 summarizing studies that demonstrate the formation and growth of EtO over time in clean canisters, called the “EtO canister effect” [U.S. EPA OAR 2021, U.S. EPA ORD 2021]. In response, ATSDR conducted an independent analysis to estimate the effect of positive bias on the Lake County, Illinois sampling data. This analysis led to an adjustment of measured EtO concentrations in Lake County using a Bayesian Generalized Additive Model (GAM) which allowed for better estimates of EtO concentrations that people may have been breathing in the community (Section 4.2 and Appendix H for more information).

A third issue is the potential that an interferent during laboratory analysis of EtO air samples may result in reported higher EtO concentrations than what is actually in the air. In November 2018, U. S. EPA released a statement that results of EtO air monitoring conducted prior to October 2018 may have reported higher EtO concentrations in air due to the potential for trans-2-butene to be an interferent

during laboratory analysis. U.S. EPA stated that they made a change to the analytical method to prevent this potential issue in the analysis of future air quality samples and that they were making the technical information about this change available for other laboratories. In May 2024, U.S. EPA discussed with ATSDR the possibility that ethyl nitrite may be an interferent potentially increasing EtO in some measured samples in Lake County, Illinois. ATSDR explored whether GAM-adjusted EtO concentrations in Lake County were likely related to facility emissions or if they were more likely explained by other factors such as uncharacterized background sources or positive bias due to data quality challenges. This analysis is detailed in Section 6.1 Exposure Pathway Analysis.

2.2 Site Descriptions and Histories

Medline and Vantage are two industrial EtO emissions sources in Lake County, Illinois. Medline is a commercial sterilizer located at 1160 Northpoint Boulevard in Waukegan, Illinois. Vantage, located at 3938 Porett Dr. in Gurnee, Illinois, manufactures ingredients used in personal care, food, and industrial products. The facilities are approximately 3 miles apart. Both are in a mixed residential, industrial, and commercial area (Figure 3 and Appendix A, Figure A1).

EtO is a flammable, tasteless, colorless gas that does not have an odor at the levels that have been measured in communities [ATSDR 2020]. The majority of EtO is produced in large volumes in factories and primarily used to make other chemicals, especially ethylene glycol, the primary ingredient in antifreeze, polyester, and some consumer products [ATSDR 2020]. Outside of chemical manufacturing, smaller amounts of EtO are used to sterilize about fifty percent of sterilized medical devices in the United States. Medical devices made from certain polymers (plastic or resin), metals, or glass, or that have multiple layers of packaging or hard-to-reach places (for example, catheters) are likely to be sterilized with ethylene oxide [FDA 2023]. EtO is also used to fumigate items that cannot be sterilized by steam such as food, cosmetics, and plastic devices. EtO is classified as a human carcinogen by the inhalation route by U.S. EPA [U.S. EPA 2016], the International Agency for Research on Cancer (IARC) [IARC 2012], and the National Toxicology Program (NTP) at the National Institutes of Environmental Health Sciences [NTP 2021]. U.S. EPA considers EtO to have a mutagenic mode of action, meaning it can directly affect DNA [IARC 2012].

2.2.1 Vantage Specialty Chemicals Site History and Description

Vantage acquired the Gurnee facility from Lambent Petroferm in 2008, but the facility has handled EtO since 1988 under different owners [Vantage Specialties Inc. 2020c]. The facility uses EtO to produce ingredients that go on to be used in a variety of consumer products including household cleaners, cosmetics, and shampoo [Vantage Specialties Inc. 2020b].

The reactors in the alkoxylation area of the plant use EtO as a raw material. EtO is received at the plant in pressurized railroad tank cars and stored in an onsite pressurized storage tank. The EtO is piped into sealed reactors along with other raw materials, where they react to form chemical products. This process consumes the EtO with only a small amount of unreacted EtO left, which is then vented to a scrubber, followed by a dry bed absorption (DBA) device. The DBA was installed in April 2019, just prior to the initiation of community air sampling [IEPA 2019b]. On June 21, 2019, the Illinois Governor signed Public Act 101-0023 requiring emissions limits for facilities that use EtO for purposes other than sterilization [Illinois General Assembly 2019].

Starting in May 2019, Vantage implemented an enhanced leak detection and repair program to better detect and prevent potential EtO leaks from onsite pumps, valves, or connectors [IEPA 2019a]. In November 2019, Vantage removed a cooling tower, which was a potential source of fugitive (non-stack) EtO emissions. In December 2019, Vantage applied for a construction permit to cap annual EtO emissions to 110 pounds per year (lbs/yr) (no more than 60 lbs/yr of fugitive emissions) in compliance with new state regulations, and included requirements for monitoring, recordkeeping, and reporting [IEPA 2019c]. While Vantage had put new emissions controls in place prior the beginning of community air sampling, Vantage

was not required to reduce their emissions until their new permit took effect on December 17, 2019, when air sampling was ongoing. Under this construction permit, Vantage submits quarterly reports to IEPA that detail their total stack emissions for the year as measured by a continuous emissions monitoring system (CEMS) as well as describing and quantifying any fugitive emissions resulting from EtO leaking from components such as pumps, valves, and connectors [IEPA 2023]. Since the beginning of 2020, a third-party vendor investigates more than 700 components in the portion of the facility that handles EtO each month and reports any leaking components [Vantage Specialties Inc. 2020a]. Emissions have remained below permitted limits.

2.2.2 Medline Industries Medical Sterilizer Site History and Description

Medline uses EtO to sterilize medical equipment and devices. This facility began using EtO in 1994 to sterilize surgical trays. Medline sterilizes medical devices and surgical equipment in ten sealed sterilization chambers. Once the sterilization cycle is complete, the sterilized product is moved to one of two aeration chambers to allow EtO to off-gas from the product in a controlled environment [IEPA 2019a].

Prior to December 2019, EtO emissions from sterilization chambers were controlled by two sets of scrubbers in series, and EtO emissions from the aeration chambers were controlled by two packed-tower scrubbers and a catalytic oxidizer, all in parallel [IEPA 2019a]. On June 21, 2019, the Illinois governor signed Public Act 101-0022 requiring 100% capture of all fugitive EtO emissions within medical sterilizers, 99.9% of EtO removed from stack emissions, unannounced inspections of sterilizing facilities, and outdoor air monitoring (air sampling) taking place at minimum on a quarterly basis for EtO at sterilization facility boundaries and at community locations where modeling indicates the most potential effect [Illinois General Assembly 2019]. On May 30, 2019, the IEPA issued a construction permit to Medline to install improvements to the emission control measures and stack monitoring, allowing Medline to remain in compliance with the pending new legislative requirements [IEPA 2019d]. In late 2019 and early 2020 under the May 30, 2019 construction permit, Medline installed several new emission controls to capture fugitive emissions by placing the building under negative air pressure,
creating a “permanent total enclosure” or PTE [IEPA 2019d].

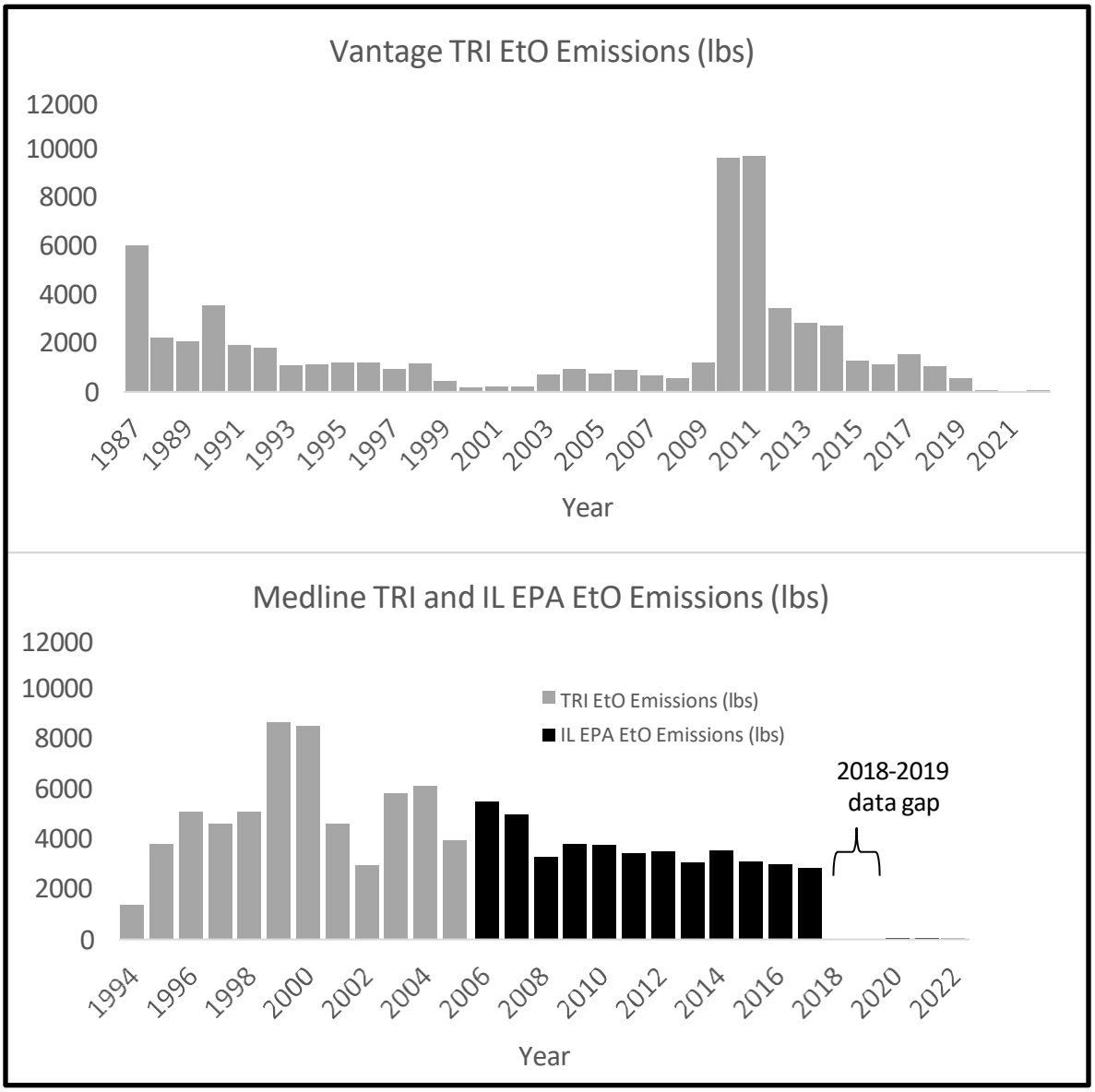
Emissions from the previous emissions control system (two packed-tower scrubbers and a catalytic oxidizer) are now ducted through two new DBAs to provide a “double scrub” and remove more EtO. DBAs are designed to remove EtO from air that has lower concentrations of EtO. DBAs also treat previously uncontrolled emissions from back vents in the sterilization area. Air from other parts of the building, such as storage areas, is treated using a packed bed scrubber [IEPA 2019a, IEPA 2019d]. The permit instituted performance requirements for control devices, a limit on emissions of 150 lbs/yr, and the installation of a CEMS with annual stack testing to verify compliance [IEPA 2019d]. Daily emissions as measured by the CEMS are reported to IEPA on a quarterly basis [IEPA 2023]. Emissions have remained below permitted limits [IEPA 2023]. The facility closed on December 13, 2019 during construction of emissions controls and began operating with these changes implemented by March 5, 2020.

2.2.3 Medline and Vantage EtO Emissions Histories

Both Medline and Vantage report emissions to the U.S. EPA’s Toxics Release Inventory (TRI). TRI is a database of industry-reported annual emissions information. TRI data are limited in that emissions may be estimated in a different fashion across different industries, facilities, and years. TRI data report the volume of EtO emitted and cannot be used to estimate EtO concentrations in the community. Further, reporting was only required starting in 1987 and does not include all facilities. Medline was not required to report to TRI and did not report emissions from 2005 to 2021 but will be required to report emissions for 2022 onward if emissions meet reporting thresholds. LCHD has published the amount of emissions per year that Medline reported to IEPA from 2006 to 2017 on their website [LCHD 2018]. Annual emissions for 2020 and 2021 could be calculated from the emissions reported from the CEMS emissions reported to IEPA [IEPA 2023]. Despite these limitations, TRI figures from Vantage demonstrate that emissions may have been higher in the past (Figure 1). Reported annual emissions rates have typically been higher at Medline

than at Vantage. Medline's annual emissions prior to 2020 have remained consistent (Figure 1). Reported emissions from 2020 onwards (after both facilities had installed new emissions controls) were markedly lower than previous emissions. Medline's current operating permit will only allow 150 pounds (lbs) of EtO emissions per year, while Vantage's permit allows 110 lbs/yr [IEPA 2019c,2019d]. Both emissions limits are significantly lower than historical reported emissions and reported emissions for both facilities are below their emissions limits.

Figure 1. Toxics Release Inventory EtO emissions from Vantage and Medline

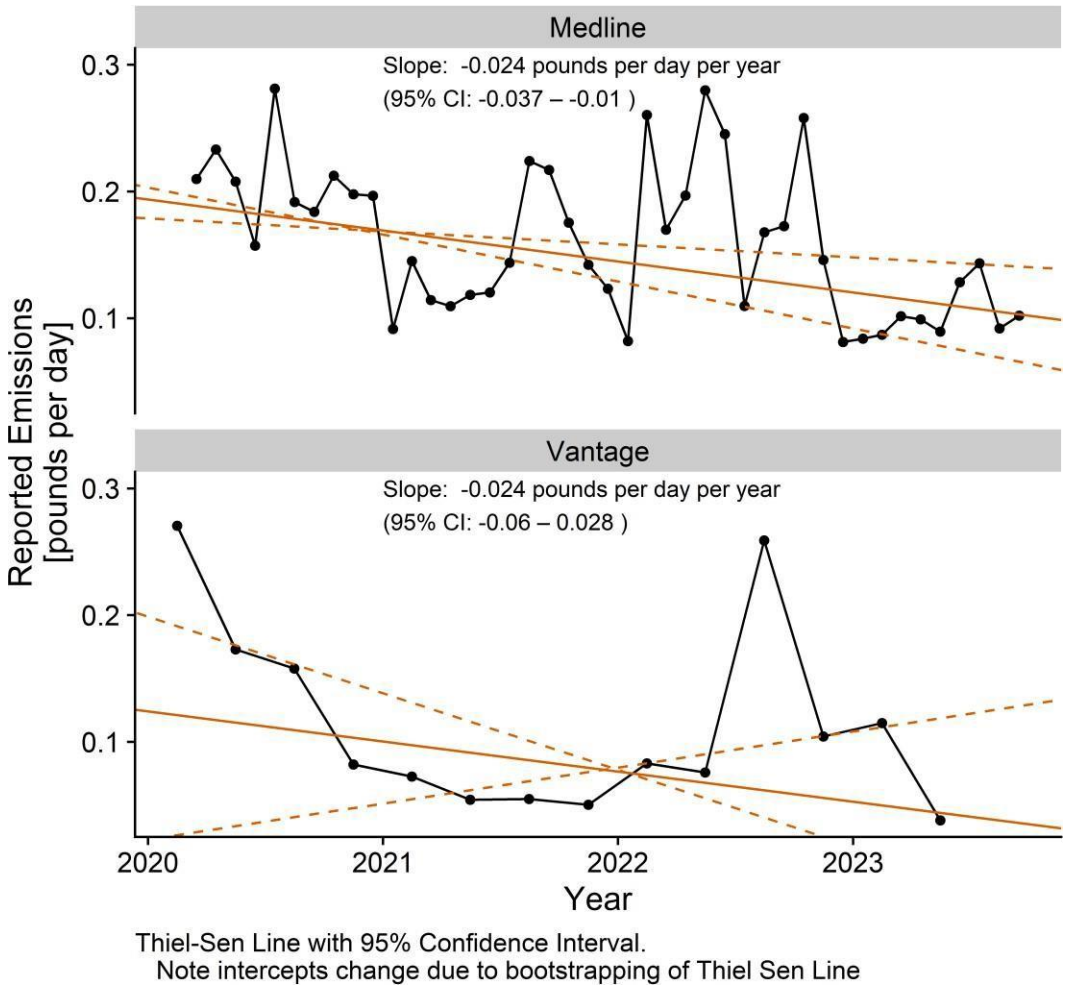


EtO = ethylene oxide; IL EPA = Illinois Environmental Protection Agency; lbs = pounds; TRI = Toxics Release Inventory

The reported emissions from the two CEMS and from the leak detection and repair program at Vantage give a more consistent and timely sense of emissions from both Medline and Vantage from 2020–2023. ATSDR examined whether there were trends in reported emissions during this time period. Figure 2 displays total emissions reported to IEPA from 2020–2023 monthly for Medline and quarterly for Vantage. Emissions are displayed in pounds per day per year. A trend line was fit to emissions over time to explore whether there were linear changes in reported emissions. The slopes of the solid orange lines on the graphs below represent the linear trends of reported emissions over time. The slopes of the dashed

lines are the upper and lower 95% confidence intervals of each trend. Both orange lines have a slightly negative (or downward) slope. The upper 95% confidence interval for Medline is less than zero, which indicates that there is a statistically significant downward trend in emissions from Medline. It is decreasing at a rate of about 8.8 pounds per year (95% confidence interval decrease of 14–3.7 pounds per year). The upper 95% confidence interval for Vantage is positive, indicating that there is not a clear linear trend for emissions over time from Vantage.

Figure 2. Reported EtO emissions in pounds per day at Medline and Vantage from 2020 to 2023



CI = confidence interval

2.3 U.S. EPA's National Air Toxics Assessment Report

The U.S. EPA National Air Toxics Assessment (NATA) was an ongoing review of air toxics in the United States. NATA is a screening tool for state, local, and tribal air agencies to identify the pollutants, emission sources and places that require further study to better understand any possible risks to public health from air toxics [U.S. EPA 2018]. As of 2022, NATA has been replaced by a similar annual effort called the Air Toxics Screening Assessment (AirToxScreen) [U.S. EPA 2022].

NATA calculates theoretical risk from national computer air modeling of emissions of 180 air pollutants from mobile sources (like cars, trucks, buses, and trains) as well as stationary sources (like factories, refineries, and power plants), yielding cancer risk estimates and noncancer hazard quotients for census tracts, counties, and states.

NATA was updated approximately every three years. The last NATA was issued August 22, 2018 and can be found at https://www.epa.gov/national-air-toxics-assessment. The report released in 2018 is called the "2014 National Air Toxics Assessment" because it is based on 2014 emissions. U.S. EPA has since released three versions of the annual AirToxScreen, with the 2019 AirToxScreen being the latest.

In 2016, U.S. EPA revised the inhalation unit risk (IUR) health guideline used to calculate lifetime excess cancer risks from breathing EtO U.S. EPA [[U.S. EPA] United States Environmental Protection Agency 2016]. The U.S. EPA inhalation unit risk is an upper bound estimate developed for evaluating the potential lifetime, excess cancer risks posed by inhalation exposure to EtO. The unit risk estimate was based on human data from a retrospective occupational epidemiology study EPA (U.S. EPA 2016). The primary sources of uncertainty in the inhalation unit risk estimate derived from the human data include the retrospective occupational EtO exposure assessment conducted for the epidemiology study, the EtO exposure-response modeling of categorical cumulative EtO exposures with cancer mortality and incidence data with a 15-year lag period in the occupational epidemiology study, and the extrapolation of high-dose occupational exposure to low-dose environmental exposures for the general public (U.S. EPA 2016). The revised IUR assumes EtO is about 30 times more potent for adults and 60 times more potent for children than the former IUR. The 2014 NATA report identified new areas of the country with higher lifetime excess cancer risk from EtO exposures due to calculating theoretical lifetime cancer risk using the new IUR. Lake County was one of 25 areas around the country identified with lifetime cancer risk in at least one census tract (a geographic area the government uses to take a U.S. population census) that is higher than 1 theoretical cancer case in 10,000 exposed people. Limitations of the NATA are similar to those of AirToxScreen and are detailed here:
https://www.epa.gov/AirToxScreen/airtoxscreen-limitations

The 2019 AirToxScreen estimated that all nearby cancer risks were less than 1 theoretical cancer case in 10,000 exposed people. The results of the 2019 AirToxScreen can be viewed here:
https://experience.arcgis.com/experience/a2eea9c204004158a85a18371d6883bc

3. Community Description

Lake County, Illinois is a primarily suburban county north of Chicago, bordered by Lake Michigan to the east and Wisconsin to the north. Waukegan, the most populous city in Lake County with about 89,000 residents, is on the shore of Lake Michigan. Gurnee is a few miles inland adjacent to Waukegan's western border and is home to about 31,000 residents [U.S. Census Bureau 2020a,2020b]. As shown on the historical wind rose on Figure A6, the most common wind direction in this area is from the southwest (toward the northeast), with significant contributions from the west, northwest, and northeast.

Vantage is adjacent to several other commercial properties to the north, south, and west of the facility.

There is a residential area with single-family homes east of Vantage, with the closest homes being about 0.2 miles from the facility (Figure 3). There is an elementary school in this community, about one-half mile east of Vantage (Appendix A, Figure A4).

The closest residential area to Medline is an apartment complex immediately across Casimer Pulaski Drive to the southeast of the facility (within 0.1 miles) (Figure 3). There is a daycare located within 0.25 miles of Medline (Appendix A, Figure A5). Other properties adjacent to Medline are commercial, including several workplaces and two hotels north of Medline. The next closest residential area is a mobile home park about 0.6 miles northeast of Medline, with 2 additional residential areas within 1 mile (Figure 3, Appendix A, Figure A5).

Approximately 6,000 people live within 1 mile of Vantage and 7,000 within 1 mile of Medline (Appendix A, Figures A2 and A3). The racial and ethnic breakdown of people living within 1 mile of Vantage and 1 mile of Medline is summarized in Table 1. The population living within 1 mile of Vantage is predominately White (62.9%), and a significant portion of the population is Hispanic (36.8%). The population living near Medline is diverse, with no clear predominant racial group. 44.7% of people living within 1 mile of Medline are Hispanic. A map of the areas within 1 mile of each facility including more detailed demographic statistics is available in Appendix A (Figure A2 and Figure A3).

Table 1. Racial and ethnic statistics of the population living within 1 mile of Medline and Vantage, estimated from the 2020 Census.

Race or Ethnicity	Percent of people within 1 mile of Vantage	Percent of people within 1 mile of Medline
White alone	62.9	22.8
Black alone	15.2	17.0
Asian alone	6.5	19.9
Some other race alone	0.3	24.4
Two or more races	15.1	15.9
Hispanic ethnicity	36.8	44.7

ATSDR's Environmental Justice Index (EJI) is a high-level mapping and screening tool used to further investigate demographic and environmental health characteristics of the communities closest to Medline and Vantage. EJI ranks give public health professionals an idea of how potential environmental burdens and social vulnerabilities in a census tract compare with the rest of the United States. Since Vantage and Medline are both near multiple census tracts, ATSDR reviewed EJI indicators for three of the census tracts within 1 mile of Vantage and three of the census tracts within 1 mile of Medline (Appendix B, Figures B1 and B2). EJI ranks are considered elevated when the EJI, which is a combination of factors related to social vulnerability and environmental burden, is higher than 75% of census tracts in the United States. The three census tracts near Vantage including the census tract where Vantage is located did not have an elevated EJI rank. The census tract containing Medline did not have an elevated EJI rank, but two census tracts with significant portions of the tracts within 1 mile east of Medline had elevated EJI ranks.

Both of the census tracts containing Vantage and Medline ranked higher than at least 75% of other U.S. census tracts on indicators related to the environmental burden of air pollution. This ranking is driven by several factors including regional air pollution problems of ground-level ozone and fine particulate matter and a high ranking for air toxics cancer risk based on results from the 2014 NATA, discussed above, which was largely driven by the modeled risk of EtO.

In the census tract containing Medline, the proportion of people who speak English less than well is higher than 90% of census tracts in the U.S. There is also a relatively high proportion of people who speak

English less than well in the two census tracts to the east of Medline. In addition, in the census tract containing Medline as well as the two census tracts to the east, a higher percentage of people do not have health insurance, and a higher percentage of units are renter-occupied than in other U.S. census tracts.

One of the EJI indicators is how much of the census tract is within a 1-mile buffer of certain types of industrial sites. For both of the census tracts containing Vantage and Medline, compared to other U.S. census tracts, a greater proportion of the area of the census tract area is within 1 mile of a facility that reports to U.S. EPA's TRI (which include both Medline and Vantage, as described above) or a facility that is covered by U.S. EPA's Risk Management Program because it uses a toxic or flammable chemical.

4. Air Sampling Data

Five EtO air sampling datasets were collected near Vantage and Medline in Lake County by four different entities. All EtO concentrations were measured by collecting outdoor air samples in metal containers called canisters over a 24-hour period and measuring the EtO concentration (how much is in the air sample).

Of the five datasets reviewed, the LCHD dataset and the ongoing Medline monthly sampling form the basis of our EtO exposure point concentrations (EPCs) and chronic health conclusions in this document, while other shorter-term datasets were used for evaluating potential health effects from short and intermediate term exposures. The source of the dataset, sampling locations, sampling dates, sample frequencies, and number of sampling locations for each dataset are described in Table 2.

Table 2. EtO air sampling datasets collected near Vantage and Medline in Lake County

Dataset: Sampling Locations	Sample Collection Date Range	Sample Frequency	Number of Sampling Locations
LCHD Phase 1: M1–M5, V1–V4, R1–R2	June 06, 2019–July 03, 2019	Every 1–3 days	11*
LCHD Phase 2: M1–M5, V1–V5, R1–R2	October 26, 2019–January 21, 2020	Every 3 days	12
LCHD Phase 3: M1–M5, V1–V5, R1–R2	April 04, 2020–May 01, 2020	Every 3 days	12
Medline Monthly Sampling: C1, CF1, F1 and F2	March 27, 2020–September 28, 2023	Once a month	4
Limited Medline Sampling: M1–M4	June 12, 2019–June 27, 2019	4 days of sampling	4
Limited Vantage Sampling: V1, V2, V6–V8	June 09, 2019–July 06, 2019	Every 3 days	5
Stop EtO Sampling	August 29, 2020–September 14, 2020	4 days of sampling	4

*Site M5 only collected one day of sampling during phase 1

4.1 LCHD EtO Air Sampling

A partnership of local and state government entities including the LCHD, the Village of Gurnee, the City of Waukegan, and the IEPA initiated sampling at five sampling locations near Medline (M1–M5), five sampling locations near Vantage (V1–V5), and two background sampling locations (R1 and R2). Sample locations are displayed on Figure 3. Figure 4 illustrates the timeline of LCHD's three phases of sampling and Medline's sampling compared to three operational periods at the Medline facility. LCHD EtO monitoring took place during the following Medline operational periods:

- Pre-closure operational period: Medline was operating prior to shutting down to install the PTE emissions control system. LCHD EtO air sampling from June to July 2019 and from October to December 2019.
- Temporary closure period: Medline was shut down to install PTE emissions control system. LCHD air sampling data from December 2019 to January 2020.
- PTE operational period: Medline re-opened in March 2020 with a new PTE emissions control system. LCHD air sampling from April to May 2020.

The LCHD EtO dataset formed the basis for evaluating chronic health risks from exposure to EtO from Vantage, as well as potential risks from exposure to EtO from Medline in the past before PTE emissions controls.

Since Vantage installed their emissions controls prior to the initiation of air sampling, all samples collected at sampling locations near Vantage would be used to evaluate current conditions at Vantage. Vantage was not required to meet the conditions outlined in their permit until December 17, 2019, which adds uncertainty as to whether the EtO air sampling conducted in 2019 is representative of current conditions. In addition, there were no sampling data to evaluate EtO concentrations prior to the installation of the DBA in April 2019.

4.2 Medline Monthly EtO Air Sampling

In June 2019, the Illinois state legislature passed Public Act 101-0022, which among other requirements, required that all commercial sterilization facilities in the state of Illinois conduct outdoor air sampling on at least a quarterly basis. As a result, Medline began an air monitoring program taking 24-hour samples once a month after they re-opened in March 2020 with additional air sampling controls. This is referred to in the consultation as the "Medline monthly sampling" dataset. Medline monthly sampling includes two fenceline sampling locations (F1 and F2) and two community sampling locations (CF1 and C1, replaced in June 2023 by C2) during the Medline PTE operational period. Sampling locations are shown on Figure 3.

The Medline monthly sampling dataset formed the basis of ATSDR's chronic health conclusions concerning current and potential future exposure to EtO for people living or working near Medline. The LCHD dataset contains limited air sampling at sampling locations from April 2020 to May 2020 near Medline after Medline re-opened (8–10 samples per sampling location) compared to the Medline monthly sampling (about 43 samples per sampling location) from March 2020 to September 2023 (Figure 4).

4.3 Background EtO Air Sampling

As described above in the LCHD air sampling section, LCHD sampling including background sampling locations R1 and R2 (Table 2). Background EtO concentrations were also sampled at LCHD's Medline sampling locations from December 13, 2019 to January 21, 2020 during Medline's closure (Table 2, Figure 4).

ATSDR also analyzed background EtO air concentration data collected every 6 days between October 2018

and September 2023 from two Ambient Air Monitoring Network sites in Cook County, Illinois. These Cook County sampling locations, Northbrook and Schiller Park, are both removed from known sources of EtO and report air contaminant concentrations to the U.S. EPA Air Quality System (AQS) database. The Northbrook air monitoring station participates in the National Air Toxics Trends Station (NATTS) network while the Schiller Park air monitoring station is part of the Urban Air Toxics Monitoring Program (UATMP). Both are operated by IEPA.

Figure 3. Map of air sampling locations near Medline and Vantage

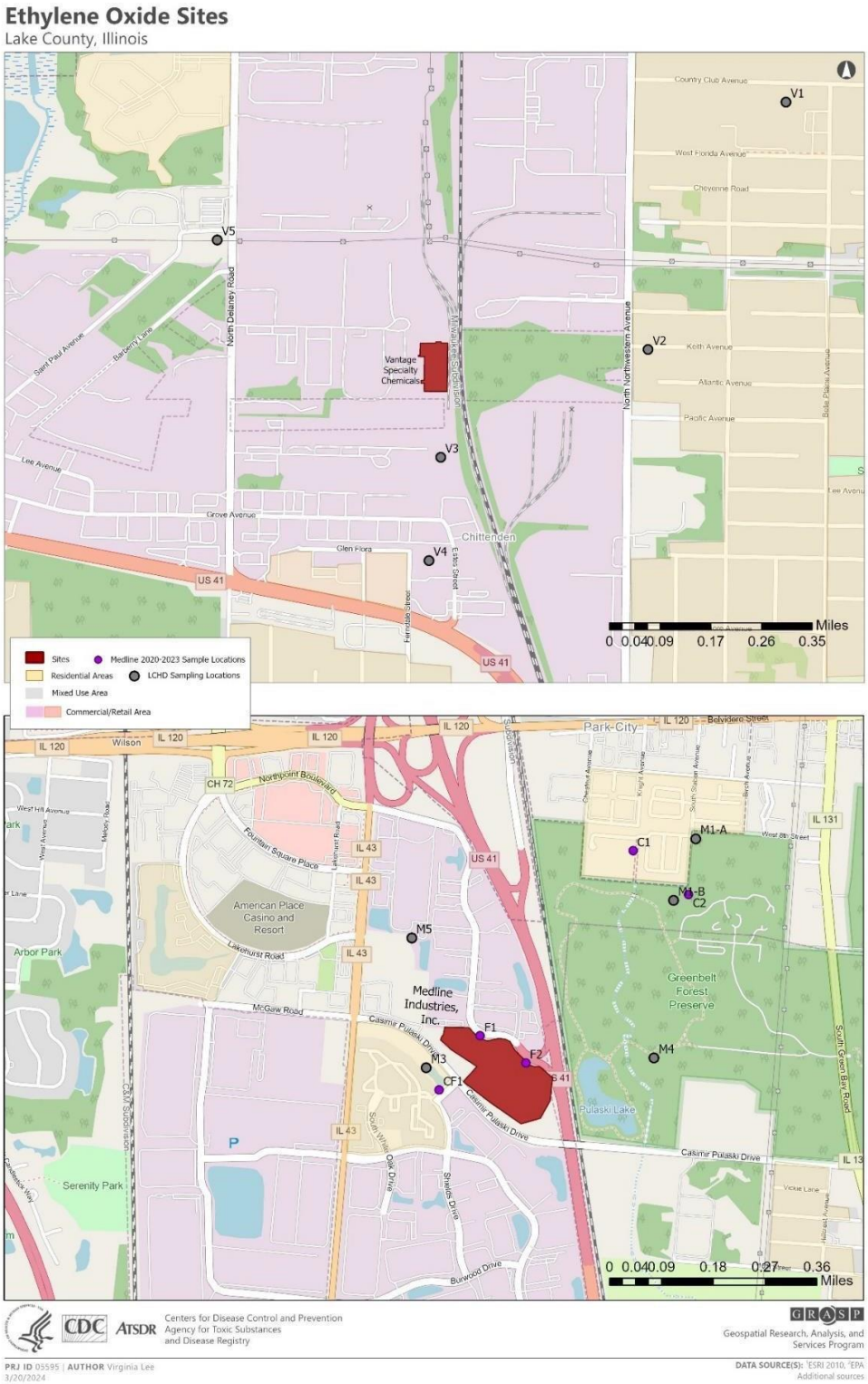


Figure 4. Medline and LCHD EtO air sampling data by Medline's operating periods

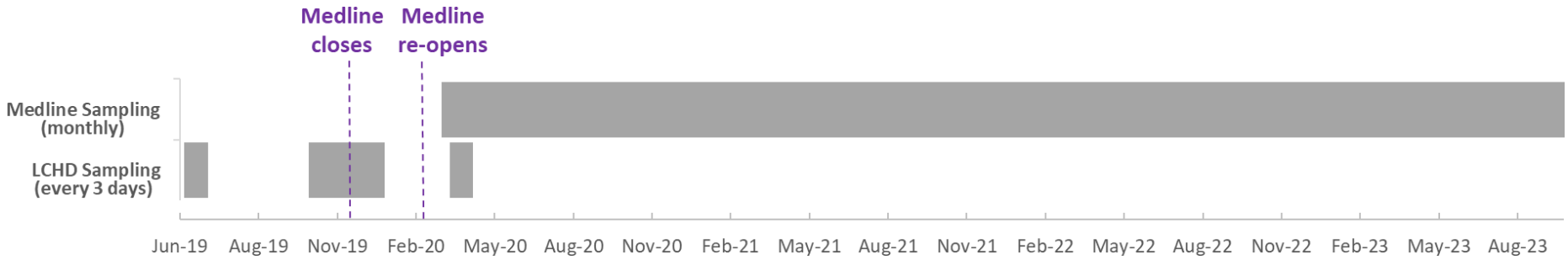


Figure 4 is a horizontal timeline from June 2019 through September 2023 with horizontal bars on the top of the timeline representing the time period of Medline monthly EtO air sampling and horizontal bars on the bottom representing the three phases of LCHD EtO air sampling. The dates Medline closed and opened are marked with vertical dotted lines. This timeline illustrates that Phase I and the first half of Phase II of LCHD's every 3-day sampling took place during Medline's pre-closure operational period. The second half of Phase II LCHD sampling took place during Medline's temporary closure period. Phase III LCHD sampling and Medline monthly sampling both took place during the PTE operating period. The Medline monthly sampling took place over a significantly longer time period (over 3 years) than the Phase III LCHD sampling (about 1 month).

5. EtO Sampling Challenges

5.1 Issues Affecting Uncertainty in Background EtO Measurements in Outdoor Air

U.S. EPA operates the NATTS program in collaboration with state, local and tribal air pollution control agencies in order to monitor air quality at 26 sites across the U.S. Since August 2022, EtO has been a tier I contaminant, meaning it is one of 19 contaminants that all NATTS are required to monitor. U.S. EPA publishes the ambient EtO air concentrations at NATTS locations and other locations throughout the U.S. on the U.S. EPA AQS online database. This EtO sampling has provided some insight into EtO concentrations away from known sources (summarized in Appendix G1), however U.S. EPA has stated that they cannot quantify background EtO concentrations [U.S. EPA 2021a].

U.S. EPA has described three issues that prevent U.S. EPA from putting an exact number on background EtO concentrations using the U.S. EPA method for EtO lab analysis (U.S. EPA analytical method TO-15) outlined briefly in a document first published to U.S. EPA's website in September 2021 [U.S. EPA 2021a]. The first issue is the uncertainty of measuring EtO concentrations near the method detection limit (MDL). Given uncertainties in measured concentrations, ATSDR uses a 95% UCL, which is a health protective estimate of the average concentration of EtO in the air that someone might breathe over many years. The second issue is from positive sampling bias due to growth of EtO in canisters used to collect air samples [U.S. EPA 2021a]. Positive sampling bias is the artificially high measurement and reporting of EtO concentrations in some outdoor air samples collected and analyzed in canisters using U.S. EPA method TO-15. U.S. EPA discovered positive sampling bias when quality assurance tests discovered the presence of low concentrations of EtO in some cleaned canisters. Positive sampling bias is caused by the "canister effect," which is the formation and growth of EtO in canisters, and results in reported concentrations of EtO that are higher than the true amount in the outdoor air being sampled. See 5.2 for ATSDR's approach for controlling for positive bias due to the canister effect.

In general, canisters are stainless steel and are lined with a coating (inert lining) on the inside that should not react to the pollutants being sampled in air. However, U.S. EPA found that certain types of lining on the inside surface of stainless-steel canisters can react with humidified air, causing the formation and growth of EtO over time. U.S. EPA's May 2021 memos summarize a study finding unacceptably high positive bias in several new electropolished canisters [U.S. EPA OAR 2021; U.S. EPA ORD 2021]. The implication of the canister effect is that it adds EtO to an air sample, causing the measured concentrations of EtO during analysis to be quantified at a higher concentration than what is actually in the air, leading to the reporting of inaccurately high measurements of EtO concentrations (positive sampling bias).

U.S. EPA reported that even though the effect of the positive bias on measured EtO concentrations is expected to be relatively small, the positive bias coupled with the greater variability of measuring low concentrations near the method detection limit imposes significant uncertainty and less confidence in the accuracy of low-level EtO concentrations [U.S. EPA 2021b]. U.S. EPA therefore concluded they do not have enough confidence in measurements of background EtO concentrations to use them to estimate risk [U.S. EPA 2021b].

U.S. EPA is continuing to investigate the formation and growth of EtO in some canisters, and the effect the positive bias has on the measurement of low-level EtO concentrations near the method detection limit (the lowest level of EtO that can be reliably measured by a given analysis method). In September 2019, U.S. EPA updated the analytical method, method TO-15A, in part to identify canisters with positive bias and to lower the method detection limit.

The third issue that affects U.S. EPA's confidence in the accuracy of measured EtO concentrations is the

potential that an interferent during laboratory analysis of EtO air samples may result in reported higher EtO concentrations than what is actually in the air. U.S. EPA shared the potential for trans-2-butene to be an interferant during laboratory analysis in November 2018 as it related to ATSDR's August 2018 letter health consultation analyzing U.S. EPA EtO air sampling data in Willowbrook, Illinois. U.S. EPA made changes to their analytical method in October 2018 to prevent trans-2-butene interference. In May 2024, U.S. EPA discussed with ATSDR the possibility that ethyl nitrite may be an interferent potentially increasing EtO in some measured samples in Lake County, Illinois.

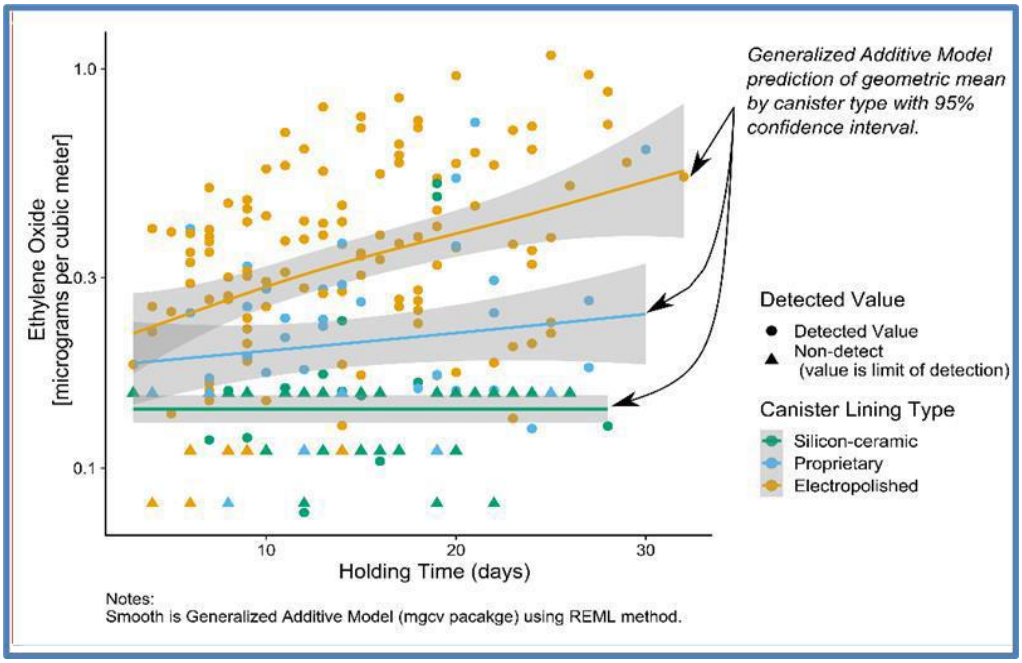
Given the potential for interference and residual positive bias from the canister effect, ATSDR took care to explore whether GAM-adjusted EtO concentrations in Lake County were likely related to facility emissions or if they were more likely explained by other factors such as uncharacterized background sources or positive bias due to data quality challenges. This analysis is detailed in section 6.1 Exposure Pathway Analysis. ATSDR found strong evidence that GAM-adjusted EtO concentrations were influenced by the facilities at several air sampling locations near Medline and Vantage.

5.2 Controlling for Positive Bias and Seasonality

To reduce the influence of positive sampling bias in EtO air concentrations measured by the Lake County Health Department, ATSDR used a Bayesian GAM analysis to adjust measured LCHD EtO air concentrations. Adjusting EtO concentrations in the LCHD dataset was important because it results in a less biased estimate of the actual EtO concentration in outdoor air someone may breathe. The GAM is discussed in greater detail in Appendix G.

ATSDR's analysis of the background EtO concentrations collected in Cook County from 2018 to 2021 found that canister lining and holding time (the amount of time between when a sample was collected and when it was analyzed) were both related to EtO concentrations (Figure 5). Samples collected in electropolished-lined canisters with longer holding times tended to have the highest EtO concentrations, likely due to EtO formation and growth in the canister, while samples collected in canisters with silicon-ceramic linings tended to have the lowest EtO concentrations (Figure 5). EtO concentrations in these silicon-ceramic canisters did not have a relationship with holding time, indicating those types of canisters were less prone to EtO formation. This finding in ATSDR's analysis of Cook County NATTS data aligns with U.S. EPA's finding that in new, electropolished canisters containing humidified air, EtO increased from below the MDL to detectable concentrations at 1 week and increased another 7–10 times after 4 or 5 weeks [U.S. EPA ORD 2021]. ATSDR also observed an apparent seasonal trend in Cook County and other locations reported in the national AQS where EtO concentrations tended to be lower in the winter and higher in the summer (Appendix G2). If not controlled for, this seasonal trend in EtO concentrations could make EtO concentrations measured during different seasons less comparable to one another. ATSDR's Bayesian GAM controlled for the effects of canister lining, holding time, and seasonal patterns in measured EtO concentrations using EtO concentrations measured at the two Cook County sites from October 2018 to March 2021.

Figure 5. EtO concentrations by canister type and holding time at Schiller Park and Northbrook air sampling locations in Cook County, Illinois October 2018–March 2021



LCHD's dataset was collected in canisters with different types of linings with varying holding times in different seasons. ATSDR used the same Bayesian GAM developed for the Sterigenics-Willowbrook Health Consultation [ATSDR 2023a] to adjust EtO concentrations in the LCHD dataset, effectively removing the influence of canister lining, holding time, and seasonal patterns (Appendix H). All analyses of LCHD data presented below are based on EtO air concentrations GAM-adjusted for canister type, holding time, and seasonal patterns.

Table C2 presents both the raw measured EtO concentrations and the GAM-adjusted EtO concentrations. The GAM adjustment results in lower EtO concentrations than the raw measured EtO concentrations because the GAM reduces the influence of positive bias introduced by the canister effect and seasonality. Note that adjusted concentrations should only be compared to other adjusted concentrations and not to raw, measured concentrations in this study. All tables and figures presented in this document display GAM-adjusted data unless otherwise noted.

Over time, NATTS have started to use a higher percentage of silicon-ceramic canisters to sample for volatile organic compounds like EtO. A subset of the newer series of silicon-ceramic canisters, introduced at Cook County sites beginning in 2021 and identified by their canister identification numbers, have measured higher EtO concentrations than in older silicon-ceramic canisters and show a relationship between holding time and EtO concentration (see Appendix H, Figure H1) indicating EtO is likely forming in some of the newer silicon-ceramic canisters. There is still no apparent relationship between EtO concentration and holding time in older silicon-ceramic canisters in circulation prior to 2021 that continue to be used at the Cook County sites.

Monthly EtO air sampling near Medline from 2020 to 2023 was conducted using exclusively silicon-ceramic canisters. EtO canisters used in Medline monthly sampling did not display a significant relationship between holding time and EtO concentration. Unlike the LCHD data, the Medline monthly sampling dataset did not include background air monitoring stations. The silicon-ceramic canister results at Cook County air sampling locations were therefore used for comparison with the Medline monthly samples. To ensure the data were comparable between the Cook County data and the Medline monthly sampling, ATSDR chose to compare EtO concentrations measured in the Medline monthly sampling to

concentrations measured in older series of silicon-ceramic canisters at Cook County which did not appear to have a positive bias (Appendix E4). ATSDR chose to use only the older silicon-ceramic canisters from the NATTS and UATMP sites in Cook County because changes in procedures in newer samples at NATTS and UATMP sites are removing canisters that exhibit growth, which changes the applicability of the GAM-estimated effects for canister effects and holding time effects for electropolished and proprietary lines canisters. However, since the Medline monthly sampling only included silicon-ceramic canisters and the Cook County sites had transitioned to using more silicon-ceramic canisters to measure EtO, ATSDR could compare EtO concentrations in the Medline monthly sampling to EtO concentrations measured in silicon-ceramic canisters at Cook County after adjusting for GAM estimated effects of seasonal patterns and holding time for older silicon-ceramic canisters (Appendix D5, E4).

The GAM adjustment ATSDR performed does not eliminate all analytic uncertainties that are present in the data, and the effects we estimated with the GAM itself have statistical uncertainties. Nevertheless, the GAM adjustment resulted in measurements at background sites that were similar to background sites in New York that utilized silicon-ceramic canisters, and produced the same seasonal trends that are present in those New York data (Appendix H, Figure H4).

6. Scientific Evaluations

6.1 Exposure Pathway Analysis

As the first step in analyzing whether a contaminant could pose a public health hazard, ATSDR considers how a contaminant at a site might go from being released from a source into the environment to entering someone's body. This analysis is called exposure pathway analysis, and it identifies whether anyone may have been exposed to a particular contaminant.

The objective of this health consultation is to determine potential health risks posed by EtO exposures in a community and to make health-protective recommendations. Therefore, we sought to distinguish EtO air exposures related to an industrial source from background EtO, EtO concentrations present in air that is not known to come from a single industrial source.

EtO in the air can come from a known source, such as Medline or Vantage. Residents and workers near Medline or Vantage could be exposed to EtO emissions from these facilities in the past, in the present, and in the future when they breathe air containing EtO emissions. ATSDR assessed whether EtO emitted from Medline or Vantage may be breathed in by people who live or work near either facility through an analysis of EtO concentrations measured at air monitoring locations near the facilities.

Vantage and Medline both made changes to improve emissions controls in 2019 and 2020, respectively. These changes mean that the amount of EtO that people living or working near Medline or Vantage may have been exposed to in the past might not be the same as the amount of EtO people are exposed to today.

The possible health effects that may occur from breathing EtO depend on how much EtO someone breathes each day and how long someone breathes a given level of EtO. In order to be exposed to EtO from Vantage or Medline, someone must live or work close enough to these facilities to breathe EtO from the facility. Factors such as how much EtO the facility is emitting and which direction the wind blows may affect how EtO spreads from the facility and where people may breathe EtO.

Background EtO concentrations are ubiquitous (commonly present) in outdoor air across the United States even away from known industrial and commercial EtO emissions sources. Lake County residents are exposed to background EtO in the outdoor air. EtO concentrations were measured in outdoor air samples in Cook County, Willowbrook, and Lake County, Illinois away from known sources or measured

when facilities were shut down. Median adjusted EtO concentrations ranged from 0.06–0.07 µg/m^3. ATSDR observed a seasonal pattern in background concentrations of EtO measured in canisters less prone to positive bias where concentrations are highest in the summer and lowest in the winter. The U.S. EPA Air Quality System (AQS) database includes 50 air sampling locations across the United States that have been measuring background EtO concentrations away from known sources since 2018, which are summarized in Appendix G. As previously mentioned, there is some uncertainty in measured EtO concentrations in the outdoor air away from industrial sources for several reasons, including 1) positive sampling bias due to the canister effect and 2) greater uncertainty in measuring concentrations near the MDL for any pollutant, including EtO [U.S. EPA 2021a]. ATSDR accounts for these issues in the EtO sampling data used to make health conclusions in this consultation through 1) GAM adjustment and 2) using a 95% UCL to estimate the EtO concentration someone may breathe in for a long time. EtO concentrations in Appendix G are not GAM-adjusted and are not directly comparable to the GAM-adjusted EtO concentrations presented in this consultation.

6.1.1 LCHD EtO Concentration Trends Near Vantage June 2019–May 2020

ATSDR analyzed LCHD's EtO air sampling during three LCHD non-continuous phases in 2019 and 2020 to explore whether there was ongoing EtO exposure for people living or working near Vantage after Vantage installed new emissions controls in April 2019. Based on LCHD air sampling at Vantage sampling locations (V1 – V5) and reference background sampling locations (R1 and R2), there is evidence Vantage may be a source of EtO at some nearby EtO air sampling locations, in addition to already existing background EtO levels. To make this determination, ATSDR evaluated trends in EtO concentrations by exploring EtO concentrations over time, comparing EtO concentrations measured near Vantage to background sites R1 and R2, and visualizing EtO concentrations at air sampling locations by wind direction and wind speed.

EtO air concentrations at 12 sampling locations in the LCHD dataset, including sample locations near Vantage, near Medline, and removed from known sources (background), are presented in Appendix C1 in Table C2. See Figure 3 for a map of LCHD sampling locations.

Adjusted median EtO concentrations at sampling locations near Vantage ranged from 0.05 µg/m^3 at V4 to 0.07 µg/m^3 at V1 (Appendix C1, Table C2). On November 13, 2019, both V1 and V2 sampling locations recorded their maximum adjusted EtO concentrations (5.3 and 8.2 µg/m^3, respectively). On that day, the wind was from the southwest and blowing from Vantage towards the V1 and V2 monitors. Several additional apparent elevations in EtO concentrations appeared at V1, V2 and V3 between November 4 and November 10, 2019. Figures D1 and D2 in Appendix D1 present a time series of EtO concentrations at V1-V5, R1 and R2, which display the higher EtO concentrations in early November 2019.

Based on analysis of the LCHD dataset, ATSDR concluded that Vantage contributed to EtO exposure for people who lived nearby. ATSDR arrived at this conclusion based on the following evidence from the LCHD dataset:

1. GAM-adjusted EtO concentrations at LCHD Vantage air sampling locations V1, V2, V3 and V5 are statistically elevated above concentrations at R1 and R2 (Appendix E2).
2. Polar plots indicate that Vantage may be adding to EtO concentrations particularly in the nearby commercial area (monitor V3) and potentially in the nearby residential area (monitor V5) (Appendix D3).

These findings suggest that in spite of the challenges in measuring EtO outlined in the previous section, GAM-adjusted EtO concentrations are likely related to facility emissions. In early November 2019, EtO concentrations were higher in several samples from multiple sampling locations near Vantage, than those measured during the rest of the sampling period (Appendix D1). It is uncertain whether the higher concentrations represented an unusual circumstance (i.e., removal of cooling tower) that happened to be reflected in the monitoring data or if episodic increases in exposure would be common enough to

influence long-term health risk. The apparent elevations and the fact that Vantage continued to make changes that likely effected their EtO emissions during air sampling add uncertainty as to whether the adjusted EtO concentrations represent the average concentration of EtO someone living or working near Vantage may be exposed to for many years.

Sampling locations R1 and R2 were meant to capture background levels of EtO. During the course of air sampling, the raw median EtO concentrations measured at R1 and R2 were 0.17 and 0.11 µg/m^3, respectively (Appendix C1, Table C2). This is within the range of raw background EtO concentrations observed at other sites across the United States away from known sources (Appendix G1, Table G1). The adjusted median background EtO concentrations at R1 and R2 were both 0.06 µg/m^3. These adjusted median background EtO concentrations are similar to median background adjusted EtO concentrations at Cook County and EtO concentrations at background sampling locations in other states that use types of canisters that are less prone to the canister effect (Appendix C1 Table C2; Appendix H Table H3).

6.1.2 EtO Concentration Trends near Medline in LCHD and Medline Monthly Sampling

At Medline, ATSDR investigated how operation and emission control changes at the Medline facility influenced EtO concentrations over time. ATSDR used the LCHD dataset, collected during three non-consecutive phases from June 2019 to May 2020, to make conclusions about EtO exposures occurring during Medline's pre-closure operational period prior to December 13, 2019. The LCHD dataset also includes air sampling that took place during Medline's closure from December 13, 2019 to March 4, 2020, and during Medline's operational time period with the PTE from April 4, 2020, to May 1, 2020.

Based on analysis of the LCHD dataset during the pre-closure operation period, ATSDR concluded that Medline was contributing to EtO exposure for people who lived and worked nearby in the past. ATSDR arrived at this conclusion based on the following evidence from the LCHD dataset:

1. EtO concentrations at the LCHD sampling location M3 were statistically significantly elevated during the pre-closure operation period compared to EtO concentrations at the same sampling location when the facility was shut down (Appendix D4, E3).
2. EtO concentrations at sampling locations M1, M3, and M4 were statistically significantly elevated above background EtO concentrations at R1 and R2 when Medline was operating pre-closure (Appendix D5, Appendix E2).
3. Polar plots (visualizations of EtO concentrations by wind direction and wind speed) indicate concentrations were higher when the wind was blowing from the direction of the facility towards sampling locations M1, M3, and M4 (Appendix D6).

The combination of the elevation of M1, M3 and M4 above background EtO concentrations measured simultaneously within the same dataset combined with the evidence of the relationship between wind direction and EtO concentrations from the polar plots strongly suggest that GAM-adjusted EtO concentrations were related to facility emissions in the past at those sampling locations.

ATSDR conducted analyses of the Medline monthly EtO sampling data collected from March 2020 to September 2023 to make conclusions about the operational time period with the PTE (after March 5, 2020). There are considerably more EtO air samples in the Medline monthly sampling dataset than the one month of sampling in the LCHD dataset (April 4, 2020–May 1, 2020) during the PTE operational time period. Based on the analysis of Medline monthly air sampling, ATSDR concluded that there is ongoing exposure to EtO from Medline for workers who work in locations immediately adjacent to the Medline property and for people who live in the two closest residential neighborhoods located within one-half mile of Medline. The supporting evidence included:

1. EtO concentrations at all four Medline monthly sampling locations were statistically significantly greater than background EtO concentrations at Northbrook and Schiller Park (Appendix D5,

Figure D6, Appendix E2).

2. EtO concentrations were higher at sampling locations closer to Medline. EtO concentrations were statistically significantly higher at the two fenceline sampling compared than at either of the community sampling locations. CF1, the closer community location, was statistically significantly higher than combined results from C1 and C2 (C1/2), the further community locations. (Appendix D5, Appendix 3, Table E5).
3. The polar plots of Medline monthly EtO concentrations at the two fenceline sampling locations (F1 and F2) show clear indication of facility EtO contribution, with some evidence of facility contribution from the polar plots at the two community sampling locations (CF1 and C1/2) (Appendix D4).

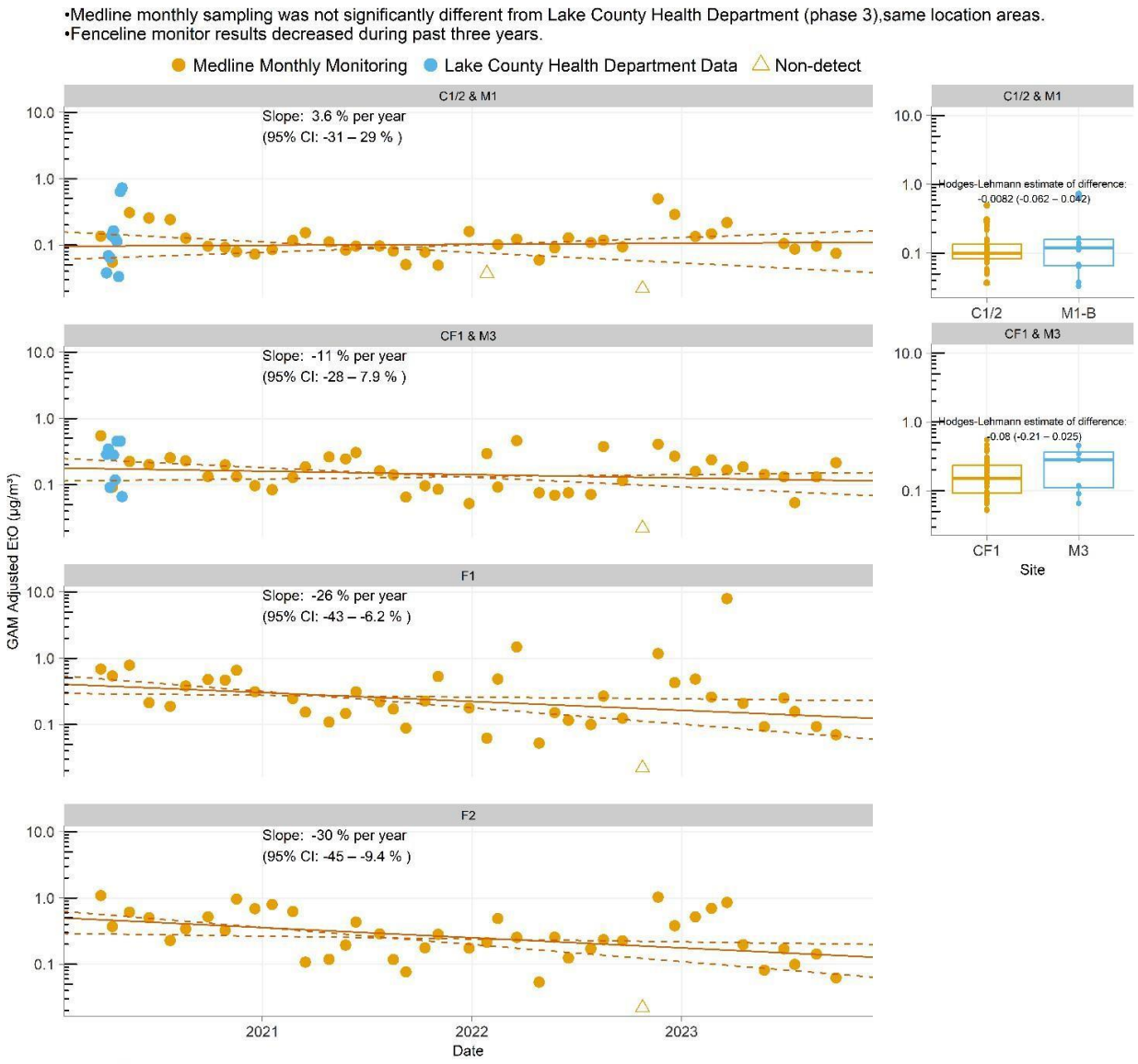
ATSDR is uncertain precisely how far from Medline EtO concentrations may be elevated during the PTE operation period since all four Medline monthly sampling locations within 0.6 miles of the facility were statistically significantly elevated above background. Both Medline emissions and EtO concentrations at the two fenceline sampling locations trended downwards (Figure 2, Appendix F2). For sites F1 and F2, the EtO concentrations typically decreased 26% and 30% per year, respectively (Figure 6, Appendix D, Figure D5).

The trends ATSDR observed at the fenceline sampling locations, including the elevation in the EtO concentrations above EtO concentrations at the community sampling locations, higher EtO concentrations being recorded on days when the wind was blowing from the direction of the facility and the fact that both Medline emissions and EtO concentrations at the fenceline sites trended downwards over the 2020-2023 time period all strongly suggest that EtO concentrations at the fenceline are closely linked to emissions from Medline. The two community sampling locations did not have the same trend downward in EtO concentrations over time (Figure 6). CF1, the closer sampling location was elevated over the farther C1/C2 community location where EtO concentrations were measured simultaneously at the same laboratory, which provides evidence that EtO concentrations at CF1 are related to facility emissions. At C1/2, EtO concentrations were elevated above background EtO concentrations at Northbrook and Schiller Park. The EtO concentrations at C1/2 were measured on different days and analyzed at different laboratories than Northbrook and Schiller Park, which adds uncertainty to this comparison. Our analysis cannot exclude the possibility that Medline may be influencing EtO concentrations at C1/2.

6.1.3 EtO Concentration Trends and Measurement Uncertainty

U.S. EPA has noted several potential sources of uncertainty in measuring EtO as described in section 5.1 including the uncertainty of measuring contaminants at concentrations near the MDL, positive sampling bias from the canister effect, and the potential for other chemicals in the air to act as interferents (be mis-identified as EtO). In ATSDR ‘s exposure pathway analysis, multiple lines of evidence showed that at some sampling locations near Vantage and near Medline adjusted EtO concentrations were related to emissions from the facility. The relationship between facility emissions and EtO concentrations observed at certain sampling locations indicates that EtO sampling data analyzed in this consultation provides information about exposure, even considering the potential limitations of the data.

Figure 6. Time trends of EtO concentrations at LCHD and Medline monthly sampling locations from 2020 to 2023 and comparisons EtO concentrations at co-located LCHD and Medline sampling locations



GAM adjusted Medline ethylene oxide (EtO) data shown by sampling location.
Replicate samples were averaged at each site and date. Regression line is Thiel-Sen Line with 95% Confidence Interval. (Note intercepts change due to bootstrapping of Thiel-Sen Line)
µg/m³: micrograms per cubic meter
Non-detect values are plotted at the limit of detection.

6.2 Screening Analysis

ATSDR screened chemicals for further evaluation by comparing EtO concentrations against ATSDR health-based comparison values (CVs). ATSDR inhalation CVs are health-protective air concentrations for a given duration of exposure to the contaminant that are not expected to cause harmful health effects. CVs may be developed for acute (less than 2 weeks), intermediate (2 weeks up to 1 year), or chronic (1 year or more) exposure durations.

Exposure to chemical concentrations detected below ATSDR's CVs are not expected to cause harmful health effects in people. Therefore, concentrations below CVs are not evaluated further. Contaminant concentrations that exceed CVs do not indicate that a health risk is likely but rather that the pollutant should be evaluated further to determine the potential public health impact.

The ATSDR CV for chronic exposure to EtO is the ATSDR cancer risk evaluation guide (CREG), which is based on U.S. EPA's IUR for EtO [ATSDR 2022]. ATSDR CREGs are estimates of the carcinogen concentrations that could cause one additional case of cancer in one million people exposed over a lifetime. The CREG for EtO considers early-life susceptibility to EtO and applies weighting factors known as age-dependent adjustment factors (ADAFs), as EtO has been designated as a mutagen (a chemical that causes genetic mutations). ATSDR's CREG for EtO is 0.00021 µg/m^3.

The ATSDR acute and intermediate CVs for EtO are based on ATSDR's acute and intermediate minimal risk levels (MRLs). An inhalation MRL is an estimate of the contaminant concentration that someone can breathe over a specific duration that is not expected to cause noncancer health effects. ATSDR's acute MRL is 720 µg/m^3, and the intermediate MRL is 126 µg/m^3 [ATSDR 2020].

In Table 3, ATSDR compared EtO concentrations over the appropriate duration of exposure to each CV. The maximum 24-hour concentration at each air sampling location was compared to the acute and intermediate CV [ATSDR 2022]. The maximum EtO concentrations did not exceed the acute and intermediate CV at any of the sampling locations. Therefore, acute, and intermediate exposure to EtO concentrations do not pose a public health hazard and were not evaluated further. For chronic EtO exposure, ATSDR screened 95% upper confidence limit of the mean EtO concentrations (95% UCL) at each sampling location against the ATSDR CREG for EtO. The CREG was exceeded at all sampling locations. Therefore, additional health evaluation of the potential health risks associated with chronic exposure to EtO in the air near Vantage and Medline in Lake County follows below.

6.3 EtO Health Effects Evaluation

To determine whether chronic exposure to EtO in the outdoor air near Vantage and Medline could adversely affect public health, ATSDR conducted an in-depth toxicological analysis by evaluating and integrating site- specific EtO air concentrations and EtO-specific noncancer and cancer health effects data from toxicologic and epidemiologic studies. This toxicological analysis assesses exposure variables (such as site-specific EtO exposures, duration, and frequency, and age of exposed population) to determine whether EtO air concentrations are present at levels that might affect public health. The findings from this toxicological analysis help ATSDR determine health conclusions and recommendations for public health actions.

To determine the site-specific EtO air concentrations that people working and living near Vantage and Medline are exposed to, ATSDR estimated GAM-adjusted EtO EPCs at each sampling location using:

- Vantage LCHD data during all three phases of sampling
- Medline LCHD data and Medline monthly sampling data during each of Medline's three operation periods (pre-closure, temporary closure, and PTE operation)

The EPCs were estimated using the 95% UCL EtO concentration at each sampling location, which is a conservative estimate of the average concentrations that provides reasonable confidence the true average is not underestimated.

Most information on health effects from chronic inhalation exposure to EtO is derived from animal studies or epidemiological and case studies of workers in occupational settings. This section presents ATSDR's in-depth toxicological review of the health effects (both noncancer and cancer) from chronic inhalation of EtO.

Table 3. Screening analysis of adjusted EtO air concentrations (µg/m³) by sampling locations and ATSDR EtO comparison values for the LCHD and Medline monthly datasets

Station	Operating Status	Study Average [95UCL*] µg/m³	Cancer CREG†: 0.00021 µg/m³ Comparison	Intermediate EMEG‡,§: 126 µg/m³ Comparison	Maximum 24-hour Sample µg/m³
M1	Operating, Pre-closure	0.15 [0.21]	Exceeds	No exceedance	0.74
M1	Closed	0.08 [0.1]	Exceeds	No exceedance	0.14
M1	Operating, PTE	0.21 [0.45]	Exceeds	No exceedance	0.72
M2	Operating, Pre-closure	0.072 [0.094]	Exceeds	No exceedance	0.23
M2	Closed	0.061 [0.078]	Exceeds	No exceedance	0.16
M2	Operating, PTE	0.11 [0.15]	Exceeds	No exceedance	0.38
M3	Operating, Pre-closure	0.73 [1.3]	Exceeds	No exceedance	7.30
M3	Closed	0.063 [0.079]	Exceeds	No exceedance	0.15
M3	Operating, PTE	0.26 [0.41]	Exceeds	No exceedance	0.46
M4	Operating, Pre-closure	0.16 [0.23]	Exceeds	No exceedance	0.88
M4	Closed	0.069 [0.084]	Exceeds	No exceedance	0.13
M4	Operating, PTE	0.15 [0.21]	Exceeds	No exceedance	0.38
M5	Operating, Pre-closure	0.07 [0.11]	Exceeds	No exceedance	0.21
M5	Closed	0.08 [0.099]	Exceeds	No exceedance	0.15
M5	Operating, PTE	0.27 [0.45]	Exceeds	No exceedance	1.70
F1¶¶	Operating, PTE	0.48 [0.89]	Exceeds	No exceedance	8.00
F2¶¶	Operating, PTE	0.36 [0.43]	Exceeds	No exceedance	1.10
CF1	Operating, PTE	0.18 [0.21]	Exceeds	No exceedance	0.55
C1/2	Operating, PTE	0.13 [0.15]	Exceeds	No exceedance	0.50
R1	N/A	0.081 [0.11]	Exceeds	No exceedance	0.78
R2	N/A	0.071 [0.1]	Exceeds	No exceedance	0.83
V1	Operating	0.17 [0.37]	Exceeds	No exceedance	5.10
V2	Operating	0.13 [0.64]	Exceeds	No exceedance	8.50
V3	Operating	0.13 [0.2]	Exceeds	No exceedance	1.90
V4	Operating	0.076 [0.15]	Exceeds	No exceedance	1.20
V5	Operating	0.079 [0.11]	Exceeds	No exceedance	0.43

* 95UCL is 95% upper confidence limit of the mean EtO concentration

† ATSDR cancer risk evaluation guide (CREG)

‡ ATSDR intermediate environmental media evaluation guide (EMEG); noncancer effects

§ Since the 24-hour maximum, average, or 95UCL values did not exceed either the intermediate or acute EMEG comparison values, further screening was not continued.

¶ ATSDR acute EMEG; noncancer effect

¶¶The adjusted UCLs used for screening did not factor in the downward trend of EtO concentrations over time at F1 and F2 and is therefore different than the UCL used to calculate cancer risk estimates at these locations

6.3.1 Noncancer Health Effects Evaluation

As part of the in-depth toxicological evaluation of noncancer effects from chronic exposure to EtO in the outdoor air near Vantage and Medline, ATSDR scientists identified and examined the relevant noncancer health effects data from EtO air exposure in animals and worker studies. The scientists then evaluated the relevant available toxicological evidence to determine the potential for noncancer effects by comparing site-specific EtO concentrations at each sampling location to the appropriate EtO concentrations with observed noncancer health effects in animal studies.

Four chronic animal inhalation studies are reported in ATSDR's Toxicological Profile for Ethylene Oxide. These studies demonstrated adverse effects at duration adjusted EtO concentrations of 18,000 to 37,800 µg/m^3. Breathing EtO at very high levels may affect several different body systems. The limitations in these animal studies prevented ATSDR from deriving a chronic inhalation ATSDR MRL (health guideline) for EtO [ATSDR 2020].

Some of the effects observed in these chronic animal studies are supported by intermediate duration animal studies reported in the toxicological profile. Reduced body weight gain and reduced survival in the offspring of pregnant rodents were observed at a slightly lower duration-adjusted concentration (12,000 µg/m^3) in an intermediate study. No adverse health effects were observed at a duration-adjusted concentration of 3,800 µg/m^3 in the same study.

Case studies in workers exposed to EtO concentrations several thousand times higher than concentrations measured in Lake County reported neuropathy (weakness, numbness, and pain in the extremities), impaired hand-eye coordination, cognitive dysfunction (deficits in normal thought function), memory loss, headache, and hand numbness. These studies were not used to derive a chronic MRL because they do not have adequate exposure-response data and were considered insufficient to establish a causal relationship between chronic EtO exposure and neurological effects in humans [ATSDR 2020].

Possible associations between breathing EtO at work and pregnancy loss have been explored in epidemiological studies of sterilizer workers. Limitations in these studies preclude drawing conclusions about whether EtO can cause miscarriage or other harmful effects related to pregnancy [ATSDR 2020].

The highest GAM-adjusted EtO EPC at any air sampling location in Lake County from June 2019 to September 2023 was 1.3 µg/m^3 at the M3 sampling location during the pre-closure operation period. The highest EtO EPC in Lake County is more than 10,000 times less than the lowest EtO concentration (12,000 µg/m^3) where health effects were observed in animal studies. ATSDR therefore concludes that noncancer health effects are not expected for people living or working near either Vantage or Medline.

6.3.2 Cancer Health Effects Evaluation

Various agencies have classified EtO as a human carcinogen by the inhalation route of exposure, including the NTP at the National Institutes of Environmental Health Sciences, U.S. EPA, and IARC [NTP 2021, U.S. EPA2016, IARC 2012]. The classification of EtO as a carcinogen by these three agencies is based on evidence of carcinogenicity in workers breathing EtO, which is summarized below, evidence of carcinogenicity in experimental animal studies, which includes evidence of lymphoid and mammary cancers, and evidence that EtO causes changes to DNA and other precursor events in humans that might be expected to lead to cancer [NTP 2021, U.S. EPA 2016, IARC 2012].

In December 2016, U.S. EPA finalized the "Evaluation of the Inhalation Carcinogenicity of Ethylene Oxide" report that provides scientific support and rationale for the hazard and dose-response assessment pertaining to the carcinogenicity from chronic inhalation exposure to EtO [U.S. EPA 2016]. U.S. EPA used epidemiological studies based on a National Institute for Occupational Safety and Health (NIOSH) cohort of workers exposed to

EtO to develop the IUR for inhalation exposure to EtO [Steenland, Whelan, Deddens, Stayner and Ward 2003, Steenland, et al. 2004]. This occupational study is a high-quality large size cohort design with males and females, adequate follow-up, absence of known confounding exposures, and individual worker exposure estimates from a high-quality exposure assessment [U.S. EPA 2016]. Workers were exposed to a measured geometric mean EtO concentration of 4,000 µg/m^3 and a modeled geometric mean of 2,100 µg/m^3 [Hornung, et al. 1994].

Steenland, Stayner and Deddens [2004] evaluated cancer mortality in the NIOSH cohort of 18,235 men and women workers. There were no statistically significant increases in mortality in the overall cohort from any cancer compared to the general U.S. population. Workers with the highest cumulative exposures and longest latency (time between EtO exposure and observed mortality) had statistically significant excess mortality for lymphoid cancers (non-Hodgkin lymphoma, myeloma, and lymphocytic leukemia) as a group in males and female breast cancer. The standardized mortality ratio (SMR) for non-Hodgkin lymphoma was statistically significantly elevated in the highest cumulative exposure group of males compared to the U.S. population, but there were not statistically significant elevations for myeloma or lymphocytic leukemia individually [Steenland, Stayner and Deddens 2004].

Steenland, Whelan, Deddens, Stayner, and Ward [2003] studied female breast cancer incidence in a subset of the original NIOSH cohort described above; this cohort included 7,576 women who were employed at one of the 14 sterilization facilities for at least one year. The authors concluded the data suggest that EtO exposure is associated with breast cancer, but the causal interpretation is weakened due to some inconsistences in exposure-response trends, possible biases due to lack of response from study participants, and incomplete cancer ascertainment [Steenland, Whelan, Deddens, Stayner, and Ward 2003].

Mikoczy, et al. [2011] studied mortality and incidence from breast and lymphohematopoietic cancers in 2,171 male and female Swedish workers in sterilizing facilities over 34 years (1972–2006). The study indicated there was a positive-response relationship with breast cancer with increased rate ratios for the upper two quartiles of cumulative exposure [Mikoczy, Tinnerberg, Björk, and Albin 2011].

The low-level outdoor air EtO concentrations measured near Vantage and Medline in Lake County are over a thousand times lower than EtO concentrations that workers were exposed to in the worker studies described above. However, these occupational epidemiologic studies represent health effects that occurred in people exposed to high levels of EtO at work over a long period of time. There have not been studies evaluating the health effects from community exposures to low-level EtO concentrations, which would include sensitive populations such as developing babies (in utero) and young children. Worker studies provide the best available information about the risk of cancer due to EtO exposure.

The primary sources of uncertainty in the inhalation unit risk estimate include the retrospective occupational EtO exposure assessment conducted for the epidemiology study, the EtO exposure-response modeling of categorical cumulative occupational EtO exposures with cancer mortality and incidence data with a 15-year lag period in the occupational epidemiology study, and the extrapolation of high-dose occupational exposure to low-dose environmental exposures for the general public [U.S. EPA 2016].

Lifetime Excess Cancer Risk Calculations

ATSDR calculated upper bound population-based estimates of lifetime excess cancer risk at each sampling location using the EPC (95% UCL of GAM-adjusted EtO concentrations), a reasonable maximum exposure (RME) scenario, and U.S. EPA's IUR to guide public health decisions. The calculated lifetime excess cancer risk estimates are designed to be protective of health, as they use reasonable upper bound exposure estimates and are likely an overestimate of the potential risk. The actual cancer risks from EtO exposure may be lower than the calculated lifetime excess cancer risk estimate. Lifetime excess cancer risk estimates form the basis for

determining whether harmful health effects are possible and as a guide in making public health conclusions and recommendations, not to predict the number of cancers in a community.

The ATSDR calculated lifetime excess cancer risk estimates from EtO exposure are not actual cancer cases, do not represent the actual cases of cancer in Lake County communities, and are not estimates of an individual's cancer risk. Therefore, ATSDR cannot determine an individual's risk of developing cancer. An individual's lifetime risk of developing cancer depends on many factors other than exposure to EtO. Any risk of developing cancer from EtO exposure is in addition to an individual's risk from other factors.

ATSDR uses calculated estimates of lifetime excess cancer risk as a tool for making recommendations to reduce exposure and protect public health. ATSDR considers any lifetime excess cancer risk estimate greater than 1 excess cancer case in 10,000 persons exposed as an elevated cancer risk and a health hazard with the potential for an increased cancer risk. Elevated lifetime excess cancer risk indicates chronic exposure levels are high enough for there to be a reasonable possibility EtO exposure over many years could cause cancer in members of the exposed population. As such, an elevated cancer risk requires a recommendation to minimize exposure to protect public health. Lifetime excess cancer risks greater than 1 in 10,000 do not necessarily mean any given individual will develop cancer due to exposure. For lifetime excess cancer risk estimates between 1 excess cases of cancer in 1,000,000 and 1 excess cases of cancer in in 10,000, ATSDR scientists use professional judgment to determine whether a cancer risk may exist.

These ATSDR calculated lifetime excess cancer risks from EtO exposure are estimated excess cancer risks in addition to the already existing lifetime risk of developing cancer in a lifetime from all causes. The lifetime risk of developing cancer from all risk factors during a lifetime is based on the incidence of cancer cases diagnosed and reported to state cancer registries across the United States. Therefore, ATSDR estimated excess cancer risks for residents and workers breathing EtO over their lifetime are estimates of excess cancer risk in addition to the already existing lifetime cancer risk of 1 out of every 2 men and 1 out of every 3 women in the United States developing cancer during their lifetime. Another example is the lifetime risk that a woman in the United States will develop breast cancer during her lifetime is 1 out of every 8 women. This means a woman has about 1 chance in 8 of developing breast cancer.

To estimate the long-term (chronic) average EtO air concentration people are exposed to from breathing EtO over their lifetime, ATSDR calculated EPCs using the 95% UCL of GAM-adjusted EtO concentrations at each sampling location during each operation time period. A 95% UCL is a conservative estimate of the average EtO concentration in the air that someone might breathe over many years. The 95% UCL provides reasonable confidence that the true average EtO concentrations is not underestimated. Vantage EPCs were calculated for each sampling location (V1-V5) from the LCHD EtO air sampling dataset collected from June 2019 to May 2020 after the installation of a new DBA emissions control device at Vantage in April 2019 (Table 4). The Medline EPCs were calculated for each sampling location (M1-M5) from the LCHD air monitoring dataset during Medline's pre-closure operation period (June 2019–December 2019), the temporary closure period (December 2019–March 2020), and the PTE operation time period (April 2020–May 2020) and from the Medline monthly air sampling dataset for each sampling location (C1/2, CF1, F1 and F2) during the PTE operation time period (March 2020 – September 2023) (Table 5). One EPC was calculated at each of the LCHD background sampling locations, R1 and R2, for the entire 2019 to 2020 LCHD sampling period to serve as a comparison for Vantage EPCs (Table 4). For Medline, background comparison EPCs were calculated for each background sampling locations R1 and R2 during each of the three different Medline operating periods. (Table 5).

For the purposes of estimating a lifetime excess cancer risk from chronic exposure to EtO concentrations, ATSDR used RME assumptions about how long, how often, and how much EtO residents and off-site workers may breathe. ATSDR's RME scenario is a continuous residential exposure duration of 24 hours a day for 33 years over a lifetime of 78 years. When exposure is ongoing or is greater than 33 years in the past, ATSDR calculates lifetime excess cancer risks based on 33 years of exposure using age-dependent adjustment

factors (ADAFs). ADAFs are used to weight risk for exposure of the youngest age ranges (infants and children) to mutagenic compounds like EtO. Mutagens are pollutants that can cause changes in the DNA of the exposed individual which can result in cancer. Pollutants that cause cancer from a mutagenic mode of action may result in a higher risk of cancer for children exposed in early life than for adults. For past exposures at Medline, ATSDR assumed 25 years of exposure instead of 33 years because the Medline facility opened in 1994. For an off-site worker scenario (workers who regularly work near, but not at Medline or Vantage), ATSDR assumed an 8.5-hour workday, 250 days a year, for 20 years [ATSDR 2021]. See Appendix G for detailed assumptions for all scenarios.

ATSDR also uses U.S. EPA's IUR which calculates upper bound lifetime, excess cancer risks. The IUR is an upper bound estimate developed for evaluating the potential lifetime, excess cancer risks posed by inhalation exposure to EtO. The unit risk estimate is based on human data from a retrospective occupational epidemiology study.

The upper bound assumptions in the EPC, RME, and IUR allow ATSDR to account for uncertainty in measurements by using protective, reasonable upper bound EtO exposure estimates to calculated lifetime excess cancer risk estimates as the basis for determining whether harmful health effects are possible. The true lifetime excess cancer risk estimate may be less than what ATSDR calculated.

ATSDR also presents in the tables below lifetime, excess cancer risks calculated using central tendency exposure (CTE) estimates, which use average estimates of how long someone may breathe EtO, how often someone may breathe EtO and how much EtO someone might breathe over their lifetime. The CTE scenario assumes exposure to EtO for the average person who lives nearby occurs as an adult, assumes exposure lasts for 12 years, which is the average time someone in the U.S. lives in one place, and assumes people are breathing the average EtO concentration rather than the 95% UCL. For workers, the CTE scenario assumes the average person works at a given job for 5 rather than 20 years.

Vantage Lifetime Excess Cancer Risk

Based on GAM-adjusted EtO concentrations measured from June 2019 to May 2020 after Vantage installed emission controls, lifetime excess cancer risks from chronic EtO exposure for residents near Vantage ranged from 20 in 10,000 at the closest residential area (0.2 miles from the site) to 3 in 10,000 within 0.6 miles northwest of the site (Table 4). From these lifetime excess cancer risks estimates, ATSDR concluded that breathing air for many years with adjusted EtO concentrations measured from June 2019 to May 2020 when pollution controls may not have been fully operational, may increase the risk of certain types of cancer for residents living within 0.6 miles of Vantage. Long-term exposure to the adjusted EtO concentrations near Vantage may increase the risk of certain types of cancer such as lymphoid cancers (non-Hodgkin lymphoma, myeloma, and lymphocytic leukemia) and female breast cancer. ATSDR is uncertain exactly how far EtO emissions from Vantage may extend, but in a given direction EtO concentrations diminish with distance from the facility.

Additionally, long term exposure may harm the health of people who work near air sampling location V2, located about 0.2 miles east of Vantage. V2 is located in a residential neighborhood, which is why ATSDR presents a lifetime cancer risk using a residential exposure scenario in the table below. However, there are also commercial areas located in between V2 and Vantage. The estimated lifetime cancer risk for people who work but do not live near air sampling location V2 was 1 in 10,000. The estimated lifetime cancer risk for people who work near V3, which is slightly closer to Vantage at 0.05 miles to the south is 0.4 in 10,000. This indicates people who work in the predominant wind direction from Vantage (northeast of Vantage) may have elevated cancer risk if they breathe the adjusted EtO concentrations measured for many years, but people who work south of the facility may not. Since air sampling was conducted from June 2019 to May

2020 and Vantage removed a cooling tower in November 2019, there is uncertainty about whether the lifetime cancer risks calculated for nearby residents and workers represent current long-term conditions. This uncertainty led ATSDR to recommend additional air sampling near Vantage.

Table 4. Lifetime excess cancer risk at sampling locations near Vantage; includes GAM-adjusted mean and EPC

Sampling Location	Exposure Scenario	Description	Distance from Vantage (miles)	Mean (µg/m³)	CTE Lifetime Excess Cancer Risk (adult)	EPC* (µg/m³)	RME Lifetime Excess Cancer Risk†
V1‡	Resident§	Spaulding Elementary School	0.6	0.17	0.8 in 10,000	0.37	10 in 10,000
V2‡	Resident¶	Northwestern and Keith	0.2	0.13	0.6 in 10,000	0.64	20 in 10,000
V3‡	Worker	Warehouse south of Vantage	0.05	0.13	0.06 in 10,000	0.19	0.4 in 10,000
V4	Resident	Waukegan Gurnee Glass	0.3	0.076	0.3 in 10,000	0.15	5 in 10,000
V5‡	Resident	Wetland near apartments	0.6	0.079	0.4 in 10,000	0.11	3 in 10,000
R1	Resident	Background site	2	0.081	0.4 in 10,000	0.10	3 in 10,000
R2	Resident	Background site	4.1	0.071	0.3 in 10,000	0.10	3 in 10,000

* EPC Exposure Point Concentration (95% upper confidence limit of GAM-adjusted EtO concentrations)

† All EtO concentration data used for lifetime excess cancer risk calculations are from LCHD, Village of Gurnee, and City of Waukegan outdoor EtO air sampling data collected between June 3, 2019 and May 1, 2020.

‡Adjusted EtO concentrations at this air sampling location were statistically significantly greater than combined EtO concentrations at R1 and R2.

§A residential scenario was used at Spaulding Elementary School (V1) because lifetime cancer risks of children who grow up in a neighborhood for many years will be higher than the lifetime cancer risk of children who attend school for several years. Estimated excess lifetime cancer risks for non-resident children and educators who attend school are less than 1 in 10,000.

¶Excess lifetime cancer risk for people who work near air sampling location V2 is 1 in 10,000.

Medline Lifetime Excess Cancer Risk

Based on the RME scenario and 95% UCL GAM-adjusted EtO concentrations measured from June 2019 to December 2019, during Medline's pre-closure operating period before the installation of new PTE emission controls, breathing EtO for many years may contribute to a small increase in lifetime risk for certain types of cancer for people who lived within 0.7 miles of Medline. Assuming 95% UCL GAM-adjusted EtO concentrations detected over the sampling period represent chronic exposure conditions, the upper bound lifetime excess cancer risk estimates from chronic EtO exposure for residents living 0.1 miles southeast and 0.7 miles northeast of Medline were elevated and could increase people's risk of certain types of cancer in

their lifetime such as lymphoid cancers (non-Hodgkin lymphoma, myeloma, and lymphocytic leukemia) and female breast cancer. During the Midline's pre-closure operating period, the calculated upper bound residential lifetime cancer risk estimates based on a RME scenario and the 95% UCL GAM-adjusted EtO concentrations at M3 (the closest residential area) was 40 excess cancer cases in 10,000 exposed people (Table 5). Lifetime excess cancer risk was estimated at 6 in 10,000 people at sampling location M1 during pre-closure operations, which was located near a residential neighborhood northeast of the facility. The pre-closure GAM-adjusted EtO concentrations measured at the LCHD air sampling locations (M2, M5) located in commercial areas were indistinguishable from background levels and not associated with elevated lifetime excess cancer risk for people who work but do not live near Medline (Table 5). However, there were no LCHD air monitors to measure concentrations that people who work immediately adjacent to the Medline facility might breathe.

After Medline reopened with new PTE emission controls in March 2020, breathing EtO for many years may contribute to a small increase in lifetime risk for certain types of cancer for people who live within 0.6 miles of Medline and people who work adjacent to Medline's northern property boundary breathing air for many years at EtO concentrations observed within 0.7 miles of the Medline plant between March 2020 and September 2023 may contribute to a small increase in lifetime excess cancer risk for certain types of cancer for residents including lymphoid cancers (non-Hodgkin lymphoma, myeloma, and lymphocytic leukemia) and female breast cancer. After March 20202, M3 (located in the nearest residential area) was the only sampling location that was statistically elevated above background EtO concentrations at R1 and R2 in the limited available LCHD sampling for the PTE operation period. However, all four sampling locations in the Medline monthly sampling data including two fenceline sampling locations (F1 and F2) as well as two community sampling locations (CF1 located in the closest residential area and C1/2 located in the northeast residential area 0.6 miles to the northeast) were elevated above background EtO concentrations at Northbrook and Schiller Park. As explained in more detail in the exposure pathways section (section 6.1), our analysis of GAM-adjusted EtO concentrations gave strong indications of facility influence at the F1 and F2, evidence of facility influence at CF1, and we could not exclude the possibility that EtO concentrations at C1/2 are slightly elevated above background concentrations. The highest EPCs were measured at the fenceline sampling locations.

The upper bound lifetime excess cancer risk estimates for people living in the two nearest residential communities near CF1 and C1/2 after Medline installed the PTE emissions control system in 2020 were calculated as 5 and 6 excess cancer cases in 10,000 exposed people. The area adjacent to the northern fenceline is commercial, so lifetime excess cancer risks were calculated for nearby workers. People who work immediately adjacent to the northern boundary of the Medline property near F1 and F2 were estimated to have a 0.8 lifetime excess risk of cancer in 10,000 exposed people which does not pose an excess cancer risk (Table 5). Lifetime excess cancer risks near F1 and F2 were calculated taking into account the downward trend of EtO concentrations at those sampling locations over time and assuming that recent concentrations are more likely to be representative of future long-term exposure conditions. This downward trend in EtO concentrations at F1 and F2 during this period, suggests that the EtO controls on the plant have become increasingly effective. For more information on the calculation of lifetime excess cancer risks at F1 and F2, see Appendix F, Section F2. ATSDR concluded if emissions continue to stay somewhat lower or trend downward at Medline, the most recent observed EtO concentrations would not pose an excess lifetime cancer risk for workers.

Table 5. Medline model-adjusted mean, exposure point concentration, and cancer risk by operating status

Sampling Location	Medline Operating Status	Mean (µg/m³)	CTE Lifetime Cancer Risk (adult)	EPC (µg/m³)	Exposure Scenario	RME Lifetime Cancer Risk*
C1/2[†]	PTE operation	0.13	0.6 in 10,000	0.15	Resident	5 in 10,000
CF1[†]	PTE operation	0.18	0.8 in 10,000	0.21	Resident	6 in 10,000
F1[†]	PTE operation	0.23[‡]	0.1 in 10,000	0.34	Worker[¶]	0.8 in 10,000
F2[†]	PTE operation	0.22[‡]	0.1 in 10,000	0.35	Worker	0.8 in 10,000
M1	PTE operation	0.21	1 in 10,000	0.45	Resident	10 in 10,000
M2	PTE operation	0.11	0.05 in 10,000	0.15	Worker	0.3 in 10,000
M3[†]	PTE operation	0.26	0.3 in 10,000	0.41	Resident	10 in 10,000
M4	PTE operation	0.15	0.07 in 10,000	0.21	Worker	0.4 in 10,000
M5	PTE operation	0.27	0.1 in 10,000	0.45	Worker	0.8 in 10,000
R1	PTE operation	0.15	0.7 in 10,000	0.22	Resident	7 in 10,000
R2	PTE operation	0.078	0.4 in 10,000	0.10	Resident	3 in 10,000
M1	Temporarily closed	0.08	0.4 in 10,000	0.10	Resident	3 in 10,000
M2	Temporarily closed	0.061	0.03 in 10,000	0.078	Worker	0.1 in 10,000
M3	Temporarily closed	0.063	0.3 in 10,000	0.079	Resident	2 in 10,000
M4	Temporarily closed	0.069	0.03 in 10,000	0.084	Worker	0.2 in 10,000
M5	Temporarily closed	0.08	0.04 in 10,000	0.099	Worker	0.2 in 10,000
R1	Temporarily closed	0.082	0.4 in 10,000	0.10	Resident	3 in 10,000
R2	Temporarily closed	0.066	0.3 in 10,000	0.082	Resident	2 in 10,000
M1[†,§]	Pre-closure operation	0.15	0.7 in 10,000	0.21	Resident	6 in 10,000
M2	Pre-closure operation	0.072	0.03 in 10,000	0.094	Worker	0.2 in 10,000
M3[†]	Pre-closure operation	0.73	3 in 10,000	1.3	Resident	40 in 10,000
M4[†]	Pre-closure operation	0.16	0.08 in 10,000	0.23	Worker	0.4 in 10,000

Sampling Location	Medline Operating Status	Mean (µg/m³)	CTE Lifetime Cancer Risk (adult)	EPC (µg/m³)	Exposure Scenario	RME Lifetime Cancer Risk*
M5	Pre-closure operation	0.07	0.03 in 10,000	0.11	Worker	0.2 in 10,000
R1	Pre-closure operation	0.055	0.3 in 10,000	0.064	Resident	2 in 10,000
R2	Pre-closure operation	0.073	0.3 in 10,000	0.13	Resident	4 in 10,000

*All data used for risk calculations are from LCHD, Village of Gurnee, and City of Waukegan outdoor EtO air sampling data collected between June 3, 2019 and May 1, 2020.

†Adjusted EtO concentrations at this air sampling location were statistically significantly greater than combined concentrations at R1 and R2 (LCHD air sampling) or Northbrook and Schiller Park (Medline monthly sampling).

‡Mean and EPCs estimated for 2023 using Bayesian GAM due to downward trend in concentrations at F1 and F2. See Appendix Section F2.

§Combined M1-A and M1-B results.

¶This is a cancer risk calculated for people who work at businesses near Medline and only takes into account risk during the workday.

Background Excess Cancer Risk

In Table 4 and Table 5, ATSDR presents excess cancer risks using our residential RME assumptions and 95% UCL EPC from the GAM-adjusted background EtO concentrations at R1, R2 and Medline air sampling locations during Medline's temporary closure. These concentrations represent what the upper bound excess cancer risk from EtO exposure might have been had Vantage and Medline not been operating.

The most reliable estimate of the upper bound excess cancer risk from background EtO in Lake County is the calculated excess cancer risk estimate derived from the 95% UCL EPC using GAM-adjusted background EtO concentrations at R1 and R2 for the entire LCHD sampling dataset as presented in Table 4. Residential excess cancer risk estimate at both sampling locations was 3 in 10,000. The GAM-adjusted mean EtO concentrations at R1 and R2 of 0.08 µg/m^3 and 0.07 µg/m^3, respectively were very similar to GAM-adjusted mean EtO concentrations at Northbrook and Schiller Park sampling locations in Cook County, Illinois (0.07 µg/m^3 and 0.08 µg/m^3, respectively) suggesting the GAM-adjusted concentrations at R1 and R2 are reasonably representative of local background concentrations of EtO (Table H3). Background GAM-adjusted mean EtO concentrations at R1 and R2 are also similar to GAM-adjusted background EtO concentrations measured in Willowbrook, Illinois [ATSDR 2023a]. The similarity in these adjusted concentrations from different locations suggest EtO concentrations and associated excess cancer risk are similar in Lake County to other places. Appendix G reports EtO concentrations from U.S. EPA's Air Quality System, GAM-not adjusted for positive bias due to the canister effect. Available evidence does not suggest that excess cancer risk from exposure to background EtO in Lake County is significantly different than exposure to background EtO elsewhere in the U.S.

ATSDR also presents residential excess cancer risk estimates for the three Medline operating periods including background EtO sampling during the temporary closure of Medline (from December 13, 2019 to January 21, 2020) in Table 5. These excess cancer risks are estimated from a few background EtO samples taken during closure of Medline (8-30 samples per estimate at each sample location, Table C2) compared to the excess cancer risks estimated from background sampling at R1 and R2 during the whole LCHD sampling period (50 and 49 samples at R1 and R2, respectively) and are therefore more uncertain than the background residential excess cancer risks presented in Table 4. ATSDR calculated residential upper bound excess cancer

risk estimates ranged from 2 to 7 in 10,000 at R1, R2, M1 during temporary closure and M3 during temporary closure. At sampling locations M2, M4 and M5 ATSDR calculated a worker upper bound excess cancer risk estimate during closure to provide a comparison to the lifetime excess cancer risk calculated from GAM-adjusted EtO concentrations at those sampling locations during pre-closure operations and PTE operations. The upper bound excess cancer risks calculated for workers from background EtO concentrations measured during Medline's temporary closure were not elevated, ranging from 0.1 to 0.2 in 10,000.

6.4 Evaluation of Health Outcome Data

6.4.1 Lifetime U.S. Population Risk of Cancer

In the United States, 1 out of every 2 men and 1 out of every 3 women will develop cancer during their lifetime [American Cancer Society 2023a]. Generally, in the United States, female breast cancer is common (1 in 8 women will develop breast cancer at some point in their lives) [American Cancer Society 2024], and blood cancers are rarer. An individual's cancer risk depends on many potential risk factors, including age, gender, genetic predisposition (such as BRCA or Lynch Syndrome gene mutations), and lifestyle behaviors (e.g., smoking). Information about the risk factors for specific types of cancer are available at the National Cancer Institute [National Cancer Institute 2015] and the American Cancer Society [American Cancer Society 2023b].

These lifetime risks of developing cancer from all risk factors during a lifetime reflect actual *observed* cancer cases across the United States. These lifetime risks should be distinguished from the lifetime excess cancer risks that ATSDR calculated in this health consultation, which are *calculated estimates of additional cancer cases* that could occur among a population exposed to EtO. Calculated lifetime excess cancer risk estimates are used to inform our conclusions and recommendations.

6.4.2 IDPH Cancer Incidence Assessment

To determine the incidence of specific cancers observed in the Lake County area, IDPH conducted a review of cancer incidence in 14 census tracts surrounding Medline and Vantage. The study examined the incidence of cancers associated with EtO exposure (breast cancer, non-Hodgkin's lymphoma, Hodgkin's lymphoma, myeloma, and lymphocytic leukemia) as well as other common cancers not associated with EtO exposure (including prostate, ovarian and bladder cancers, among others). Cancer cases diagnosed from 1998 to 2017 were obtained from the Illinois State Cancer Registry. The study compared the incidence of cancer in the study area near Medline and Vantage to cancer incidence in Cook County and Lake County. IDPH summarized the findings of this study on their website [IDPH 2021]:

> *None of the four lymphohematopoietic cancers that previous studies have found to be associated with EtO, namely, female breast, non-Hodgkin lymphoma, Hodgkin's lymphoma, and lymphocytic leukemia, were found to be increased in either males or females. Another lymphohematopoietic cancer, myeloma, showed a statistically significant elevation among females relative to the Lake County average, but the difference was reduced to non-significant when compared to the Cook County average.*
>
> *No lymphohematopoietic cancer displayed an increasing trend over time (1998 to 2017). Male lymphocytic leukemia cases were elevated at the beginning of the time period, but then decreased to expected levels in subsequent time periods. Hodgkin lymphoma in females showed a steadily declining trend over time.*
>
> *A separate analysis of pediatric cancer revealed that no childhood cancers were elevated.*

Several other cancer sites that have never been documented to be related to EtO were found to be higher (i.e., stomach and colorectal cancers for females and lung cancer in males) and other sites were found to be lower (i.e., female skin and bladder, and male bladder) than comparable populations.

The study results should be treated with caution, as the results were not consistent (i.e., male vs. female, and myeloma vs. other EtO related cancers) and the study has several important limitations and constraints (e.g., using residency as measurement of exposure, tying cancer to the residence at the time of diagnosis, lacking other risk factors, etc.). Additional studies in the future are needed to confirm these findings.

The full report is available from IDPH [IDPH 2021].

6.5 Summary of Limitations and Uncertainties

Whenever possible, ATSDR accounts for limitations by using protective, reasonable upper bound exposure estimates as the basis for determining whether harmful health effects are possible. Limitations and uncertainties of ATSDR's health consultation include:

1. The EtO concentrations at sampling locations near Vantage appeared higher than average for a short period of time. ATSDR could not confirm whether these "spikes" in EtO concentration around Vantage were due to episodic releases associated with specific operational activities at the facility or whether that occurrence was an anomaly that may not be representative of typical conditions. Notably, Vantage removed a cooling tower in November 2019 which may have previously been a source of fugitive emissions. This variability in the measured EtO concentration adds uncertainty to the calculation of average long-term exposure and associated lifetime excess cancer risk. The uncertainty in this estimate of lifetime cancer risk can be reduced by the inclusion of more data, which is the basis for the ATSDR recommendation to IEPA to collect additional outdoor EtO air data in the community near Vantage in order to better characterize current conditions.

2. The LCHD air sampling data to evaluate current conditions at Vantage spanned a total of about 5 months between June 2019 through May 2020, beginning just after Vantage installed improvements in their emission controls in April 2019. Vantage was not required to meet the emissions limits until December 2019 permit. Therefore, during the beginning of the sampling period pollution controls may not have been fully operational. Ideally, chronic exposures are evaluated with data collected over longer durations that can reflect seasonal and temporal variability, but also the impact of variable rates of EtO emissions over time. Because our assessment of EtO exposure is limited to data from this timeframe, there is some uncertainty as to whether this is representative of the current level of exposure and associated risk.

3. Medline monthly sampling did not have a background air sampling location, so concentrations were compared to Northbrook and Schiller Park background air sampling locations. Since Northbrook and Schiller Park data were not collected simultaneously and used the different laboratory and sampling methods, there may be differences between EtO concentrations from the two sets of sampling data that bias the comparison of Medline monthly sampling near-source sites with background sampling locations.

4. The laboratory that measured EtO concentrations in the Medline monthly sampling method switched between cryogenic and non-cryogenic methods during the sampling period, which may have caused inconsistencies in measured EtO concentrations over time.

5. ATSDR has limitations in our ability to estimate the lifetime excess cancer risk associated with EtO exposure for people who live near the Medline and Vantage facilities. There are several factors that

contribute to this uncertainty:

a. EPA's current air sampling and laboratory methods (Method TO-15A) to analyze EtO in outdoor air can only report EtO concentrations that are about 200 times higher than ATSDR's screening value for cancer, which is based on a risk of 1 additional cancer case among a population of 1 million exposed individuals.
b. Outdoor EtO air concentrations as low as 0.03 µg/m3, which is lower than background EtO concentrations in Lake County, would represent a lifetime excess cancer risk greater than 1 additional cancer case in 10,000 people exposed, which is considered an elevated lifetime cancer risk.
c. The MDL is defined as the "the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results" [U.S. EPA 2016]. There is generally a higher degree of confidence in quantifying the concentration of any chemical when it is measured well above the MDL, compared to measuring a concentration that is near the MDL. Since the EtO concentrations measured at the background sampling locations and at the various community sampling locations near the Medline and Vantage facilities are only two or three times the MDL, this introduces variability and some uncertainty into the EtO concentrations. This variability is random and is not specific to EtO. ATSDR typically accounts for variability in environmental data by using a 95% UCL to estimate an EPC, regardless of whether the contaminant concentrations measured are near the MDL. Greater variability in concentrations results in a higher 95% UCL to account for greater uncertainty, ensuring our conclusions are still health protective.
d. Other chemicals may be mistakenly measured as EtO, which can artificially inflate EtO concentrations measured in outdoor air. ATSDR investigated several lines of evidence to explore whether other potential sources, including sources of other chemicals, may be contributing to EtO concentrations. We saw evidence of facility contribution at air sampling locations located nearest to Medline and Vantage. The relationship between facility emissions and EtO concentrations observed at certain sampling locations indicates that EtO sampling data analyzed in this consultation provides information about exposure, even considering the potential limitations of the data.

6. The positive bias in EtO air measurement due to the canister effect and holding time (i.e., EtO growth inside a canister) resulted in uncertainty about the accuracy of the EtO measurements reported by the laboratory, particularly in the LCHD sampling data where multiple canister types were used. In addition, seasonal patterns introduced variation in concentrations that could affect estimates of long-term exposure. To address this issue, ATSDR used a Bayesian GAM to adjust EtO concentrations to effectively removing the influence of canister lining, holding time, and seasonal patterns. The Bayesian GAM provides better estimates of cancer risk by minimized the impact of positive bias, but it does not remove all uncertainty resulting from positive sampling bias.

7. TRI data suggest emissions at Vantage may have been higher in the past. However, due to a lack of long-term sampling data, we cannot fully evaluate historical trends or chronic exposures in the community to quantify past cancer risks.

8. TRI data compared to data Medline reported to Illinois EPA also suggest that Medline emissions may have been higher in the past. In addition, the facility was working to install new emissions controls shortly before it shut down on December 13, 2019. Available outdoor air data may therefore be an underestimate of past exposures, limiting our assessment of past lifetime excess cancer risk.

9. An information data gap exists in the scientific toxicologic literature on how human exposure to lower EtO concentrations affect development of adverse health outcomes, especially in utero and in young children.

Young children may be particularly susceptible to adverse health effects from chronic EtO exposure. ATSDR uses U.S. EPA's ADAFs to calculate lifetime excess cancer risk that accounts for potential greater cancer risk for children exposed to mutagenic compounds.

6.6 Medical Questions and Concerns

Community members and local officials have inquired about medical monitoring (biological testing) for EtO exposure. While there are medical tests that can indicate exposure to EtO, these tests cannot determine the source of exposure or if an existing or future health problem may be related to EtO exposure. ATSDR does not recommend blood testing for community settings.

ATSDR recommends that community members who are concerned about EtO exposures or have health-related questions talk with their doctor. Important additional steps in maintaining health and detecting problems early include keeping up to date with regular checkups and recommended age-appropriate medical screening tests (e.g., breast cancer screening recommended by the U.S. Preventive Services Taskforce) [United States Preventative Services Taskforce 2016] and being evaluated by their doctor between checkups if unusual symptoms or concerns arise. Clinicians interested in learning more about EtO exposure and health may also access ATSDR resources on EtO for clinicians through our website at the links below. Community members who wish to speak to their doctors about their exposure may recommend these resources for their doctors.

- ATSDR Clinician Brief: Ethylene Oxide | ATSDR (cdc.gov)
- Clinician Overview of Ethylene Oxide | ATSDR (cdc.gov)

Healthcare providers seeking more information and guidance about EtO exposure and potential health effects can consult with experts trained in environmental medicine located at:

Great Lakes Center for Reproductive and Children's Environmental Health at the University of Illinois at Chicago
Website: https://childrensenviro.uic.edu/
Phone: 866-967-7337
Email: ChildrensEnviro@uic.ed

In addition to advice from their doctor, individuals or concerned community members seeking more information can also contact experts using the phone number or email above.

7. Conclusions

ATSDR evaluated LCHD EtO air sampling data collected in three non-continuous phases from June 2019 to May 2020 and Medline monthly EtO air sampling data collected from March 2020 to September 2023 to assess health risks for people who live, work, or attend school near Medline or Vantage. ATSDR calculated lifetime excess cancer risks using GAM-adjusted EtO concentrations to account for the effects of canister lining, holding time, and seasonal patterns. ATSDR used calculated estimates of lifetime excess cancer risk as a tool for deciding whether public health actions are needed to protect health. These cancer risks are not an actual estimate of cancer cases in a community and do not represent an individual's cancer risk. ATSDR reached five conclusions from this evaluation.

Conclusion 1, Health effect: cancer, Facility: Vantage, Sampling time: June 2019–May 2020

Breathing air for many years with adjusted EtO concentrations measured from June 2019 to May 2020, when pollution controls may not have been fully operational, may increase the risk of certain types of cancer for residents living within 0.6 miles of Vantage and people who work within ¼ mile of Vantage's northern or eastern property boundary.

Basis for Decision

- EtO is classified as carcinogenic to humans from breathing EtO in the air over many years [U.S. EPA 2016]. The best evidence of which cancers might be associated with breathing EtO comes from studies of workers exposed to high levels over a long period of time. Evidence from human epidemiological studies is strong but less than conclusive in associating specific cancers with EtO exposure [U.S. EPA 2016].
- Studies of a large cohort of workers observed a dose-response in the incidence of female breast cancer and breast cancer mortality in women [Steenland et al. 2003; Steenland, Stayner, and Deddens 2004]. A study from the same cohort also found increased mortality in male workers from certain lymphoid cancers (non-Hodgkin lymphoma [also known as non-Hodgkin's lymphoma or NHL], myeloma, and lymphocytic leukemia as a group) [Steenland, Stayner, and Deddens 2004; U.S. EPA 2016; IARC 2012].
- For residents and workers breathing EtO over many years, ATSDR calculated the upper bound population-based estimates of lifetime excess cancer risk designed to be protective of health, as they use reasonable upper bound exposure estimates and are likely an overestimate of the potential risk. This calculated lifetime excess risk of cancer from EtO exposure may contribute a small increased risk in addition to the already existing lifetime risk of cancer from all causes.
- ATSDR estimated lifetime excess cancer risks at five LCHD sampling locations near Vantage (V1 through V5) based on RME assumptions and the 95% UCL of GAM-adjusted EtO concentrations measured long-term during three non-continuous phases of sampling from June 2019 to May 2020. These air samples were collected after Vantage installed a new dry bed absorption system in April 2019 to better control EtO emissions. The pollution controls may not have been fully operational until the air permit for Vantage came into effect in December 2019.
- The calculated upper bound lifetime excess cancer risk estimates for people who live near sampling locations within 0.6 miles of Vantage ranged from 3 to 20 in 10,000 people (Table 4 and Figure 3). ATSDR considers these estimated lifetime excess cancer risks from long-term breathing of EtO concentrations measured in the air to be an elevated cancer risk.
- The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close you live or work to the facility.
- Lifetime excess cancer risks calculated using average or typical assumptions rather than upper bound assumptions about exposure ranged from 0.3 to 0.8 in 10,000 for adults living near Vantage.
- Estimated upper bound lifetime excess cancer risks for people who work but do not live near Vantage were elevated at air sampling location V2, 0.2 miles to the east of Vantage, but not at other air sampling locations including a sample location closer to the facility (i.e., V3, 0.05 miles south of Vantage.) This indicates people who work in the predominant wind direction from Vantage (northeast of Vantage) may have elevated cancer risk but people who work south of the facility may not.
- Adjusted EtO concentrations at four of five sampling locations (V1, V2, V3, and V5) were statistically higher than adjusted EtO concentrations measured at the background sampling locations (R1 and R2) (Section 5.1.1, Appendix D2, Appendix E2).
- The farthest air sampling from the facility is 0.6 miles away. ATSDR does not know precisely how far from the facility people living nearby may be at elevated risk because EtO concentrations were elevated at four of five air sampling locations. EtO concentrations would be expected to decrease with distance within a given direction from the facility.
- In early November 2019, EtO concentrations at several sampling locations near Vantage were higher than EtO concentrations measured during the rest of the sampling period (Section 5.1.1, Appendix D1), which may have been due to the removal of a cooling tower that month. Additionally, although Vantage had emissions controls installed prior to the beginning of sampling, the new permit did not come into effect until December of 2019. These facts add uncertainty in the long-term estimates of lifetime cancer risk.
- Long-term air sampling was not available to assess EtO concentrations and associated lifetime cancer risk prior to June 2019.

Conclusion 2, Health effect: cancer, Facility: Medline, Sampling time: March 2020–September 2023, Operating

period: Operating, PTE

ATSDR cannot exclude the possibility that breathing air for many years with EtO levels measured within 0.7 miles of the Medline plant between March 2020 and September 2023 could increase the risk of certain types of cancer for residents. However, any potential increase in risk would likely be small over a person's lifetime. Air sampling locations adjacent to the Medline plant show a downward trend in EtO concentrations during this period, which suggests that the EtO controls on the plant have become increasingly effective. The most recent observed EtO levels adjacent to Medline are low enough to not pose an excess lifetime cancer risk for off-site workers.

Basis for Conclusion 2

- ATSDR calculated lifetime excess cancer risk based on RME assumptions and the 95% UCL of GAM-adjusted EtO concentrations measured in Medline's monthly sampling from March 2020 to September 2023 at four air sampling locations within 0.6 miles of Medline. These air samples were collected after Medline installed the PTE emissions control system in March 2020 to better control EtO emissions.
- The estimated lifetime excess cancer risk from long-term breathing of EtO in the air for people who live in the apartments 0.1 miles southwest of Medline was 5 in 10,000, and it was 6 in 10,000 for people who live in the neighborhood about 0.5 miles northeast of Medline. ATSDR considers these estimated lifetime excess cancer risk estimates from long-term breathing EtO concentrations measured in the air to be an elevated cancer risk (Table 3 and Figure 3).
- Lifetime excess cancer risks calculated using average or typical assumptions rather than upper bound assumptions about EtO exposure were 0.6 and 0.8 in 10,000 for adults living near Medline.
- Concentrations have trended downward at the two fenceline sampling locations (F1 and F2) as have emissions from Medline (Section 5.1.2, Section 5.3.2, Appendix F2). This downward trend in EtO concentrations was not observed at the community sampling locations (CF1 and C1, later replaced by C2).
- The estimated lifetime excess cancer risk from EtO exposure for people who work immediately northeast of the facility is 0.8 in 10,000 assuming more recent (2023) EtO concentrations are more representative of what people working near Medline will breathe in the future than concentrations measured earlier in the March 2020– September 2023 sampling period.
- Statistical testing concluded adjusted EtO concentrations from all four air sampling locations including two fenceline air sampling locations (F1 and F2), one location northeast of Medline (C1, later replaced by C2), and the sampling location near the apartment complex (CF1) were elevated compared to background EtO concentrations measured at the Northbrook and Schiller Park air sampling locations in Cook County, Illinois (Section 5.1.2, Appendix D5, Figure D6, Appendix E2).
- ATSDR is uncertain precisely how far the elevated lifetime cancer risk may extend from Medline in any given direction. EtO concentrations were highest at the fenceline monitors (F1 and F2), decreased at the nearest community monitor (CF1), and decreased still more at the farthest community sampling location (C1 and C2) (Section 5.1.2, Section 5.3.2, Appendix F2). The farthest air sampling location was 0.7 miles from the facility. EtO concentrations would be expected to continue decreasing with distance within a given direction from the facility.
- The lifetime excess cancer risk estimates are based on breathing EtO over many years. There is not a health hazard of increased lifetime excess cancer risk from breathing EtO from Medline for people living or working near Medline for time periods less than 1 year.
- The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close you live or work to the facility.

Conclusion 3, Health effect: cancer, Facility: Medline, Sampling time: June–December 2019, Operating period: Operating, pre-closure

ATSDR concludes breathing EtO for many years prior to December 2019 could have harmed the health of

people who lived within 0.6 miles of Medline. Based on EtO concentrations measured from June–December 2019, before the installation of new emission controls, long-term exposure to EtO near Medline may have increased the risk of certain types of cancers.

- ATSDR estimated lifetime cancer risk at five LCHD air sampling locations near Medline (M1 through M5) based on RME assumptions and the GAM-adjusted EtO concentrations measured from June 2019 to December 2019. These air samples were collected before Medline installed the PTE emissions control system in March 2020 to better control EtO emissions.
- Estimated lifetime cancer risk during the pre-closure operational period for the nearest residential area (near monitor M3) was 40 in 10,000, and it was 5 in 10,000 near a neighborhood northeast of the facility (near monitor M1). ATSDR considers these estimated lifetime excess cancer risks from long-term breathing EtO concentrations measured in the air to be an elevated cancer risk (Table 5 and Figure 3).
- Estimated lifetime excess cancer risks calculated using the average or typical assumptions rather than upper bound assumptions about exposure for adults who live near Medline were 0.3 in 10,000 at M1 and 1 in 10,000 at M3.
- Statistical tests showed adjusted EtO concentrations at the three closest sampling locations within 0.6 miles of Medline, including two residential areas (M3 and M1) and a local park (M4), were higher than background EtO concentrations at R1 and R2 (Section 5.1.2, Appendix D5, Appendix E2). The EtO air sampling data were collected from June–December 2019 during the pre-closure operational time period before new PTE emissions controls were installed in March 2020.
- Long-term air sampling was not collected prior to June 2019 to assess exposure to EtO concentrations and associated lifetime excess cancer risks before June 2019.
- The amount of exposure time required to exceed the 1 in 10,000 excess cancer risk threshold can range from a year or two, to decades and depends on the age of the individual when exposure occurred (e.g., child or adult) and how close you live or work to the facility.

Conclusion 4, Health effect: noncancer, Facility: Medline and Vantage, Sampling time: June 2019–September 2023, Operating period: Operating, PTE

ATSDR concludes that breathing EtO in the air near Medline and Vantage is not expected to result in noncancer health effects. This conclusion applies to the measured EtO concentrations at all sampling locations during all phases of facility operations.

- The highest measured EtO air concentrations near Medline and Vantage were well below the noncancer health guidelines and significantly below the lowest concentrations that have been reported to result in noncancer health effects in scientific studies of acute (less than 2 weeks), intermediate (2 weeks to 1 year), and chronic (greater than 1 year) exposure to EtO. This conclusion applies to EtO concentrations measured during all operating periods at Medline and post installation of new controls at Vantage.
- People who live, work, go to school, or traveled near these Medline or Vantage facilities are not expected to have noncancer health effects from exposure to EtO concentrations that were detected in the community.

Conclusion 5, Health effect: cancer, Background EtO, Sampling time: June 2019–May 2020

EtO concentrations measured at background sites in Lake County away from Medline and Vantage and near Medline when the facility was closed were similar to background levels observed across the United States. Lifetime excess cancer risk from EtO exposure for people living or working in other parts of Lake County removed from Medline or Vantage is similar to EtO-related cancer risk for people living or working in other areas without a major EtO source.

- Estimates of background concentrations are challenging due to measurement uncertainty from sources

including EtO concentration increases in canisters and compounds that may mimic EtO during chemical analysis [US EPA ORD 2021]. ATSDR's use of the GAM limits the impact of positive bias due to the canister effect.

- ATSDR lifetime excess cancer risk estimates are designed to be protective of health, as they use reasonable upper bound exposure estimates as the basis for determining whether harmful health effects are possible.
- ATSDR estimated lifetime excess cancer risk based on RME assumptions and the 95% UCL of GAM-adjusted EtO air concentrations measured during the LCHD study at background sampling locations (R1 and R2) from June 2019 to May 2020 and at five sampling locations (M1 through M5) when Medline was temporarily closed from December 13, 2019 to January 21, 2020.
- Estimated residential lifetime excess cancer risk at R1 and R2 for the entire LCHD sampling period was 3 in 10,000 at both background sampling locations (Table 4).
- When Medline temporarily closed, the residential upper bound lifetime excess cancer risks ranged from 2 to 4 in 10,000 at each sampling location (Table 5).
- ATSDR considers these estimated upper bound residential excess cancer risks from long-term breathing of background EtO concentrations measured in the air to be an elevated cancer risk.
- The most reliable estimate of residential excess cancer risk is up to 3 in 10,000 based on all the available background EtO concentration data collected during the LCHD study from June 2019 to May 2020. Lifetime excess cancer risk is also reported for R1 and R2 during Medline's three operating periods for comparability. These cancer risks tend to be more variable because they are based on fewer samples to estimate risk. They ranged from 2 to 7 in 10,000.
- Excess cancer risks calculated using average or typical assumptions rather than upper bound assumptions about exposure for adults were 0.3 and 0.4 in 10,000 at R1 and R2, respectively.

Next Steps

Following ATSDR's public health assessment evaluation of available information and EtO air concentrations:

ATSDR recommends that Illinois EPA and the two facilities investigate potential sources of EtO emissions that may affect outdoor EtO air concentrations at the closest residential areas and adjacent businesses. Further, ATSDR recommends that additional air sampling is conducted at Vantage to better characterize long-term EtO exposure.

ATSDR recommends that U.S. EPA continue to work to:

- Improve analytical methods with lower *detection limits* so that EtO can be accurately measured at lower concentrations.

- Better understand EtO concentrations in background outdoor air and sources of EtO in outdoor air in order to accurately estimate exposure to EtO.

ATSDR is committed to continued support of local, state, and federal health and environmental agencies. When requested, ATSDR can evaluate additional EtO air sampling data.

ATSDR recommends local residents with health concerns related to EtO exposure talk with their doctor.

In addition to advice from their doctor, individual community members can contact experts in environmental medicine using the information below.

Great Lakes Center for Reproductive and Children's Environmental Health at the University of Illinois at Chicago Website:
https://childrensenviro.uic.edu/

Phone: 866-967-7337 **Email:** ChildrensEnviro@uic.edu

8. Who prepared this document?

Current ATSDR authors
Lydia Hoadley, MSPH
Health Assessor, Central Section, Office of Community Health Hazard Assessment/ATSDR/ CDC

James Durant, MSPH, CIH
Senior Environmental Scientist and Data Analyst, Exposure Investigation Section, Office of Community Health Hazard Assessment/ATSDR/ CDC

Former ATSDR authors
Michelle Colledge, PhD, MPH
Former Expert Research Officer (retired), Region 5, Office of Community Health Hazard Assessment/ATSDR/ CDC

Mark Johnson, PhD, DABT
Former Regional Director (retired), Region 5, Office of Community Health Hazard Assessment/ATSDR/CDC

Technical Consultants
Corey Anderson
Geospatial Statistician, Office of Innovation and Analytics/ATSDR/CDC

Virginia Lee
Geospatial Analyst, Office of Innovation and Analytics/ATSDR/CDC

Appendix A: Site and Area Demographic Maps and Windrose

Figure A1. Medline and Vantage site map

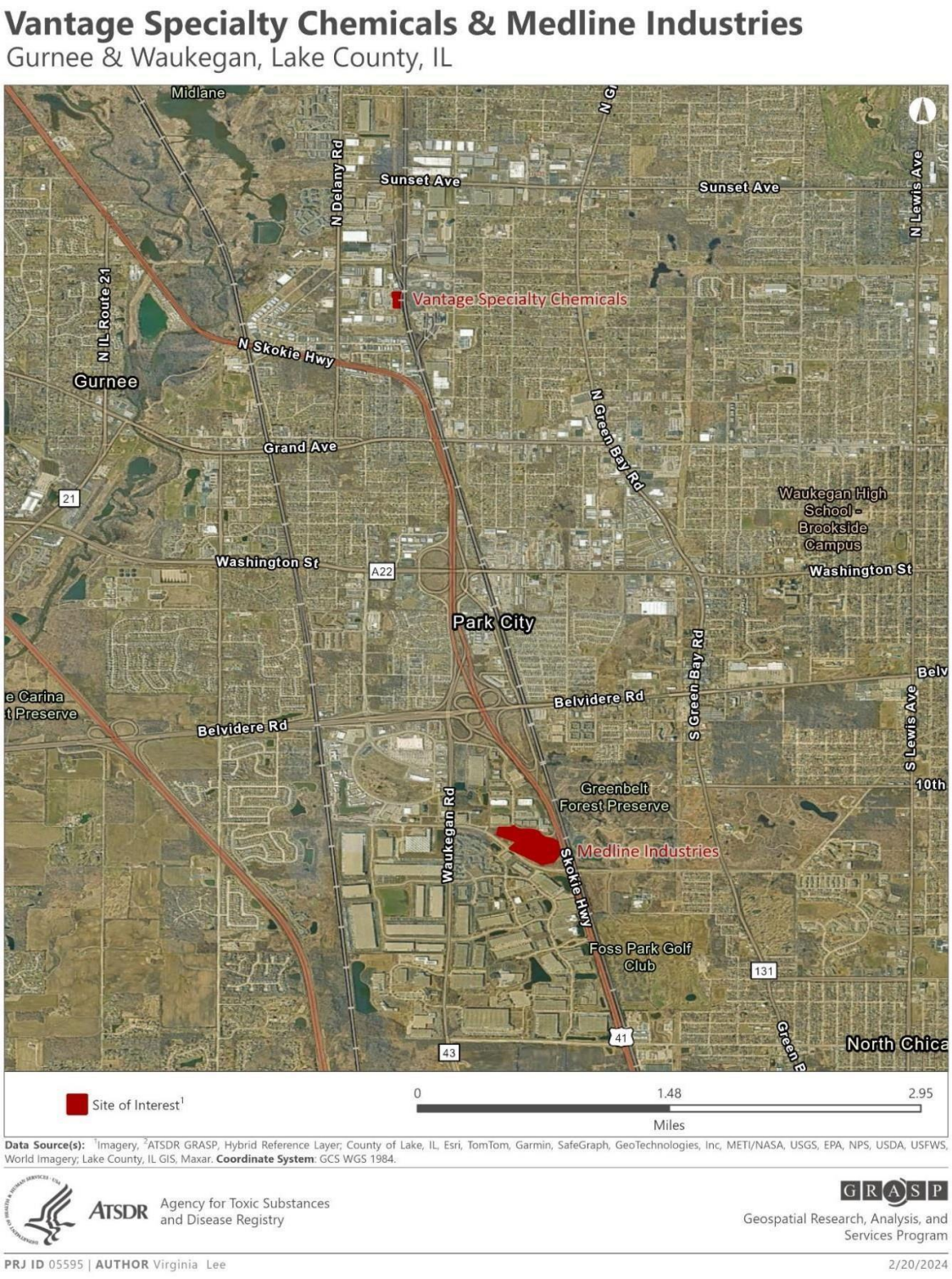


Figure A2. Site and demographic statistics within 1 mile of Vantage Specialty Chemicals

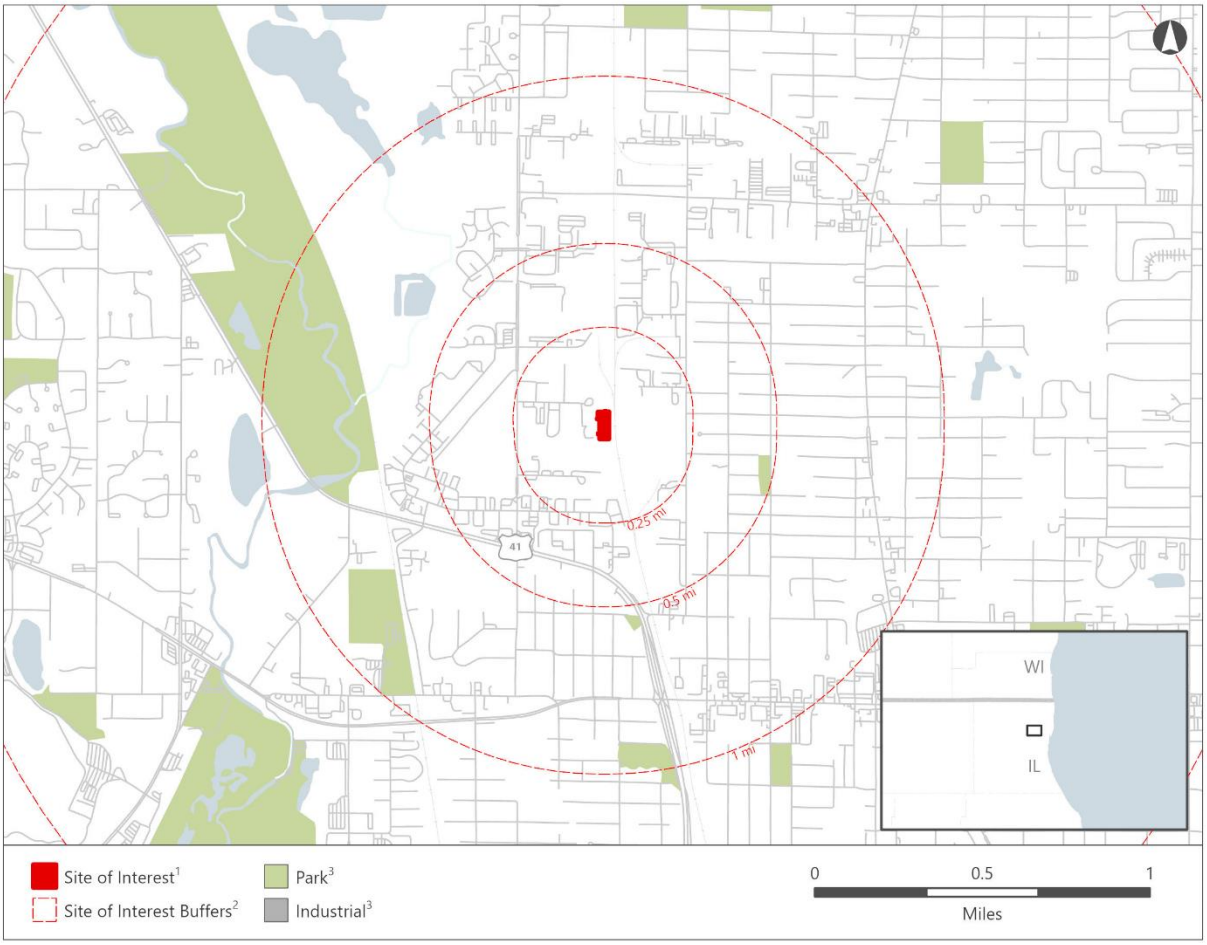
Vantage Specialty Chemicals

Gurnee, Lake County, IL

INTRODUCTORY MAP SERIES

SITE & DEMOGRAPHIC SNAPSHOT

EPA FACILITY ID NOT AVAILABLE



Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2010	2020	Change	Measure	2010	2020	Change
Total Population	6,057	6,019	+0%	Two or More Races	315	910	+188%
White Alone	3,784	2,531	-33%	Hispanic or Latino[6]	1,494	2,213	+48%
Black Alone	990	916	-7%	Children Aged 6 and Younger	560	498	-11%
Am. Indian & AK Native Alone	32	99	+209%	Adults Aged 65 and Older	499	839	+68%
Asian Alone	374	391	+4%	Females Aged 15 to 44	1,447	1,315	-9%
Native Hawaiian & Other Pacific Islander Alone	5	5	+0%	Housing Units	2,587	2,501	-3%
Some Other Race Alone	554	1,156	+108%	Housing Units Pre-1950	166	126	-24%

Data Sources: [1]Imagery, [2]ATSDR GRASP, [3]TomTom 2021Q3, [4]US Census 2020 Demographic and Housing Characteristics. **Notes:** [5]Calculated using area-proportion spatial analysis method, [6]Indivi identifying origin as Hispanic or Latino may be of any race. **Coordinate System:** NAD 1983 StatePlane Illinois East FIPS 1201 Feet

ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 05595 | **AUTHOR** Virginia Lee

2/21/2024

Figure A3. Site and demographic statistics within 1 mile of Medline Industries

Medline Industries

Waukegan, Lake County, IL

INTRODUCTORY MAP SERIES

SITE & DEMOGRAPHIC SNAPSHOT

EPA FACILITY ID NOT AVAILABLE

Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2010	2020	Change	Measure	2010	2020	Change
Total Population	6,734	7,005	+4%	Two or More Races	247	1,113	+350%
White Alone	2,898	1,596	-44%	Hispanic or Latino[6]	3,065	3,130	+2%
Black Alone	931	1,191	+27%	Children Aged 6 and Younger	937	784	-16%
Am. Indian & AK Native Alone	48	120	+150%	Adults Aged 65 and Older	412	583	+41%
Asian Alone	988	1,396	+41%	Females Aged 15 to 44	1,698	1,727	+1%
Native Hawaiian & Other Pacific Islander Alone	4	2	-50%	Housing Units	2,807	2,881	+2%
Some Other Race Alone	1,615	1,582	-2%	Housing Units Pre-1950	145	214	+47%

Data Sources: [1]Imagery, [2]ATSDR GRASP, [3]TomTom 2021Q3, [4]US Census 2020 Demographic and Housing Characteristics. **Notes:** [5]Calculated using area-proportion spatial analysis method, [6]Indivi identifying origin as Hispanic or Latino may be of any race. **Coordinate System:** NAD 1983 StatePlane Illinois East FIPS 1201 Feet

ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 05595 | **AUTHOR** Virginia Lee

2/21/2024

Figure A4. Points of interest within 1 mile of Vantage Specialty Chemicals Gurnee, Illinois

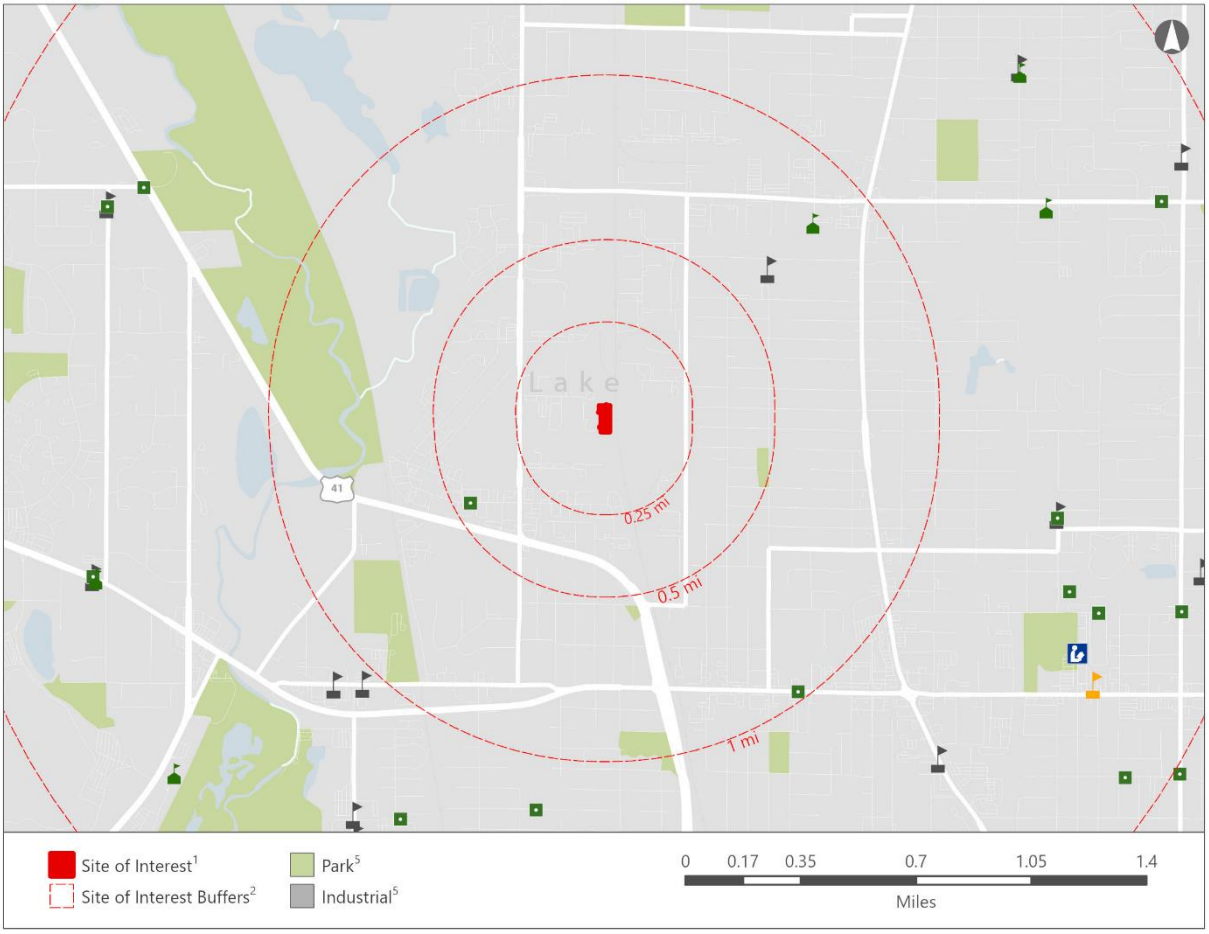
Vantage Specialty Chemicals

Gurnee, Lake County, IL

INTRODUCTORY MAP SERIES

COMMUNITY FACILITIES

EPA FACILITY ID NOT AVAILABLE



The **Community Facility Points of Interest Map** depicts the site of interest and community gathering centers in the local area. Information on number, type, and distribution of these facilities is important to efforts to communicate findings to the local population.

Community Facility Points of Interest

Within specified distance of site boundary. Not all buffers may be shown on map

Facility	.25 mile	.50 mile	1 mile
Libraries[3]	0	0	0
Schools[3]	0	0	1
Colleges/Universities[4]	0	0	0
City Halls[3]	0	0	0
Civic Centers[3]	0	0	0
Courthouses[4]	0	0	0
Places of Worship[4]	0	1	2
Day Care Centers[4]	0	0	1
Parks[5]	0	1	5

Data Sources: [1]Imagery, [2]ATSDR GRASP, [3]HERE NorthAmerica 2020R3, [4]HIFLD Open Feature Service, [5]TomTom 2021Q3. **Coordinate System**: NAD 1983 StatePlane Illinois East FIPS 1201 Feet

ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 05595 | **AUTHOR** Virginia Lee

2/21/2024

Figure A5. Points of interest within 1 mile of Medline Industries in Waukegan, IL

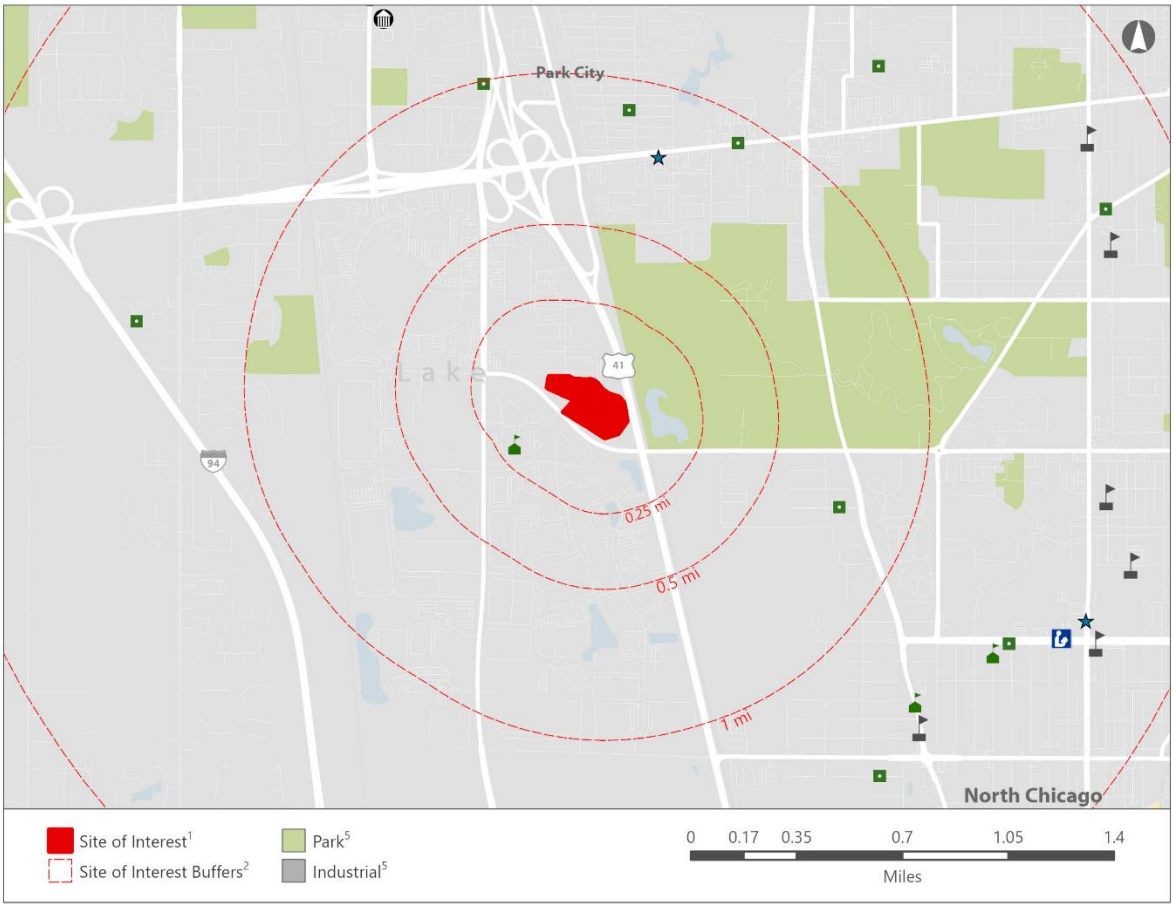
Medline Industries

Waukegan, Lake County, IL

INTRODUCTORY MAP SERIES

COMMUNITY FACILITIES

EPA FACILITY ID NOT AVAILABLE



The **Community Facility Points of Interest Map** depicts the site of interest and community gathering centers in the local area. Information on number, type, and distribution of these facilities is important to efforts to communicate findings to the local population.

Community Facility Points of Interest

Within specified distance of site boundary. Not all buffers may be shown on map

Facility	.25 mile	.50 mile	1 mile
Libraries[3]	0	0	0
Schools[3]	0	0	0
Colleges/Universities[4]	0	0	0
City Halls[3]	0	0	1
Civic Centers[3]	0	0	0
Courthouses[4]	0	0	0
Places of Worship[4]	0	0	4
Day Care Centers[4]	1	1	1
Parks[5]	1	1	2

Data Sources: [1]Imagery, [2]ATSDR GRASP, [3]HERE NorthAmerica 2020R3, [4]HIFLD Open Feature Service, [5]TomTom 2021Q3. **Coordinate System**: NAD 1983 StatePlane Illinois East FIPS 1201 Feet

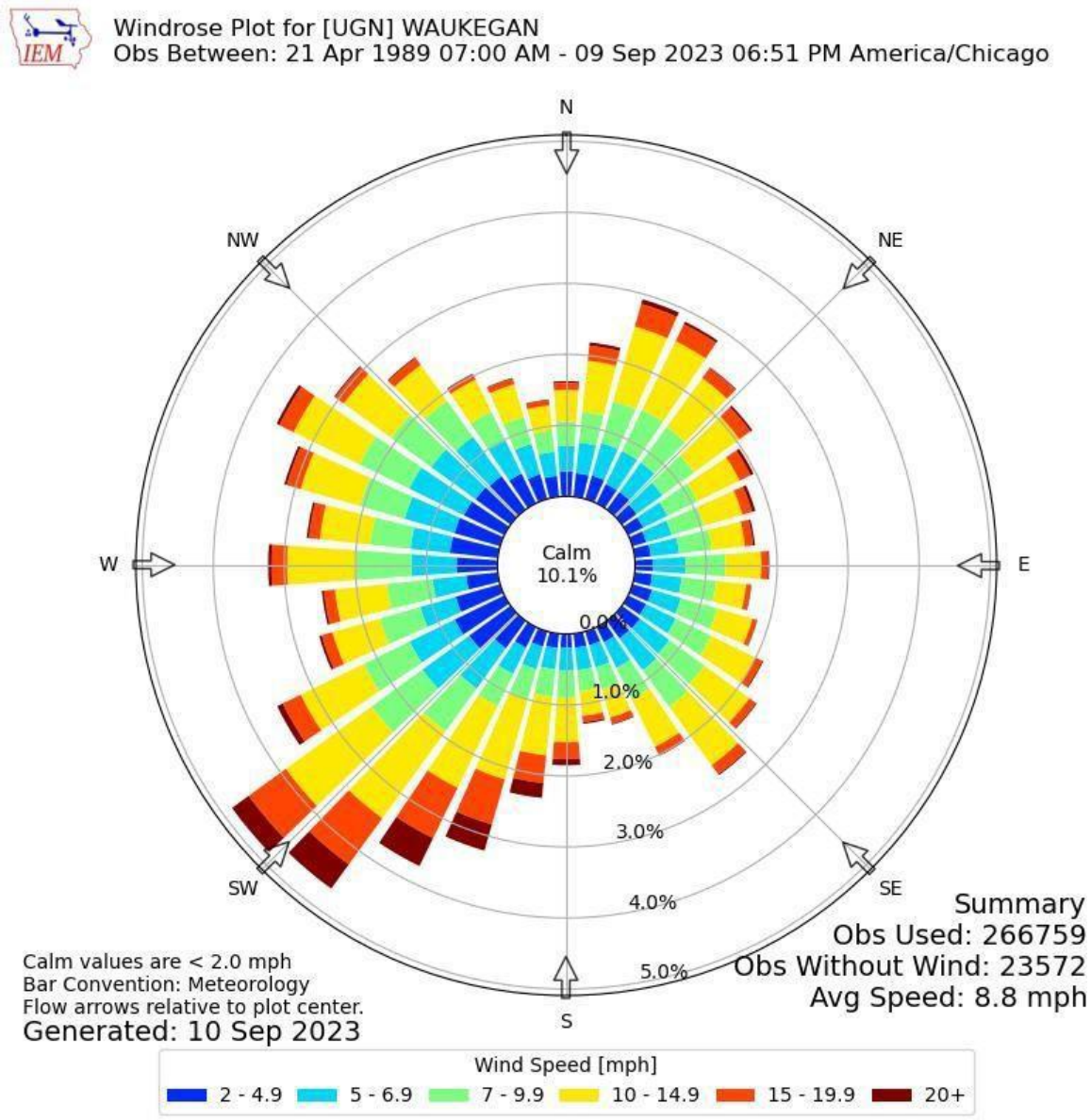
ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 05595 | **AUTHOR** Virginia Lee

2/21/2024

Figure A6. Windrose plot for Waukegan Airport, 1989-2023



Windrose generated by the Iowa Environmental Mesonet (IEM) using data from the Waukegan National Airport Automated Surface Observing System (ASOS). https://mesonet.agron.iastate.edu/sites/windrose.phtml?station=UGN&network=IL_ASOS

Appendix B: ATSDR Environmental Justice Index (EJI) for Census Tracts near Medline and Vantage

The maps and tables below present scores and components of the ATSDR Environmental Justice Index (EJI) high-level mapping and screening tool for census tracts located no further than one mile from Vantage and Medline. EJI scores census tracts using a percentile ranking. For example, an EJI ranking of 0.85 signifies that 85% of tracts in the nation rank lower on social vulnerability and environmental burden and 15% rank higher in those areas [Centers for Disease Control and Prevention 2022]. According to the EJI technical documentation:

> *The EJI is intended as a high-level mapping and screening tool that characterizes cumulative impacts and patterns of environmental injustice across the U.S. The EJI is a useful starting place for investigating issues of distributive and procedural justice and their effects on health and well-being… [T]he EJI is not intended as the following:*
>
> - *A definitive tool for labeling "EJ Communities" or characterizing all EJ issues.*
> - *A full representation of current or future social, environmental, or health characteristics*
> - *A representation of risk or exposure for a given community or area* [McKenzie 2022].

For more information on EJI see: https://www.atsdr.cdc.gov/placeandhealth/eji/index.html

The figures below map the EJI rank of census tracts within a 1-mile radius of Vantage (Figure B1) or Medline (Figure B2). The tables present how the three census tracts with substantial portions of the tract within 1-mile of Vantage (Table B1) and the three census tracts within 1-mile of Medline (Table B2) rank on each of the indicators related to either environmental burden or social vulnerability that factor into the overall EJI.

Figure B1. ATSDR Environmental Justice Index (EJI) ranking of census tracts within 1 mile of Vantage

Vantage Specialty Chemicals

Gurnee, Lake County, IL

INTRODUCTORY MAP SERIES

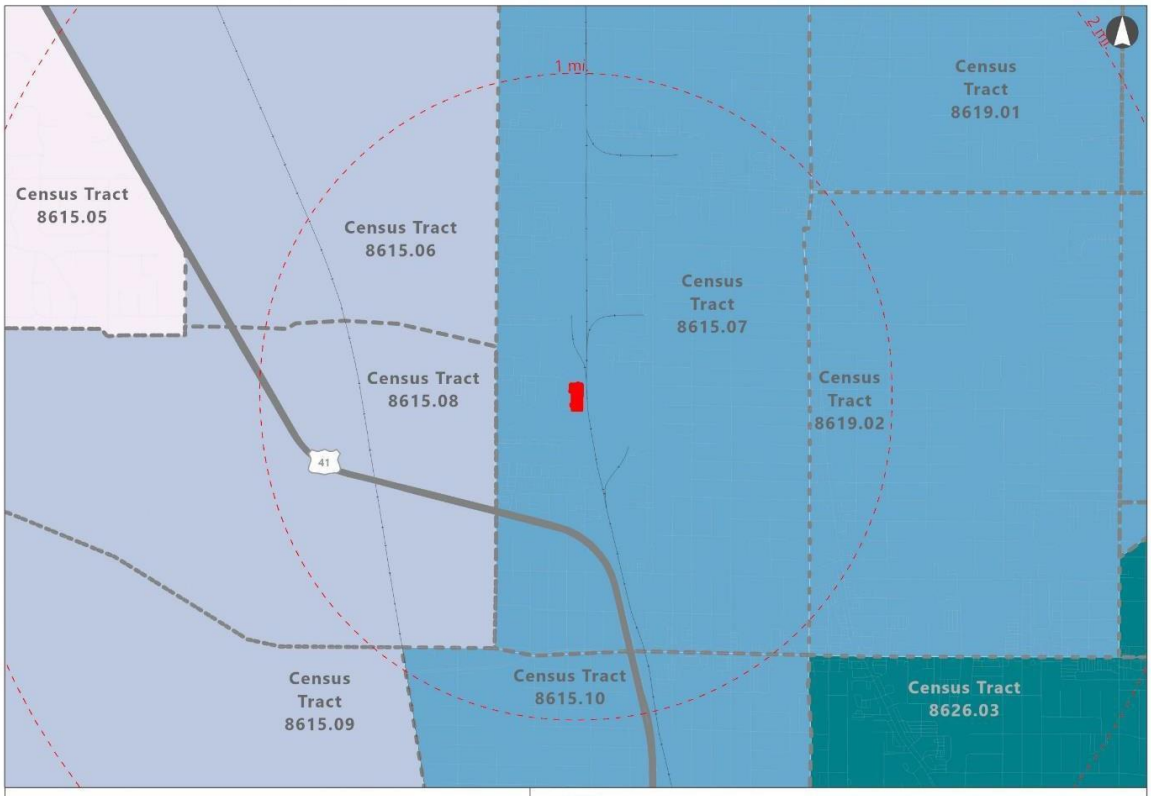
ENVIRONMENTAL JUSTICE INDEX

EPA FACILITY ID NOT AVAILABLE

The **Environmental Justice Index (EJI 2022)**[1] measures the cumulative impacts of environmental burden through the lens of environmental justice and health equity. Cumulative impacts are the total harm to human health that occurs from the combination of environmental burden, pre-existing health conditions, and social factors. The EJI Map can be used to identify areas that may require special attention or additional action to improve health and health equity. The EJI 2022 comprises 36 indicators organized into three modules of 1) social vulnerability, 2) environmental burden, and 3) health vulnerability. Indicators include measures of poverty, race/ethnicity, air pollution, proximity to hazardous sites and land uses, as well as chronic disease prevalence. Overall EJI scores are calculated by combining scores from the three EJI Modules. The EJI scores indicated in this map are based on percentile rankings of U.S. census tracts for all 48 continental U.S. states (note: Alaska, Hawaii, and territories were excluded due to data limitations).

Environmental Justice Index (2022)

No Data | Lowest Burden | Highest Burden



Population estimate[5] for the highest EJI ranked tracts within specified buffer areas. Not all buffers may appear on map. The zero-mile buffer indicates the population within the site of interest boundary.

0 mile	1 mile	2 miles	5 miles
0	0	6,364	62,262

Site of Interest[3]

Site of Interest Buffers[4]

Census Tract[2]

0 0.15 0.3 0.6

Miles

Data Sources: [3]ATSDR, [4]ATSDR GRASP. **Notes**: [1]CDC/ATSDR, [2]EJI scores census tracts using percentile ranking which represents the proportion of tracts (or counties) that experience cumulative impacts equal to or lower than a tract of interest. EJI domain rankings include air pollution, potentially hazardous and toxic sites, built environment, transportation infrastructure, water pollution, racial/ethnic minority status, socioeconomic status, household characteristics, housing type, and pre-existing chronic disease burden. [5]Calculated using area-proportion spatial analysis method. Population data from US Census 2020 Demographic and Housing Characteristics. **Reference**: Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry. 2022 Environmental Justice Index. Accessed Aug 2022. https://www.atsdr.cdc.gov/placeandhealth/eji/index.html.

ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 11585 | **AUTHOR** Elvira McIntyre

FINAL - FOR PUBLIC RELEASE

4/4/2024

Table B1. ATSDR Environmental Justice Index (EJI) component ranking of census tracts within 1 mile of Vantage

Environmental Justice Indicator	Census tract 8615.07	Census tract 8615.06	Census tract 8615.08
Social Vulnerability Rank	0.64	0.28	0.30
Environmental Burden Rank	**0.95**	**0.75**	**0.78**
Environmental Justice Index Rank	0.66	0.37	0.40
Minority Status	0.64	0.73	0.58
Socioeconomic Status	0.59	0.33	0.49
- Poverty	0.39	0.32	0.30
- No High School Diploma	0.69	0.33	0.27
- Unemployment	**0.89**	0.17	**0.81**
- Housing Tenure	0.49	**0.75**	0.70
- Lower-Income Households	0.47	0.70	0.60
- Lack of Health Insurance	0.72	0.28	0.33
- Lack of Internet Access	0.27	0.16	0.43
Household Characteristics	0.37	0.49	0.16
- Age 65 and Older	0.21	0.17	0.36
- Age 17 and Younger	0.66	**0.90**	0.49
- Civilian with a Disability	0.31	0.16	0.23
- Speaks English "Less than Well"	0.68	**0.76**	0.46
Housing Type	**0.76**	0.00	0.00
- Group Quarters	0.67	0.00	0.00
- Mobile Homes	0.59	0.00	0.00
Air Pollution	**0.88**	0.72	**0.82**
- Ozone	**0.88**	**0.82**	**0.88**
- PM2.5	**0.77**	**0.77**	**0.79**
- Diesel Particulate Matter	0.57	0.55	0.67
- Air Toxics Cancer Risk	**0.90**	0.42	0.56
Potentially Hazardous & Toxic Sites	**0.85**	**0.76**	**0.81**
- National Priority List Sites	0.00	0.00	0.00
- Toxic Release Inventory Sites	**0.85**	0.71	**0.79**
- Treatment, Storage, and Disposal Sites	0.00	0.00	0.00
- Risk Management Plan Sites	**0.92**	**0.80**	**0.87**
Built Environment	0.15	0.12	0.03
- Lack of Recreational Parks	0.39	0.39	0.39
- Housing Built Pre-1980	0.38	0.11	0.20
- Lack of Walkability	0.37	0.60	0.18
Transportation Infrastructure	**0.96**	0.69	0.70
- High-Volume Roads	0.47	0.62	**0.77**
- Railways	**0.79**	**0.79**	0.67
- Airports	**0.93**	0.00	0.00
Impaired Surface Water	0.53	0.53	0.53
High prevalence of asthma?	No	No	No

Environmental Justice Indicator	Census tract 8615.07	Census tract 8615.06	Census tract 8615.08
High prevalence of cancer?	No	No	No
High prevalence of high blood pressure?	No	No	No
High prevalence of diabetes?	No	No	No
High prevalence of poor mental health?	No	No	No

Figure B2. ATSDR Environmental Justice Index (EJI) ranking of census tracts within 1 mile of Medline

Medline Industries

Waukegan, Lake County, IL

INTRODUCTORY MAP SERIES

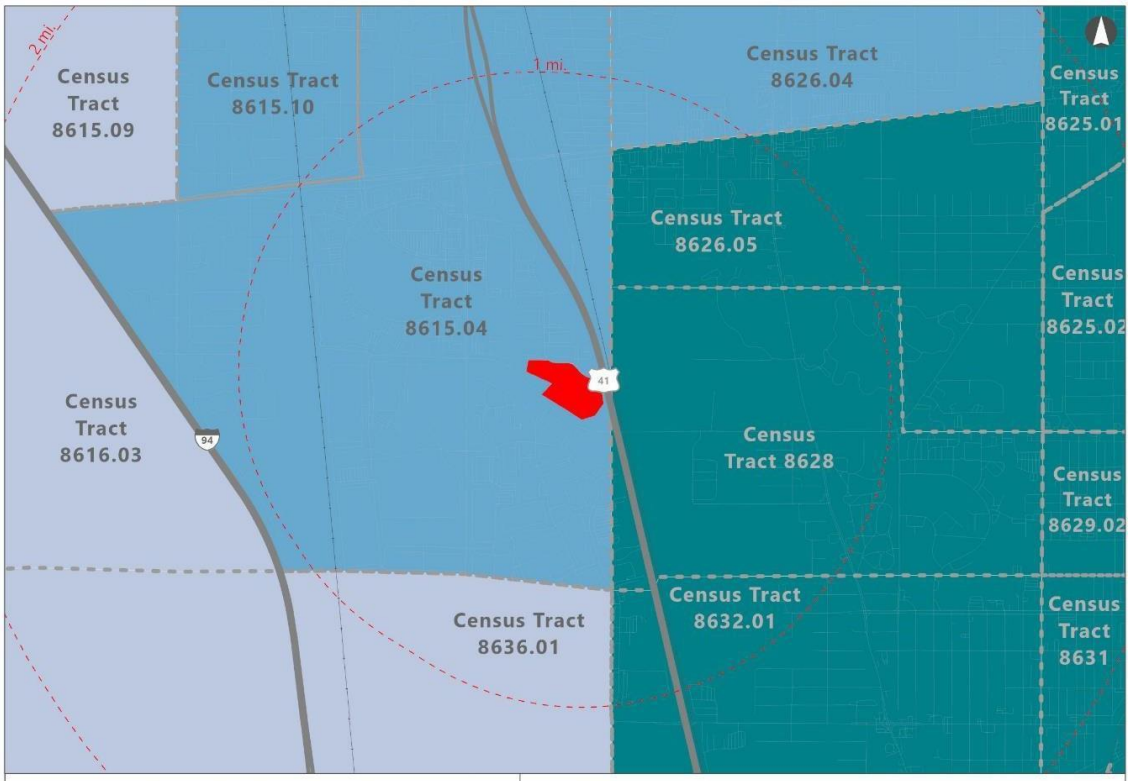
ENVIRONMENTAL JUSTICE INDEX

EPA FACILITY ID NOT AVAILABLE

The **Environmental Justice Index (EJI 2022)**[1] measures the cumulative impacts of environmental burden through the lens of environmental justice and health equity. Cumulative impacts are the total harm to human health that occurs from the combination of environmental burden, pre-existing health conditions, and social factors. The EJI Map can be used to identify areas that may require special attention or additional action to improve health and health equity. The EJI 2022 comprises 36 indicators organized into three modules of 1) social vulnerability, 2) environmental burden, and 3) health vulnerability. Indicators include measures of poverty, race/ethnicity, air pollution, proximity to hazardous sites and land uses, as well as chronic disease prevalence. Overall EJI scores are calculated by combining scores from the three EJI Modules. The EJI scores indicated in this map are based on percentile rankings of U.S. census tracts for all 48 continental U.S. states (note: Alaska, Hawaii, and territories were excluded due to data limitations).

Environmental Justice Index (2022)

No Data | Lowest Burden | Highest Burden



Population estimate[5] for the highest EJI ranked tracts within specified buffer areas. Not all buffers may appear on map. The zero-mile buffer indicates the population within the site of interest boundary.

0 mile	1 mile	2 miles	5 miles
0	1,909	17,208	61,301

Site of Interest[3]

Site of Interest Buffers[4]

Census Tract [2]

0 0.17 0.35 0.7

Miles

Data Sources: [3]ATSDR, [4]ATSDR GRASP. **Notes**: [1]CDC/ATSDR, [2]EJI scores census tracts using percentile ranking which represents the proportion of tracts (or counties) that experience cumulative impacts equal to or lower than a tract of interest. EJI domain rankings include air pollution, potentially hazardous and toxic sites, built environment, transportation infrastructure, water pollution, racial/ethnic minority status, socioeconomic status, household characteristics, housing type, and pre-existing chronic disease burden. [5]Calculated using area-proportion spatial analysis method. Population data from US Census 2020 Demographic and Housing Characteristics. **Reference**: Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry. 2022 Environmental Justice Index. Accessed Aug 2022. https://www.atsdr.cdc.gov/placeandhealth/eji/index.html.

ATSDR Agency for Toxic Substances and Disease Registry

GRASP Geospatial Research, Analysis, and Services Program

PRJ ID 11585 | AUTHOR Elvira McIntyre

FINAL - FOR PUBLIC RELEASE

4/4/2024

Table B2. ATSDR Environmental Justice Index (EJI) component ranking of census tracts within 1 mile of Medline

Environmental Justice Indicator	Census tract 8615.04	Census tract 8626.05	Census tract 8628
Social Vulnerability Rank	0.69	**0.99**	**0.88**
Environmental Burden Rank	**0.91**	0.74	**0.98**
Environmental Justice Index Rank	0.67	**0.96**	**0.99**
Socioeconomic Status	0.71	**0.94**	**0.94**
- Poverty	0.55	**0.93**	**0.92**
- No High School Diploma	**0.78**	0.73	**0.96**
- Unemployment	0.69	**0.99**	**0.87**
- Housing Tenure	**0.80**	**0.90**	**0.94**
- Lower-Income Households	0.47	**0.88**	**0.94**
- Lack of Health Insurance	**0.88**	**0.82**	**0.81**
- Lack of Internet Access	0.30	0.64	0.45
Household Characteristics	0.29	**0.94**	**0.91**
- Age 65 and Older	0.03	0.43	0.07
- Age 17 and Younger	**0.76**	**0.77**	**0.94**
- Civilian with a Disability	0.07	0.65	**0.78**
- Speaks English "Less than Well"	**0.90**	**0.84**	**0.82**
Housing Type	0.62	**0.96**	0.00
- Group Quarters	0.00	**0.95**	0.00
- Mobile Homes	**0.96**	0.74	0.00
Air Pollution	**0.97**	**0.95**	**0.96**
- Ozone	**0.89**	**0.88**	**0.89**
- PM2.5	**0.79**	**0.79**	**0.79**
- Diesel Particulate Matter	**0.79**	0.70	0.69
- Air Toxics Cancer Risk	**1.00**	**1.00**	**1.00**
Potentially Hazardous & Toxic Sites	**0.79**	0.48	**0.95**
- National Priority List Sites	0.00	0.00	0.00
- Toxic Release Inventory Sites	**0.75**	**0.79**	**0.86**
- Treatment, Storage, and Disposal Sites	0.00	0.00	**0.92**
- Risk Management Plan Sites	**0.86**	0.00	**0.82**
Built Environment	0.06	0.17	0.21

Environmental Justice Indicator	Census tract 8615.04	Census tract 8626.05	Census tract 8628
- Lack of Recreational Parks	0.39	0.39	0.39
- Housing Built Pre-1980	0.13	0.50	0.54
- Lack of Walkability	0.42	0.29	0.32
Transportation Infrastructure	**0.78**	0.48	0.68
- High-Volume Roads	**0.77**	0.45	0.65
- Railways	**0.79**	0.54	**0.75**
- Airports	0.00	0.00	0.00
Impaired Surface Water	0.68	0.72	0.74
High prevalence of asthma?	No	**Yes**	**Yes**
High prevalence of cancer?	No	No	No
High prevalence of high blood pressure?	No	**Yes**	**Yes**
High prevalence of diabetes?	No	**Yes**	**Yes**
High prevalence of poor mental health?	No	**Yes**	**Yes**

Appendix C: Description of EtO Air Sampling Data Reviewed by ATSDR

C1. Lake County EtO air sampling datasets used to evaluate chronic health effects

ATSDR used two datasets to estimate EtO exposure point concentrations and lifetime excess cancer risk. The LCHD sampling data collected at 12 locations using 13 air monitors (one was relocated). 24-hour samples were collected from June 2019 to May 2020 during three different phases. During phase 1 (June 6– July 3, 2019) sample collection was more frequent and irregular (every 1–3 days). In phase 2 (October 26, 2019– January 21, 2020) and phase 3 (April 4, 2020– May 1, 2020) samples were collected every three days. In addition, Medline conducted monthly sampling at two fenceline locations (F1 and F2) as well as two community locations (CF1 and C1/2) starting in March 2020. ATSDR analyzed the monthly sampling conducted through September 2023. Sampling near Medline is currently ongoing. Sampling locations for the LCHD and Medline monthly sampling are described in Table C1.

Table C1. Sampling location names, locations, and distance from facility for the LCHD three phases of sampling from June 2019 to May 2020 and Medline monthly sampling from March 2020 to September 2023

Sampling location	Dataset	Location Description	Distance and direction from site
M1-A	LCHD	SE corner of N. Palmieri and Staben, Waukegan	0.7 miles NE of Medline
M1-B	LCHD	Greenbelt Forest Preserve - Shelter B	0.55 miles NE of Medline
M2	LCHD	3106 Belvidere Road, Waukegan	1 mile NE of Medline
M3	LCHD	Pulaski Road and S. Shields Drive, Waukegan	0.1 miles SW of Medline
M4	LCHD	FP access west of Green Bay Road, Waukegan	0.4 miles ENE of Medline
M5	LCHD	800 S. Northpoint Blvd., Waukegan	0.3 miles NNW of Medline
R1	LCHD	O'Plaine Rd & Russell Ave, Gurnee	2 miles SW of Vantage; 1.85 miles NW of Medline
R2	LCHD	7000 Washington Street, Gurnee	4.1 miles WSW of Vantage; 4.85 WNW Medline
V1	LCHD	2000 Belle Plaine Ave, Gurnee	0.6 miles NE of Vantage

V2	LCHD	SE corner Northwestern and Keith, Gurnee	0.23 miles E of Vantage
V3	LCHD	3886 Morrison Drive, Gurnee	0.05 miles South of Vantage
V4	LCHD	1200 Estes Drive, Gurnee	0.33 miles South of Vantage
V5	LCHD	36016 N Delany Rd	0.60 miles WNW of Vantage
C1	Medline monthly	Community Northeast (program start through Q1 2023), near M1	0.55 miles NE of Medline
C2	Medline monthly	Community Northeast (Starting Q2 2023)	0.55 miles NE of Medline
CF1	Medline monthly	Community and Facility Southwest (near LCHD M3)	0.1 miles SW of Medline
F1	Medline monthly	Facility North	On N Medline fenceline
F2	Medline monthly	Facility East	On NE Medline fenceline

To understand exposure to EtO in Lake County, it was important to understand how exposure changed over time. Comparison over time allowed us to compare concentrations near Medline when open (the pre-closure operational time period in 2019 and the operational time period with PTE from 2020 to 2023) to concentrations when closed. It was also important to understand how exposure changed over space, such as whether EtO concentrations are higher near the facility.

There were several complicating factors that made comparisons of EtO concentrations measured at different times and in different locations more difficult:

1. EtO concentrations across the United States appear to follow a seasonal pattern of higher concentrations in the summer and lower concentrations in the winter.
2. As the U.S. EPA became more aware of the influence of the "canister effect" from 2018 through 2019, sampling in Lake County tended to use more silicon-ceramic canisters over time to reduce the influence of positive bias. EtO concentrations measured in silicon-ceramic canisters tend to be lower than concentrations measured in other canister types, all else being equal.
3. Air sampling locations may have had a different rate of silicon-ceramic canister usage, which could affect the EtO concentrations measured at that location.

In order to understand the EtO exposures that may have resulted from the facility, we needed to control for factors unrelated to the facilities like the canister effect and seasonal variation that can change EtO concentrations. In this appendix we present both "raw" measured data which is the reported EtO concentrations and do not control for these factors and "adjusted" data which is the GAM-adjusted EtO

concentrations and do control for these factors. This adjustment does not change our overall health conclusions; however, using adjusted data helped to better define the risk of cancer and the contribution of Medline and Vantage to EtO concentrations. The methods used to analyze and adjust the data are discussed in detail in this appendix.

Because some of the reported EtO concentrations were below analytic detection limits, we calculated summary statistics after estimating non-detect values using robust regression on order statistics [Helsel 2012]. This approach computes regression statistics to estimate the percentiles of the censored (non-detected) measurements. ATSDR calculated the median, mean, and 95% upper confidence limits (95% UCL) of the mean EtO concentrations for each air sampling location in the LCHD air sampling dataset in Lake County. For risk evaluation purposes, we used the 95% UCL percentile bootstraps [Manly 2007] to ensure that we were not underestimating exposures due to sampling errors [ATSDR 2023b, U.S. EPA 2015,Millard 2013].

Table C2. Descriptive statistics of raw and adjusted ethylene oxide outdoor air concentrations collected by LCHD near Vantage and Medline by sampling location and operational period

Operational Period	Sampling Location	Number of Valid Samples [Detected]	Number of Invalid Samples	Raw Median (µg/m³)	Raw Range Detected (µg/m³)	Detection Limits (µg/m³)	Adjusted Median (µg/m³)	Adjusted Range Detected (µg/m³)
Medline Operating	M1	28[22]	2	0.170	0.06 – 4.3	0.045	0.074	0.022 – 0.74
Medline Closed	M1	13[13]	1	0.190	0.06 – 0.3	0.045	0.078	0.023 – 0.14
Medline Operating, PTE	M1	10[10]	0	0.250	0.11 – 2.5	0.045	0.120	0.033 – 0.72
Medline Operating	M2	26[19]	0	0.120	0.06 – 0.62	0.045	0.051	0.027 – 0.23
Medline Closed	M2	14[14]	0	0.110	0.06 – 0.24	0.045	0.055	0.026 – 0.16
Medline Operating, PTE	M2	10[10]	0	0.150	0.05 – 0.39	0.045	0.078	0.051 – 0.38
Medline Operating	M3	30[29]	0	0.240	0.06 – 10	0.045	0.069	0.025 – 7.3
Medline Closed	M3	14[14]	0	0.120	0.06 – 0.27	0.045	0.062	0.033 – 0.15
Medline Operating, PTE	M3	8[8]	2	0.400	0.09 – 0.67	0.045	0.280	0.066 – 0.46

Operational Period	Sampling Location	Number of Valid Samples [Detected]	Number of Invalid Samples	Raw Median (µg/m³)	Raw Range Detected (µg/m³)	Detection Limits (µg/m³)	Adjusted Median (µg/m³)	Adjusted Range Detected (µg/m³)
Medline Operating	M4	25[20]	1	0.170	0.08 – 0.75	0.045,0.0585	0.091	0.028 – 0.88
Medline Closed	M4	12[12]	2	0.170	0.05 – 0.24	0.045,0.0585	0.064	0.035 – 0.13
Medline Operating, PTE	M4	10[10]	0	0.190	0.05 – 0.76	0.045,0.0585	0.140	0.044 – 0.38
Medline Operating	M5	17[14]	0	0.150	0.05 – 0.81	0.045	0.053	0.015 – 0.21
Medline Closed	M5	13[13]	1	0.210	0.05 – 0.31	0.045	0.079	0.017 – 0.15
Medline Operating, PTE	M5	10[10]	0	0.380	0.1 – 2.2	0.045	0.120	0.042 – 1.7
Medline Operating	R1	26[21]	0	0.150	0.07 – 0.58	0.045	0.047	0.029 – 0.11
Medline Closed	R1	14[13]	0	0.160	0.09 – 0.51	0.045	0.063	0.044 – 0.18
Medline Operating, PTE	R1	10[10]	0	0.300	0.05 – 1	0.045	0.065	0.051 – 0.78
Medline Operating	R2	26[18]	0	0.110	0.06 – 1.3	0.045	0.040	0.019 – 0.83
Medline Closed	R2	14[14]	0	0.085	0.05 – 0.3	0.045	0.066	0.022 – 0.13
Medline Operating, PTE	R2	9[9]	1	0.200	0.07 – 0.83	0.045	0.078	0.027 – 0.12
Vantage Operating	V1	50[45]	4	0.160	0.045 – 5.3	0.045	0.076	0.0097 – 5.1
Vantage Operating	V2	48[41]	2	0.180	0.05 – 8.9	0.045,0.0585	0.073	0.034 – 8.5

Operational Period	Sampling Location	Number of Valid Samples [Detected]	Number of Invalid Samples	Raw Median (µg/m³)	Raw Range Detected (µg/m³)	Detection Limits (µg/m³)	Adjusted Median (µg/m³)	Adjusted Range Detected (µg/m³)
Vantage Operating	V3	51[46]	3	0.210	0.05 – 2	0.045	0.074	0.013 – 1.9
Vantage Operating	V4	48[41]	2	0.140	0.05 – 1.9	0.045	0.056	0.015 – 1.2
Vantage Operating	V5	37[36]	3	0.130	0.05 – 0.73	0.045	0.071	0.032 – 0.43

Table C3. Descriptive statistics of Medline monthly EtO concentrations by sampling location

Operations	Site	Number of Valid Samples [Detected]	Number of Invalid Samples	Raw Median (µg/m³)	Raw Range Detected (µg/m³)	Detect on Limits (µg/m³)	Adjusted Median (µg/m³)	Adjusted Range Detected (µg/m³)
PTE Operating	C1/2	41[39]	0	0.120	0.053 – 0.54	0.0318, 0.0251	0.096	0.05 – 0.5
PTE Operating	CF1	43[42]	0	0.180	0.042 – 0.59	0.0253	0.140	0.052 – 0.55
PTE Operating	F1	42[41]	1	0.270	0.053 – 6.7	0.02525	0.220	0.052 – 8
PTE Operating	F2	43[42]	0	0.340	0.06 – 1.1	0.0253	0.250	0.054 – 1.1

C2. Sample invalidation in the LCHD and Medline datasets

On September 2, 2020, in response to inquiries from Vantage Specialty Chemicals regarding potential invalidation of samples due to canister pressure, the Director of Environmental Health at the LCHD sent a formal request to U.S. EPA's Region 5 Air and Radiation Division to make recommendations about whether "any samples results should be flagged or invalidated due to quality assurance concerns" [Mackey 2020]. In a letter response dated October 6, 2020 [Siegel 2020], U.S. EPA advised that several observations should be invalidated due to a final laboratory measurement indicating there was no remaining vacuum in the canister, which means the canister could have stopped collecting outdoor air before the end of the 24-hour sampling period. In addition, U.S EPA recommended the invalidation of several observations where the initial canister vacuum as measured in the field was less than 28 inches Hg [Siegel 2020]. Finally, some pollutants may co-elute with EtO, meaning that they may be misidentified as EtO. U.S. EPA defines criteria to prevent mis-identifying compounds [Batelle 2016]. The U.S. EPA recommended invalidating two samples that fell outside of these criteria and therefore could not be positively identified as EtO. LCHD concurred with these invalidations, and those samples are marked as invalid in the dataset ATSDR analyzed. The number of invalid samples by sampling location and operational period is reported in Table C2.

ATSDR applied the criterion invalidating any sample that was at ambient pressure as measured in the laboratory from U.S. EPA's letter to LCHD to the sampling conducted by Medline from 2020–2023. As a result, ATSDR invalidated three samples with final pressure as measured in the laboratory indicating that there was no remaining vacuum in the canister (Table C3).

C3. Other air sampling data collected in Lake County

ATSDR evaluated data collected by Medline, Vantage and the community group Stop EtO. The data were not used to calculate exposure point concentrations (EPCs) because the LCHD dataset had more samples for each operating phase. The concentrations measured by Medline and Vantage at LCHD sites were very similar to those measured in the LCHD dataset. Medline and Vantage collected 24-hour samples in June and July 2019. Note this was before Medline had installed its new emissions control system. Stop EtO sampled after LCHD had finished sampling when Medline was operating as a permanent total enclosure (PTE) in August and September 2020.

Table C4. Descriptive statistics of other ethylene oxide investigation raw air sampling data by sampling collection station and sampling phase

Program	Sampling Location	Phase	Number of Valid Samples [Detected]	Duplicates	Median (µg/m³)	Range Detected (µg/m³)
Medline	M1	phase 1	4 [3]	1	0.21	0.18 – 0.38
	M2	phase 1	3 [1]	0	0.07	0.26 – 0.26
	M3	phase 1	4 [4]	1	2.88	0.46 – 5.1
	M4	phase 1	4 [3]	1	0.36	0.29 – 0.45
Vantage	V1	phase 1	11 [9]	2	0.13	0.10 – 0.26
	V2	phase 1	12 [12]	3	0.26	0.07 – 0.46
	V6	phase 1	9 [9]	2	0.34	0.15 – 0.63

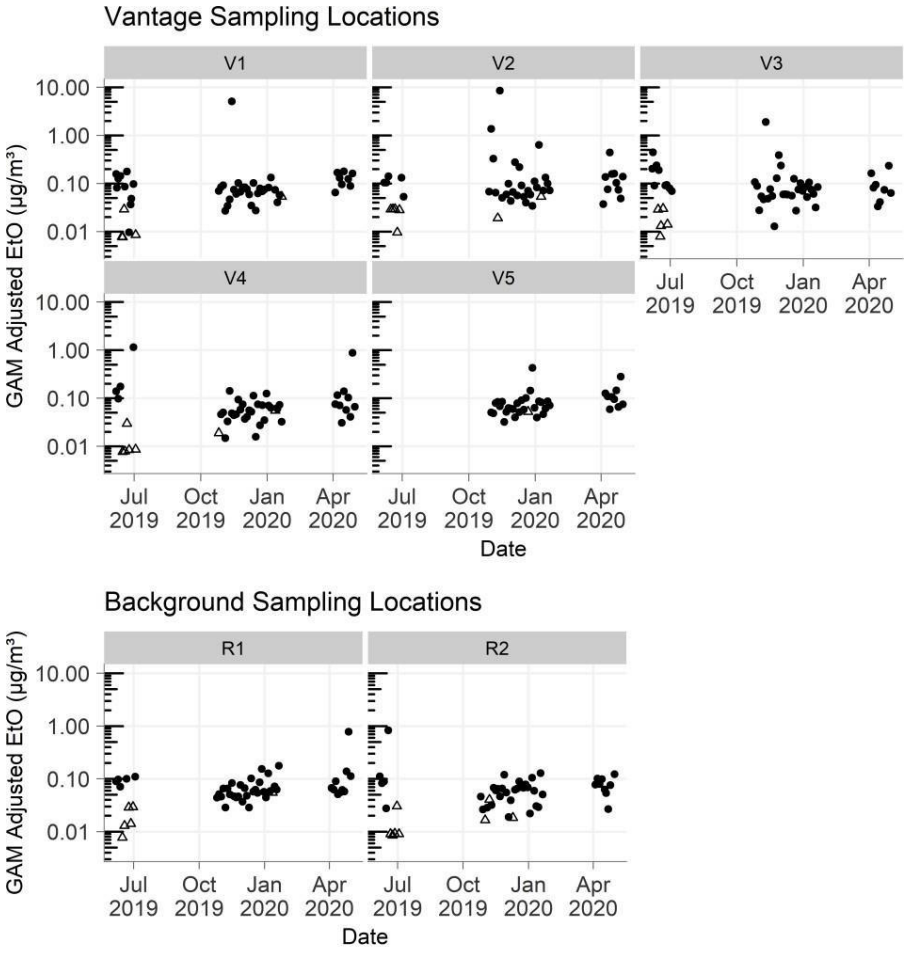
Program	Sampling Location	Phase	Number of Valid Samples [Detected]	Duplicates	Median (µg/m³)	Range Detected (µg/m³)
	V7	phase 1	9 [9]	1	0.19	0.06 – 0.3
	V8	phase 1	11 [10]	2	0.18	0.10 – 0.26
STOP ETO	Near Medline Facility	phase 3	4 [4]	0	0.72	0.49 – 1.3
	Near Vantage Facility	phase 3	4 [4]	0	0.75	0.5 – 1.3
	North of Medline Warehouse	phase 3	1 [1]	0	1.35	1.35 – 1.35
	South of Medline Warehouse	phase 3	1 [1]	0	0.51	0.51 – 0.51

Appendix D: Temporal and Spatial Trends of EtO Concentrations Near Vantage and Medline

D1. Trends in EtO Concentrations Over Time Near Vantage

To view how the generalized additive model (GAM) adjusted EtO concentrations have changed over time, ATSDR plotted GAM-adjusted EtO concentrations collected by the Lake County Health Department and Community Health Center (LCHD) at the Vantage sampling locations (V1– V5) and background sampling locations (R1 and R2) from June 6, 2019 to May 1, 2020. See Figure D1 and Figure 3 for map. At sampling locations near Vantage, there was not an obvious temporal trend, but there was an apparent increase in EtO concentrations on November 13, 2019 at V1 and V2, with both stations recording their maximum adjusted EtO concentrations (5.3 and 8.2 µg/m^3, respectively) on that day. On those days, the wind was from the southwest and blowing from Vantage towards the V1 and V2 monitors. Several additional apparent elevations in concentrations appeared at V1, V2 and V3 between November 4, 2019 and November 10, 2019 (see Figure D1).

Figure D1. Time trends of adjusted EtO concentrations at Vantage and background LCHD sampling locations in June 2019 through May 2020



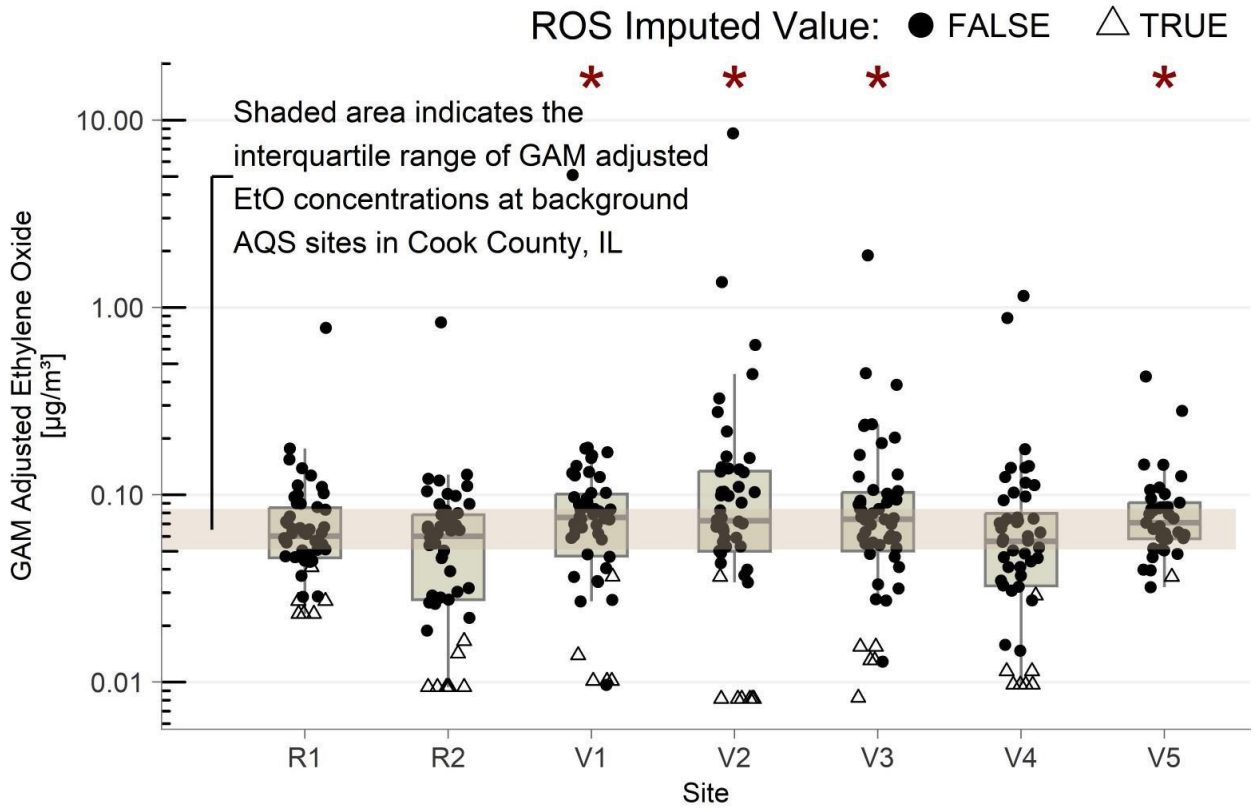
GAM adjusted Lake County Health Department ethylene oxide (EtO) data shown by sampling location. Samples were collected in three periods over the course of a year. Non-detect values are plotted at the limit of detection.

D2. Comparison of EtO Concentrations Near Vantage to Background EtO Concentrations

ATSDR statistically compared GAM-adjusted LCHD EtO concentrations near the Vantage facility to reference background concentrations at R1 and R2 combined from June 6, 2019 to May 1, 2020 (See Appendix E2 for details). In Figure D2, concentrations at each of LCHD's Vantage sampling locations (V1–V5) and the two LCHD background sampling locations (R1 and R2) are represented by a box plot where the line in the center of the boxplot represents the median adjusted EtO concentration and the rectangular area represents the interquartile range or the range containing half of the adjusted EtO concentrations at a given sampling location. The horizontal beige bar is the interquartile range for adjusted EtO concentrations measured at the two Cook County sampling locations. This provides a visual reference of adjusted background EtO concentrations away from known EtO sources in Illinois form October 2018 to March 2021. The asterisks indicate sampling locations with adjusted EtO concentrations that are statistically elevated above background adjusted background EtO concentrations at R1 and R2.

For sampling locations near Vantage, sampling locations V1, V2, V3, and V5 had concentrations that were statistically significantly elevated over background at R1 and R2 (Figure D2, Appendix E2). Median values at Vantage sampling locations fell within the range of concentrations observed at background sampling locations at R1 and R2, but the highest EtO concentrations at several Vantage sampling locations were much greater than the highest concentrations measured at background R1 and R2 sampling locations. These findings appear to be driven partially by several samples at multiple sampling locations in early November 2019 when EtO concentrations at several sampling locations near Vantage were higher than EtO concentrations measured during the rest of the sampling period. It is uncertain whether the higher EtO concentrations represented an unusual circumstance that happened to be reflected in the sampling data or if episodic increases in exposure would be common enough to influence long-term health risk.

Figure D2. Boxplots of GAM-adjusted EtO concentrations at Vantage and reference background LCHD sampling locations from June 2019 to May 2020



Notes:
ROS: Robust Regression on Order Statistics
GAM: Generalized Additive Model
AQS: US Environmental Protection Agency Air Quality System
µg/m³: micrograms per cubic meter
Dunn's many to one test compared to site combined R1 and R2 p value:
. p< 0.1, * p < 0.05, ** p< 0.01, *** p <0.001

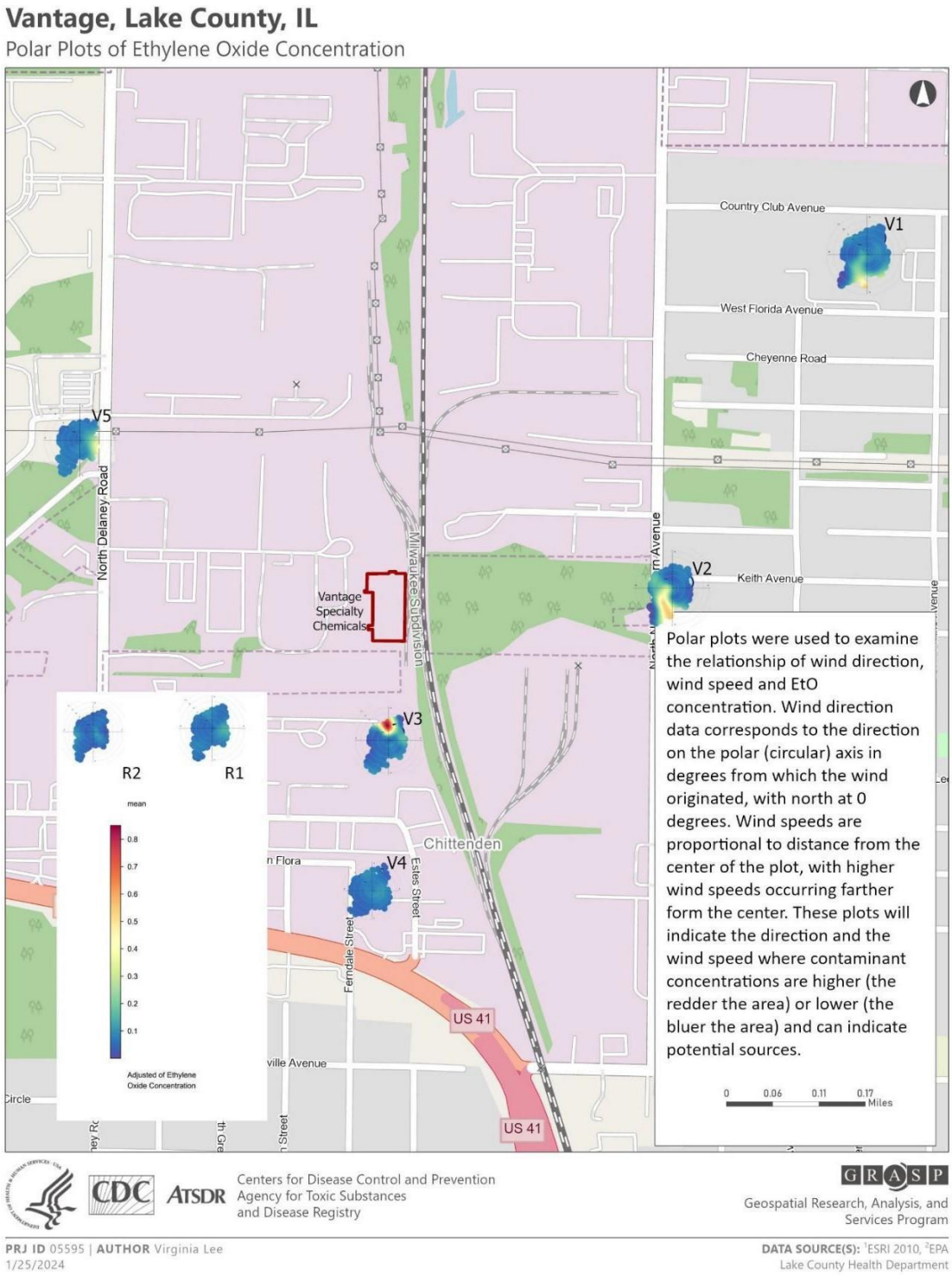
D3. Spatial Trends of EtO Concentrations near Vantage by Wind Direction and Wind Speed

Polar plots can be used to visually identify the source of pollutant emissions by displaying the relationship between pollutant concentrations and wind direction and speed at specific sampling locations. These plots are qualitative visualizations of spatial trends, not statistical tests. Polar plots visualize EtO concentrations (represented by color) by wind direction (represented by radial location on the plot) and wind speed (represented by distance from the center of the plot). Location on the plot indicates which direction the winds were blowing from on a given day and distance from the center represents wind speed. The warmer (redder) colors represent higher EtO concentrations, and cooler (bluer) colors represent lower EtO concentrations. Polar plots show evidence that EtO concentrations were influenced by a nearby industrial source when warmer colors are facing toward a source. Conditions where the EtO concentrations are independent of wind direction and speed show a polar plot that is a uniform blue color, indicating that the specific EtO source cannot be determined. If EtO from a source such as Medline or Vantage were influencing nearby concentrations, one would expect to see a polar plot where warmer (redder) colors gradually fade into bluer (cooler) colors. Polar plots that are uniformly blue with no clear gradient potentially indicate lack of influence from a source. Random

fluctuations in EtO concentrations may cause small areas of warmer colors, particularly at the farthest edges of the plot that are not source related. Gradient changes in color that extend into the center of the plot are more likely to be source related than anomalous “spots” of color on the edges of the plot.

Figure D3 shows the GAM-adjusted EtO concentration color gradient on polar plots at each LCHD Vantage sampling location from 2019 to 2020. The adjusted EtO concentrations at the closest sampling location (V3) are higher (redder color) when the wind is blowing from the facility, with some indication of a potential relationship between wind direction and speed and EtO concentrations at sampling location V5. Polar plots at other Vantage sampling locations (V1, V2 and V4) did not show a clear relationship between wind direction, wind speed, and EtO concentration.

Figure D3. Polar plots of LCHD GAM-adjusted EtO concentrations at Vantage sampling locations from June 2019 to May 2020



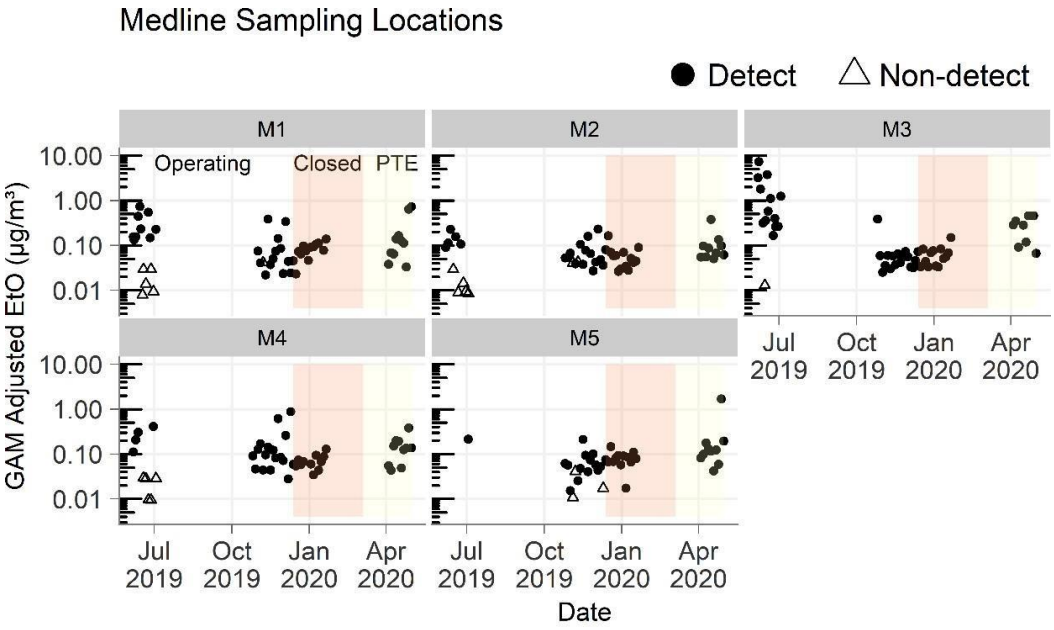
D4. Trends in EtO Concentrations Over Time Near Medline

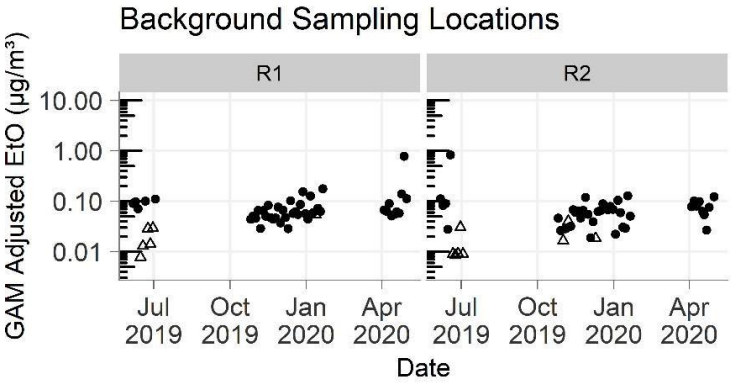
LCHD EtO Sampling from June 2019 to May 2020

To view how GAM-adjusted EtO concentrations have changed over time, ATSDR plotted GAM-adjusted LCHD concentrations at the Medline sampling locations (M1 – M5) and background sampling locations (R1, R2) during the three different Medline operational time periods from June 6, 2019, to May 1, 2020. See Figure D4 and Figure 3 for map. Figure D4 is color coded by the three different periods of operation at Medline (pre-closure operating period in white, temporary closure period in red, and PTE operation period in yellow) for the Medline sampling location. Median GAM-adjusted concentrations for LCHD sampling locations near Medline for each operating period ranged from 0.05 µg/m^3 at M5 when Medline was closed to 0.27 µg/m^3 at M3 when Medline was operating before new controls were installed.

Statistical testing (described in Appendix E) showed adjusted EtO concentrations were elevated at M3 both prior to facility shutdown and after the facility reopened compared to adjusted concentrations measured when Medline was closed from December 13, 2019– January 21, 2020. Adjusted EtO concentrations were not statistically distinct from shut down concentrations measured at any other sampling location other than M3. A lack of statistical finding does not necessarily mean there is no difference from background adjusted EtO concentrations at other sampling locations, especially for these low sample size statistical tests.

Figure D4. Time trend of LCHD GAM-adjusted EtO concentrations at Medline and background LCHD sampling locations June 2019 through May 2020





Explanation:
GAM adjusted Lake County Health Department ethylene oxide (EtO) data shown by sampling location. Samples were collected in three periods over the course of a year. Sites near Medline (M1 – M5) show if the Medline facility was operating, closed, or operating with permanent total enclosure (PTE) controls. Non-detect values are plotted at the limit of detection.

Medline Monthly EtO Sampling from March 2020 to September 2023

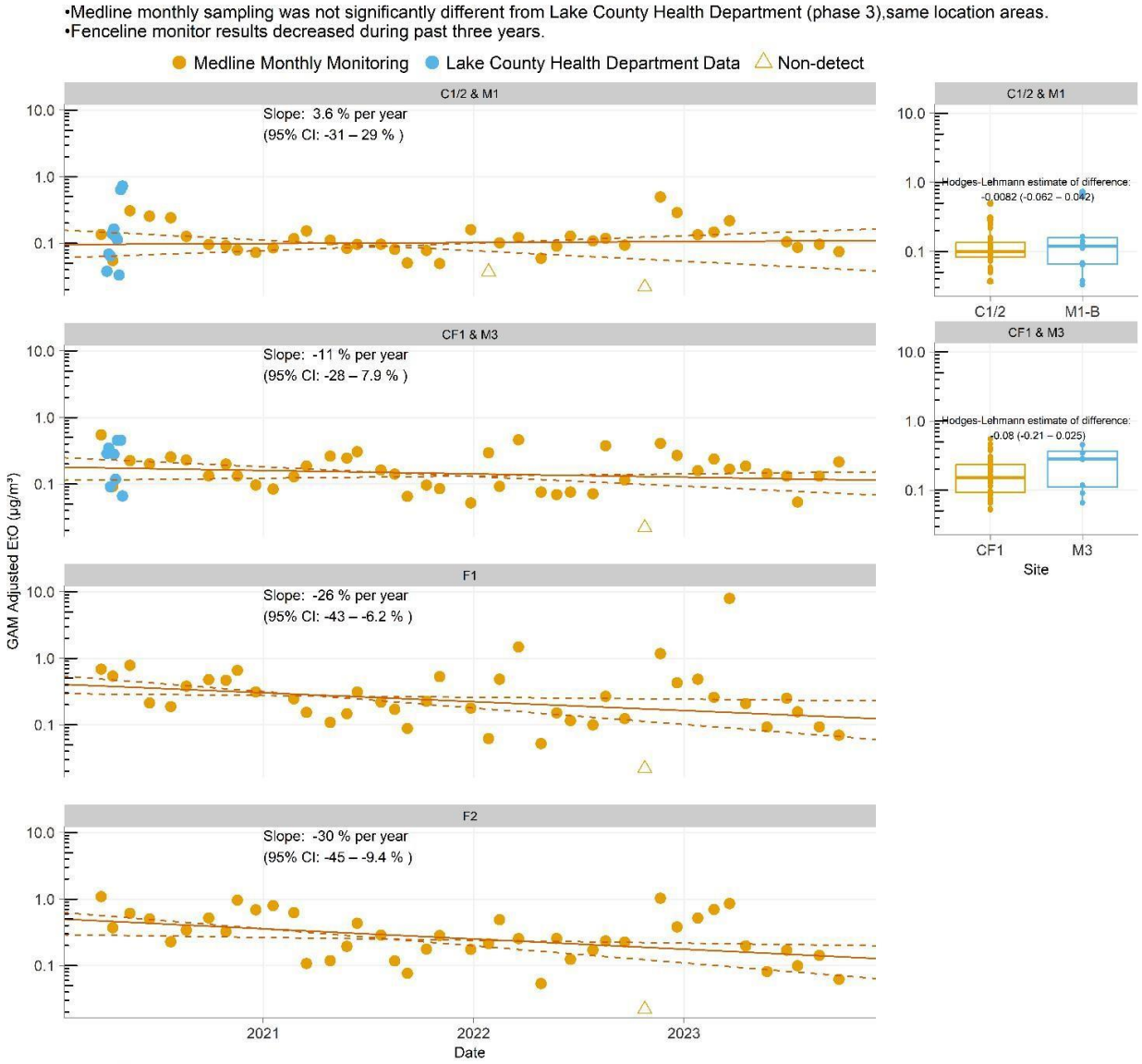
Medline monthly EtO air sampling from March 2020 to September 2023 includes 43 unique sampling events at two air sampling locations near the Medline property boundary (F1 and F2) and two residential areas near Medline (C1/2, CF1) during the PTE operation time period after Medline re-opened on March 8, 2020. Figure D5 displays the Medline monthly EtO concentrations in orange over time at each air sampling location. The Medline monthly sampling is ongoing. Median EtO concentrations at each Medline monthly sampling location ranged from 0.12 µg/m^3 for the neighborhood northeast of Medline (C1 and C2) to 0.36 µg/m^3 at one of the fenceline monitors (F2).

Figure D5 displays EtO concentrations over time at each air monitor in the Medline monthly sampling in orange. The slopes of the solid orange lines on the graphs below represent the linear trends of EtO concentrations at each air sampling location over time. The slopes of the dashed lines are the upper and

lower 95% confidence intervals of each trend. Log EtO concentrations decreased in a statistically significant fashion over time at the fenceline air sampling locations. There was no linear, statistically significant trend in EtO concentrations measured at the two community sampling locations (C1/2, CF1).

LCHD collected some EtO air sampling data at sampling locations M1– M5 (8–10 samples per sampling location) during the PTE operation time period from April 4, 2020, to May 1, 2020. LCHD sampling and Medline monthly sampling had some air sampling locations located in similar areas (see Figure 3 for map). Both LCHD M3 and Medline CF1 sampling locations were located southeast of Medline near the closest residential area. Both LCHD M1 and Medline C1 (later replaced by C2) sampling locations were located near the residential area northeast of the facility. Figure D5 also compares these two pairs of sampling locations located near each other. The LCHD adjusted EtO concentrations in blue measured during the PTE operation time period from sampling location M3 is plotted on the CF1 time series. In the boxplots to the right of the time series, EtO concentrations at M3 (blue) are compared to EtO concentrations at CF1 (orange). Similarly, M1 concentrations during the PTE operation time period are plotted on the C1/2 time series and concentrations from the pair of sampling locations are compared using boxplots. Concentrations measured at these pairs of air sampling locations were similar in the LCHD and Medline monthly sampling, with no statistical difference between M3 and CF1 or M1 and C1/2.

Figure D5. Time trends of EtO concentrations at LCHD and Medline monthly sampling locations from 2020 to 2023 and comparisons EtO concentrations at co-located LCHD and Medline sampling locations



GAM adjusted Medline ethylene oxide (EtO) data shown by sampling location.
Replicate samples were averaged at each site and date. Regression line is Thiel-Sen Line with 95% Confidence Interval. (Note intercepts change due to bootstrapping of Thiel-Sen Line)
µg/m³: micrograms per cubic meter
Non-detect values are plotted at the limit of detection.

D5. Comparison of EtO Concentrations Near Medline to Background EtO Concentrations

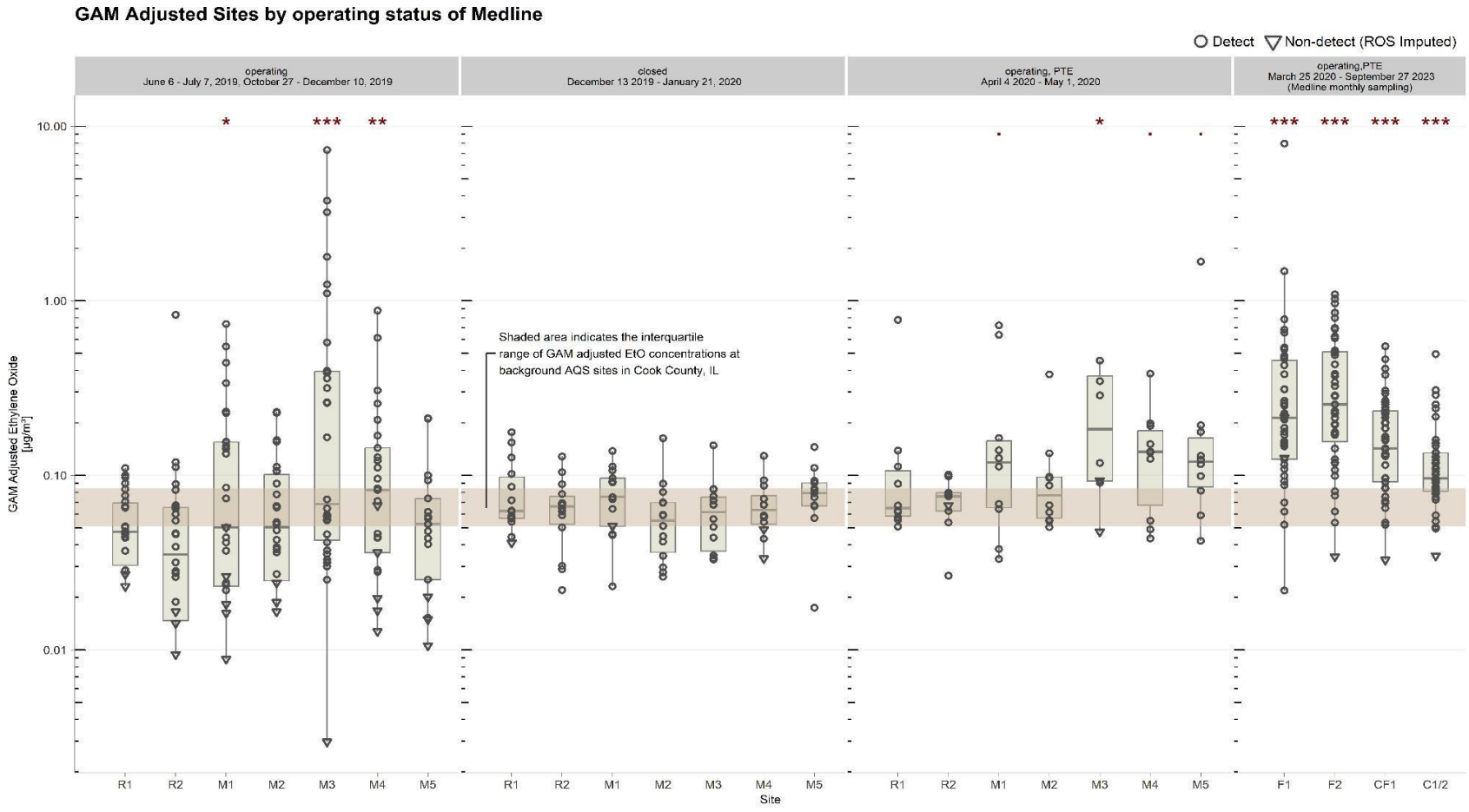
In Figure D6, LCHD GAM-adjusted EtO concentrations collected from June 6, 2019 to May 1, 2020 at LCHD air sampling locations (M1– M5) near Medline and LCHD background air sampling locations (R1 and R2), and Medline monthly EtO from March 2020 to September 2023 at sampling locations C1/2, CF1, F1 and F2 are represented in box plots for each air sampling location. See Figure 3 for map. In each boxplot, the line in the center of the boxplot represents the median adjusted EtO concentration and the rectangular area represents the interquartile range or the range containing half of the adjusted EtO concentrations at a given sampling location. The horizontal red shaded bar in the background of the plot represents the interquartile range for adjusted EtO concentrations measured at the Northbrook and Schiller Park sampling locations in Cook County from October 2018 to March 2021. This red shaded bar provides a visual reference of adjusted background EtO concentrations away from known sources in Illinois. Adjusted LCHD EtO concentrations are plotted for each of the three operational periods at Medline (pre-closure operation period, temporary closure operation period, and PTE operation period). The asterisks indicate EtO concentrations that are statistically elevated above background EtO concentrations.

ATSDR conducted statistical tests to compare GAM-adjusted EtO concentrations at LCHD sampling locations against GAM-adjusted EtO concentrations at background R1 and R2 measured during the same time period. For LCHD sampling locations near Medline, ATSDR found that when Medline was operating pre-closure (prior to December 10, 2019), GAM-adjusted EtO concentrations at LCHD sampling locations M1, M3 and M4 were statistically significantly elevated above background GAM-adjusted EtO concentrations at sampling locations R1 and R2 (Figure D6, Appendix E2). After Medline reopened with the PTE system on March 8, 2020, adjusted EtO concentrations at LCHD sampling location M3 were once again statistically significantly elevated above adjusted background EtO concentrations measured at R1 and R2 from April 4, 2020 to May 1, 2020. The adjusted EtO concentrations at some LCHD sampling locations appear to be higher and more variable when Medline re-opened with a PTE system, compared to adjusted EtO concentrations when Medline was temporarily closed, particularly at M3. However, no other LCHD sampling locations were statistically different ($p<0.05$) from adjusted EtO concentrations measured during the closure period. The small number of LCHD air samples (8–10 per sampling location) collected at LCHD sampling locations during the PTE operational period limits the statistical power to confirm if there are differences in EtO concentrations.

At the LCHD Medline sampling locations, ATSDR compared GAM-adjusted EtO concentrations measured during the pre-closure operational period to GAM-adjusted background concentrations measured during the temporary shutdown at each sampling location. Pre-closure adjusted EtO concentrations at M3 were statistically significantly elevated compared to adjusted EtO concentrations at M3 during shutdown. See Figure D6. Pre-closure adjusted EtO concentrations were highly variable with M3, the sampling location located adjacent to the nearest residential area, having the highest EtO concentration. While sterilization operations at Medline were temporarily closed, none of the nearby LCHD sampling locations were statistically different from R1 and R2 (Figure D6).

The EtO concentrations at Medline monthly sampling locations during the PTE operation period from 2020 to 2023 were statistically compared to EtO concentrations measured at Northbrook and Schiller Park background air sampling stations in Cook County. During the Medline monthly sampling, EtO concentrations at all four Medline monthly air sampling locations were statistically significantly greater than EtO concentrations at background Northbrook and Schiller Park sampling location. See Figure D6 and see Appendix E2 for detailed discussion of statistical tests.

Figure D6. Boxplot of LCHD and Medline monthly EtO concentrations at sampling locations near Medline and at background sampling locations by three Medline operation periods



Notes:
ROS: Robust Regression on Order Statistics
GAM: Generalized Additive Model
PTE: Permanent Total Enclosure System
µg/m³: micrograms per cubic meter
Dunn's many to one test compared to site combined R1 and R2 p value (note Medline Monthly data compared to all R1 and R2 data for entire sampling period):
. p< 0.1, * p < 0.05, ** p< 0.01, *** p <0.001

D6. EtO Concentrations Near Medline by Wind Direction and Wind Speed

Polar plots can be used to visually identify the source of pollutant emissions by displaying the relationship between pollutant concentrations and wind direction and speed at specific sampling locations. These plots are qualitative visualizations of spatial trends, not statistical tests. Polar plots visualize EtO concentrations (represented by color) by wind direction (represented by radial location on the plot) and wind speed (represented by distance from the center of the plot). Location on the plot indicates which direction the winds were blowing from on a given day and distance from the center represents wind speed. The warmer (redder) colors represent higher EtO concentrations, and cooler (bluer) colors represent lower EtO concentrations. Polar plots show evidence that EtO concentrations were influenced by a nearby industrial source when warmer colors are facing toward a source. Conditions where the EtO concentrations are independent of wind direction and speed show a polar plot that is a uniform blue color, indicating that the specific EtO source cannot be determined. If EtO from a source such as Medline or Vantage were influencing nearby concentrations, one would expect to see a polar plot where warmer (redder) colors gradually fade into bluer (cooler) colors. Polar plots that are uniformly blue with no clear gradient potentially indicate lack of influence from a source. Random fluctuations in EtO concentrations may cause small areas of warmer colors, particularly at the farthest edges of the plot, that are not source related. Gradient changes in color that extend into the center of the plot are more likely to be source related than anomalous “spots” of color on the edges of the plot.

The polar plots for Medline are divided by operating status (Figure D7–D9). During pre-closure operation period prior to the installation of the PTE, the LCHD GAM-adjusted EtO concentrations appeared to be higher (redder color) when the wind was blowing from the facility at LCHD air sampling locations M1, M3 and M4. (Figure D7 and Figure D8) During the temporary closure period, the polar plots of LCHD GAM-adjusted EtO concentrations appeared to be a uniform blue color, meaning that wind direction may not have influenced EtO concentrations at those air sampling locations (Figure D7). During the PTE operation period, the contribution of EtO emissions from the facility to nearby sampling locations was less clear from the polar plots of LCHD GAM-adjusted EtO concentration, although there appeared to be some relationship between wind direction, wind speed and concentration at some sampling locations (Figure D7, Figure D9). The polar plots of Medline monthly EtO concentrations at the two fenceline sampling locations (F1 and F2) show clear indication of facility EtO contribution, with more some evidence of facility contribution from the polar plots at the two community sampling locations (CF1 and C1/2). (CF1 and C1/2).

Figure D7. Polar plots of LCHD GAM-adjusted EtO concentrations and Medline monthly sampling EtO concentrations at air sampling locations near Medline during pre-closure operation period, temporary closure period, and PTE operation period

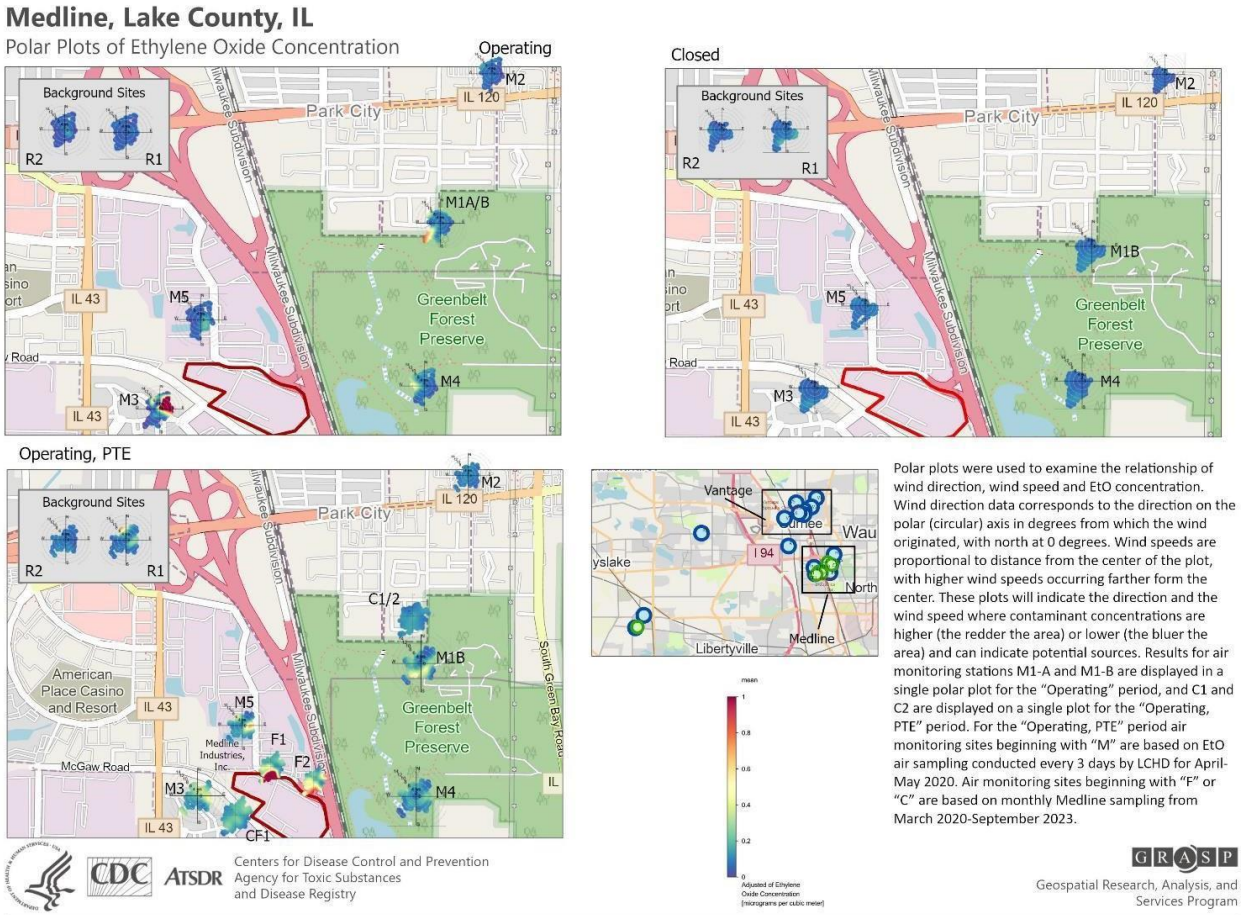


Figure D8. Polar plots of LCHD GAM-adjusted EtO concentrations at air sampling locations near Medline during pre-closure operation period (June 2019–December 2019)

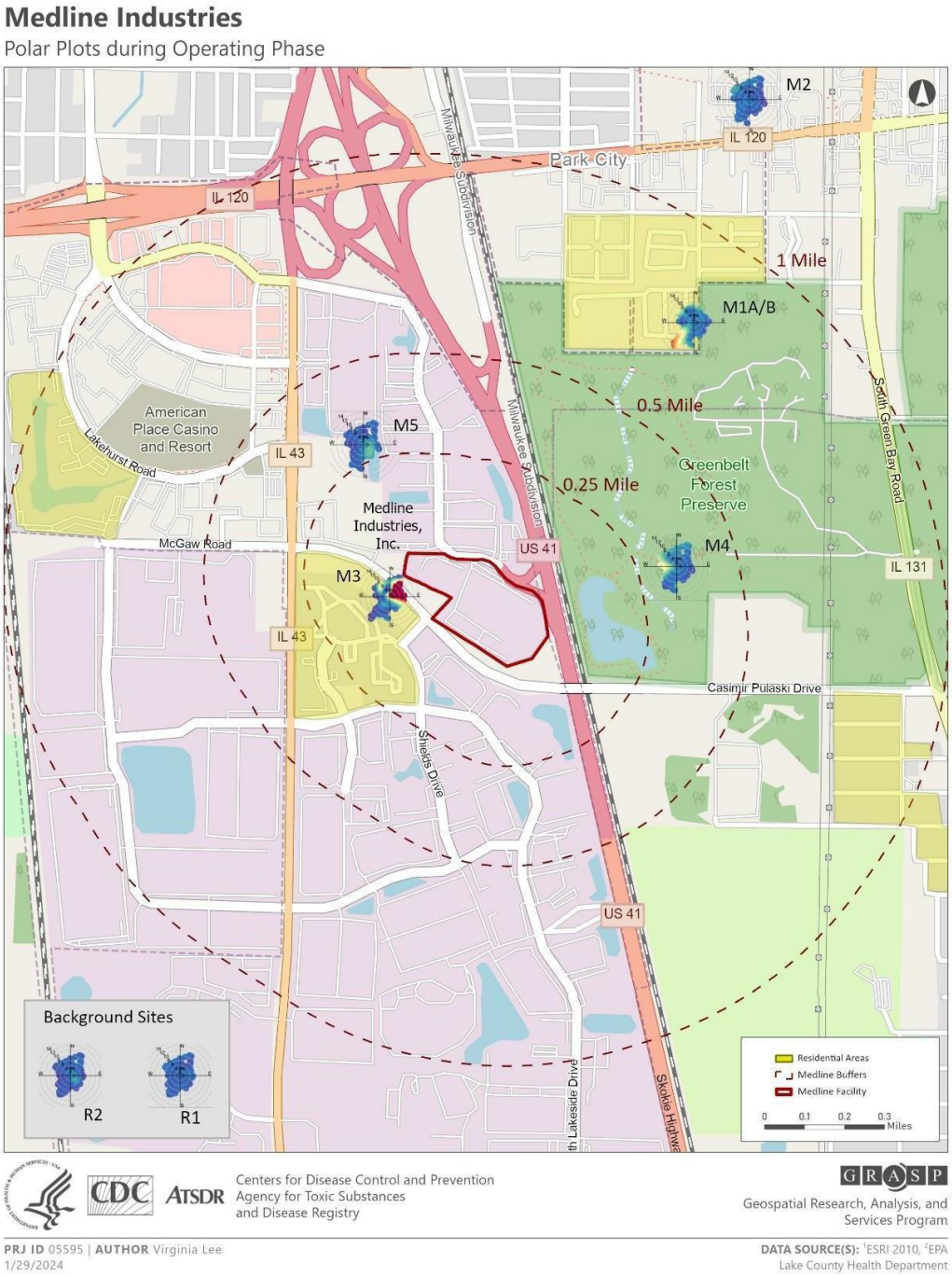
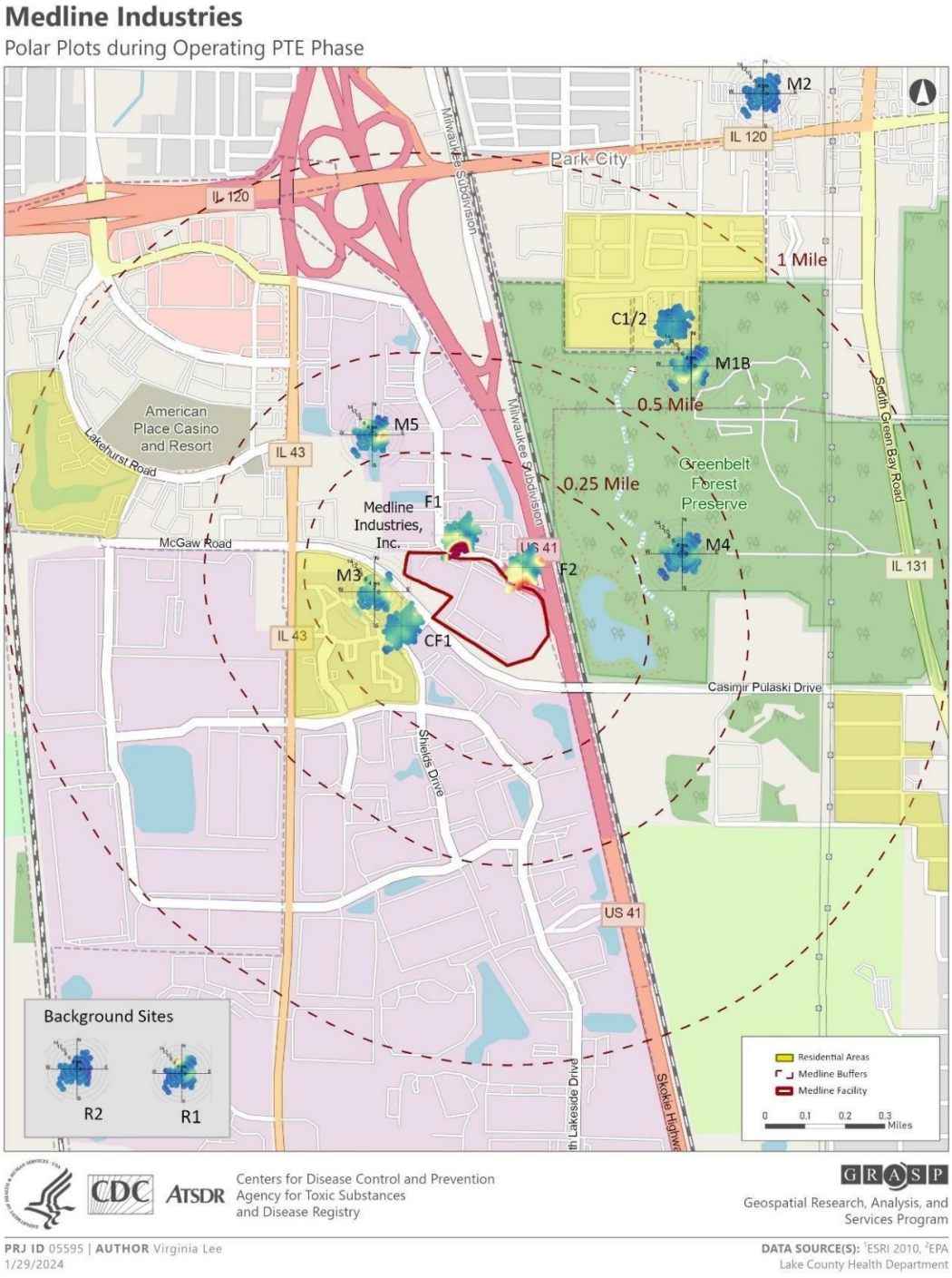


Figure D9. Polar plots of LCHD GAM-adjusted EtO concentrations and Medline monthly sampling EtO concentrations near Medline during the PTE operation period



Appendix E: Statistical Methods and Results for Analyses of Trends and Comparisons Between Sampling Locations

E1. Theil-Sen: 2020–2023 Emissions Trend for Vantage and Medline

ATSDR used a Theil-Sen method to estimate a trend in EtO emissions reported to Illinois Environmental Protection Agency (IEPA) from 2020–2023 for both Medline and Vantage using the OpenAir package in R. The Theil-Sen estimate is the median of all slopes between pairs of points within a dataset. A Theil-Sen estimate has the advantage over a linear regression of not requiring the data be normally distributed and being resistant to outliers [Carslaw 2023].

E2. Statistical tests used to compare GAM-adjusted EtO concentrations at sampling locations near Medline and Vantage to EtO concentrations at background sampling locations

Statistical tests can help scientists determine whether a difference, such as a difference in EtO concentrations at two sampling locations, is real or if it may have been caused by chance alone. ATSDR conducted Dunn's tests implemented in the "PMCMRplus" [Pohlert 2021] package in R to compare GAM-adjusted EtO concentrations measured at each near source sampling location to background concentrations at sampling locations R1 and R2. A nonparametric procedure was favored to account for the fact that environmental data, including EtO concentrations, are typically heavily right-skewed, and may have outliers present. False discovery rate was controlled using the Benjamini and Hochberg adjustment [Benjamini 1995].
Controlling for false discovery rate was considered an appropriate balance between type I and type II error rates for these limited-power tests [Helsel 2012].

Dunn's test was performed to compare concentrations collected June 2019-May 2020 at each LCHD Vantage sampling location (V1 to V5) to R1 and R2 combined (R1 ∪ R2 = R). The null hypothesis was rejected in favor of the alternative (= "greater") for sampling locations V1, V2, V3 and V5 (Table E1).

Table E1. Dunn's test results comparing GAM-adjusted EtO concentrations at LCHD Vantage sampling location (V1 to V5) to background sampling locations R1 and R2 combined (= R) sampling June 2019–May 2020.

Comparison	z value	Pr(>z)*
V1 - R <= 0	**2.40**	**0.019**
V2 - R <= 0	**2.70**	**0.017**
V3 - R <= 0	**2.30**	**0.020**
V4 - R <= 0	0.08	0.470
V5 - R <= 0	**1.90**	**0.036**

*Statistical tests results where p<0.05 are bolded. Alternative is site greater than R.

For the analysis of the Medline sampling in the LCHD dataset, three separate sets of pairwise Dunn's tests were conducted, representing each Medline operating period. For each set, GAM-adjusted EtO concentrations at each

Medline sampling location (M1 to M5) were compared to background.

concentrations (R) measured during the same Medline operating period. During the initial operating period, the null hypothesis of no difference in median EtO concentration was rejected in favor of the alternative (= "greater") for comparisons to sampling locations (M1, M3 and M4). During the shutdown period no Medline sampling locations were statistically distinguishable from background. When the facility reopened with PTE, the null hypothesis was rejected in favor of the alternative (= "greater") for the comparison to site M3 (Table E2).

Table E2. Dunn's test result comparing GAM-adjusted EtO concentrations at LCHD Medline sampling locations to combined background sampling locations R1 and R2 concentrations (R) by Medline operating periods. Sampling conducted across three operating phases June 2019–May 2020.

Medline Operating Period	Comparison	z value	Pr(>z)*
Medline pre-closure operating	**M1 - R <= 0**	**2.400**	**0.01300**
Medline pre-closure operating	M2 - R <= 0	0.820	0.26000
Medline pre-closure operating	**M3 - R <= 0**	**3.700**	**0.00062**
Medline pre-closure operating	**M4 - R <= 0**	**3.000**	**0.00380**
Medline pre-closure operating	M5 - R <= 0	0.580	0.28000
Medline temporarily closed	M1 - R <= 0	1.200	0.30000
Medline temporarily closed	M2 - R <= 0	-1.200	0.89000
Medline temporarily closed	M3 - R <= 0	-0.860	0.89000
Medline temporarily closed	M4 - R <= 0	-0.250	0.89000
Medline temporarily closed	M5 - R <= 0	1.300	0.30000
Medline PTE Operating	M1 - R <= 0	1.400	0.09200
Medline PTE Operating	M2 - R <= 0	0.053	0.48000
Medline PTE Operating	**M3 - R <= 0**	**2.800**	**0.01300**
Medline PTE Operating	M4 - R <= 0	1.600	0.09200
Medline PTE Operating	M5 - R <= 0	1.700	0.09200

*Statistical tests results where p<0.05 are bolded. *Alternative is site greater than R.*

The Medline monthly sampling did not include a background air sampling location. ATSDR compared GAM-adjusted EtO concentrations at each sampling location for the Medline monthly sampling conducted from March 2020– September 2023 to combined GAM-adjusted EtO concentrations at R1

and R2 measured during the three phases of LCHD sampling from June 2019 to May 2020. The null hypothesis of no difference in median EtO concentration was rejected in favor of the alternative (= "greater") for all Medline monthly sampling air sampling locations (Table E3). This provided supporting evidence that Medline monthly sample locations were elevated above background concentrations. However, the preferred background comparison for the Medline monthly sampling was to the NATTS and UATMP sampling locations in Cook County because EtO concentrations measured at those two sample locations during the same general time period and there were more samples.

Table E3. Dunn's test result comparing GAM-adjusted EtO concentrations at Medline monthly sampling locations collected near Medline from March 2020 to September 2023 to combined LCHD background air sampling locations R1 and R2 concentrations from June 2019 to May 2020

Comparison	z value	Pr(>z)*
C1 - R <= 0	**3.9**	**<0.001**
CF1 - R <= 0	**6.2**	**<0.001**
F1 - R <= 0	**8.3**	**<0.001**
F2 - R <= 0	**8.8**	**<0.001**

*Statistical tests results where p<0.05 are bolded. *Alternative is site greater than R.*

E3. Comparing EtO Concentrations from LCHD Sampling Near Medline Across Medline's Three Operating Periods

ATSDR performed a series of Dunn's tests, implemented using the "PMCMRplus" [Pohlert 2021] package in R to compare GAM-adjusted EtO concentrations measured at each Medline sampling location during pre-closure operations and PTE operations to GAM-adjusted EtO concentrations measured during the closure period. False discovery rate was controlled using the Benjamini and Hochberg adjustment [Benjamini 1995]. The null hypothesis was rejected in favor of the alternative hypothesis that operation concentrations were greater than closure concentrations at the M3 sampling location for the operation time period and the PTE operation time period (Table E4).

Table E4. Dunn's test result comparing GAM-adjusted EtO concentrations at each LCHD Medline sampling location during the pre-closure operation period and during the PTE operation period to GAM-adjusted EtO concentrations during the closure period

Site	Comparison	z value	Pr(>z)*
M1	Pre-closure operation - closed <= 0	0.37	0.3600
M1	PTE operation- closed <= 0	1.10	0.2800
M2	operation - closed <= 0	0.25	0.4000
M2	PTE operation- closed <= 0	1.50	0.1300
M3	**operation - closed <= 0**	**1.80**	**0.0370**
M3	**PTE operation - closed <= 0**	**2.60**	**0.0086**
M4	operation - closed <= 0	1.40	0.0850

Site	Comparison	z value	Pr(>z)*
M4	PTE operation – closed <= 0	1.70	0.0840
M5	operation - closed <= 0	-1.70	0.9500

E4. Comparing EtO Concentrations from Medline Monthly Sampling to Cook County NATTS and UATMP Sites

ATSDR compared the Medline monthly sampling EtO concentrations from March 2020 to September 2023 to the NATTS at Northbrook, and the Urban Air Toxics Monitoring Program sampling location at Schiller Park using data from Northbrook and Schiller Park from February 2020 to June 2023 (note last two quarters of 2023 data had not been posted as of date of this analysis). As discussed, there were a variety of canisters lining types used at Northbrook and Schiller Park, and ATSDR's earlier GAM model would not accurately adjust for canister effects and holding times in the new NATTS and UATMP samples because newer U.S. EPA testing procedures are systematically removing canisters that are affected by the canister effect.

Furthermore, newer silicon-ceramic canisters (canisters were identified as newer using serial numbers provided by EPA [Xi 2024]) at Northbrook and Schiller Park have shown EtO growth related to holding time. ATSDR modeled the interaction of the newer and old silicon-ceramic type canisters and holding time, along with a cyclic smooth of Julian day on the log of EtO concentration using a Bayesian GAM in order to explore differences in EtO concentrations measured in older and newer silicon-ceramic canisters. This model formulation was identical to the model used to develop adjustments for the effects of canister type, holding time, and seasonality in the LCHD EtO concentrations. However, only older and newer silicon-ceramic canister types were considered.

There was a high probability that newer silicon-ceramic canisters had higher EtO concentrations compared to older silicon-ceramic canisters (probability of direction = 94%). There was evidence that holding time increased EtO concentrations in newer silicon-ceramic canisters (probability of direction = 96%) and some evidence that the same effects were occurring, albeit at a lower effect level, in older silicon-ceramic canisters (probability of direction = 80%). The model is summarized in Table E5, and Figure E1, and Figure E2. Table E5 presents a 95% credible interval. The true effect has a 95% probability of falling within the credible interval given the observed data.

U.S. EPA did not start to use the newer silicon-ceramic canisters until March of 2022 (Figure E2). Therefore, ATSDR did not use the newer silicon-ceramic canisters in the comparison of Medline monthly sampling to Northbrook and Schiller Park. Nevertheless, there were 91 and 76 older silicon-ceramic canister samples at Schiller Park and Northbrook, respectively. ATSDR used the same GAM used to adjust the LCHD data to adjust these data for the effects of holding time and seasonal patterns previously noted.

The limits of detection were generally higher at the Northbrook and Schiller Park sites compared to the Medline monthly sampling data, resulting in different rates of nondetect values in the dataset at different GAM-adjusted limits of detection. This situation limits the usefulness of the Dunn's test for comparing across the datasets (values below the highest GAM-adjusted nondetect would score as ties for the purpose of the test). Furthermore, comparisons of the Medline monthly data to each other (for instance comparing results to C1/2) is useful. ATSDR therefore used the Peto-Peto nonparametric test [Helsel 2012, Peto and Peto 1972] followed by an all-pairs comparison using the Peto-Peto test, GAM-adjusted to control for false discovery rate [Benjamini 1995].

Results of the Peto-Peto test for overall differences was highly significant ($p < 0.001$). Pairwise comparisons of the sites show that:

- The fenceline sites (F1 and EF) were significantly higher than either Northbrook, Schiller Park, or C1/2 (the most distant Medline monthly sampling site).
- C1/2 and CF1 were significantly higher than either Northbrook or Schiller Park
- All sites, including Schiller Park, had higher levels than the Northbrook Site
- The two fenceline monitors were not significantly different from each other ($p = 0.54$)

The degree of the effects can be seen in Figure E3. We performed the above analysis, including GAM-adjustment of new silicon-ceramic canisters and results were not markedly different from above. As noted, we chose not to adjust electropolished and proprietary canisters in comparing the NATTS and UATMP data to compare to the Medline monthly data. These coefficients have changed in 2021, 2022 and 2023 due to newer humidified air blanking procedures.

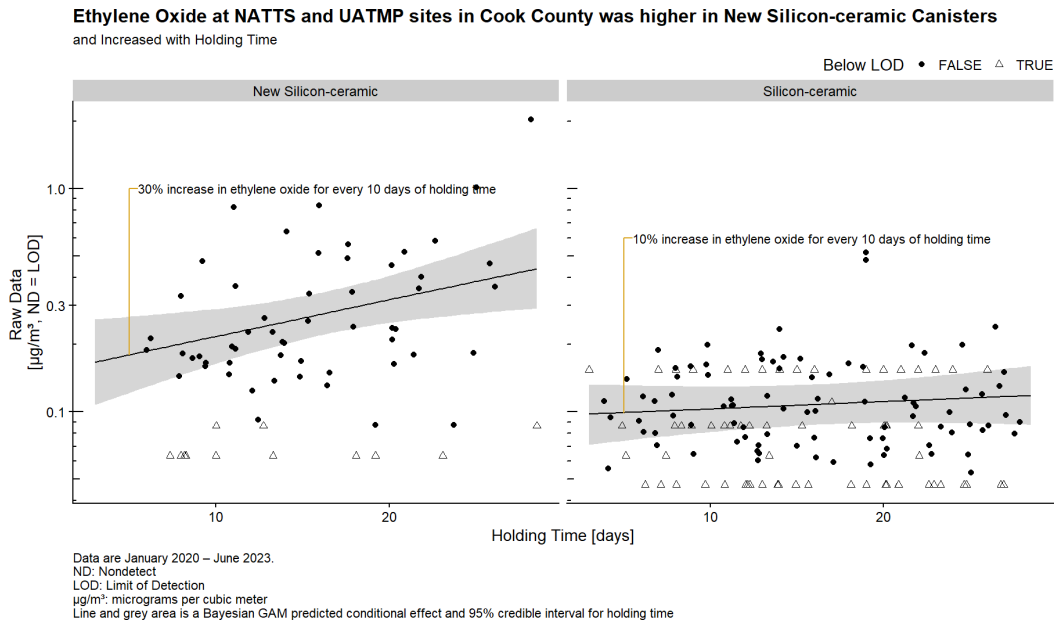
Table E5. GAM coefficients for silicon-ceramic canisters in NATTS/UATMP data from Northbrook and Schiller Park February 2020 – June 2023

Coefficient	Median Estimate	95% Credible Interval	Probability of Direction	Rhat	Effective Sample Size
Intercept	-2.74	[-3.05, -2.4]	100%	1.000	8265
Holding Time	0.01	[-0.01, 0.03]	80.09%	1.000	8058
New silicon-ceramic canister	0.45	[-0.10, 1.01]	94.19%	1.000	8144
Holding time: New silicon-ceramic canister	0.03	[-0.00, – 0.063]	95.83%	1.000	8147

Table E6. Peto-Peto test p-values comparing GAM-adjusted Medline monthly data (March 2020-September 2023) and GAM-adjusted silicon-ceramic canisters collected at Cook County NATTS/UATMPS sites (February 2020– June 2023)

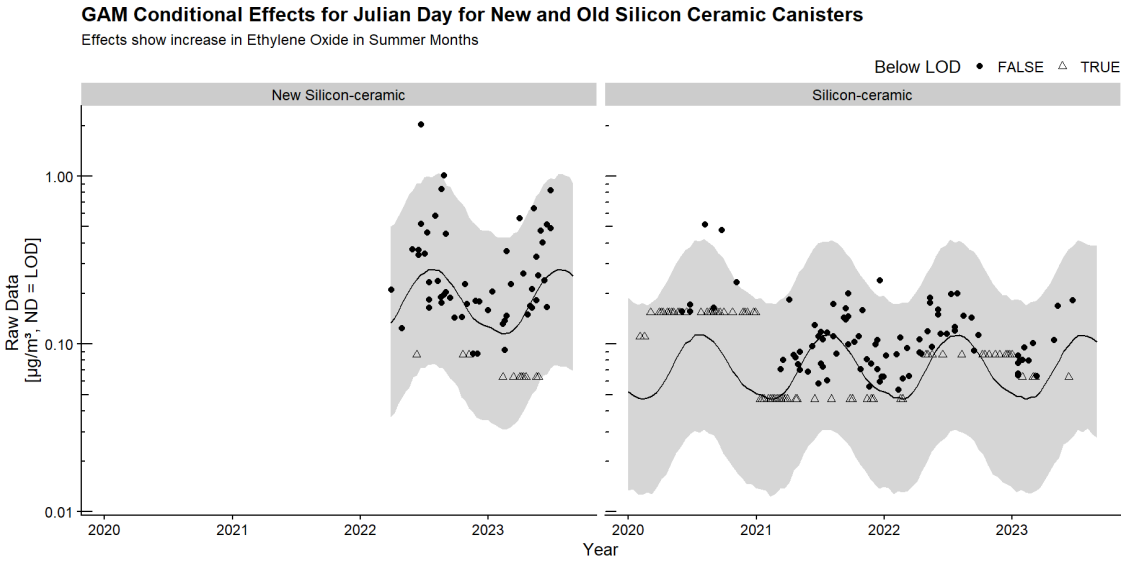
Site	Number of GAM-adjusted Silicon-Ceramic Samples	Percent Nondetect	C1/2	CF1	F1	F2	Schiller Park	Northbrook
C1/2	41	4.9	–	–	–	–	–	–
CF1	43	2.33	0.016	–	–	–	–	–
F1	42	2.38	< 0.001	0.013	–	–	–	–
F2	43	2.33	< 0.001	0.0018	0.53	–	–	–
Schiller Park	91	56.6	< 0.001	< 0.001	< 0.001	< 0.001	–	–
Northbrook	76	39.6	< 0.001	< 0.001	< 0.001	< 0.001	0.035	–

Figure E1. Relationship of ethylene oxide concentration to holding time Northbrook and Schiller Park



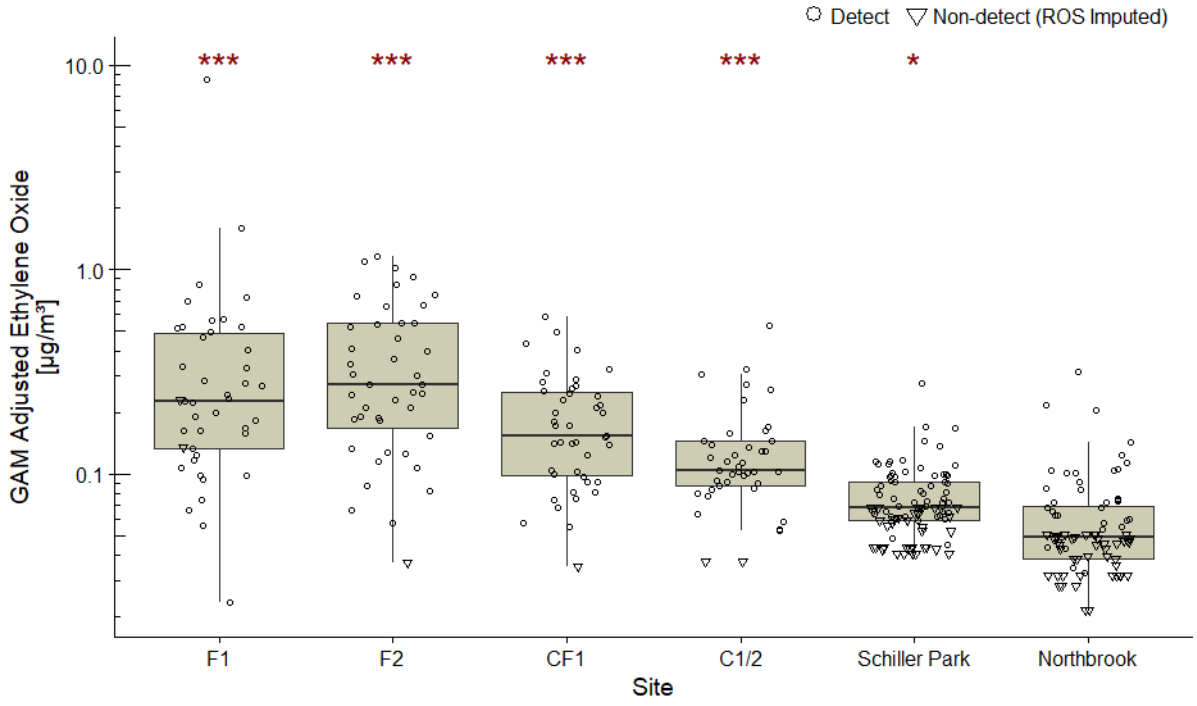
Data are January 2020 – June 2023.
ND: Nondetect
LOD: Limit of Detection
µg/m³: micrograms per cubic meter
Line and grey area is a Bayesian GAM predicted conditional effect and 95% credible interval for holding time

Figure E2. GAM conditional effect of Julian day on EtO concentrations at Northbrook and Schiller Park



Data are January, 2020 – June 2023.
ND: Nondetect
LOD: Limit of Detection
µg/m³: micrograms per cubic meter
Line and grey area is a Bayesian GAM predicted conditional effect and 95% credible interval for Julian day.

Figure E3. Boxplot of GAM-adjusted EtO concentrations measured at sampling locations near Medline during Medline monthly sampling from March 2020 to September 2023



Notes:
ROS: Robust Regression on Order Statistics
GAM: Generalized Additive Model
µg/m³: micrograms per cubic meter
Peto-Peto compared to Northbrook site p value (note false discovery rate adjust using Benjamini and Hochberg [1995]):
. p< 0.1, * p < 0.05, ** p< 0.01, *** p <0.001

E5. Statistical test used to compare GAM-adjusted EtO concentrations measured at LCHD and Medline monthly sampling air sampling locations with similar locations

ATSDR used a Wilcoxon rank-sum test to compare GAM-adjusted EtO concentrations measured by LCHD (April 2020- May 2020) and Medline monthly sampling (March 2020–September 2023) during the PTE operating time period at air monitors with similar locations. For the air sampling locations compared, the Hodges-Lehmann estimate, which is the median of the differences in ranked EtO concentrations, and the 95% confidence interval on the Hodges-Lehmann estimate are reported in Figure E2 and reproduced below (Table E7). The confidence interval on the Hodges-Lehmann estimate included zero in both comparisons, meaning that we cannot reject the null hypothesis that GAM-adjusted EtO concentrations from these pairs of air sampling locations are equivalent.

Table E7. Hodges-Lehmann estimate of differences between GAM-adjusted EtO concentrations at LCHD (April 2020–May 2020) and Medline monthly sampling (March 2020–September 2023) co- located air sampling locations

Comparison	Location	Hodges-Lehmann estimate	95% confidence interval
C1/2-M1 = 0	Neighborhood NE of Medline	-0.0082	-0.062-0.042
CF1-M3 = 0	Neighborhood S of Medline	-0.08	-0.21-0.025

E6. Analysis of Emissions on Sampling Days

ATSDR performed a Wilcoxon Rank sum test comparing emissions reported from Medline's continuous emissions monitoring system on days when the monthly air sampling was performed (March 2020–September 2023) compared to non-sampling days. ATSDR could not reject the null hypothesis that there is no difference between emissions on days when sampling was performed compared to emissions on days when there is no air sampling (p=0.31, Hodges-Lehman estimate= 0.013, 95% CI=-0.012-0.041).

Appendix F: Calculating Exposure Point Concentrations and Lifetime Excess Cancer Risk

F1. Exposure point concentrations (EPCs)

To estimate lifetime excess cancer risk, ATSDR calculated an exposure point concentration (EPC) at each LCHD and Medline monthly sample location. EPCs for LCHD sample locations near Medline (M1–M5), near Vantage (V1–V5) and at background locations (R1 and R2) are calculated using GAM-adjusted EtO concentrations collected during the three sampling phases from June 6, 2019- May 1, 2020. For each Medline sampling location, three EPCs were calculated for each Medline operating period: (1) pre-closure operating period before new PTE controls were installed (June 6, 2019 –December 12, 2019); (2) temporary closure period while Medline was shut down (December 13, 2019 – January 1, 2020); and (3) PTE operating period while Medline was operating with new controls (April 4, 2020 – May 1, 2020). EPCs were also calculated for the Medline monthly sampling locations (C1/2, CF1, F1, F2) using EtO concentrations collected from March 2020 to September 2023 during the Medline PTE operating period.

The EPCs are calculated using the 95% upper confidence limits of the mean (95% UCL) to estimate the long-term (chronic) average EtO concentration in the air that someone might breathe over many years. The 95% UCL is a conservative estimate of the average EtO concentration that provides reasonable confidence that the true average EtO concentration is not underestimated. When there is less data to calculate a 95% UCL, the 95% UCL tends to be higher, which is a health-protective approach of addressing the greater uncertainty in estimating a typical concentration from few samples. However, because the UCL is influenced by sample size and variability, 95% UCLs at different air sampling locations are not always directly comparable to one another. It is more informative to use typical (mean or median) values to compare EtO concentrations at different sites.

Figure F1 shows the mean and 95% confidence interval of GAM-adjusted EtO concentrations at LCHD sampling locations near Vantage compared to combined GAM-adjusted EtO concentrations at LCHD background sampling locations R1 and R2 during the entire LCHD sampling period. EtO concentrations at near-source sampling locations were generally higher and more variable than concentrations at the combined background sampling locations.

Figure F1. Mean and 95% confidence interval of GAM-adjusted EtO concentrations collected from June 6, 2019– May 1, 2020 at LCHD sampling locations near Vantage and combined LCHD background sampling locations

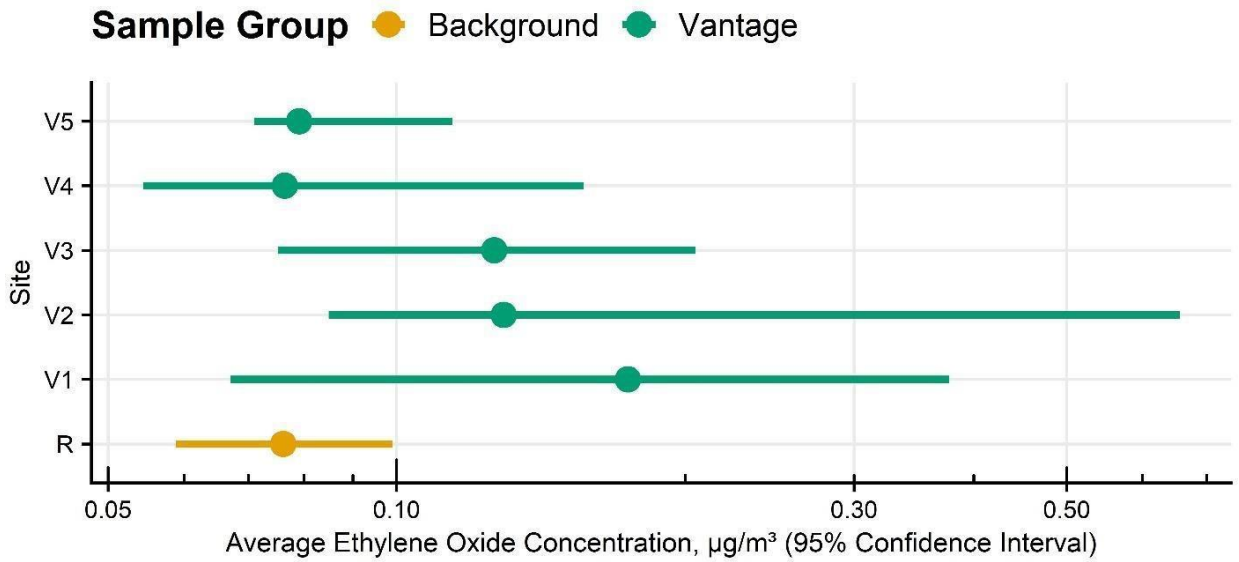


Figure F2 shows the mean and 95% confidence interval of GAM-adjusted EtO concentrations at LCHD sampling locations near Medline and combined background sampling locations (R1, R2) during different Medline operating periods from June 2019 to May 2020. Both sample variability and sample size (which is lowest for the operating PTE period) affect how wide the confidence interval is. The 95% UCL that ATSDR uses to calculate lifetime excess cancer risk is near the upper end of the confidence interval illustrated for each site. LCHD sampling locations near Medline had the widest confidence intervals for the period of time during the Medline pre-closure operating period before the PTE emissions control system was installed, indicating greater variability in EtO concentrations during that time period.

Figure F3 displays mean and 95% confidence interval of GAM-adjusted EtO concentrations measured at Medline's monthly sampling locations from March 2020 to September 2023 and combined LHCD background sampling locations (R1 andR2) from June 2019 to May 2020. GAM-adjusted EtO concentrations were higher and more variable at the fenceline sampling locations F1 and F2, lower and less variable at the nearest community sampling location (CF1), and lower still at the farther community sampling locations (C1 and C2). The lowest and least variable concentrations were measured at the combined LCHD background sampling locations (R1 and R2).

Figure F2. Mean and 95% confidence interval of GAM-adjusted EtO concentrations at LCHD sampling locations near Medline and combined background sampling locations from June 2019 to May 2020 by Medline operating period.

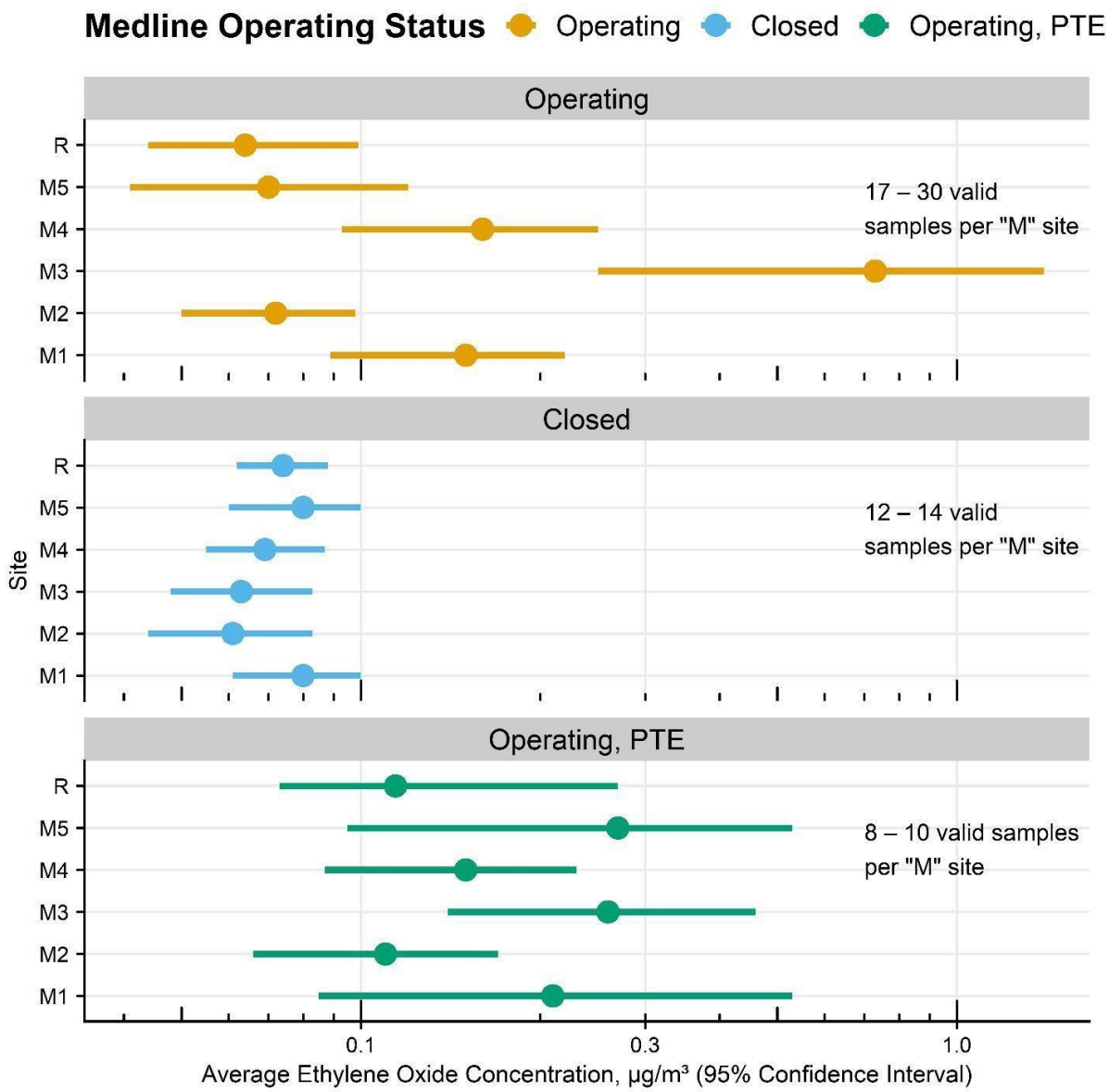
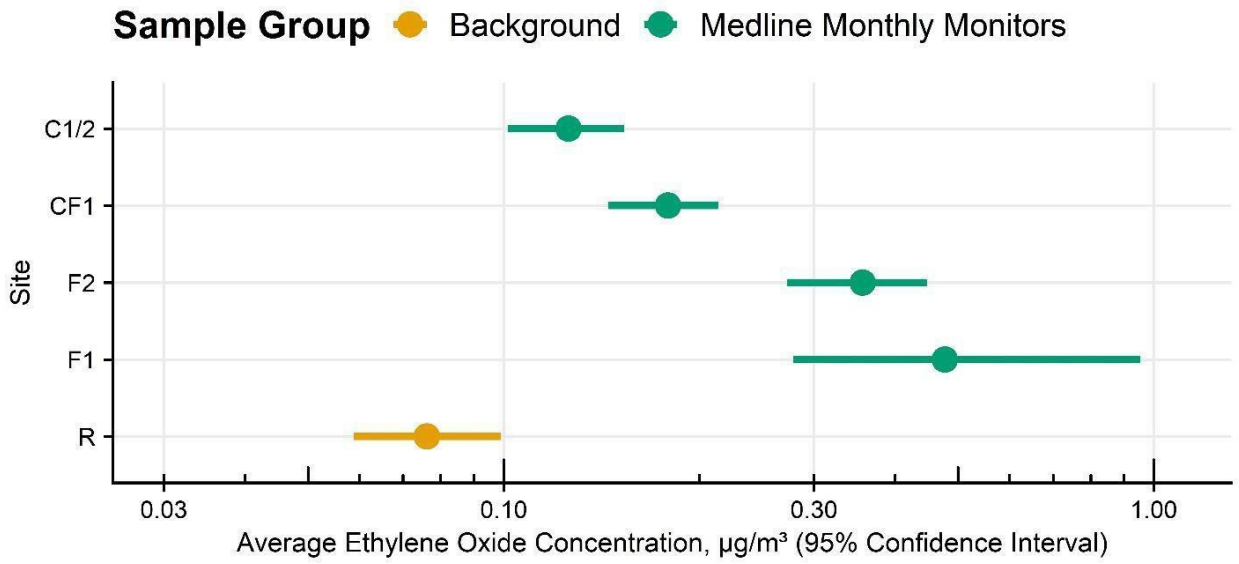


Figure F3. Mean and 95% confidence interval of EtO concentrations measured at Medline monthly sampling locations during Medline PTE operating period from March 2020 to September 2023 and at LCHD combined background sampling locations from June 2019 to May 2020



F2. Estimating EPCs at Medline F1 and F2 using a Bayesian model of exposure

EtO concentrations at both fenceline sampling locations F1 and F2 near Medline on the downwind side of the Medline buildings have a significant downward trend (Figure D5). The downward trend is supported by the significant downward trend in the reported continuous emissions monitoring system (CEMS) data analyzed in Figure 2.

The entire sampling period may not be an accurate representation of current and future conditions given that EtO concentrations are going down over time. ATSDR explored what an appropriate EPC might be if more recent EtO concentrations measured in 2023 are more representative of EtO exposures moving forward. ATSDR used a Bayesian regression to model the log of the GAM-adjusted EtO concentrations to sampling location and the GAM smooth effects of decimal date (using a cubic regression spline). ATSDR used R statistical software with analytical packages NADA 1.6; NADA-2 1.0.2; tidyverse 1.3.1; mgcv 1.8-35; brms 2.16.3; tidybayes 3.0.1; EnvStats 2.4, bayestestR 0.11.5, asbio 1.7, and effectsize 0.6.0.1. We then used this model to predict mean EtO concentrations for the end of the third quarter 2023 and generated point and highest density interval estimates for the modeled means.

The results of the model are summarized in Table F1, and the conditional effects estimates for sampling locations and conditional smooth for the effects of date. The probability of direction for site effects (58%) indicates low probability that F1 and F2 are significantly different, while there is strong indication that there is a trend in EtO by date (probability of direction >99%). Using posterior simulation, the most likely estimates of mean EtO concentrations at sites F1 and F2 were 0.227 and 0.23 µg/m^3, respectively during 2023. The upper 95% credible interval for F1 and F2 was 0.344 and 0.340, respectively (Figure F5). An EPC that reflects 2023 conditions could be derived from the upper 95% credible interval.

The calculated lifetime excess cancer risk estimates associated with the EPCs calculated at sampling locations F1 and F2 using this method would be 0.8 excess cases of cancer in 10,000 for both sampling locations. If EtO concentrations at F1 and F2 remain at 2023 levels or continue to decrease, there may not be a concern for increased lifetime excess cancer risk for people who work near Medline's northern property boundary in the future.

Table F1. GAM coefficients condition effects of date on EtO at sampling locations F1 and F2

Coefficient	Median Estimate	95% Credible Interval	Probability of Direction	Rhat	Effective Sample Size
Intercept	-1.41	[-1.68, -1.15]	100%	1.000	4892
Sampling location (F2)	0.04	[-0.03, 0.05]	58.03%	1.000	5588
Smooth (Decimal Date)	0.64	[-0.12, 1.33]	99.91%	1.000	5171

Figure F4. GAM model conditional effects of date on EtO at sampling locations F1 and F2

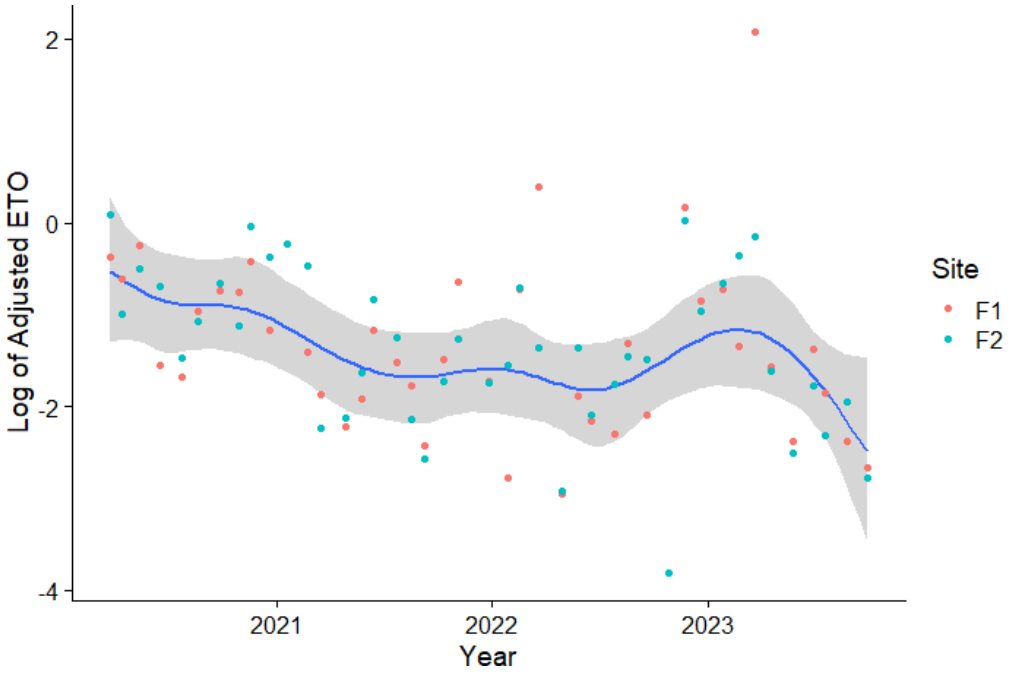
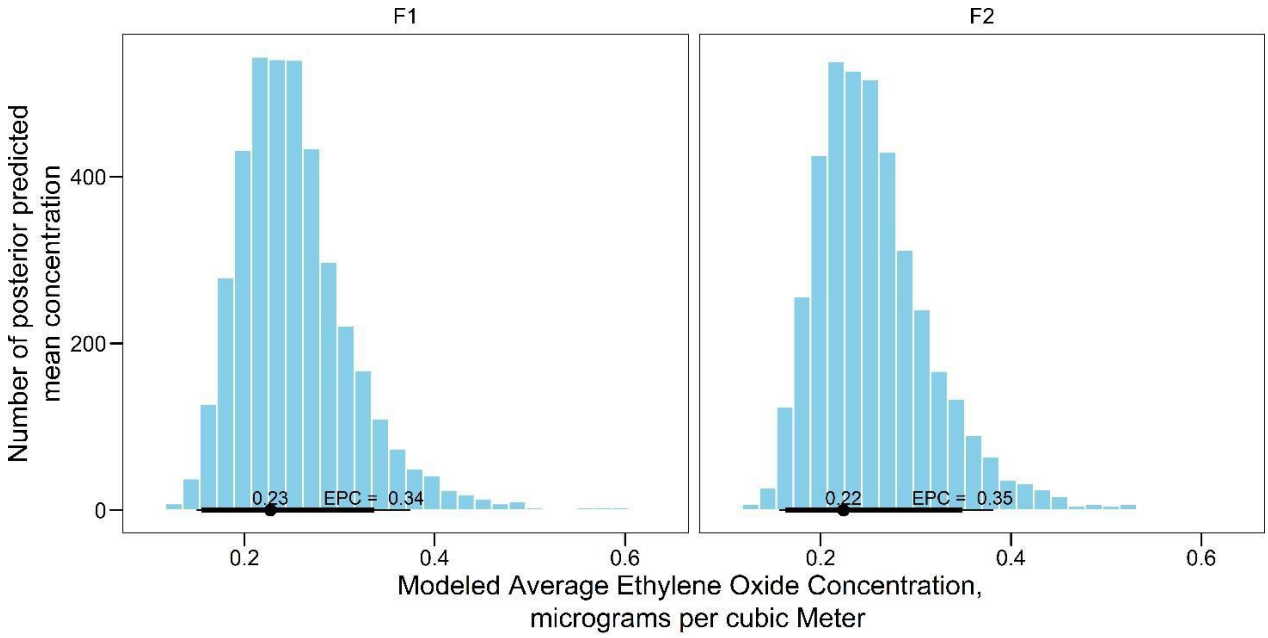


Figure F5. GAM predicted mean EtO concentrations at sampling locations F1 and F2 for 2023



Point indicates most probable mean.
Interval is the 90% and 95% Highest Density Region.
The There is less than a 5% probability that the mean is higher than the EPC (Exposure Point Concentration).

F3. Exposure Assumptions for Calculating Lifetime Excess Cancer Risks

ATSDR has default exposure scenarios for residential and off-site workers when calculating health risk estimates outlined in ATSDR's public health assessment guidance [ATSDR 2021]. For chronic exposure, ATSDR uses an average life expectancy value of 78 years for adults, a 33-year residential occupancy period (ROP) (time of exposure from when a person moves into a residence and the time the person moves out or dies), and continuous exposure frequency assumptions of 24-hours a day, 7 days a week, and 52 weeks a year. These assumptions result in a reasonable maximum exposure (RME) factor of one (exposure factor (EF) = 1) for *noncancer* residential health outcomes. Further, ATSDR also used the RME appropriately adjusted EF for *cancer* residential assessment. The EF for cancer chronic residential exposure is 0.42 (33-year exposure duration/78 years of life expectancy). ATSDR did not use the default residential scenario to evaluate previous chronic residential exposure conditions at Medline because the facility had only been open 25 years at the time when the new emissions controls were installed in 2020. ATSDR therefore used 25 years/78 years (EF for cancer residential health outcomes of 0.33) to calculate the past lifetime cancer risk estimates for the chronic residential exposure scenario at Medline. Table F3 summarizes these chronic exposure assumptions for default and site-specific assessments. ATSDR's health conclusions are based off the RME scenario, but ATSDR also calculated a CTE scenario for refence of cancer risk calculations using exposure assumptions that reflect an average exposure duration and EtO concentration. The CTE residential scenario assumes a 12-year residential occupancy period starting at birth and the off-site worker scenario assumes 5 years at a particular workplace rather than 20 years.

Because EtO is a mutagenic compound, ATSDR uses age-dependent adjustment factors (ADAF) to weight early life exposure. When applying the ADAFs, ATSDR calculated lifetime excess cancer risk from measured EtO concentrations by multiplying the U.S. EPA IUR (2.99×10^{-3} per $\mu g/m^3$) for lifetime EtO exposure by the ATSDR EtO EPC (95% UCL) and adjusting for 33 years of residential exposure from birth (Table F2). For CTE cancer risks, ATSDR used a mean EtO concentration rather than a 95% UCL.

Table F2. Calculation of lifetime excess cancer risk by age and total cancer risk for the current chronic residential EtO exposure scenario

Age Range (years)	ADAF*	U.S. EPA unadjusted IUR†	EPC‡ (µg/m³)	Duration Adjustment	Partial Cancer Risk by Age Range
0 to <2	10	2.99×10^{-3}	*Site-specific*	2 years/78 years	= ADAF*IUR*EPC*DA
2 to <16	3	2.99×10^{-3}	*Site-specific*	14 years/78 years	= ADAF*IUR*EPC*DA
16 to 33	1	2.99×10^{-3}	*Site-specific*	17 years/78 years	= ADAF*IUR*EPC*DA
0 to 33	---	---	---	---	SUM OF PARTIAL CANCER RISK

*Age-Dependent Adjustment Factors

†United States Environmental Protection Agency's Inhalation Unit Risk per µg/m³

‡Exposure Point Concentration in micrograms per meter squared

For nearby off-site workers, ATSDR assumed a full-time RME scenario for workers who work 8.5 hours a day (8.5 hr/24 hr), 5 days a week (5 days/7 days) for 50 weeks per year for 20 years at the same location (RME). ATSDR used the RME conditions (i.e., 95th percentile work tenure of 20 years and a 50 wk/yr, 5 d/wk, 8.5 hr/day exposure) for the worker's lifetime cancer risk assessment EF of 0.078 (Table F3). For the Vantage monitor V1 located at Spaulding Elementary School, a lifetime cancer risk for students who do not live nearby is reported in a footnote to Table F4. The assumptions used in calculating that lifetime cancer risk for students who attend 2 years of pre-K through grade 2 school are reported in Table F3 below.

Table F3. Residential and occupational assumptions for chronic cancer reasonable maximum exposure (RME) scenarios*

RME Scenarios	Exposure Factors-Cancer†	Exposure Frequency & Duration
Medline past residential (birth until 25 years)	0.33	$\frac{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 25\ yr}{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 78\ yr}$
Residential (birth until 33 years)	0.42	$\frac{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 33\ yr}{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 78\ yr}$
Off-site worker (adult exposure)	0.078	$\frac{8.5\ \frac{hr}{d} \times 5\ \frac{d}{wk} \times 50\ \frac{wk}{yr} \times 20\ yr}{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 78\ yr}$
Spaulding Elementary School student, non-resident	0.016	$\frac{9.3\ \frac{hr}{d} \times 5\ \frac{d}{wk} \times 47\ \frac{wk}{yr} \times 5\ yr}{24\ \frac{hr}{d} \times 7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 78\ yr}$

*Agency for Toxic Substances and Disease Registry. 2020. Guidance for Inhalation Exposures. Atlanta, Ga: U.S. Department of Health and Human Services, Public Health Service, December 2020.

F4. Lifetime excess cancer risk estimates from chronic EtO exposure near Vantage and Medline in Lake County

ATSDR generally considers estimated lifetime excess cancer risks greater than 1 in 10,000 an elevated risk that could increase people's risk of cancer in their lifetime. Chronic EtO exposure (years) could harm the health of residents by increasing the risk of certain types of cancer. Because background concentrations in Lake County and in other parts of the U.S. result in an estimated cancer risk for a resident of greater than 1 in 10,000, the exploration of contributions from each facility was important to the analyses presented in this consultation. For more information on ATSDR's analysis of the EtO contribution at sampling locations near Vantage in Gurnee and Medline in Waukegan, see Appendix D. Estimated lifetime excess cancer risks between 0.01 in 10,000 and 1 in 10,000 are considered on a case-by-case basis.

Table F4. Lifetime excess cancer risk by exposure scenario at sampling locations near Vantage: includes GAM-adjusted mean EtO concentration and EtO exposure point concentration (EPC)

Sampling Location	Exposure Scenario	Description	Distance from Vantage (miles)	Mean ($\mu g/m^3$)	CTE Lifetime Excess Cancer Risk (adult)	EPC* ($\mu g/m^3$)	RME Lifetime Excess Cancer Risk†
V1‡	Resident§	Spaulding Elementary School	0.6	0.17	0.8 in 10,000	0.37	10 in 10,000
V2‡	Resident¶	Northwestern and Keith	0.2	0.13	0.6 in 10,000	0.64	20 in 10,000
V3‡	Worker	Warehouse south of Vantage	0.05	0.13	0.06 in 10,000	0.19	0.4 in 10,000
V4	Resident	Waukegan Gurnee Glass	0.3	0.076	0.3 in 10,000	0.15	5 in 10,000
V5‡	Resident	Wetland near apartments	0.6	0.079	0.4 in 10,000	0.11	3 in 10,000
R1	Resident	Background site	2	0.081	0.4 in 10,000	0.10	3 in 10,000
R2	Resident	Background site	4.1	0.071	0.3 in 10,000	0.10	3 in 10,000

* EPC Exposure Point Concentration (95% upper confidence limit of GAM-adjusted EtO concentrations)

† All EtO concentration data used for lifetime excess cancer risk calculations are from LCHD, Village of Gurnee, and City of Waukegan outdoor EtO air sampling data collected between June 3, 2019 and May 1, 2020.

‡Adjusted EtO concentrations at this air sampling location were statistically significantly greater than combined EtO concentrations at R1 and R2.

§A residential scenario was used at Spaulding Elementary School (V1) because lifetime excess cancer risk estimates for children who grow up in a neighborhood for many years will be higher than the lifetime excess cancer risk estimates for children who attend school for several years. Estimated lifetime excess cancer risks for non-resident children and educators who attend

school are less than 1 in 10,000.

¶Excess lifetime cancer risk estimate for people who work near air sampling location V2 is 1 in 10,000.

¶¶Lifetime excess cancer risk estimates at F1 and F2 were calculated taking into account the downward trend of concentrations over time, assuming recent concentrations are more likely to be representative of long term exposure conditions. For more information, see Appendix F, Section F2.

Table F5. Lifetime excess cancer risk by Medline operating period and exposure scenario at sampling locations near Medline; including GAM-adjusted mean EtO concentration and EtO exposure point concentration (EPC)

Sampling Location	Medline Operating Status	Mean (µg/m³)	CTE Lifetime Cancer Risk (adult)	EPC (µg/m³)	Exposure Scenario	RME Lifetime Cancer Risk*
C1/2[†]	PTE operation	0.13	0.6 in 10,000	0.15	Resident	5 in 10,000
CF1[†]	PTE operation	0.18	0.8 in 10,000	0.21	Resident	6 in 10,000
F1[†]	PTE operation	0.23[‡]	0.2 in 10,000	0.34	Worker[¶]	0.8 in 10,000
F2[†]	PTE operation	0.22[‡]	0.2 in 10,000	0.35	Worker	0.8 in 10,000
M1	PTE operation	0.21	1 in 10,000	0.45	Resident	10 in 10,000
M2	PTE operation	0.11	0.5 in 10,000	0.15	Worker	0.3 in 10,000
M3[†]	PTE operation	0.26	0.3 in 10,000	0.41	Resident	10 in 10,000
M4	PTE operation	0.15	0.07 in 10,000	0.21	Worker	0.4 in 10,000
M5	PTE operation	0.27	0.03 in 10,000	0.45	Worker	0.8 in 10,000
R1	PTE operation	0.15	0.7 in 10,000	0.22	Resident	7 in 10,000
R2	PTE operation	0.078	0.4 in 10,000	0.10	Resident	3 in 10,000
M1	Temporarily closed	0.08	0.4 in 10,000	0.10	Resident	3 in 10,000
M2	Temporarily closed	0.061	0.03 in 10,000	0.078	Worker	0.1 in 10,000
M3	Temporarily closed	0.063	0.3 in 10,000	0.079	Resident	2 in 10,000
M4	Temporarily closed	0.069	0.03 in 10,000	0.084	Worker	0.2 in 10,000
M5	Temporarily closed	0.08	0.04 in 10,000	0.099	Worker	0.2 in 10,000
R1	Temporarily closed	0.082	0.4 in 10,000	0.10	Resident	3 in 10,000
R2	Temporarily	0.066	0.3 in 10,000	0.082	Resident	2 in 10,000

	closed					
M1[†,§]	Pre-closure operation	0.15	0.7 in 10,000	0.21	Resident	6 in 10,000
M2	Pre-closure operation	0.072	0.03 in 10,000	0.094	Worker	0.2 in 10,000
M3[†]	Pre-closure operation	0.73	3 in 10,000	1.3	Resident	40 in 10,000
M4[†]	Pre-closure operation	0.16	0.08 in 10,000	0.23	Worker	0.4 in 10,000
M5	Pre-closure operation	0.07	0.03 in 10,000	0.11	Worker	0.2 in 10,000
R1	Pre-closure operation	0.055	0.3 in 10,000	0.064	Resident	2 in 10,000
R2	Pre-closure operation	0.073	0.3 in 10,000	0.13	Resident	4 in 10,000

*All data used for risk calculations are from LCHD, Village of Gurnee, and City of Waukegan outdoor EtO air sampling data collected between June 3, 2019 and May 1, 2020.

[†]Adjusted EtO concentrations at this air sampling location were statistically significantly greater than combined concentrations at R1 and R2 (LCHD air sampling) or Northbrook and Schiller Park (Medline monthly sampling).

[‡]Mean and EPCs estimated for 2023 using Bayesian GAM due to downward trend in concentrations at F1 and F2

[§]Combined M1-A and M1-B results.

[¶]This is a cancer risk calculated for people who work at businesses near Medline and only takes into account risk during the workday.

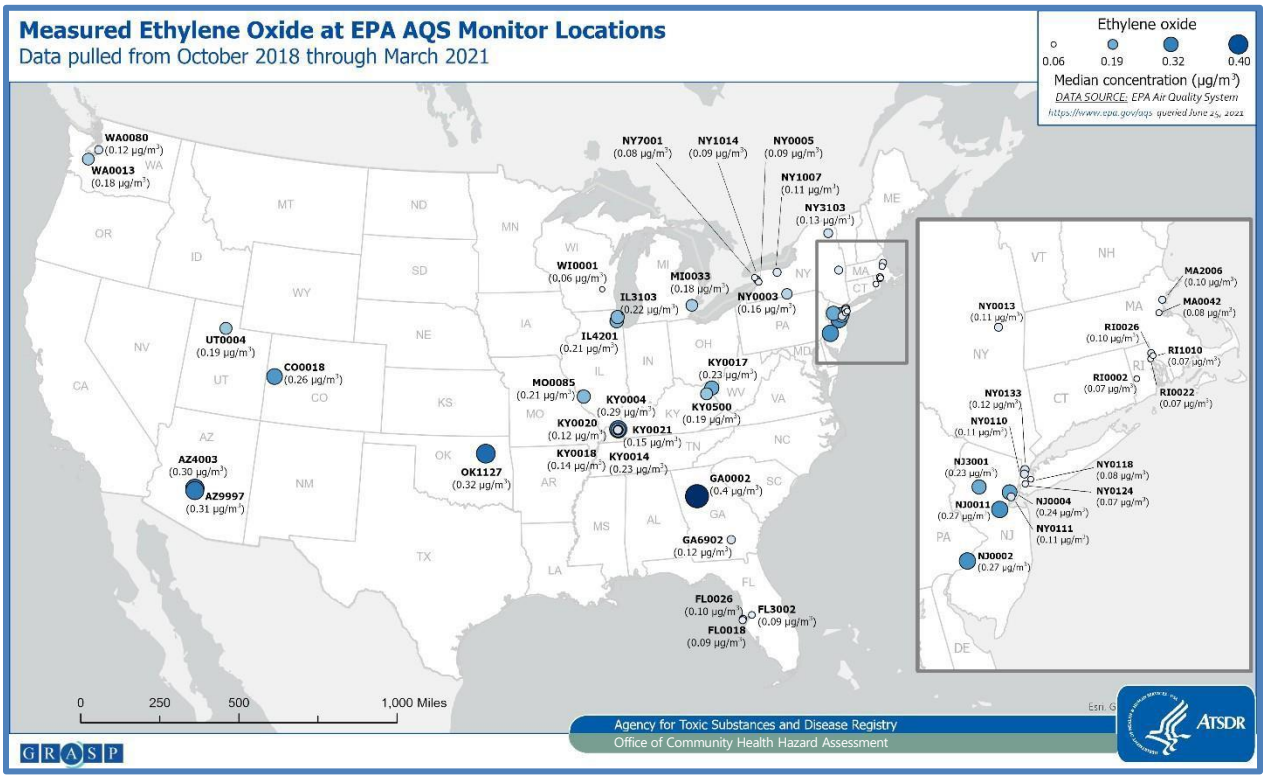
Appendix G: EtO Concentrations Throughout the United States

G1. AQS EtO Data Summary

Prior to U.S. EPA's initiation of national analysis of EtO in fall of 2018, there was little information about what constitutes "normal," "background," or "non-source identified" EtO concentrations in outdoor air across the United States in the scientific literature. To evaluate outdoor EtO concentrations across the United States, ATSDR accessed data from U.S. EPA's Air Quality System (AQS). AQS contains outdoor air pollution data collected by EPA, state, local, and tribal air pollution control agencies from thousands of monitors. AQS also contains meteorological data, descriptive information about each sampling location (including its geographic location and its operator), and data quality assurance/quality control information [U.S. EPA 2021b]. EtO AQS data were initially sampled and analyzed using EPA's Method TO-15 with gradual adoption of Method TO-15a beginning after its publication in September 2019. ATSDR evaluated the median, 95% confidence interval, and range of EtO concentrations detected across the United States at 46 air sampling stations in 16 states that have collected EtO air samples from October 2018 to March 2021 (Figure G1). In general, there is a wide range of median EtO concentrations across sampling stations of 0.064-0.340 $\mu g/m^3$. The dataset has stations identified by U.S. EPA as Urban Air Toxics Strategy stations (UATS) sites, National Air Toxics Trends Sites (NATTS), or State and Local Air Monitoring Stations (SLAMS) that are intended to inform national outdoor air quality for hazardous air pollutants in areas not believed directly impacted by industrial pollutants.

Note that the EtO concentrations reported to AQS are raw, measured values. The analysis of raw data without investigating the canister effect makes it difficult to determine whether detections of EtO are a product of the EtO canister effect (positive bias) or if EtO was actually ubiquitously present at low concentrations. Prior to the identification of this issue, different types of canisters (e.g., silicon-ceramic, SUMMA canister proprietary lining, and electropolished) were used for environmental sampling, almost always interchangeably.

Figure G1. National air monitoring stations reporting median EtO measurements between October 2018 and March 2021[*]



[*] *Data are unadjusted. Median EtO concentrations may be influenced by the EtO canister effect, described below.*

Table G1: Descriptive statistics: median, 95% confidence interval, and range of EtO concentrations (µg/m³) detected across the United States AQS[§] 2018–2021[±]

State (Station ID)	Number of Samples [Number Detected][*]	Median EtO Concentration	Median 95% CI	Range EtO Concentration
Arizona (04-013-4003)	60[49]	0.280	0.230 – 0.380	< 0.108 – 0.826
Arizona (04-013-9997)	131 [107]	0.320	0.250 – 0.390	< 0.108 – 1.420
Colorado (08-077-0018)	113[89]	0.230	0.180 – 0.300	< 0.108 – 1.375
Florida (12-103-0018)	59[56]	0.088	0.074 – 0.097	< 0.014 – 0.205
Florida (12-103-0026)	64[59]	0.086	0.072 – 0.100	< 0.108 – 0.256
Florida (12-057-3002)	96[89]	0.079	0.070 – 0.088	< 0.108 – 0.214
Georgia (13-089-0002)	61[58]	0.340	0.200 – 0.460	< 0.051 – 6.102
Georgia (13-069-0002)	9[5]	0.063	0.048 – 0.980	< 0.051 – 2.772
Illinois (17-031-3103)	129[92]	0.180	0.150 – 0.250	< 0.108 – 0.961
Illinois (17-031-4201)	148[103]	0.180	0.140 – 0.250	< 0.108 – 1.082
Kentucky (21-139-0004)	27[26]	0.290	0.200 – 0.340	< 0.108 – 0.828
Kentucky (21-157-0014)	30[26]	0.230	0.170 – 0.320	< 0.108 – 1.424
Kentucky (21-019-0017)	6[6]	0.230	0.085 – 0.660	0.085 – 0.662
Kentucky (21-157-0018)	24[11]	0.120	0.076 – 0.180	< 0.108 – 0.367
Kentucky (21-157-0020)	20[7]	0.064*	0.033 – 0.130	< 0.108 – 0.380
Kentucky (21-157-0021)	26[11]	0.095*	0.048 – 0.290	< 0.108 – 1.512

State (Station ID)	Number of Samples [Number Detected]*	Median EtO Concentration	Median 95% CI	Range EtO Concentration
Kentucky (21-043-0500)	137[99]	0.180	0.140 – 0.220	< 0.108 – 0.864
Massachusetts (25-025-0042)	70[30]	0.081	0.069 – 0.094	< 0.090 – 0.740
Massachusetts (25-021-2004)	63[37]	0.099	0.071 – 0.120	< 0.090 – 0.824
Massachusetts (25-009-2006)	76[45]	0.094	0.082 – 0.100	< 0.090 – 0.216
Michigan (26-163-0015)	7[1]	NA	NA	< 0.108 – 0.232
Michigan (26-163-0033)	131[92]	0.170	0.140 – 0.200	< 0.108 – 1.051
Missouri (29-510-0085)	128[96]	0.200	0.170 – 0.230	< 0.108 – 0.923
New Jersey (34-007-0002)	103[82]	0.250	0.190 – 0.300	< 0.108 – 0.920
New Jersey (34-039-0004)	87[64]	0.250	0.180 – 0.300	< 0.108 – 0.706
New Jersey (34-023-0011)	107[80]	0.250	0.170 – 0.310	< 0.108 – 1.426
New Jersey (34-027-3001)	101[67]	0.200	0.150 – 0.280	< 0.108 – 0.841
New York (36-101-0003)¶	87[86]	0.160	0.140 – 0.170	< 0.054 – 0.402
New York (36-101-0003)¶	67[66]	0.140	0.120 – 0.150	< 0.054 – 0.319
New York (36-029-0005)	76[59]	0.096	0.081 – 0.110	< 0.054 – 0.411
New York (36-001-0013)	100[93]	0.110	0.098 – 0.130	< 0.054 – 0.744
New York (36-005-0110)	94[90]	0.110	0.100 – 0.120	< 0.054 – 0.303
New York (36-085-0111)	70[68]	0.110	0.100 – 0.130	< 0.054 – 1.526
New York (36-047-0118)	47[38]	0.095	0.078 – 0.120	< 0.054 – 0.629
New York (36-081-0124)	115[91]	0.080	0.069 – 0.093	< 0.054 – 0.253
New York (36-005-0133)	119[119]	0.120	0.110 – 0.130	0.066 – 0.219
New York (36-055-1007)	117[100]	0.110	0.098 – 0.120	< 0.054 – 0.397
New York (36-029-1014)	78[66]	0.100	0.090 – 0.120	< 0.054 – 1.000
New York (36-063-7001)	54[42]	0.089	0.075 – 0.110	< 0.054 – 0.183
Oklahoma (40-143-1127)	41[26]	0.280	0.210 – 0.400	< 0.108 – 0.787
Pennsylvania (42-003-0008)	13[6]	0.130*	0.073 – 0.420	< 0.108 – 0.578
Rhode Island (44-003-0002)	59[32]	0.092	0.062 – 0.100	< 0.090 – 0.569
Rhode Island (44-007-0022)	58[32]	0.072	0.064 – 0.090	< 0.090 – 0.450
Rhode Island (44-007-0026)	57[32]	0.099	0.085 – 0.100	< 0.090 – 0.1746
Rhode Island (44-007-1010)	60[25]	0.076	0.071 – 0.100	< 0.090 – 0.464
Utah (49-011-0004)	117[77]	0.180	0.140 – 0.230	< 0.108 – 1.386
Washington (53-067-0013)	47[32]	0.180	0.120 – 0.240	< 0.108 – 0.769
Washington (53-033-0080)	110[59]	0.110	0.090 – 0.130	< 0.108 – 0.679
Wisconsin (55-027-0001)	56[6]	0.068*	0.054 – 0.087	< 0.108 – 0.320
Wisconsin (55-079-0010)	14[1]	NA	NA	< 0.108 – 0.203

**less than 50% of samples were above the detection limit.*

§ http://www.epa.gov/aqs

± *Censored data were imputed using robust regression on order statistics.*

¶ *Note that NY station 0003 had noticeably higher EtO measurements than other NY stations. This station is at an atmospheric research facility, in a remote, high elevation forested area.*

**Valid samples are samples not flagged as invalid in AQS; detected values are those reported above detection limits or alternate detection limits.*

G2. Evidence of Seasonal Pattern

Data from individual AQS sites in Florida and New York are visualized below in Figures G2 and G3 as examples for the purpose of illustrating seasonal patterns in EtO. EtO concentrations in these states, measured exclusively using silicon-ceramic canisters, show far less variability (EtO median concentrations of 0.08–0.16 µg/m^3) than states that used different types of canisters for outdoor air quality measurements, like Illinois. EtO in Florida (Figure G2) and New York (Figure G3) follows an apparent seasonal pattern, with EtO rising in early summer, peaking in mid-summer, then declining in the fall. Note Massachusetts also exclusively uses silicon-ceramic canisters and also showed an apparent peak in the mid-summer EtO concentrations, but the seasonal pattern in the winter months was not as visually apparent due to the higher method detection limit (MDL) (Figures G4 and G5). The EtO concentrations at these stations stay relatively stable and low through winter and spring. Higher EtO concentrations are observed in these stations in the spring/summer, regardless of where in the state the monitor was located. However, because the Cook County sites used all three canister types, this trend is not distinguishable in Illinois (Figure G4).

Figure G2. EtO concentrations at three Florida AQS air monitoring stations (October 2018–March 2021)

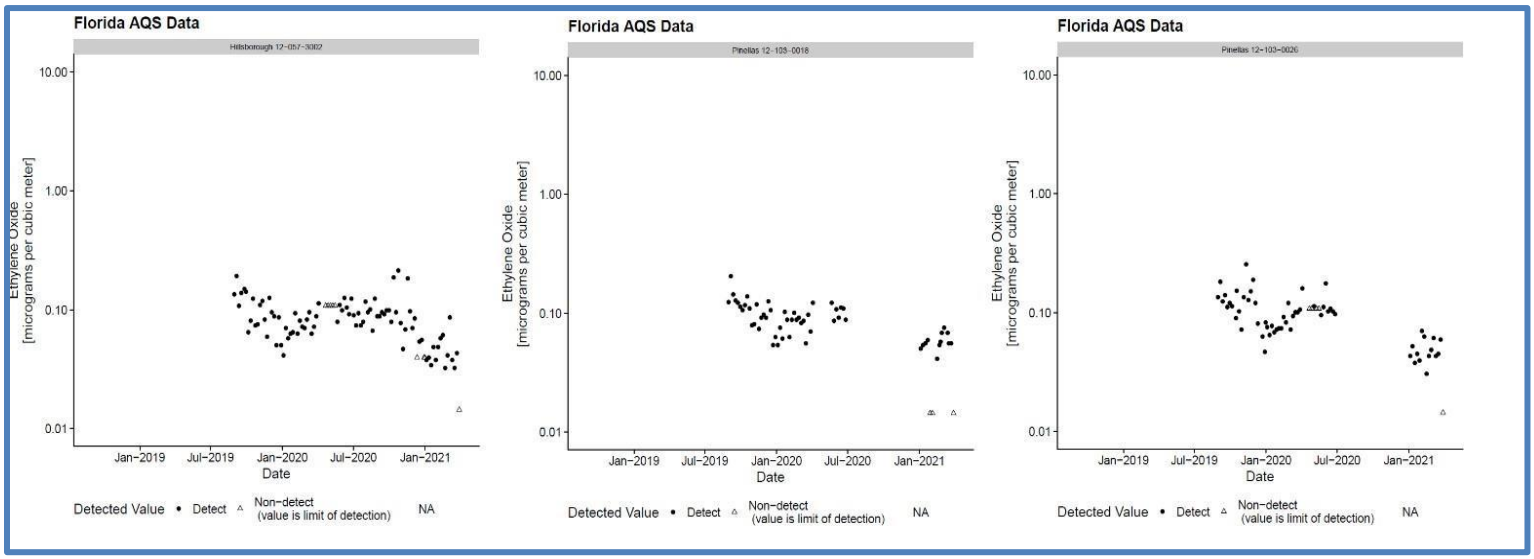


Figure G3. EtO concentrations at 12 New York AQS air monitoring stations

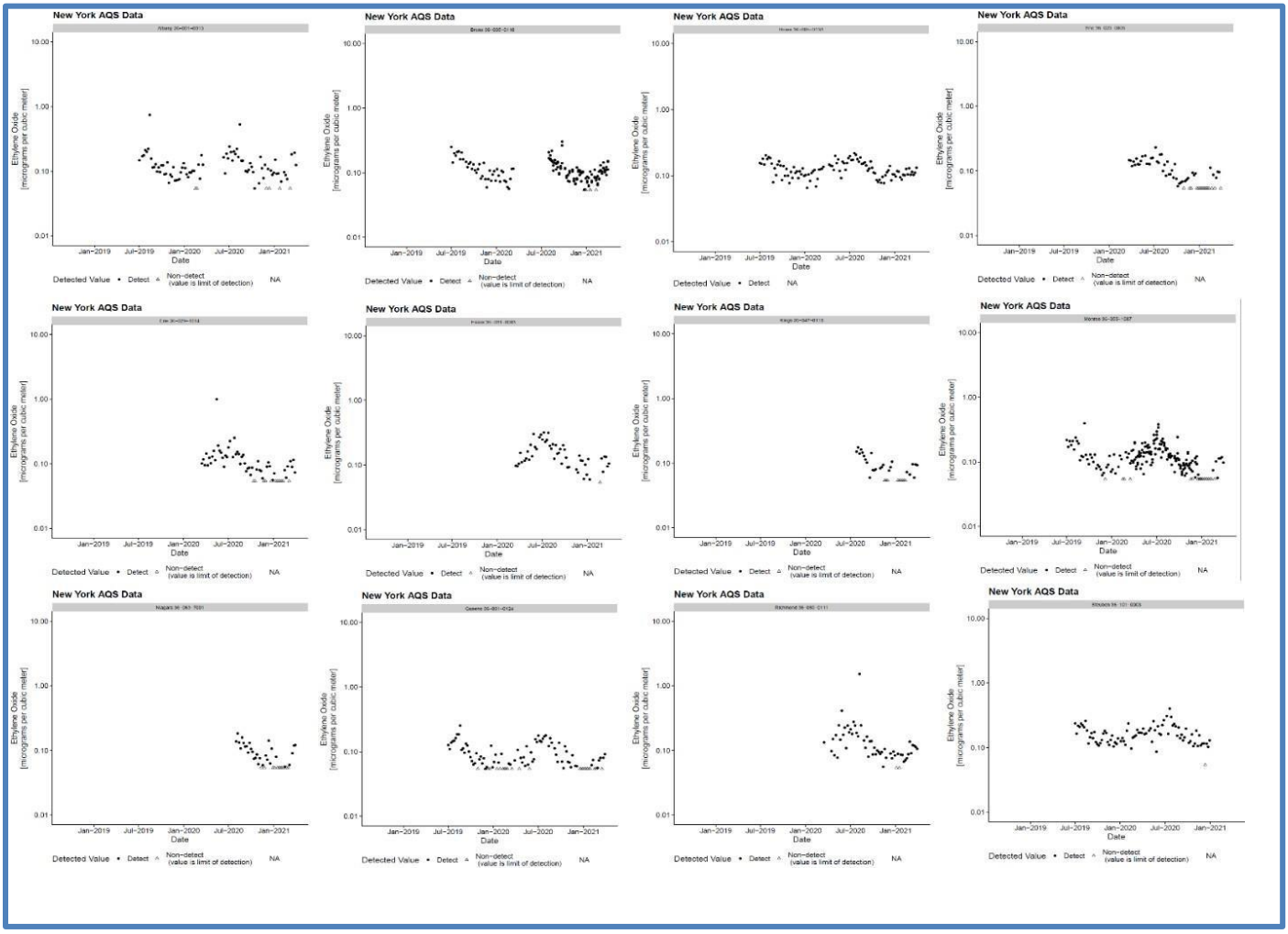
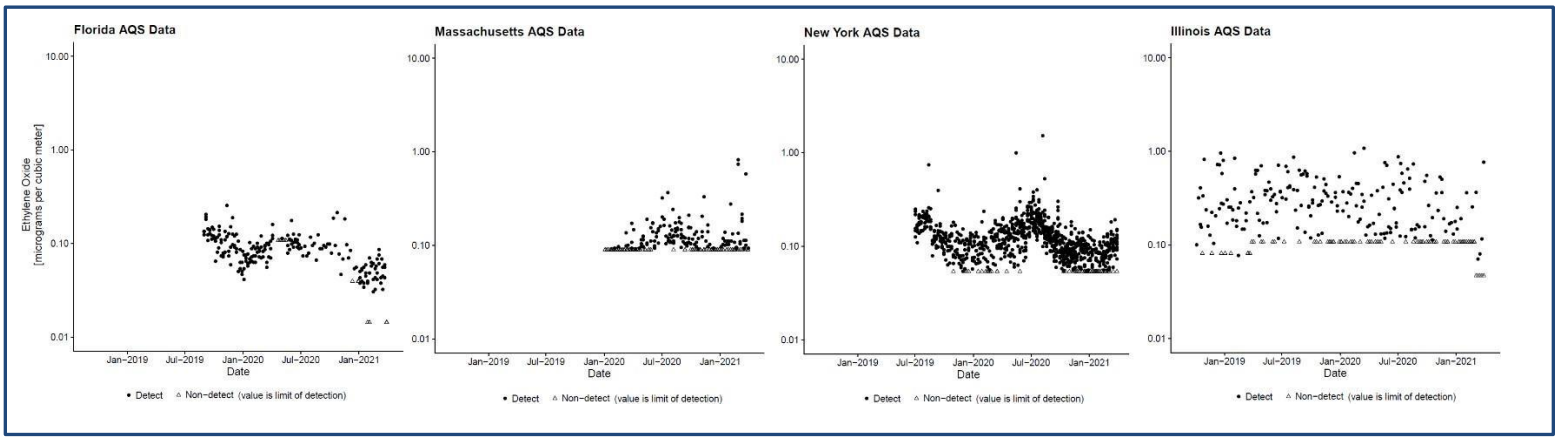
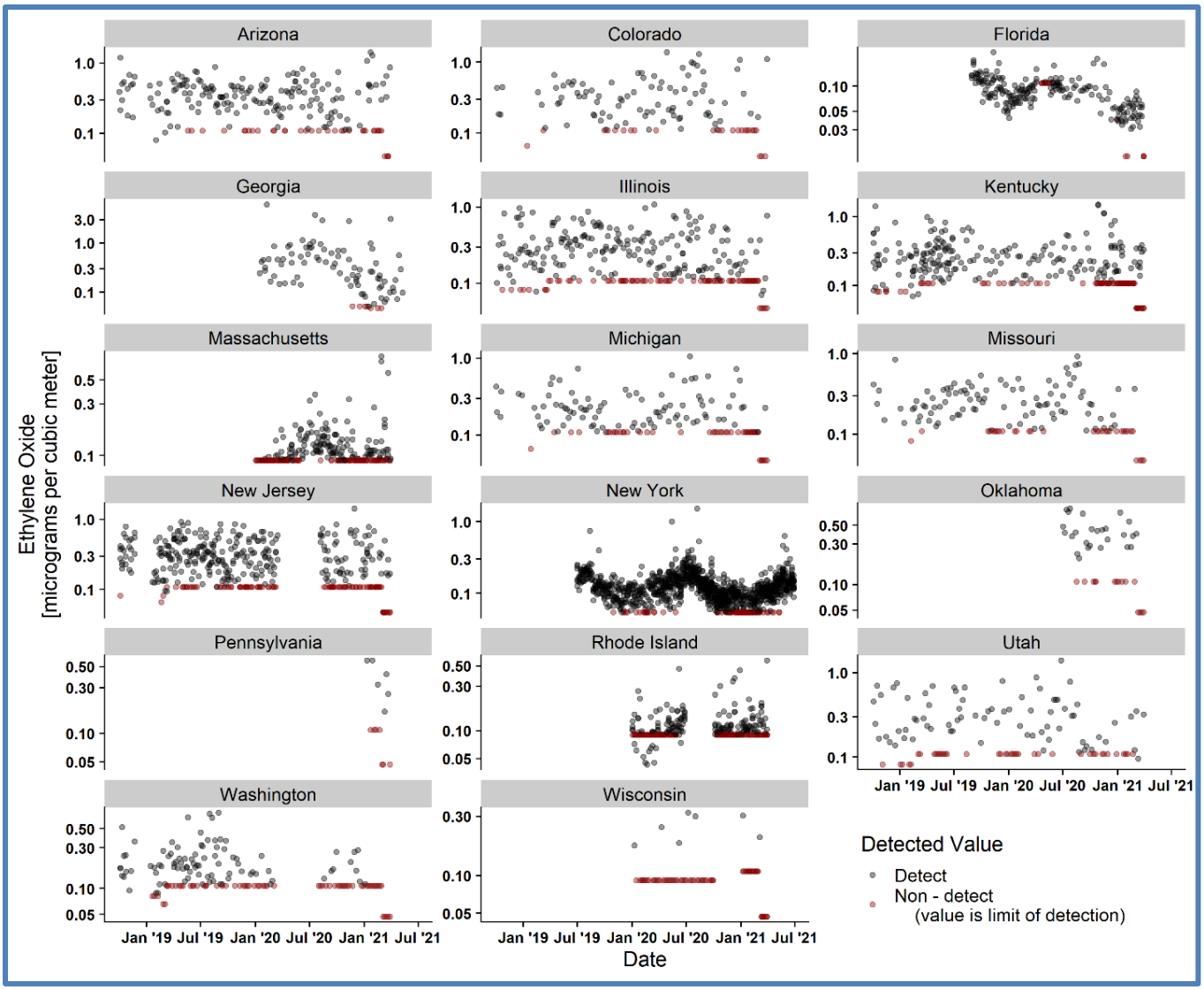


Figure G4. Example of EtO concentration trends in areas without EtO sources: silicon-ceramic at a NY air monitoring station vs. mixed canisters at IL air monitoring station (October 2018–March 2021)



This trend is clearer when state data are aggregated into a single image (see Figure G5). EtO samples collected using mixed canister types (all states except FL, MA, and NY) tended to exhibit higher and more variable EtO concentrations and did not exhibit a seasonable pattern. This observation warrants investigation into potential atmospheric reactions or biologic/unidentified industrial sources of background EtO in outdoor air.

Figure G5. Aggregated AQS outdoor EtO concentrations collected by state (October 2018–March 2021)



1. *source: www.epa.gov/aqs*

Appendix H: GAM Adjustment of EtO data

As described in more detail below, the canister effect results in a positive sampling bias with higher measured and reported EtO concentrations in some canisters than are actually present in the air. In this section, we describe a Bayesian fitted Generalized Additive Model ("GAM") built to adjust EtO datasets by controlling for canister lining type and holding time within the context of an apparent seasonal effect. This approach, which subtracts the modeled effects of lining, holding time, and season from non-silicon-ceramic sample concentrations, is appropriate to quantify concentrations and trends for site-specific assessments when sufficient local background air quality monitoring data exist.

H1. Positive Bias ("EtO Canister Effect")

ATSDR is currently working on multiple health consultations in several states to evaluate community exposures near medical sterilizers that use EtO as the predominant sterilizing agent. In late September 2020, U.S EPA informed ATSDR of widespread positive bias in the U.S. EPA Air Quality System (AQS) database resulting from the growth of EtO in clean canisters. This growth, called the EtO "canister effect," is believed to result from humidified air reacting with the lining of various canister types. ATSDR requested a written summary of the magnitude of this issue, and in response, U.S. EPA issued a plain language document [U.S. EPA2021a]. In their assessment, U.S. EPA utilized practices that were updated in the revised federal reference method for EtO analysis, Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Method TO-15 (revision is TO-15A) to identify problematic canisters in analyses of canister types [U.S. EPA2021a, U.S. EPA 2021c].

On May 7, 2021, U.S. EPA Office of Research and Development (ORD) issued a Memorandum on their investigation on the "Effect of Canister Type on Background Ethylene Oxide Concentrations." U.S. EPA/ORD found that initial one-week results showed EtO concentrations in the samples stored in the silicon-ceramic lined canisters were below the method detection limit (MDL) for all samples, whereas EtO was measured at detectable concentrations in all of the samples stored in electropolished canisters. After the 4 – 5 week holding period, the background EtO concentrations observed in the silicon-ceramic canisters were below the MDL for the majority of the samples. However, the EtO concentrations in the electropolished canisters had increased over the 4 – 5 week hold time by a factor of 7 to 10 times from the initial one-week values corresponding to EtO concentrations substantially higher than typical outdoor EtO concentrations [U.S. EPA ORD 2021].

U.S. EPA/ORD concluded: *While results generated from this research effort are considered preliminary, these early findings indicate electropolished canisters may not be suitable for ambient EtO monitoring as they may contribute an unacceptably high positive EtO bias in ambient samples for sample holding periods longer than a few days [U.S. EPA ORD 2021]*.

In a Technical Note Memo from the EPA Office of Air Quality and Performance Standards (OAQPS) on May 25, 2021 [U.S. EPA OAR 2021], EPA concluded that the "chemical mechanism of EtO formation and growth in a subset of canisters remains unclear and merits further investigation." U.S. EPA also reported that the canister type, age, and cleaning methods can influence the magnitude of the canister effect, that this effect appears to diminish with multiple and repeated cleanings, and that even the effect can be variable even within canisters of the same age, holding time and lining type. Method TO-15A includes procedures to better identify potentially problematic canisters and other measures to mitigate the effect of canister bias. It has replaced method TO-15 as the preferred method for measuring volatile organic compounds, including EtO. Given the potential of the canister effect to vary by canister (even within the same canister lining type), ATSDR analyzed hundreds of samples collected at background air

sampling stations and in communities we are studying to understand the potential effects of canister lining type and holding time and better estimate background EtO levels.

H2. EtO air sampling data used to build the GAM

To evaluate outdoor EtO both in Illinois and across the United States, ATSDR accessed data from U.S. EPA's Air Quality System (AQS). As a referent of background EtO exposure in areas unaffected by EtO sources, we evaluated the National and Urban Air Toxics data collected in two locations (the Northbrook and Schiller Park air monitoring stations) of Cook County, IL between October 2018 through March 2021. The differences in EtO concentrations between the two sites is small and not statistically significant (Wilcoxon Rank Sum p = 0.5, Hodges-Lehmann estimator: 0.00002, 95% confidence interval -0.0008 – 0.003 $\mu g/m^3$). Therefore, we combined data from these two stations for the purposes of building the GAM that corrects for effects of cylinder linings, holding time, and seasonal patterns on EtO concentration. We applied the GAM, built with robust background data, to the LCHD data to remove the "noise" of the canister effect and better estimate EtO concentrations and resulting health implications for cancer and noncancer health effects and trends in the data.

ATSDR received lab reports and canister identifying information from U.S. EPA and its contract lab, Eastern Research Group. We downloaded environmental data from AQS for all sites in the United States reporting EtO data from October 2018 through March 2021 and received original lab reports with information regarding canisters used from LCHD. The national data, including those in Cook County, generally adhere to sample collection on a 1-in-6-day schedule [U.S. EPA 2023]. The number of samples per canister type derived from lab reports is reported in Table H1.

Table H1. Canister type and holding times in valid Cook County samples

Canister Lining	N [Below detection]	% Total cans used	Median holding time (days)
Electropolished	124 [12]	53.7%	14
Proprietary	45 [14]	19.5%	13
Silicon-Ceramic	62 [48]	26.8%	15

H3. Methods

Software:
ATSDR used R statistical software to analyze EtO concentrations reported in the Lake County air investigation as well as background EtO air data collected in Cook County, Illinois and in other states that use silicon-ceramic canisters [R Core Team 2021]. R version 4.1.2 with analytical packages NADA 1.6; NADA-2 1.0.2; tidyverse 1.3.1; mgcv 1.8-35; brms 2.16.3; tidybayes 3.0.1; EnvStats 2.4, bayestestR 0.11.5, asbio 1.7, and effectsize 0.6.0.1 were used for statistical modeling and generating all tables and figures in this report. The details of the statistical approach for this assessment are presented below.

Bayesian fitted GAM:
ATSDR used Hamiltonian Monte Carlo (HMC) based Bayesian analysis to develop models describing the effects of canister lining type, sample holding time, and seasonal patterns on observed levels of EtO. The R brms package was used to interface with the Stan platform (version 2.21.0). The Stan/brms computational framework supplies robust Bayesian inference as well as methods for explicit treatment of censored data [Kurz 2021]. We chose Stan because we could formulate the model to explicitly

describe censoring (nondetects) of the EtO results. We considered nine candidate models and compared them with each other using Bayes Factors [Makowski, et al. 2019] to assess the relative evidence for the models to each other. HMC was performed with default weak priors and with 4 chains, 20,000 burn in and 20,000 post burn in samples, with a thinning of 10.

H4. Results of the GAM adjustment

ATSDR observed the influence of lining type, holding time, and seasonal patterns on the raw data in the Cook County, Illinois datasets. Figure H1 shows that concentrations measured in electropolished canisters were the highest, and EtO concentrations in electropolished canisters tended to be greater the longer the holding time was. Canisters with a proprietary lining type generally measured concentrations that were lower than electropolished canisters but higher than concentrations measured in silicon-ceramic canisters. Silicon-ceramic canisters measured the lowest concentrations and, in the data, collected from October 2018–March 2021 there was no measurable relationship between holding time and concentration in silicon-ceramic canisters.

In comparison to states that only used silicon-ceramic canisters (FL, MA, NY), Illinois and other states that used a mix of canister lining types had no discernable seasonal pattern, and generally higher reported EtO measurements. However, when controlling for canister lining type, holding time and the interaction between those two factors, the Bayesian GAM adjustment predicted there was an effect of season with higher concentrations in the summer and lower concentrations in the winter (Figure H2). We investigated the optimal model of holding time, canister type, and seasonal effects in a stepwise fashion. Our final model (presented here) represents the optimal configuration of these variables that was generalizable to the data at Lake County, the model had the highest Bayes factor.

To better estimate the seasonal effect in the Cook County data, ATSDR:

- modeled the holding time smooth terms as interactive linear terms because there was no evidence of nonlinear effects (because the model with smooths showed a near linear term in the GAM).
- because we observed seasonal patterns in the silicon-ceramic AQS data, ATSDR used a cyclic spline based smooth of the effect of Julian day using a cyclic spline.
- The model is (note the star * is an interactive term):

*log(EtO) ~ sample holding time * canister lining type + s(Julian day) + error*

The GAM had an adjusted r-squared suggesting that about 49% of the EtO concentrations reported were explained by can type, sample holding time, and cycling seasons in the data we evaluated (See Table H2 and Figures H1 and H2). The appearance of the seasonal effect when controlling for other factors and the effect of adjusting for the seasonal effect is illustrated in Figure 3.

Table H2. Bayesian GAM model-linear interaction of lag by canister type and smoothed date (parametric coefficients)

Coefficient	Median Estimate	95% Credible Interval	Probability of Direction	Rhat	Effective Sample Size
Intercept	-2.77	[-3.41, -2.21]	100%	1.000	7798
Sample holding time	0.01	[-0.03, 0.05]	76.29%	1.000	7725
Proprietary lining	0.64	[-0.12, 1.33]	95.96%	1.000	7773
Electropolished lining	0.99	[0.38, 1.65]	99.95%	1.000	7832
Interaction of Lag: Proprietary lining	0.02	[-0.02, 0.07]	78.72%	1.000	7746
Interaction of Lag: Electropolished lining	0.03	[-0.01, 0.07]	93.64%	1.000	7640

***Notes**: Median estimate is median of HMC posterior. 95% Credible interval the shortest interval that contains 95% of the posterior distribution and represents the uncertainty of the parameter estimate. Probability of Direction is an index which can range from 50% to 100% that measures the probability that an effect is in a particular direction. Rhat is measure of convergence of the HMC chains and should be 1 or close to 1. Effective Sample Size is the number of independent samples with similar estimation power as the 8000 samples in HMC simulation.*

Figure H1. GAM prediction of holding time by canister type vs. Cook County data

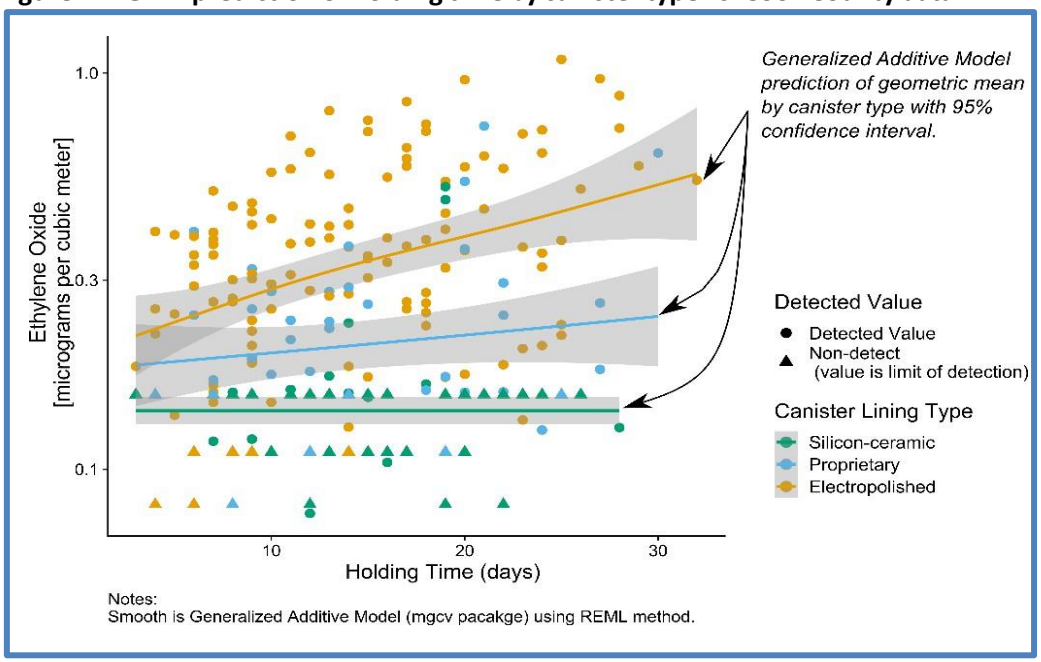


Figure H2. Smooth effect of Julian day (day of the year from 1 to 365)

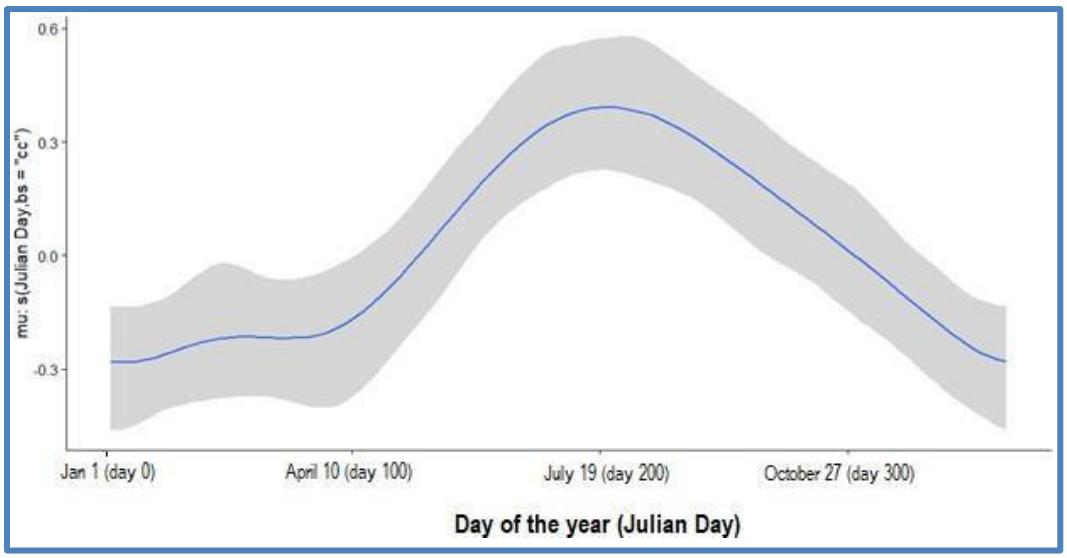
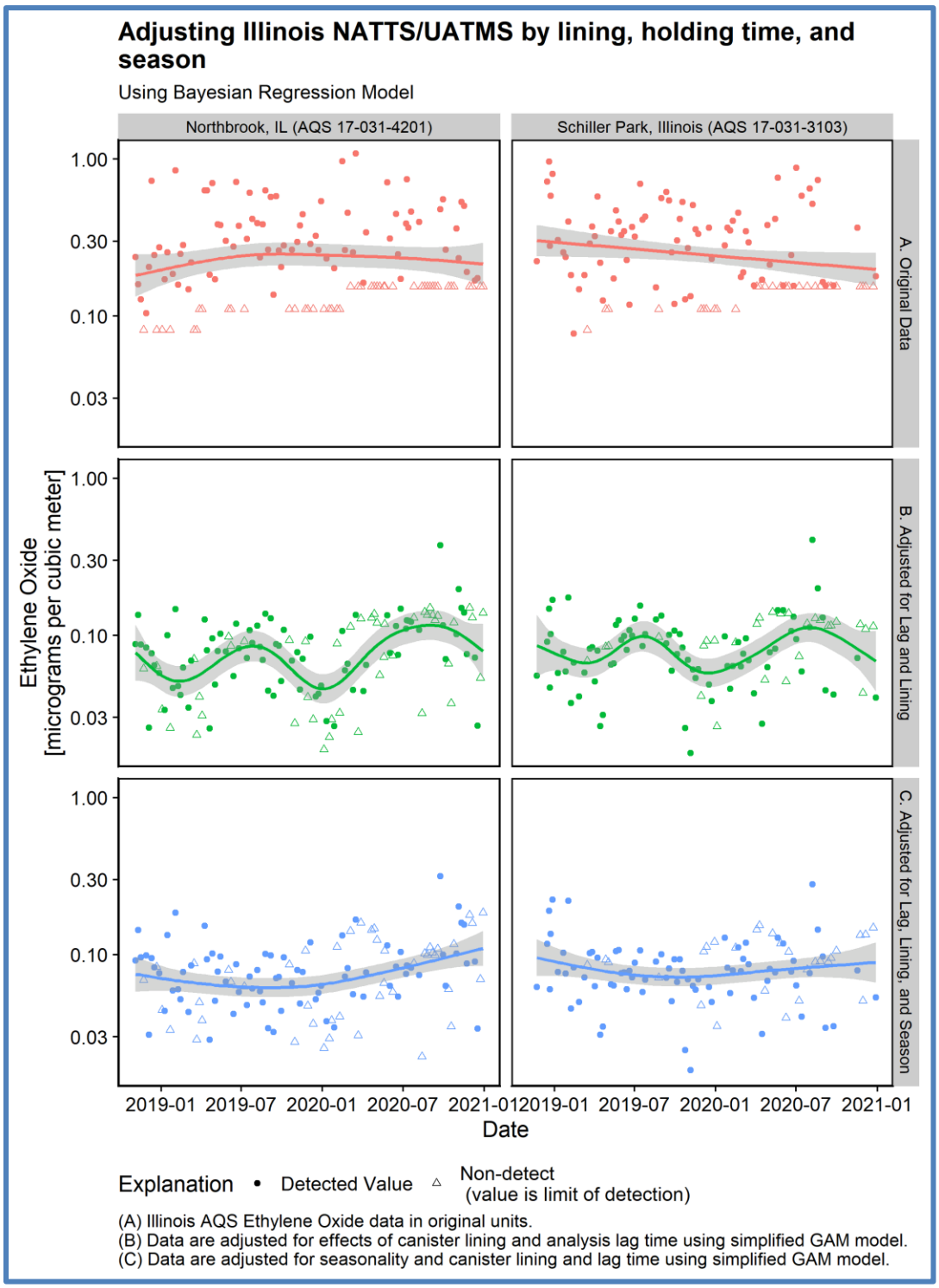


Figure H3. Illinois EtO AQS measurements, simplified GAM model



Using the coefficients of the GAM model, we adjusted the EtO concentrations measured in Cook County for canister type and seasonal patterns (Figure H3). To show the relative influence of each factor on measured values of EtO, we illustrate in this figure three pairs of time series of EtO concentrations at the Northbrook (left column of the three pairs of time series) and Schiller Park (right column of the three pairs of time series) air monitoring stations from October 2018 through March 2021. The time series are as follows:

1. The top two time series in red display a scatter plot and trend line of EtO concentrations which have little or no pattern;
2. The trendlines through the GAM-adjusted EtO concentrations in green (middle two time series), where the model is controlling for lining type and sample holding time, which reveals the seasonal pattern of EtO concentrations at the Illinois background sites, illustrated by the wavy line with higher EtO concentrations in the summer and lower concentrations in the winter; and
3. the GAM-adjusted data in blue, where the model is controlling for lining type, sample holding time, and season, revealing an estimated background concentration if these factors were not present. The GAM-adjusted concentrations are lower than the original concentrations in red and no longer display a seasonal pattern because that is being controlled for through the Julian day term in the model.

Table H3 shows how the model predicts EtO concentration if all the samples were collected with silicon-ceramic canisters (the preferred canister for EtO quantification). For the two AQS sites in Cook County, the overall mean was 0.28 µg/m^3 (unadjusted) with a Bayesian GAM-predicted mean (controlling for can type, holding time, and season) of 0.073 µg/m^3; note that the mean of all silicon-ceramic lined canisters for these sites is 0.098 µg/m^3, although this is imputed using ROS with data that are 77% non-detect, which would make these estimates approximate. The model estimated mean and median concentrations of EtO in Cook County are below EPA's method detection limit (MDL). A Bayesian GAM was chosen in part to account for the effects introduced by values below the MDL (censored values).

Table H3. Comparison of raw and Bayesian GAM-adjusted background data[±]

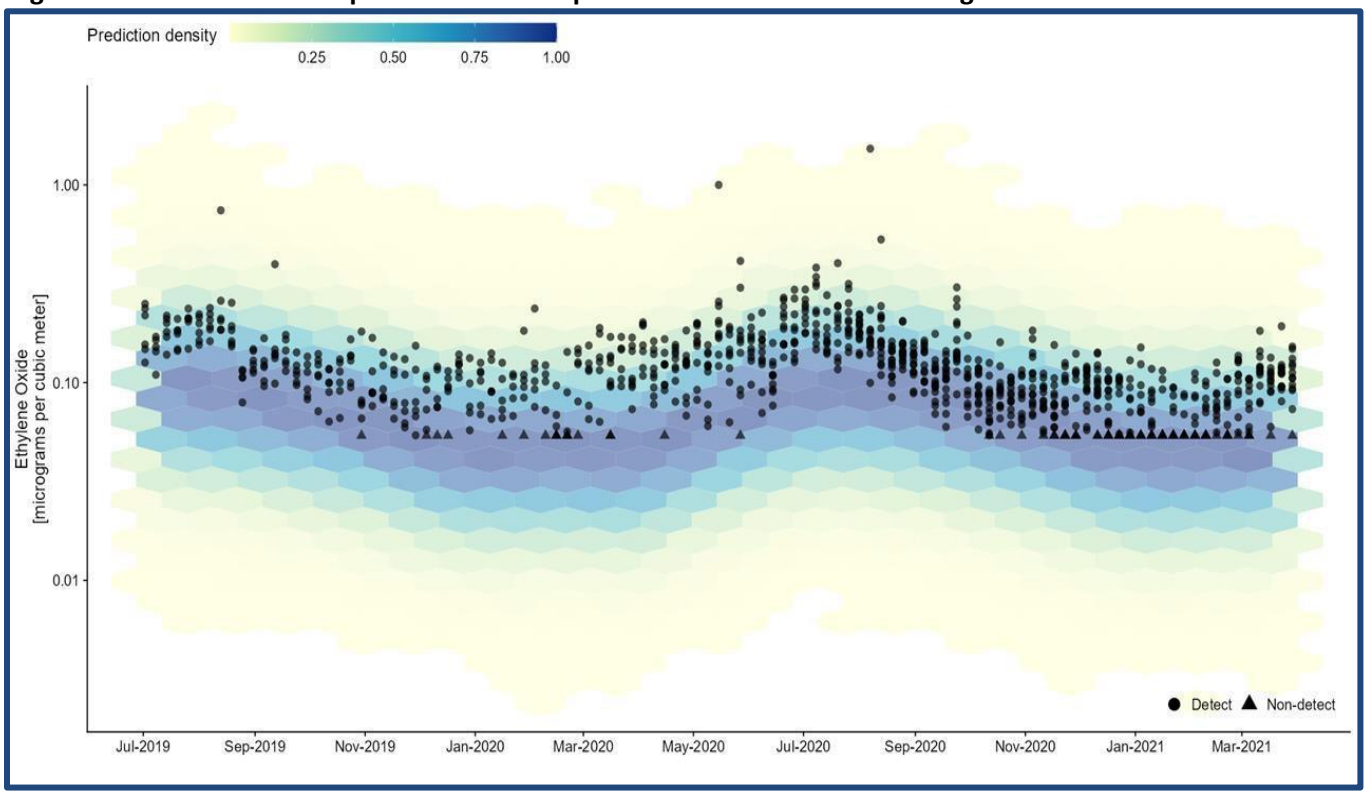
Site	Raw mean EtO- All canister types (µg/m^3)	Raw Silicon-Ceramic mean EtO (µg/m^3)	Raw Silicon-Ceramic median EtO (µg/m^3)	Adjusted mean EtO (µg/m^3)	Adjusted median EtO (µg/m^3)
Northbrook, IL	0.269 (n=125; 46 NDs; 95% CI: 0.233 – 0.309)	0.079 (n=34; 26 NDs; 95% CI: 0.0513– 0.122)	0.0480 (95% CI: 0.0307 - 0.0821)	0.0696 (95% CI: 0.0623 - 0.078)	0.0578 (95% CI: 0.0555 - 0.0637)
Schiller Park, IL	0.286 (n=106; 28 NDs; 95% CI: 0.249 – 0.327)	0.104 (n=30; 22 NDs; 95% CI: 0.081 – 0.133)	0.0821 (95% CI: 0.0646 – 0.116)	0.0773 (95% CI: 0.0695 - 0.0861)	0.0677 (95% CI: 0.0645 - 0.0766)
All Cook County[§]	0.277 (n=231; 74 NDs; 95% CI: 0.25 – 0.306)	0.0983 (n=62; 48 NDs; 95% CI: 0.072 – 0.125)	0.0768 (95% CI: 0.0608 – 0.0964)	0.0732 (95% CI 0.0679- 0.0791)	0.0626 (95% CI 0.0607– 0.0672)
New York (12 sites) [¶]	See Median (n=1162; 104 NDs)	See Median (n=1162; 104 NDs)	0.0801-0.150 (95% CI range 0.0695- 0.158)	N/A	N/A
Florida (3 sites)	See Median (n=213;16 NDs)	See Median (n=213;16 NDs)	0.079-0.086 (95% CI range 0.070- 0.097)	N/A	N/A
Massachusetts (3 sites)	See Median (n=209;97 NDs)	See Median (n=209;97 NDs)	0.081-0.099 (95% CI range 0.069- 0.100)	N/A	N/A

[±] *Raw, censored data were imputed using robust regression on order statistics.*

§ Cook County includes data from Northbrook and Schiller Park.
¶ Note that NY station 0003 had noticeably higher EtO measurements than other NY stations. This station is at an atmospheric research facility, in a remote, high elevation forested area.

To illustrate the seasonal pattern in background data from IL (GAM-adjusted for canister type and holding time) and NY (measured using silicon-ceramic canister), the IL GAM-adjusted data were overlaid with NY background data in Figure H4. New York was used in this figure because there are 12 sites across the state that allow a robust comparison of seasonal patterns in NY to the IL GAM. Both states showed similar seasonality, with EtO peaking in July and lowest in winter months.

Figure H4. New York data imposed over model-predicted smoothed Illinois background EtO[±]



Explanation: This time series of EtO concentrations from July 2019 through March 2021 shows EtO concentrations measured at New York air monitoring stations in AQS, represented by the black dots, compared to the model prediction density of EtO concentrations of the Bayesian GAM controlling for canister type, holding time and the interaction of the two effects. New York background outdoor EtO air data are collected with only silicon-ceramic canisters. The prediction density is the density of 1000 predictions of silicon-ceramic canisters with 7 days holding time using the model developed with Illinois AQS data. The blue shaded area represents higher density prediction density, meaning the model predicts that it is more probable that EtO concentrations fall in that range. The prediction density of the model shows a very similar seasonal effect as was observed in silicon-ceramic canisters in New York. The concentrations measured in New York fall close to or within the highest model prediction density areas for the Cook County sites.

H5. Summary of ATSDR's analysis of the EtO canister effect

The model ATSDR utilized to adjust for seasonal pattern, canister lining, and holding time estimated that canisters with electropolished lining and proprietary lining demonstrated the greatest bias relative to silicon-ceramic canisters (~169% and 89%, respectively). The model has terms for an exponential growth of EtO concentrations in the time elapsed between sample collection and sample analysis (i.e., sample "holding time"). While a small amount of bias has been observed in canisters with proprietary lining ("SUMMA canisters") and silicon-ceramic lining, they do not show as much growth over time as electropolished canisters. We found that electropolished canisters reported the highest bias (~3.0% EtO increase per day of holding time), followed by the proprietary SUMMA canisters (~2.0% EtO increase per day of holding time), with silicon-ceramic canisters showing the least bias (~1.0% EtO increase per day of holding time). After controlling for the canister lining and sampling holding time, the GAM-adjusted background data in IL showed a seasonable effect (high in summer and low in winter). The seasonal trending is nearly identical to that observed in 12 NY and three FL background air quality monitoring sites where data are collected exclusively in silicon-ceramic canisters. Our GAM model estimates median background EtO concentrations are approximately 0.06 µg/m^3 at the IL air quality monitoring stations in Cook County. Preliminary data suggest median background EtO concentrations are similar at other air quality monitoring sites where silicon-ceramic canisters are exclusively used (MA, NY, FL). These findings warrant additional investigation into the potential mechanisms that would explain ubiquitous and seasonally trending background concentrations of EtO. Our findings also support adjusting for positive sampling bias when using a canister sampling fleet with multiple canister lining types.

ATSDR evaluated canister characteristics and holding time for two Cook County background sites. From this analysis, we conclude:

1. Canisters with electropolished lining have the highest EtO bias, followed by canisters with proprietary lining, and silicon-ceramic canisters have the least EtO bias over time. This relationship appears to be exponential in electropolished canisters and warrants adjustment of non-silicon-ceramic canister data to correct bias introduced by the canister effect in datasets with mixed canister lining types.
2. Seasonal patterns are observed in monitoring locations with samples collected in silicon-ceramic lined cans.
3. ATSDR generated a GAM that controlled for the effects of can lining and holding time, yielding adjusted time trends that show a seasonal trend of EtO.
4. The GAM-adjusted mean background concentration in Cook County was approximately 0.073 µg/m^3, which appears to be similar to NY (0.115 µg/m^3) and FL (0.09 µg/m^3). Further, the seasonal effect revealed in the IL GAM appears to occur during the same months as that observed in these states.
5. Investigation of ubiquitous EtO in the atmosphere is warranted; seasonal trending suggests that EtO can be produced to some extent by atmospheric chemical reactions, possibly with co-pollutants, solar radiation, or other meteorologic factors (humidity, temperature, etc.), biologic sources, or perhaps uncharacterized industrial emissions.

Appendix J: References

Amendment to The Environmental Protection Act, Public Act 101-0023, Illinois General Assembly (2019). Accessed April 11, 2023. https://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=101-0023

[ATSDR] Agency for Toxic Substances and Disease Registry. 2020. Toxicological Profile for Ethylene Oxide. Atlanta, GA., December 22, 2023. https://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=734&tid=133.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2021. Guidance for Inhalation Exposures. April 11, 2023. https://www.atsdr.cdc.gov/pha-guidance/resources/ATSDR-EDG-Inhalation-508.pdf.

[ATSDR] Agency for Toxic Substances and Disease Registry. Public Health Assessment Guidance Manual (PHAGM). April 11, 2023. https://www.atsdr.cdc.gov/pha-guidance/index.html.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2023a. Public Comment Version Evaluation of Ethylene Oxide Concentrations in Outdoor Air Near Sterigenics Willowbrook, DuPage County, Illinois. Atlanta, GA., December 26, 2023. https://wwwn.cdc.gov/TSP/PHA/PHAListing.aspx?StateIndicator=IL .

[ATSDR] Agency for Toxic Substances and Disease Registry. 2023b. Exposure Point Concentration Guidance for Discrete Sampling. Atlanta, GA., April 11, 2023. https://www.atsdr.cdc.gov/pha- guidance/resources/EPC-Guidance-for-Discrete-Sampling-508.pdf.

American Cancer Society. Lifetime Probability of Developing and Dying from Cancer, 2017-2019. 2023a. Accessed June 21, 2023. https://www.cancer.org/healthy/cancer-causes/general-info/lifetime-probability-of-developing-or-dying-from-cancer.html

American Cancer Society. Cancer and Risk Prevention. American Cancer Society. 2023. Accessed June 21, 2023, https://www.cancer.org/cancer/risk-prevention.html

American Cancer Society. Key Statistics for Breast Cancer. Accessed February 1, 2024, https://www.cancer.org/cancer/types/breast-cancer/about/how-common-is-breast-cancer.html

Batelle. Technical Assistance Document for the National Air Toxics Trends Station Program Revision 3: section 4.2.8.5.3. 2016. Accessed December 26, 2023. https://www3.epa.gov/ttnamti1/files/ambient/airtox/NATTS%20TAD%20Revision%203_FINAL%20October%202016.pdf

Benjamini YH, Y Controlling the false discovery rate: a practical and powerful approach to multiple testing. Journal of the Royal Society. 1995;Series B(57):289-300.

Carslaw D. The openair book. Accessed February 1, 2024, https://bookdown.org/david_carslaw/openair/

Centers for Disease Control and Prevention. Environmental Justice Index. Accessed February 20, 2024, https://www.atsdr.cdc.gov/placeandhealth/eji/index.html

Food and Drug Administration. Sterilization for Medical Devices. Accessed December 22, 2023, 2023. https://www.fda.gov/medical-devices/general-hospital-devices-and-supplies/sterilization-medical-devices#why

Helsel D. Statistics for Censored Environmental Data Using Minitab and R. 2 ed. Wiley Series in Statistics in Practice. John Wiley & Sons, Inc.; 2012:325.

Hornung RW, Greife A, Stayner LT, Steenland NK, Herrick RF, Elliott LJ, et al. Statistical model for prediction of retrospective exposure to ethylene oxide in an occupational mortality study. American journal of industrial medicine. 1994;25 6:825-36.

[IEPA] Illinois Environmental Protection Agency. 2019a. Fact Sheet Medline Industries Application for Construction Permit. https://epa.illinois.gov/content/dam/soi/en/web/epa/topics/community-relations/sites/ethylene-oxide/documents/medline-factsheet.pdf.

[IEPA] Illinois Environmental Protection Agency. Fact sheet: Application for construction permit and proposed draft permit 2019b. Accessed December 22, 2023. https://epa.illinois.gov/content/dam/soi/en/web/epa/topics/community-relations/sites/ethylene-oxide/documents/vantagefact-sheet.pdf

[IEPA] Illinois Environmental Protection Agency. 2019c. Construction Permit NSPS Source Vantage Specialties, Inc. Springfield, IL., April 11, 2023. https://epa.illinois.gov/content/dam/soi/en/web/epa/topics/community-relations/sites/ethylene-oxide/documents/19100015.pdf.

[IEPA] Illinois Environmental Protection Agency. 2019d. Construction Permit NESHAP Source Medline Industries. Springfield, IL., April 11, 2023. https://epa.illinois.gov/content/dam/soi/en/web/epa/topics/community-relations/sites/ethylene-oxide/documents/medline-industries-19020013-final.pdf.

[IEPA] Illinois Environmental Protection Agency. Illinois EPA information on Ethylene Oxide. 2023;

Illinois Department of Public Health. 2021. Cancer Incidence near Two Facilities Utilizing Ethylene Oxide, Lake County, Ill., 1998-2017. May 1, 2022. https://dph.illinois.gov/content/dam/soi/en/web/idph/publications/idph/data-and-statistics/epidemiology/cancer-registry/Lake%20County%20IL_EtO_98-17%20FINAL.pdf.

[LCHD] Lake County Health Department. Ethylene Oxide (EtO) Emissions at Sterigenics, Medline, and Vantage. Accessed June 7, 2022, https://www.lakecountyil.gov/DocumentCenter/View/27441/Ethylene-Oxide-EtO-Emissions-at-Sterigenics-Medline-and-Vantage

The Matt Haller Act, Public Act 101-0022, Illinois General Assembly (2019). Accessed April 11, 2023. https://www.ilga.gov/legislation/publicacts/fulltext.asp?Name=101-0022

International Agency for Research on Cancer. 2012. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans; Ethylene Oxide. Lyon, France. April 11, 2023. https://publications.iarc.fr/115

Kurz S. Doing Bayesian Data Analysis in brms and the tidyverse v 0.4.0. 2021. https://bookdown.org/content/3686/stan.html

Mackey LLCHD. Request for assistance with further analysis of Ethylene Oxide sample results. In: Siegel KUSER, editor. 2020.

Makowski D, Ben-Shachar MS, Lüdecke D. bayestestR: Describing Effects and their Uncertainty, Existence and Significance within the Bayesian Framework. The Journal of Open Source Software. 2019;4(40)

Manly BFJ. Randomization, Bootstrap and Monte Carlo Methods in Biology. 3 ed. Statistical Science Series. Chapman & Hall/CRC; 2007.

McClenny WA, Holdren MW. 1999. Method TO-15: Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed By Gas Chromatography/ Mass Spectrometry (GC/MS). Washington, DChttps://www.epa.gov/sites/default/files/2019-12/documents/to-15a_vocs.pdf.

McKenzie BB, A.; Bogovic, S.; Conn, M.; Dent, A.; Flanagan, B.; Freelander, L.; Grossman, M.; Kashani, M.; Lehnert, E.; Lewis, B.; Mirsajedin, A.; Owusu, C.; Richardson, G.; Sharpe, J.D.; Shin, M.; Werner, A. 2022. Technical Documentation for the Environmental Justice Index 2022. Atlanta, GA. February 29, 2024. https://www.atsdr.cdc.gov/placeandhealth/eji/docs/EJI-2022-Documentation-508.pdf.

Mikoczy Z, Tinnerberg H, Björk J, Albin M. Cancer incidence and mortality in Swedish sterilant workers exposed to ethylene oxide: updated cohort study findings 1972-2006. Int J Environ Res Public Health. Jun 2011;8(6):2009-19. doi:10.3390/ijerph8062009

[NTP] National Toxicology Program. 2021. Report on Carcinogens: 1998 Background Document for Ethylene Oxide. Research Triangle Park, NC., April 11, 2023. https://ntp.niehs.nih.gov/ntp/newhomeroc/other_background/ethyloxide_oneapp_508.pdf.

EnvStats: An R Package for Environmental Statistics. Version 2.7.0. Springer; 2013. https://github.com/alexkowa/EnvStats

National Cancer Institute. Risk Factors for Cancer. National Institutes of Health. Updated December 23, 2015. Accessed June 21, 2023, 2023. https://www.cancer.gov/about-cancer/causes-prevention/risk

Peto R, Peto J. Asymptotically Efficient Rank Invariant Test Procedures. Journal of the Royal Statistical Society Series A (General). 1972;135(2):185-207. doi:10.2307/2344317

Calculate pairwise comparisons of mean rank sums extended. Version R package version 1.9.3. 2021. Accessed January 1, 2022. https://CRAN.R-project.org/package=PMCMRplus

R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing; 2021.

Siegel KUSER. EPA letter Lake County sampling response. In: Mackey LLCHD, editor. 2020.

Steenland K, Whelan E, Deddens J, Stayner L, Ward E. Ethylene oxide and breast cancer incidence in a cohort study of 7576 women (United States). Cancer Causes Control. Aug 2003;14(6):531-9. doi:10.1023/a:1024891529592

Steenland K, Stayner L, Deddens J. Mortality Analyses in a Cohort of 18 235 Ethylene Oxide Exposed Workers: Follow up Extended from 1987 to 1998. Occupational and Environmental Medicine. 2004;61(1):2-7.

U.S. Census Bureau. 2020a. DP1 Profile of General Population and Housing Characteristics 2020: DEC Demographic Profile Waukegan city, Illinois. https://data.census.gov/table/DECENNIALDP2020.DP1?q=Waukegan,%20Illinois%20population%202020%20census.

U.S. Census Bureau. 2020b. DP1 Profile of General Population and Housing Characteristics 2020: DEC Demographic Profile Gurnee village, Illinois. https://data.census.gov/table?q=Gurnee,%20Illinois%20population%202020%20census.

[U.S. EPA OAR] United States Environmental Protection Agency Office of Air and Radiation. 2021. Technical Note: The Ethylene Oxide (EtO) Canister Effect. Research Triangle Park, NC. April 11, 2023. https://www.epa.gov/sites/production/files/2021-05/documents/technical-note-on-eto-canister-effect-052521.pdf.

[U.S. EPA ORD] United States Environmental Protection Agency Office of Research and Development. 2021. Effect of Canister Type on Background Ethylene Oxide Concentrations. Research Triangle Park, NC. https://www.epa.gov/sites/production/files/2021-05/documents/ord-eto-canister-background-memo-05072021.pdf.

[U.S. EPA] U.S. Environmental Protection Agency. 2016. Definition and Procedure for the Determination of the Method Detection Limit Revision 2. https://www.epa.gov/sites/default/files/2016-12/documents/mdl-procedure_rev2_12-13-2016.pdf

[U.S. EPA] United States Environmental Protection Agency. 2015. User's Guide-ProUCL Version 5.1. April 11, 2023. https://www.epa.gov/land-research/proucl-software.

[U.S. EPA] United States Environmental Protection Agency. 2016. Evaluation of the Inhalation Carcinogenicity of Ethylene Oxide. Washington, DC. April 11, 2023. https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/1025tr.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2018. 2014 Nata: Fact Sheet. Research Triangle Park, NC. June 20, 2023. https://www.epa.gov/sites/default/files/2018-08/documents/2014_nata_overview_fact_sheet.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2021a. EPA's Work to Understand Background Levels of Ethylene Oxide. Research Triangle Park, NC. April 11, 2023. https://www.epa.gov/hazardous-air-pollutants-ethylene-oxide/epas-work-understand-background-levels-ethylene-oxide.

[U.S. EPA] United States Environmental Protection Agency. Air Quality System: Air Toxics. Accessed June 25, 2021. https://www3.epa.gov/ttn/amtic/toxdat.html#data

[U.S. EPA] United States Environmental Protection Agency. 2021c. EtO Technical Webinar. April 11, 2023. https://www.epa.gov/sites/production/files/2021-05/documents/eto-technical-webinar-041521-w-qandas.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2022. Air Toxics Screening Assessment. Research Triangle Park, NC. May 11, 2022. https://www.epa.gov/AirToxScreen.

[U.S. EPA] United States Environmental Protection Agency. Ambient Monitoring Technology Information Center (AMTIC) Sampling Schedule Calendar. Accessed January 3, 2024, https://www.epa.gov/amtic/sampling-schedule-calendar

United States Preventative Services Taskforce. Breast Cancer: Screening. Accessed April 11, 2023, 2023. https://www.uspreventiveservicestaskforce.org/uspstf/recommendation/breast-cancer-screening

Vantage Specialties Inc. Construction Permit No. 19100016 Quarterly Report - Q1 2020. 2020a.

Vantage Specialties Inc. Our Commitment to the Community. Accessed March 10, 2022, https://web.archive.org/web/20220117105209/https://www.vantagegrp.com/en-US/General/Page/e70eaaea-6ddf-4e86-9622-99658b0aa167/Gurnee-Community-Update

Vantage Specialties Inc. Vantage History. Accessed March 10, 2022, https://web.archive.org/web/20211207151336/https://www.vantagegrp.com/en-US/General/Page/c02bff7d-a261-4c33-99ca-a07ac58c4911/Company-History

Xi C. Sampling/analytical details for IL NATTS ethylene oxide data. In: Caudill M, editor. Email ed2024.