Characterization of Ethylene Oxide Concentrations in Communities near Commercial Sterilization Facilities in the Salt Lake Valley

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Ethylene Oxide (EtO) Background

Ethylene oxide (EtO) is an odorless, colorless gas used to sterilize medical equipment and other heat or water-adverse products such as spices and lumber. EtO is also used in the manufacturing of other products, such as antifreeze and plastics.

Ethylene Oxide Health Risks

Long-term human exposure to EtO is associated with an increased incidence of cancer. In 2016, the EPA reassessed the carcinogenicity of EtO, **increasing its toxicity value by 60 times for children and 30 times for adults**. Using this updated cancer risk value, an initial risk assessment analysis conducted in 2018 showed that EtO might be causing risk near medical sterilization facilities, but facilities in Utah did not show up in this analysis.

UDAQ and University of Utah EtO Study

Knowing that there are two sterilization facilities in Utah, BD Medical and Sterigenics (**Figure 1**), and that the 2018 analysis is limited by its low resolution, researchers at Utah DAQ applied for competitive EPA funding to further investigate EtO levels in the region. They planned a study with three main objectives:

1. Ambient silonite canister sampling at strategic locations near the facilities and at background sites. 16 sampling sites (11-12 near facilities and 4-5 background) were selected.
2. Sampling during the wintertime and summertime to assess seasonal differences in EtO concentrations. Samples were collected once every three days for eight weeks in both seasons.
3. Modeling health risk using a variety of HEM-3 simulations and comparing to measured concentrations. More on this topic can be found at Skyler Spooner's poster titled:

A Comparison of Ambient Air Ethylene Oxide Modeling Estimates from Facility Stack and Fugitive Emissions to those Modeled from Canister-based Ambient Air Measurements in the Salt Lake Valley

Figure 2

Facility Emissions (2021 Values)

Facility	Emissions (PTE) TPY	Emissions (Actual) TPY	Fugitive Emissions (%)
BD Medical (BD) Residential area in Sandy	0.24	0.35*	95
Sterigenics (SG) Industrial area near airport	2.1	0.98	97

* Total HAPs emission limit is 1.77 TPY. PTE to 0.1145 in 2022

Sampling Challenges

Ambient sampling of EtO is challenging for a number of reasons. Those most relevant to this study are:

- Growth of EtO within canisters, possibly increasing with hold time, leading to erroneously high EtO concentrations especially at lower (background) concentrations.
- Stand-alone timer malfunction due to low temperatures (in the winter) impacting solenoid valve closure (**Figure 2**, red circle).
- Temperature fluctuations and heavy rainfall impacted canister flow rates, which are calibrated in the lab and not able to adjust to variable field conditions.

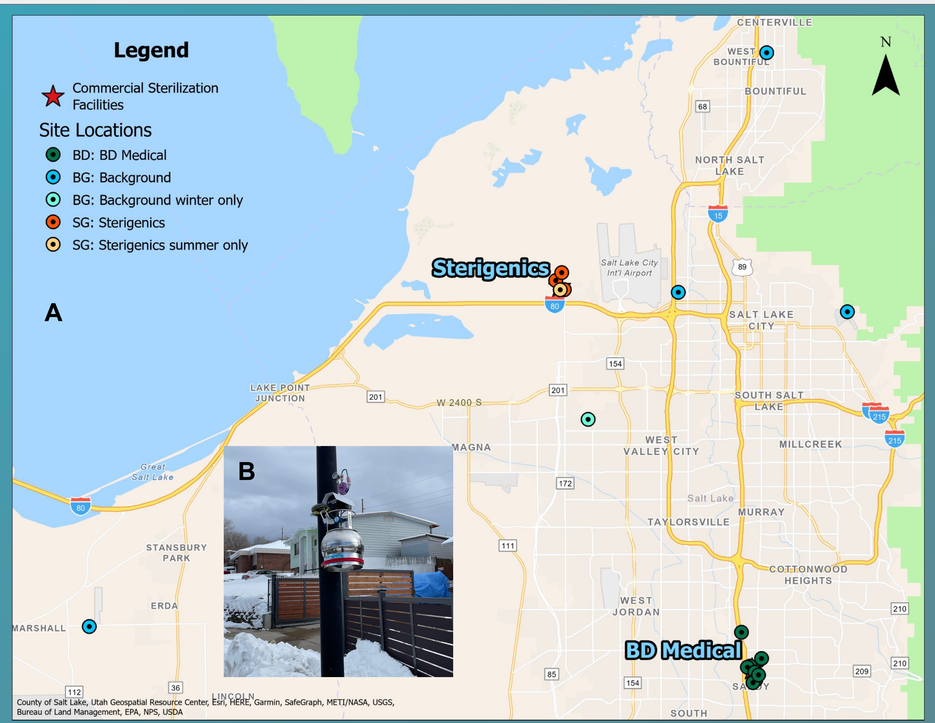
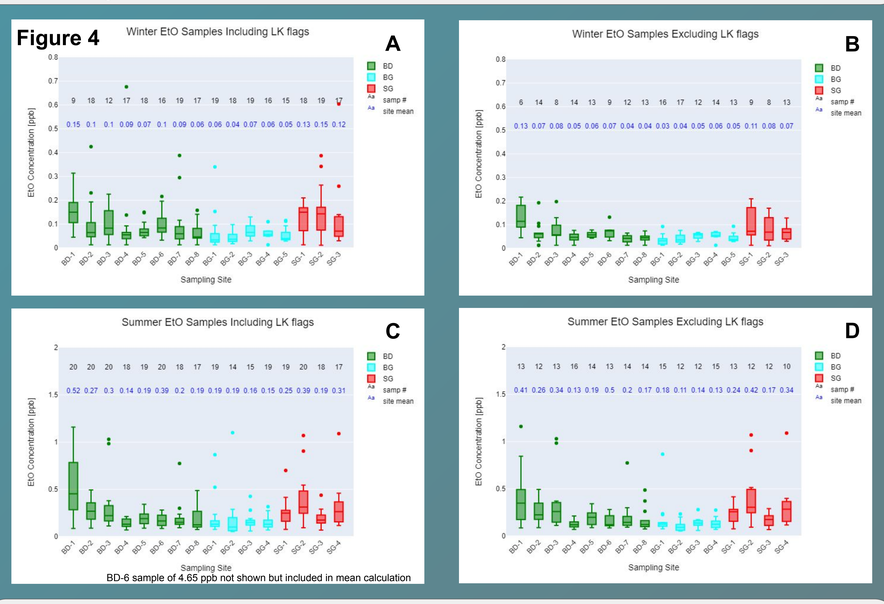
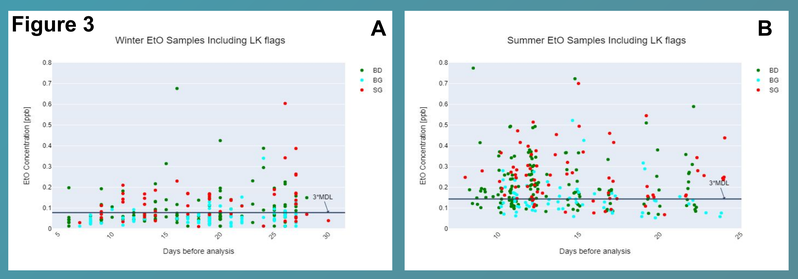


Figure 1. A Location of medical equipment sterilization facilities, Sterigenics (orange dots) and BD Medical (green dots). Background locations (cyan dots) include locations in Erda and West Bountiful. Inset photo (**B**) shows an example of measurement site setup, a silonite canister (with timer and inlet) attached to a light pole about two meters above ground level.





EtO Growth and LK Flagging

ERG includes an "LK" flag for samples > 3*MDL with a >14 holding time to indicate the possibility of canister growth and erroneously high values.

Growth of EtO within canisters was not clearly observed during the winter (**A**) or summer (**B**) sampling period. More controlled testing is necessary to determine if growth is a function of hold time, canister coating, or other factors.

Sampling Site Results, With and Without LK flags

In most cases, removing the LK flags in both the winter and summer sampling periods did not statistically change the mean value (blue text) of the EtO found at the site. A two-sample KS test supports that data with and without LK flag were pulled from statistically similar distributions.

Even if the data are only viewed in a qualitative way, samples collected closer to facilities are consistently higher than those collected at background sites. The summertime site means are greater than the wintertime site means.

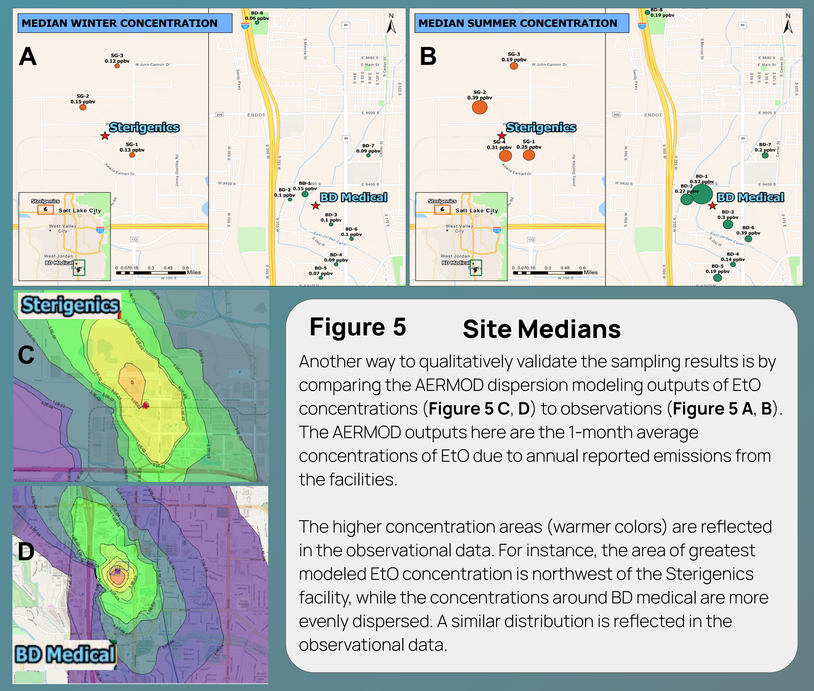
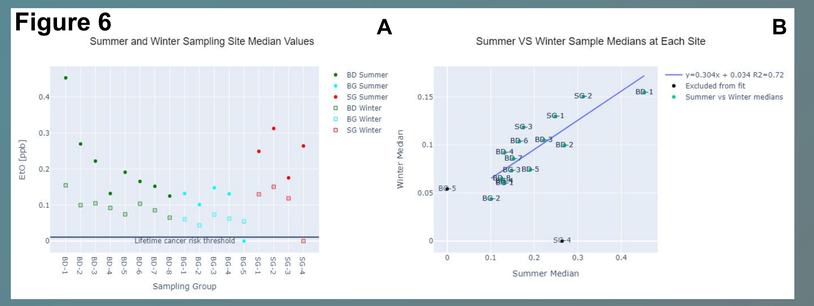


Figure 5 Site Medians

Another way to qualitatively validate the sampling results is by comparing the AERMOD dispersion modeling outputs of EtO concentrations (**Figure 5 C**, **D**) to observations (**Figure 5 A**, **B**). The AERMOD outputs here are the 1-month average concentrations of EtO due to annual reported emissions from the facilities.

The higher concentration areas (warmer colors) are reflected in the observational data. For instance, the area of greatest modeled EtO concentration is northwest of the Sterigenics facility, while the concentrations around BD medical are more evenly dispersed. A similar distribution is reflected in the observational data.



Seasonal Differences and Cancer Risk

Figure 6 A includes the median EtO observation at each sampling site for both the summer and winter season. The lifetime cancer risk threshold (0.011 ppb) is the level at which 100 additional cancer cases out of 1 million people would be present assuming a 24/7 exposure from birth to 70 years of age. This threshold is meant to be very protective.

The site median values are a snapshot in time and likely include biases in sampling and lab analysis. However, seasonal patterns remain. Summer median levels are alway higher than winter levels, suggesting additional chemistry or EtO sources during the summer months. Also of note, sites that were consistent between summer and winter were well correlated (R^2 of 0.72, **B**) suggesting consistent EtO transport and emission patterns for near-source sites.

Additional information, funding sources and acknowledgements

Updates on this work are available at:
https://deq.utah.gov/air-quality/ethylene-oxide-study

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