Health Consultation

Evaluation of the Potential Public Health Implications of Ambient Air Exposures in Timnath, Colorado

September 2022

Prepared by: Colorado Department of Public Health and Environment Under Cooperative Agreement with the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry.

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Abbreviations and acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
CA	concentration in air
CDPHE	Colorado Department of Public Health and Environment
CO-AP	Colorado APPLETREE Program
COPCs	contaminants of potential concern
EC	exposure concentration
HI	hazard index
HQ	hazard quotient
IUR	inhalation unit risk
LOAEL	lowest observed adverse effect level
MRL	minimal risk level
NOAEL	no observed adverse effect level
OEHHA	Office of Environmental Health Hazard Assessment (California)
ppb	parts per billion
ppm	parts per million
RME	reasonable maximum exposure
TCEQ	Texas Commission on Environmental Quality
TRV	toxicological reference value
UCL	upper confidence limit
ug/m^3	micrograms per cubic meter
US EPA	United States Environmental Protection Agency
VOCs	volatile organic compounds

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Foreword

The Colorado Department of Public Health and Environment's (CDPHE) Colorado APPLETREE Program has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR) through the Partnership to Promote Local Efforts to Reduce Environmental Exposure (APPLETREE) Program. ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for the health issues related to hazardous waste. This health consultation was prepared in accordance with the methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on health issues associated with specific exposures so that the state or local department of public health can respond quickly to requests from concerned residents or agencies regarding health information on hazardous substances. The Colorado APPLETREE Program evaluates sampling data collected by our partners, determines whether exposures have occurred or could occur in the future, reports any potential harmful impacts, and then recommends actions to protect public health.

The findings in this report are relevant to conditions at the site during the time this health consultation was conducted and should not necessarily be relied upon if site conditions or land use changes in the future.

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Summary

Introduction

Residents of the Northern Colorado Town of Timnath expressed concerns to the town about odors and potential health impacts of emissions from the Alpine Cabinet Company. This company is a hardwood cabinet manufacturing facility located in Old Town Timnath. It is also near homes, the Timnath Elementary School, and other businesses. Reported health concerns included headaches, dizziness, nosebleeds, lightheadedness, sore throats, poor tastes in the mouth, and cancer. To respond to the complaints and concerns, the town collected data on the levels of volatile organic compounds (VOCs) in the area surrounding Alpine and asked our Colorado APPLETREE program to evaluate the potential risk to nearby residents.

The town collected data in 2016 and 2018, and then collected a more robust dataset in 2021. In 2021, the town collected samples when VOC levels in the air were noticeably higher, as well as over longer and regular periods of time. The dataset includes results for up to 55 VOCs. Some of these VOCs have the potential to cause non-cancer effects and cancer in humans.

Our program evaluated the data and considered the potential acute and chronic health risks to nearby residents and schoolchildren. We also examined odor thresholds for VOCs to help answer questions from community members about the relationship between odors and health impacts. The analysis did not address any contributions of nearby sites to regional-scale ozone, particulate matter, or other air pollutants. As with all health risk assessments of this nature, risk estimates are theoretical and should not be used to indicate actual health risks to individuals. Limitations of this evaluation include available sampling data and lack of information on actual exposures. Due to these limitations, the exposure estimates used in this evaluation account for high-end, or reasonable maximum exposures.

Conclusion

Based on our review of the sampling data, we conclude that exposure to the VOCs measured in the air near the Alpine Cabinet Company in Timnath are not expected to harm the health of nearby residents and schoolchildren. Odors are also not expected to result in acute or chronic health impacts.

This review is not able to definitively identify where the VOCs came from. VOCs can come from many different sources in the environment. Headaches, dizziness, and nosebleeds are not included in this review. There are many causes for these health effects. Some people may be more sensitive to these effects than others which cannot be measured easily.

Basis for decision

Concentrations of VOCs measured in the air were below levels known to result in acute (one-hour and one-day) and chronic non-cancer health impacts. We checked the short-term risk using the highest amounts of VOCs found in the air samples. We also checked the long-term risk from samples collected over 169 days. Samples collected over a longer period

of time are best for evaluating long-term risk. To be the most protective in assessing the risk for cancer and non-cancer health effects in schoolchildren and nearby residents, we looked at the potential risk from each of the contaminants of concern. We also checked the potential risk of all contaminants of concern combined. We calculated several metrics (hazard quotients, hazard indices, cancer risk). None of these metrics indicated high or unacceptable risk.

Overall, the air data collected suggests that acute and chronic VOC exposures and odors are not likely to harm human health.

Next steps

Air monitoring over the years has demonstrated that the amounts of VOCs are below amounts at which harmful health effects may occur. No further VOC monitoring is necessary at this time. However, we recommend that residents continue to monitor less serious odor-associated health effects, such as lightheadedness and sore throats. People can report these concerns to Timnath on the odor complaint form (Town of Timnath, 2022a). Also, if additional environmental data are identified in the future, the findings of this health consultation should be reconsidered.

Purpose

The purpose of this document is three-fold: 1) identify potential public health impacts from the inhalation of volatile organic compounds (VOCs) in the Town of Timnath, 2) recommend actions to reduce exposure and risk, if necessary, and 3) identify which VOCs may be associated with odors reported in Timnath.

Background

Site description and rationale

The Town of Timnath is a small statutory town in Larimer County, Colorado. It was founded in 1882 and is located approximately five miles southeast of Fort Collins and 55 miles north of Denver. Timnath Elementary School (Image A2) is located approximately 1,000 feet northwest of Old Town Timnath. This school has around 42 staff members and approximately 450 kindergarten through 5th grade students.

Residents of Timnath have formally and informally reported concerns regarding odors and related health effects to the Town of Timnath from 2016 to present. Reported odors are anecdotally associated with Alpine Cabinet Company, a hardwood cabinet manufacturing company in Old Town, Timnath (Image A1). Most complaints have been reported from locations 500-700 feet north and south from Alpine.

The number of odor complaints motivated the town to enlist Colorado State University (CSU) to collect eleven air samples and test for volatile organic compounds (03/10/16 to 04/26/16). A project status report outlining the data and risks was issued by CSU on May 23, 2016 (CSU, 2016).

On March 27, 2018, the Timnath Town Council adopted a nuisance odor ordinance that established the procedures and thresholds for determining a nuisance odor using a “Nasal Ranger” and how odor complaints could be submitted (Town of Timnath, 2018). Odor complaints have been submitted formally after this ordinance and investigated by the town’s Code Enforcement Officer. Investigations revealed that none of these incidents violated Timnath’s odor ordinance (Town of Timnath, 2020b).

On Sept. 19, 2018, the Timnath Code Enforcement officer met with Alpine to engage them regarding odor complaints and potential mitigation strategies. Alpine identified that they had been considering odor mitigation strategies, including switching to a low VOC lacquer. CSU and the town organized a second air sample collection (10 samples) to coincide with the use of this low VOC lacquer (10/29/18 to 11/02/18). A 2018 project report detailing the data and risks from measured VOCs was issued by CSU on Nov. 29, 2018 (CSU, 2018a). A 2018 follow-up project report comparing 2016 and 2018 data was completed on Dec. 2, 2018 (CSU, 2018b).

On Jan. 21, 2019, the Town of Timnath requested assistance from the Colorado APPLETREE program (CO-AP) to assess potential health effects of industrial operations within town limits using the 2016 and 2018 air sample data. The Colorado Department of Public Health and

Environment completed a Letter Health Consultation using this data on April 30, 2019 (CDPHE, 2019a). This document concluded that

> "...both the 2016 and 2018 air sampling indicated a low risk of short- or long-term harmful health effects due to VOC exposures in the vicinity of Alpine Cabinet. The department recommends additional air sampling if odors or health effects continue near this location."

Additional caveats noted the short time frame of sampling, lack of an exhaustive panel of VOC analytes, and that VOCs from sampling represented an aggregate sample from all sources in the area.

Since the first issuance of a CPDHE-emissions permit on Jan. 16, 2009 (08LR0955), five inspections (2003, 2008, 2012, 2015, and 2020) determined that Alpine had been in compliance with permit exemptions or permit limits (CDPHE, 2020a). The Town of Timnath, CSU, and CO-AP held town meetings in late 2020 to determine future actions related to the odors. A letter from Alpine on Jan. 14, 2021 reiterated that the company has consistently been within its air permit and Timnath odor monitoring limits. The company also made numerous structural and process improvements to mitigate odor emissions. These changes include using finishing products with lower VOCs, reducing overspray of sealants and paints by reducing sprayer tip size, moving the high VOC finish location farther from Old Town Timnath, upgrading the filter media, increasing the motor size on exhaust fans, and raising the height of the exhaust stacks. Timnath, CSU, and CO-AP released a series of FAQs and a "Downtown Timnath Air Quality Overview" on Jan. 15, 2021 to address many of the residents' health and other concerns (Town of Timnath, 2021a, 2021b).

CSU and Timnath initiated additional sampling for VOCs in the spring 2021 to supplement the data collected in 2016 and 2018. It was decided to use a longer-term three-method air collection strategy to elicit public engagement (public canister collection), enable collection of samples during peak VOC levels (triggered canister collection), and enable systematic collection over a longer period of time (weekly/monthly canister collection; upwind/downwind). From June 24 to Dec. 2, 2021, Timnath and CSU collected 86 samples: 28 weekly samples (14 background, 14 near-source); 4 blank samples; 48 SPOD canister-triggered samples; and 6 resident-triggered canister samples.

This health consultation is primarily focused on the latest air data set to evaluate the potential for health impacts in Timnath due to VOCs and identify whether any VOCs might be associated with reported odors. Resident canister samples, trigger canisters, and months-long weekly air sample collection strategy enabled a more refined estimate of both short-term and long-term risk than previously available. It should be noted there are numerous other potential odor sources in the immediate area including a salon, brewery, construction site, rail line, and many other businesses. The Colorado Oil and Gas Conservation Commission's Geographic Information System (GIS) Online viewer (COGCC, 2022) identifies three to four oil or gas wells within a one-mile radius from the Timnath Town Center. Interstate 25 also passes by Timnath, approximately 3,000 feet to the west. All of these facilities and operations may contribute to VOC loads and odor experienced in Timnath.

It is outside the scope of this evaluation to determine the potential VOC load from any one source. Rather, this evaluation focuses on the potential health effects related to all VOCs measures in the air in Timnath.

Demographics

The 2020 United States Census (U.S. Census, 2022) indicates that "Timnath town" had 4,998 people in 2019. Ninety-six percent of these were white, 0% black/African American or Native Hawaiian/other Pacific Islander, 0.2% American Indian and Alaska Native, 2.4% Asian, and 1.4% two or more races. Approximately 5% of Timnath's population were Hispanic or Latino. Timnath population growth rates are estimated at 677% from 2010 to 2020, but the overall proportion of races has remained similar to current demographics.

ATSDR Geospatial Research, Analysis, and Services Program (GRASP) "uses geospatial science, analysis, technology, and visualization to examine the relationship between place and health." A GRASP site profile using 2010 census data suggests that the population of Timnath is 94% Caucasian. Children 6 years and younger, adults 65 years and older, and females aged 15 to 44 years old represent 5.9%, 14.6%, and 15.9% of the population, respectively (Image A4).

Colorado EnviroScreen (CDPHE, 2022) identifies disproportionately impacted communities in Colorado. Timnath (GEOID 08069002501) has an EnviroScreen percentile of 23.2 at the census tract level. The overall EnviroScreen "score" means that 23.2% of the census tracts in Colorado are less likely to be affected by environmental health injustices than those in the Timnath census tract. Conversely, this also means that 76.8% of the census tracts in Colorado are more likely to be affected by environmental health injustices than the census tract that includes Timnath. Specifically, the pollution and climate burden percentile is 50.7 and the health and social factors percentile is 18.3 at the census tract level. The higher either of these two percentiles indicates a more environmentally-burdened or susceptible and vulnerable population, respectively.

Community health concerns

Community health concerns regarding local industrial odors have been voiced sporadically by Timnath town residents since at least 2016. These odors have anecdotally been associated with the Alpine Cabinet Company. Odor complaints have included health effects such as lightheadedness, sore throats, and noxious tastes. In addition, residents have expressed concerns about developing cancer from exposure to VOCs in air. These concerns were collated from a series of odor complaints submitted to Timnath and conversations with residents and local officials.

Less serious health effects such as headaches, dizziness, and nosebleeds were also reported but are not included in this assessment. There are many causes for these health effects and some people may be more sensitive to these effects than others. The level at which some people may experience these health effects cannot be measured easily and it is difficult to determine the exact causes. As such, these health effects cannot be captured using current risk assessment frameworks and were not considered further in this evaluation. Even though these effects are not covered in risk assessment paradigms, residents are encouraged to continue monitoring and documenting odor-related health effects.

Discussion

Potential sources of odors and VOCs

Alpine Cabinet Company has been anecdotally identified as a potential source of VOCs and odors in the Old Town area. According to a 2020 air permit inspection report, Alpine (08LR0955) released approximately 7.9 tons of VOCs in 2019. This level is well within their permitted level of 22 tons of VOCs per year.

In general, cabinet manufacturing facilities are known to be a source of VOCs. The amount of VOCs released to the air depends on a variety of factors from the process and materials used, to the controls installed in the facility such as vent hoods and air scrubbers. Alpine has made process improvements such as upgrading emission controls and using finishing materials with lower levels of VOCs. It is not clear how these improvements have affected the amount of VOCs emitted from the facility, but these changes have likely reduced the amount of VOCs released to air (CSU, 2018b).

As noted above in the “Site Description and Rationale”, other commercial facilities exist in the area of Old Town Timnath.With many potential sources of VOCs in the area, it is difficult to determine the exact contribution of VOCs from each source. Many “near-source” air samples were collected in the vicinity of Alpine since the odors have been associated with this facility. “Background” air samples were also collected in areas that are not thought to be impacted by emissions from Alpine. These samples provide a higher level set of data for consideration of the relative source contribution.

More extensive monitoring of stationary, mobile, and area-wide air pollution sources would be necessary to determine a more accurate relative source contribution for VOCs in Timnath air over time. This is not currently necessary because human health risk is negligible when considering conservative exposures from all VOCs from all sources.

This evaluation focuses on the potential health risks of VOCs measured in air and whether the odors that people experience in Timnath are potentially associated with health effects. It is outside the scope of this evaluation to pinpoint sources of VOCs.

Air sampling overview

2016-2018

Abbreviated air sampling plans were carried out by CSU in 2016 and 2018. In 2016, eleven air samples (7 near source, 4 background) were collected in the early spring (March-April). Collection of these samples coincided with odor events. In 2018, 10 air samples (5 near source, 5 background) were collected in late fall (October-November) following a change in the manufacturing process designed to lessen VOC emissions. One of these samples may have been influenced by heavy traffic in the downtown area at the time of collection.

2021

An expanded air sampling plan was initiated by CSU in 2021 (June-December) in order to support longer-term and more robust risk analyses. Three collection methods were used during this period: 1) public canister collection to elicit public engagement, 2) SPOD-triggered canister collection to automatically enable collection of samples during peak VOC concentrations, and 3) weekly routine canister collection to obtain longer term data. Efforts in 2021 resulted in the collection of 86 samples collected from 06/24/21 to 12/02/21.

Currently, it is unknown if industries or commercial operations in the area were operating at the time of air sample collection. Weekly and SPOD air samples were not timed to particular processes or times of increased mechanical ventilation at Alpine or other industries. Resident samples were, however, collected in response to perceived odor events.

Environmental sampling and data used for exposure evaluation

Sample collection

SPOD total VOC (TVOC) air measurements

Continuous air total VOC (TVOC) measurements were collected 3-5 feet above the ground using a Sensit Technologies SPOD mounted on a tripod. The Sensit SPOD has a photoionization detector (PID) and wind sensor that detects VOCs in the 10 parts per billion (ppb) to 2 parts per million (ppm) range (referenced to isobutylene). The Sensit SPOD samples the air at 1 minute intervals and can detect source plumes when combined with wind speed and direction. Overall TVOC measurements are semi-quantitative, but TVOC concentrations above a CSU-determine threshold limit can also open a manifold, allowing the collection of an air sample into an evacuated steel air canister. Forty-eight SPOD trigger events in this study resulted in the collection of air samples.

Air canister samples

The sample collection procedure for weekly and resident collected samples is detailed in CSU (2018a).

Sample analysis

Weekly, SPOD, and resident-collected canisters

All canisters picked up or transported from Timnath were taken to the CSU Atmospheric Science Department for laboratory analysis. A multichannel Gas Chromatograph Flame

Ionization Detector Mass Spectrometer (GC-FID-MS) was used in the lab to determine concentrations[1] of 55 VOC analytes (Table B1).

Sample number, location, and timing

Between June 24 and Dec. 2, 2021, 86 non-composite samples were collected: 28 weekly (14 background, 14 near-source); 4 blank, 48 SPOD-triggered canisters; and six resident-triggered canisters (Table C1). Sample canisters were collected from a variety of locations around Timnath. Weekly air canister samples were collected from 2 locations, 1) 300 feet due south of Alpine, and 2) 2100 feet due north of Alpine. SPOD-triggered canister samples were also taken 300 feet due south of Alpine. Triggered samples were taken in the same southerly place as weekly samples, but after the detection of VOC concentration peaks.

Six samples were collected by Timnath residents. Resident samples captured VOC concentrations related to detectable odors. Two samples were collected 350 feet to the south-southwest of Alpine (09/01/21 1:20pm, 09/13/21 1:15pm). Two samples were collected 700 feet south of Alpine (10/19/21 8:55am, 11/11/21 4:10pm). Two samples were collected 400 feet to the north-northwest of Alpine (09/16/21, 2:15pm, 2:56pm). One sample collector noted that no hissing sound was heard upon canister activation (10/19/21). The results of this canister did not affect conclusions.

Data summary

Descriptive statistics for data collected in 2016, 2018, and 2021 are presented in Tables C2, C3, and C4 respectively. These statistics include the minimum, mean, maximum, number of samples, and detection frequency for each contaminant in each year.

Sample timing and locations differed for all three years of collection (Image A3). 2016 samples were collected in the early spring (March 10 to April 26). 2018 samples were collected in the late fall (Oct. 29 to Nov. 2). 2021 samples were collected from the summer into the winter (June 17 to Dec. 22).

Detection frequencies for all contaminants were similar over the years, irrespective of sample collection timing. Most compounds were detected in all air samples collected (100% detection frequency). Benzene was detected in 100% of the samples and ranged from 0.06 to 28.58 micrograms per cubic meter (μg/m^3).

The highest concentrations of compounds were observed in air samples taken using the trigger canisters when compared to weekly or resident-collected samples. This was expected, since the SPOD-trigger canisters monitor the air continuously after setup and air samples are automatically collected only after exceeding a high TVOC threshold.

In addition, the overall site summations or averages from near-source and background locations were not statistically different from each other. Five of the 55 individual VOCs measured (n-octane, ethylbenzene, m-/p-xylene, o-xylene, and isopropanol) were statistically

[1] Results were reported by CSU in parts per billion (ppb). These concentrations were then converted to μg/m^3 to allow comparison to odor and toxicity thresholds in this evaluation.

different when comparing background locations to near-source locations (Appendix H). The estimated means for these VOCs were all higher in near-source locations than background locations, suggesting that these VOCs might be from adjacent emission sources. The statistical difference between the estimated concentrations of VOCs from near-source and background locations is not likely to have an effect on the outcome of this evaluation.

Selection of contaminants of potential concern

The highest concentration of contaminants were screened against conservative comparison values (CVs) established by federal and state agencies in order to identify contaminants of potential concern (COPCs) that needed further evaluation. If the highest concentration of a VOC was below the CV, no further evaluation was necessary, as exposures to contaminants at this level were not expected to result in adverse or harmful health impacts. On the other hand, if a contaminant was above the CV, it was considered a COPC. The maximum concentration of non-carcinogenic compounds that exceeded 10% of the toxicity CV or the odor CV minus 10% were also considered COPCs to account for the contribution of multiple VOCs. Exceeding a CV did not necessarily indicate that the contaminant posed a public health hazard. The amount of the contaminant, duration and exposure route, exposure probability, and the health status and lifestyle of the exposed individual are important factors in determining the potential for adverse health impacts.

This comparison resulted in 10 non-cancer COPCs (benzene, ethylbenzene, isopropanol, m-/p-xylene, o-xylene, 1,2,4-trimethylbenzene, cyclopentane, n-hexane, n-nonane, and n-pentane; Table C5), two cancer COPCs (benzene and ethylbenzene; Table C6), and six odor COPCs (acetone, ethylbenzene, toluene, m-p-xylene, 1,4-diethylbenzene, and styrene; Table C7). The summary of all COPCs can be seen in Table C8.

Not all contaminants had toxicity or odor CVs. Three of the 55 VOCs analyzed (ethane, methane, and propane) did not have toxicity-based CVs and were not screened. Five of the 55 VOCs analyzed (2-ethyltoluene, 3-ethyltoluene, 4-ethyltoluene, cyclopentane, and n-propylbenzene) did not have odor-based CVs and were not screened for potential odor threshold exceedances.

Conceptual site model

The conceptual site model describes the contaminants of potential concern, contaminated sources, and the potential exposure pathways by which different types of populations (e.g. residents and schoolchildren) might come into contact with contaminated media. Exposure pathways are classified as either complete, potential, or eliminated. Only complete exposure pathways can be fully evaluated and characterized to determine the public health implications. A complete exposure pathway consists of five elements: a source, a contaminated environmental medium and transport mechanism, a point of exposure, a route of exposure, and a receptor population.

The overall conceptual site model for all complete and potential pathways at Timnath is presented below (Table 1).

Table 1. Conceptual site model and exposure pathway elements for VOCs in Timnath

Pathway Name	Source	Contaminated Media	Point of Exposure	Potentially Exposed Population	Route of Exposure	Time Frame	Pathway Complete?
Outdoor air	VOC emissions related to Alpine or other sources	Ambient outdoor air	Ambient outdoor air	Residents, tourists, workers (shops, venues, school), and students and staff at Timnath Elementary School	Inhalation	Present and future	Yes

Public health implications

The purpose of this evaluation was to determine whether exposures to COPCs that exceed the screening values for inhalation exposures might be associated with adverse health effects. This required the comparison of site-specific exposure concentrations (ECs) with an appropriate toxicity reference value (TRV). As described above, 10 non-cancer COPCs, two cancer COPCs, and six odor COPCs were identified as COPCs and required further evaluation. Designation as a COPC did not necessarily mean that the compound would cause an adverse effect, just that a more refined analysis was needed to determine if the COPC might pose a potential health issue.

The more refined analysis started with estimating a reasonable concentration of a COPC in the air. These concentrations were used to estimate a population's exposure concentration (EC) based on various scenarios such as residential living or attending a school. ECs are a high-end, yet reasonable concentration of a contaminant that people could be exposed to based on the available environmental data. Different ECs were calculated for estimating cancer risk and acute and chronic non-cancer risks (detailed description in Appendix C and D). Cancer risk was calculated for the two carcinogenic COPCs. All ten COPCs, including the two carcinogenic COPCs, were evaluated for both acute and chronic non-cancer health risks.

Estimation of concentrations in the air

A detailed description of how concentrations in air (CA) were determined for use in this assessment is included in Appendix D. For acute exposures, the CA was the highest sample concentration for each VOC collected over the entire 2021 sampling period. For chronic exposures, near-source weekly data was first imported into ProUCL (version 5.1.002) to determine and remove outliers. Outliers were identified, removed, and then the revised data sets were re-evaluated in ProUCL to estimate a 95% upper confidence limit (UCL).

Estimation of residential and school exposures

A detailed description of how residential and school exposures were determined is included in Appendix D. In brief, acute, or short-term exposures were evaluated over a period of one hour and one day for the 10 non-cancer COPCs (benzene, ethylbenzene, isopropanol, m-/p-xylene, o-xylene, 1,2,4-trimethylbenzene, cyclopentane, n-hexane, n-nonane, and n-pentane). Acute one-day residential scenarios used 24 hours per day and one day per year to estimate ECs. Acute one-day school scenarios used nine hours per day and one day per year to estimate ECs. Chronic residential and school scenarios used different exposure assumptions. Chronic residential scenarios used 24 hours per day and 365 days per year for a period of 33 years (birth to age 33). Chronic school scenarios used nine hours per day and 200 days per year for a period of six years (kindergarten through fifth grade).

The residential exposure scenario had the most protective exposure assumptions for all populations and is likely to overestimate the potential exposure to most children and staff at Timnath Elementary school that do not reside locally. The residential exposure scenario could be a reasonable, albeit conservative exposure estimate for those people that live nearby.

Workers at potential sites in downtown Timnath will have lower exposures than residents, so were not included in this assessment.

Estimation of non-cancer risk

Toxicological reference values (TRVs) are estimates of a concentration of VOCs below which adverse health effects are unlikely to occur. TRVs for this assessment were established by federal and state agencies. When two or more TRVs are available, the most conservative TRV (most protective) is selected. A more detailed toxicological discussion for some contaminants can be seen in Appendix E.

The potential for non-cancer health effects was assessed for all 10 contaminants of potential concern by comparing the ECs to the related TRV. The ratio of the EC to the TRV for each VOC contaminant is called the hazard quotient (HQ). Summed hazard quotients for all 10 COPCs is termed the hazard index (HI). HQs or HIs at or below one are levels at which adverse health effects are not expected. HQs or HIs above one (potential exposures are higher than toxicity reference values) indicate the need for further assessment (Appendix D).

Acute health hazards

The potential for acute (short-term) one-hour and one-day health risks were evaluated for all 10 COPCs. The acute health hazard evaluations assume the highest concentrations of VOCs in air that were measured in the 2021 sampling data and the potential non-cancer health impacts.

One-hour exposures

The estimated acute one-hour HQs and aggregate one-hour acute HIs for the school and residential exposure scenarios are equal to one, which indicates that non-cancer health effects are not likely to occur. Specifically, the HQs and HIs for acute one-hour exposures were 1.1 and 1.1 or less, respectively.

Benzene accounted for most of the non-cancer acute risk in one-hour scenarios (Table F1, G1; 92.4-97.8%). A HQ or HI equal to one indicates that it is unlikely that non-cancer health effects will actually occur because there are uncertainty factors included in the TRVs used in this evaluation. As an example, for benzene, the chronic non-cancer TRV includes an uncertainty factor of 10 to account for human variability and sensitivity (ATSDR, 2007a).

One-day exposures

For one-day, acute exposures, **t**he maximum VOC concentrations were used again to estimate the acute daily risk. Overall, the HQs and HIs for acute 1 day exposures were at or below one (Table F1, G1; HI = 0.011-1.04), so adverse health effects are not likely in either the residential or school scenarios for this exposure duration. Once again, benzene accounted for most of the non-cancer acute hazard in the one-day scenarios (67.2-95.2%).

Chronic non-cancer health hazards

Chronic exposure to VOCs can result from long-term background and source emissions. Constant exposures are best modeled with data statistics that reflect an average of exposure over a lifetime. The recommended statistic for representing this central tendency is the 95% UCL of the arithmetic mean. This UCL is used to address uncertainty in site data and allows risk assessors to have reasonable confidence that the true site average will not be underestimated.

The UCLs of datasets that had outliers removed were used in the estimation of residential or school exposure concentrations as outlined in Appendix D.

Overall, the HQs and HIs for chronic exposures were far below one (Table F2, G2; HI = 0.0134-0.0822), so adverse health effects were not expected in residential or school scenarios for this chronic exposure duration.

As with the acute exposures, out of the 10 COPCs, benzene accounted for most of the non-cancer chronic health hazard (57.9-62.0%).

Estimation of cancer risk

The potential for cancer health effects was assessed for two carcinogenic COPCs (benzene and ethylbenzene). As with chronic risks, the 95% UCL of weekly samples was used to estimate ECs. ECs representing continual exposure for six years (school) and 33 years (residential) out of a 78-year lifespan were multiplied by EPA inhalation unit risk values (IURs) to estimate lifetime cancer risk. Risks from both carcinogens were added to estimate the aggregate risk.

Cancer risks below 1×10^{-6} are considered negligible. In general, risk levels below one in ten thousand people exposed (in other words: 100 in one million people exposed or 1×10^{-4}) are considered low risk.

Cancer risk from residential exposures estimated using weekly near-source samples was 1.51×10^{-6} for benzene, 2.28×10^{-7} for ethylbenzene, and 1.74×10^{-6} for aggregate estimates (Table F3, G3). Cancer risk in school scenarios estimated using weekly near-source samples was much less than residential scenarios, with the aggregate risk only reaching 6.49×10^{-8}. The highest estimated cancer risk was therefore 1.7 excess cancer cases in a million people exposed over a lifetime of exposure. In other words, if one million people were consistently exposed to the average measured concentrations over a period of 33 years, we would expect at most an additional 1.7 cancer cases. It must be noted that residential cancer risk assumes a continuous 24-7 exposure for 33 years. Many people do not stay or live in the same place for this many years, so these estimates are conservative. Estimates associated with the school are also conservative in that prevailing winds are usually in the opposite direction from Alpine.

There is a low increase in overall cancer risk for individual and combined estimated cancer risks for school or residential exposures.

Estimation of risks from odor COPCs

Maximum concentrations of six compounds exceeded odor screening thresholds (acetone, ethylbenzene, toluene, m-p-xylene, 1,4-diethylbenzene, and styrene; Table C7). None of these compounds had acute, chronic, or cancer risks above a health concern threshold. Smelling these compounds, therefore, was not expected to have any lasting human health impact.

Child health considerations

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than adults from certain kinds of exposure to hazardous substances. Children typically spend more time playing outdoors than adults. Children are shorter than adults, which means they breathe dust, soil, and vapors closer to the ground. Children also breathe through their mouths more than adults, have different metabolism rates, and have lower body weights. This can result in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing and medical care, and for risk identification. Thus adults need as much information as possible to make informed decisions regarding their children's health.

Children could be a subpopulation at increased risk because of factors that could lead to greater susceptibility to the effects of benzene exposure, including that their organs and tissues that make blood cells are less mature (EPA, 1998). Some studies correlate parental occupational exposures to benzene with increased risk for children. In 1998, it was determined that "the data to make quantitative adjustments for these factors" did not exist (EPA, 1998). While the available evidence has been reviewed more recently, there are many limitations with existing studies, and further research is needed "to adequately assess the potential for age-related increased susceptibility to benzene" (ATSDR, 2007a).

Limitations and uncertainties

This section highlights the major assumptions and limitations that are specific to this evaluation and may over- or underestimate exposures and health hazards. The magnitude of this uncertainty is generally unknown.

Uncertainties associated with sample collection include:

1) Duration. The vacuum collection duration was approximately one minute for each canister. There is uncertainty as to whether this is representative of a larger period of exposure (e.g. one hour, 24 hours, one year).
2) Timing. Collection of air samples takes place at weekly intervals and also at times representing maximum VOC (trigger canisters) or odor detections (residents). There is uncertainty as to whether these samples are representative of longer-term or truely maximum VOC exposures.
3) Location. There is uncertainty as to whether the collection locations are representative of the potential source(s) or target(s) of interest, given that wind direction and other atmospheric conditions are not consistent over time.

Uncertainties associated with sample spectrum and analysis include:

1) Spectrum of VOC analytes. Many very volatile VOCs (VVOCs), VOCs, and semi-volatile VOCs (SVOCs) that might influence risk have not been included in the analysis. There is uncertainty as to how these would have influenced these conclusions.
2) Spectrum of non-VOC analytes. This assessment did not include other non-VOC atmospheric co-contaminants such as particulate matter, ozone, metals, biological pathogens, and others. There is uncertainty as to how the lack of consideration of non-VOC contaminants would have influenced these conclusions.
3) Analyte laboratory analysis. Additional details on the levels of detection, level of quantitation, other data qualifiers, and additional method details could reduce uncertainties associated with data use and estimated statistics.

Uncertainties associated with toxicology reference values and risk estimates include:

1) Toxicological and odor threshold values. There is uncertainty as to whether the assumptions integrated into each toxicity and screening value are representative of Colorado and how compounds without values would contribute to the risks associated with VOC inhalation in Timnath.
2) Exposure assessments. Outdoor air VOC concentrations were used to represent a person's exposure to VOCs in Timnath even though most people spend a large majority of their time indoors. There is uncertainty as to how indoor VOC concentrations may differ from outdoor concentrations.
3) Risk assumptions. CO-AP uses 10% of toxicity screening values to account for the effects of multiple contaminants, the hazard index (HI) approach to account for

combined risks of non-carcinogens, and aggregate risk to account for combined risks of carcinogenic contaminants. It is expected that this will conservatively overestimate the risk from exposure to VOCs.

Conclusions

Based on a review of the sampling data available, CO-AP concludes that exposure to the volatile organic compounds measured in Timnath air are not expected to harm the health of nearby residents and or those attending school. The data also suggests that odors experienced by community members are not expected to result in acute or chronic health impacts, because these exposures were below non-cancer and cancer toxicity thresholds.

CO-AP determined that concentrations of VOCs measured in the air were below levels known to result in acute (one-hour and one-day) and chronic non-cancer health impacts. Conclusions regarding acute risk were based on maximum VOC concentrations from discrete samples collected during high VOC periods. Conclusions based on chronic risk were from discrete samples collected over an extended duration of time (169 days). The use of samples collected over an extended duration of time and statistical collation into a conservative 95% upper confidence level are preferred for chronic exposure assessments. Conservatisms expressed in chronic exposures are also applied in the estimation of cancer risk. There is a low increase in overall cancer risk for individual and combined estimated cancer risks for school or residential exposures.

These conclusions are based on the VOCs that have been measured and those that could be assessed by the available lab technologies. Application of additional sampling technologies could expand the repertoire of VOC information available for the estimation of risk at Timnath, but there is no guarantee that any risk estimates would change. The VOCs assessed in this health consultation represent many of the hazardous contaminants present in Colorado and therefore are a good selection to represent the largest potential risks.

Overall, the data collected suggests that acute and chronic VOC exposures and odors are below any levels of concern and are not likely to harm human health.

Recommendations

Air monitoring in 2016, 2018, and 2021 confirms that VOCs are present in the air of Timnath. The concentrations of these contaminants are below that which are expected to produce adverse health effects.

No further formal VOC monitoring is necessary for Timnath, Colorado at this time.

We also recommend that residents continue to monitor less serious odor-associated health effects, such as lightheadedness, and report them to Timnath on the odor complaint form (Town of Timnath, 2020a).

Public health action plan

The Colorado APPLETREE Program will continue to work with CSU and the Town of Timnath to provide additional support as needed related to the findings in this report.

Report preparation

The Colorado Department of Public Health and Environment's Colorado APPLETREE Program prepared this health consultation for the Town of Timnath in Larimer County, Colorado under a cooperative agreement with the Agency for Toxic Substances and Disease Registry, a federal public health agency. It is in accordance with approved agency methodology and the procedures existing at the time the health consultation was initiated. This report was supported in part by funds from the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. The findings and conclusions in these reports are those of the author(s) and do not necessarily represent the views of the Agency for Toxic Substances and Disease Registry or the U.S. Department of Health and Human Services. This document has not been revised or edited to conform to agency standards.

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Appendix A. Images

Image A1. A Google Street view of Timnath looking North into town from the railroad crossing on South Colorado Road 5 (photo taken August 2021). Note the Colorado Feed and Grain Landmark right front, Great Western railroad tracks on the left front, Alpine Cabinet left middle, and Farmers Insurance/Fine and Funky clothing store in the right middle of the photo.

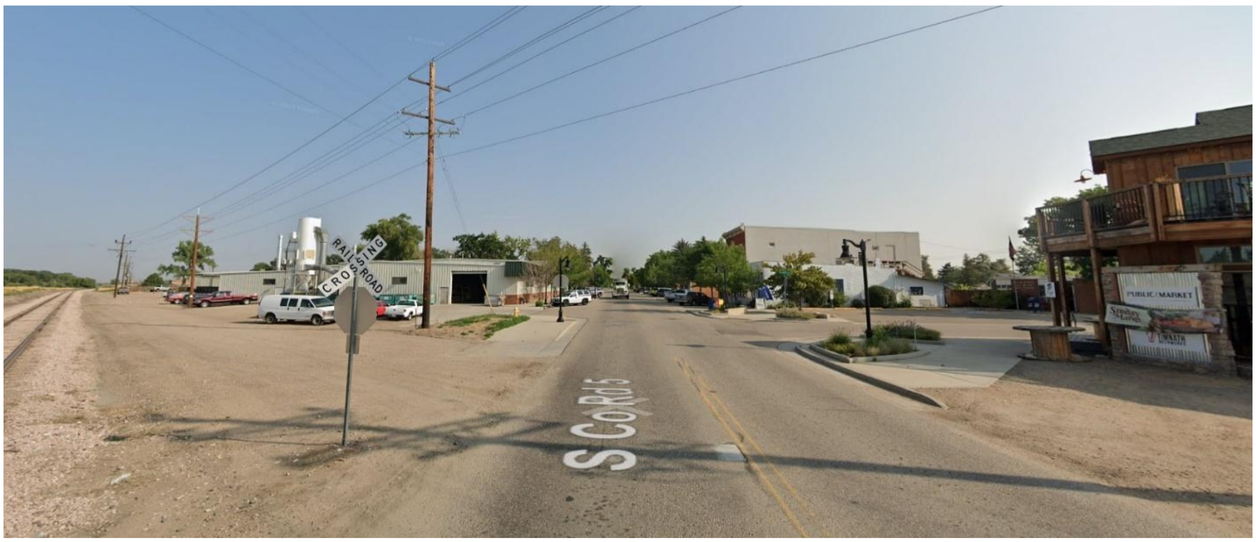


Image A2. A Google Street view of Timnath looking South into town near the Timnath Elementary School on South Colorado Road 5 (photo taken August 2021). Note Timnath Elementary School to the front right and center of the photo.

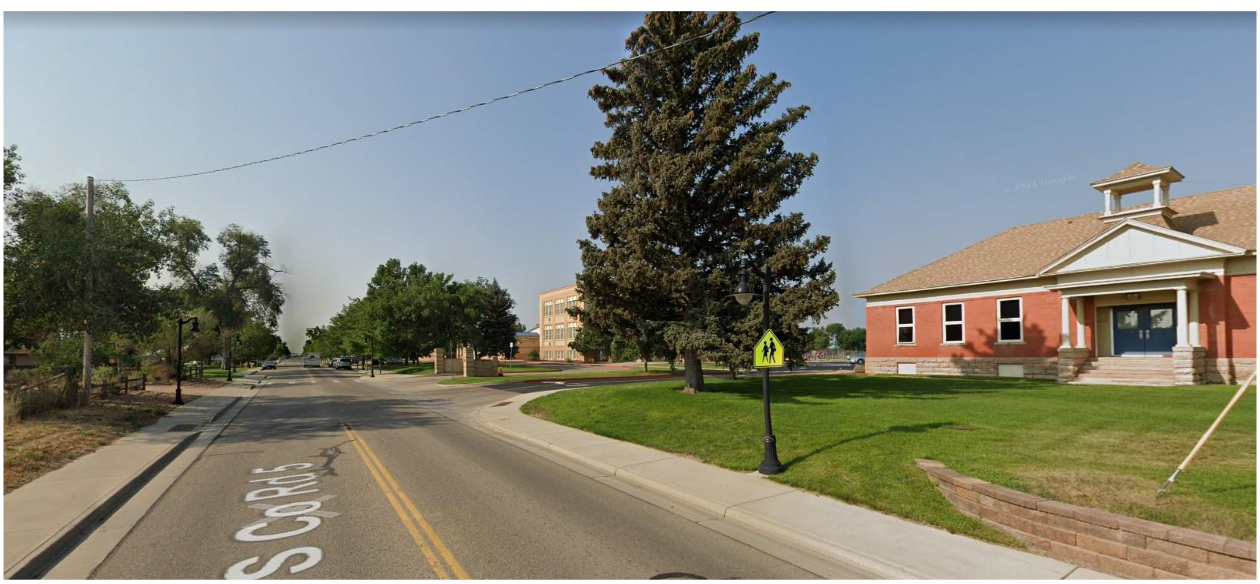


Image A3. Satellite Map of Timnath and the 2016, 2018, and 2021 approximate air sample locations (Orange dots – 2016, Yellow dots – 2018, Green dots – 2021).

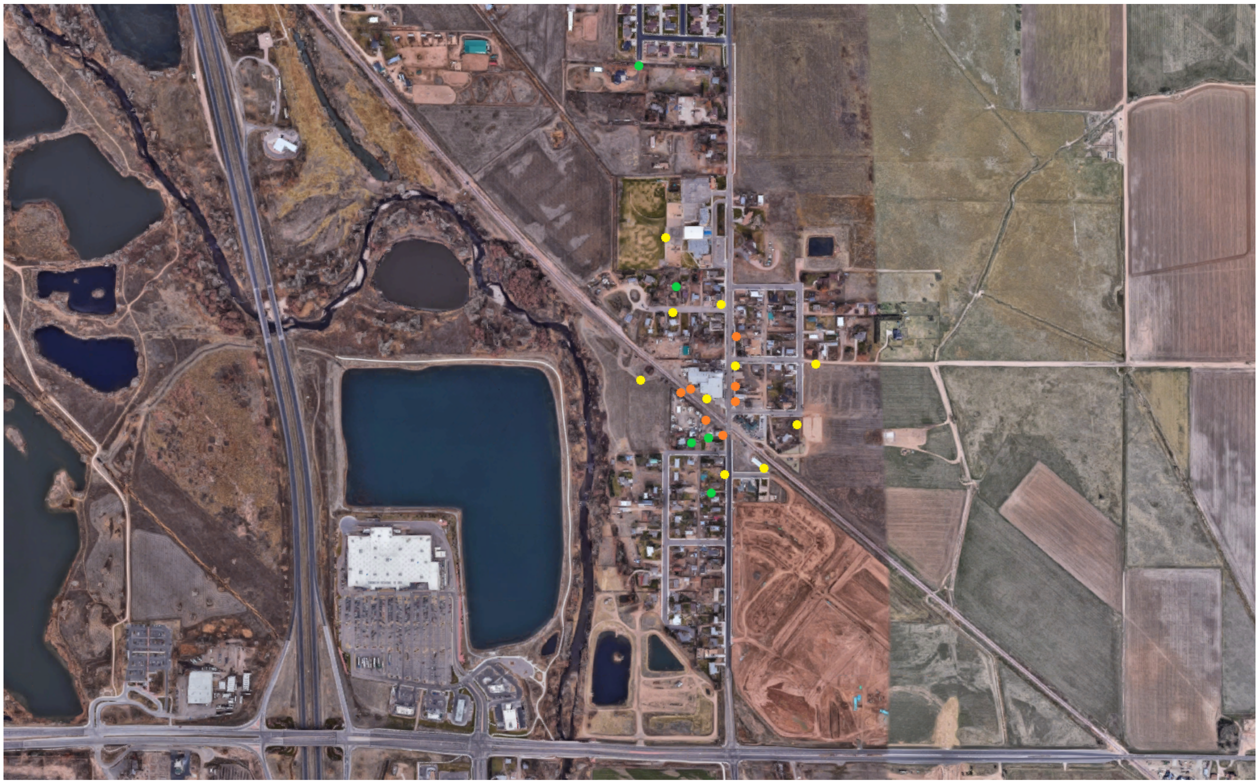


Image A4. ATSDR GRASP General Site Profile for Timnath, Colorado.

EPA FACILITY ID UNAVAILABLE

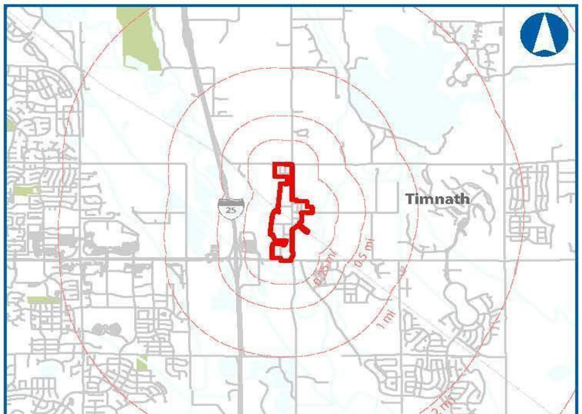
INTRODUCTORY MAP SERIES

Timnath, CO

Timnath, Larimer County, CO

GENERAL SITE PROFILE

Site Vicinity Map



Site of Interest[1] | Industrial[3] | 0 0.5 1 Miles
Site of Interest Buffers[2] | Airport[3]
Park[3] | Military Base[3]

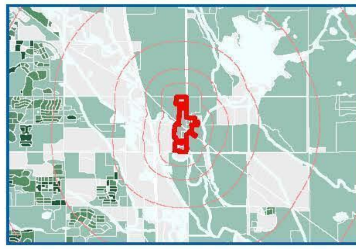
The **General Site Profile Map** depicts the hazardous waste site of interest, along with any airport, industrial, military, or park land uses. It also provides community demographic and housing statistics.

Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

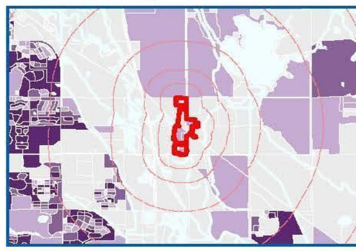
Measure	2000	2010	Change
Total Population	485	390	-19%
White Alone	455	366	-19%
Black Alone	0	4	N/A
Am. Indian & Alaska Native Alone	8	2	-75%
Asian Alone	1	2	+100%
Native Hawaiian & Other Pacific Islander Alone	0	0	+0%
Some Other Race Alone	8	6	-25%
Two or More Races	14	11	-21%
Hispanic or Latino[6]	33	29	-12%
Children Aged 6 and Younger	42	23	-45%
Adults Aged 65 and Older	39	57	+46%
Females Aged 15 to 44	97	62	-36%
Housing Units	192	189	-1%
Housing Units Pre 1950	134	15	-88%

General Population Density



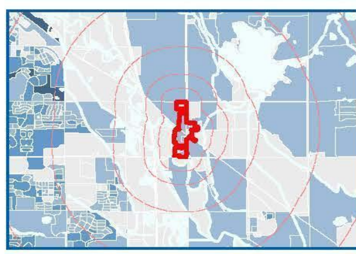
Population Density by Census Block[4] (No. per sq. mi.)
- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

Sensitive Populations



No. of Children 6 Yrs & Younger by Census Block[4]
- Zero
- 1 to 5
- 6 to 10
- > 10

No. of Adults 65 Yrs & Older by Census Block[4]
- Zero
- 1 to 10
- 11 to 100
- > 100



No. of Females Aged 15 to 44 Yrs by Census Block[4]
- Zero
- 1 to 20
- 21 to 100
- > 100

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom 2019Q1. [4]US Census 2010. **Notes:** [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
Projection: Projection used for all map panels is NAD 1983 CORS96 StatePlane Colorado North FIPS 0501 Ft US.

PRJ 06176 JXA0 10/20/21

GRASP

Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences

ATSDR

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Appendix B. Target analyte list for air samples

Table B1. List of VOCs screened for in 2021 air samples

CAS	Analyte	CAS	Analyte	CAS	Analyte	CAS	Analyte
100-41-4	ethylbenzene	110-82-7	cyclohexane	589-81-1	3-methylheptane	74-84-0	ethane
100-42-5	styrene	111-65-9	n-octane	590-18-1	c-2-butene	74-85-1	ethene
103-65-1	n-propylbenzene	111-84-2	n-nonane	591-76-4	2-methylhexane	74-86-2	ethyne
105-05-5	1,4-diethylbenzene	115-07-1	propene (propylene)	592-27-8	2-methylheptane	74-98-6	propane
106-97-8	n-butane	124-18-5	n-decane	611-14-3	2-ethyltoluene	75-05-8	acetonitrile
106-98-9	1-butene	127-18-4	tetrachloroethylene	620-14-4	3-ethyltoluene	75-28-5	i-butane
108-08-7	2,4-dimethylpentane	141-93-5	1,3-diethylbenzene	622-96-8	4-ethyltoluene	78-78-4	i-pentane
108-38-3, 106-42-3	m+p xylene	142-82-5	n-heptane	624-64-6	t-2-butene	78-79-5	isoprene
108-67-8	1,3,5-trimethylbenzene	287-92-3	cyclopentane	627-20-3	c-2-pentene	78-93-3	methyl ethyl ketone
108-87-2	methylcyclohexane	526-73-8	1,2,3-trimethylbenzene	646-04-8	t-2-pentene	79-01-6	trichloroethylene
108-88-3	toluene	540-84-1	2,2,4-trimethylpentane	67-63-0	isopropanol	95-47-6	o-xylene
109-66-0	n-pentane	565-59-3	2,3-dimethylpentane	67-64-1	acetone	95-63-6	1,2,4-trimethylbenzene
109-67-1	1-pentene	565-75-3	2,3,4-trimethylpentane	71-43-2	benzene	98-82-8	i-propylbenzene
110-54-3	n-hexane	589-34-4	3-methylhexane	74-82-8	methane		

Note:

CAS - Chemical Abstracts Service number, VOC - Volatile organic compound
Gray shading indicates VOCs that were also analyzed in 2016 and 2018 studies.

Appendix C. Data summary and selection of contaminants of potential concern (COPCs)

Conceptual site assessment and sample strategy

An abbreviated conceptual site model identified inhalation as the primary route of outdoor exposure to VOCs for people in the Timnath area. Collection of discrete air samples (in canisters) under a variety of situations and times was therefore undertaken to assess the potential risk from exposure to VOCs. Canister air sampling was thought to adequately reflect the inhalation route of exposure and the VOCs a person might be exposed to in this area. Air sample analysis targeted 55 VOCs that might potentially contribute to the greatest risk from inhalation.

Data collection, analysis, and processing

Canister air samples were collected at a variety of times around Timnath using three different strategies (resident-initiated collection, SPOD-triggered canister collection, and weekly automatic canister collection; Table C1). Each canister with an air sample was transported to the Atmospheric Sciences Department Laboratory at CSU for the determination of 55 individual VOC concentrations (in ppb). These data were then validated by CSU staff and provided to CO-AP.

CO-AP converted these ppb data to micrograms per meter-cubed ($\mu g/m^3$) in order to expedite comparison to odor and toxicity thresholds. These converted data were then imported into ProUCL software (version 5.2) in order to estimate descriptive statistics (Tables C2-C4). Descriptive statistics (maximum concentrations) were compared to toxicity screening values (Tables C5 and C6) or odor screening values (Table C7) to determine which VOCs would be contaminants of potential concern (COPCs, Table C8).

Table C1. Description of sampling phase, dates, and number of measurements

Sampling Phase	Sampling Dates	Sample Number	Sample Period Duration (days)
2016	03/10/2016 – 04/26/2016	11	21
2018	10/29/2018 – 11/01/2018	10	9
2021 - Resident	09/01/2021 – 11/11/2021	6	71
2021 - SPOD	06/28/2021 – 12/02/2021	48	158
2021 - Weekly	06/17/2021 – 12/02/2021	28	169

Note:
Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection, Weekly - weekly automatic canister collection

Table C2. Summary of VOC concentrations (sampling dates 03/10/2016 – 04/26/2016)*

VOC	CAS	Minimum (µg/m³)	Mean (µg/m³)	Maximum (µg/m³)	Sample Number	Detection Frequency (%)
Acetone	67-64-1	4.73	70.49	239.18	11	100
Benzene	71-43-2	0.17	0.38	0.70	11	100
Ethylbenzene	100-41-4	0.02	4.90	30.25	11	81
Isopropanol	67-63-0	2.05	52.46	225.36	11	100
Methyl Ethyl Ketone	78-93-3	0.64	2.89	9.12	11	100
Toluene	108-88-3	0.12	3.61	17.96	11	100
Xylene, m- + p-	108-38-3, 106-42-3	0.01	21.25	135.48	11	81
Xylene, o-	95-47-6	BDL	6.54	39.36	11	100

Note:
BDL - Below detection levels, CAS - Chemical Abstracts Service number, VOC - Volatile organic compound
*As presented in CDPHE, 2019b.

Table C3. Summary of VOC concentrations (sampling dates 10/29/2018 – 11/02/2018)*

VOC	CAS	Minimum (µg/m³)	Mean (µg/m³)	Maximum (µg/m³)	Sample Number	Detection Frequency (%)
Acetone	67-64-1	0.60	4.59	7.67	10	90
Benzene	71-43-2	0.17	0.52	1.05	10	100
Ethylbenzene	100-41-4	0.02	0.20	0.60	10	70
Isopropanol	67-63-0	0.07	3.94	11.16	10	90
Methyl Ethyl Ketone	78-93-3	0.16	0.87	1.74	10	100
Toluene	108-88-3	0.14	1.70	8.97	10	100
Xylene, m- + p-	108-38-3, 106-42-3	0.04	0.85	3.09	10	90
Xylene, o-	95-47-6	BDL	0.27	0.99	10	80

Note:
BDL - Below detection levels, CAS - Chemical Abstracts Service number, VOC - Volatile organic compound
*As presented in CDPHE, 2019b.

Table C4. Summary of VOC concentrations (sampling dates 06/17/2021 – 12/02/2021)

VOC	CAS	Minimum (µg/m³)	Mean (µg/m³)	Maximum (µg/m³)	Sample Number	Detection Frequency (%)
Acetone	67-64-1	3.28	161.46	924.53	82	100
Benzene	71-43-2	0.09	1.90	28.58	82	100
Ethylbenzene	100-41-4	0.06	4.40	32.19	82	100
Isopropanol	67-63-0	0.27	20.36	107.67	82	97.5
Methyl Ethyl Ketone	78-93-3	0.32	3.09	38.96	82	98.8

Toluene	108-88-3	0.25	8.60	180.56	82	100
Xylene, m- + p-	108-38-3 106-42-3	0.19	16.92	109.67	82	100
Xylene, o-	95-47-6	0.09	4.78	29.87	82	100
1,2,3-trimethylbenzene	526-73-8	0.01	0.16	3.96	82	100
1,2,4-trimethylbenzene	95-63-6	0.03	0.60	18.13	82	100
1,3,5-trimethylbenzene	108-67-8	0.01	0.15	4.63	82	100
1,3-diethylbenzene	141-93-5	0.00	0.03	0.81	82	100
1,4-diethylbenzene	105-05-5	0.01	0.14	3.08	82	100
1-butene	106-98-9	0.01	0.20	3.76	82	100
1-pentene	109-67-1	0.00	0.08	1.05	82	64.6
2,2,4-trimethylpentane	540-84-1	0.00	0.95	57.03	82	98.8
2,3,4-trimethylpentane	565-75-3	0.00	0.34	23.05	82	97.6
2,3-dimethylpentane	565-59-3	0.01	0.41	6.33	82	98.8
2,4-dimethylpentane	108-08-7	0.00	0.21	7.88	82	100
2-ethyltoluene	611-14-3	0.01	0.14	3.25	82	100
2-methylheptane	592-27-8	0.00	0.43	8.74	82	75.6
2-methylhexane	591-76-4	0.02	0.26	4.02	82	97.6
3-ethyltoluene	620-14-4	0.02	0.35	9.63	82	100
3-methylheptane	589-81-1	0.00	0.29	6.90	82	87.8
3-methylhexane	589-34-4	0.00	0.35	5.82	82	98.8
4-ethyltoluene	622-96-8	0.01	0.14	3.39	82	100
Acetonitrile	75-05-8	0.24	1.15	4.92	82	98.8
c-2-butene	590-18-1	0.00	0.08	2.53	82	100
c-2-pentene	627-20-3	0.00	0.05	0.87	82	62.2
Cyclohexane	110-82-7	0.00	0.48	13.20	82	95.1
Cyclopentane	287-92-3	0.01	1.84	133.45	82	100
Ethane	74-84-0	1.17	8.87	34.61	82	100
Ethene	74-85-1	0.08	2.91	95.43	82	100
Ethyne	74-86-2	0.09	1.30	57.99	82	100
i-butane	75-28-5	0.09	1.58	4.70	82	100
i-pentane	78-78-4	0.26	3.48	67.19	82	100
i-propylbenzene	98-82-8	0.00	0.34	5.17	82	100
Isoprene	78-79-5	0.00	0.51	6.37	82	100
Methane	74-82-8	1,231.33	1,345.31	1,667.17	82	100
Methylcyclohexane	108-87-2	0.01	1.28	43.19	82	100
n-butane	106-97-8	0.02	4.67	19.92	82	100
n-decane	124-18-5	0.03	0.57	8.04	82	100
n-heptane	142-82-5	0.04	1.06	20.42	82	100

n-hexane	110-54-3	0.09	2.60	128.62	82	100
n-nonane	111-84-2	0.04	0.43	3.87	82	100
n-octane	111-65-9	0.05	0.69	11.17	82	100
n-pentane	109-66-0	0.18	3.89	128.97	82	100
n-propylbenzene	103-65-1	0.01	0.13	2.26	82	100
Propane	74-98-6	0.47	8.48	26.38	82	100
Propene (propylene)	115-07-1	0.04	1.37	32.62	82	100
Styrene	100-42-5	0.01	0.47	16.10	82	100
t-2-butene	624-64-6	0.00	0.11	3.42	82	100
t-2-pentene	646-04-8	0.00	0.08	1.30	82	68.3
Tetrachloroethylene	127-18-4	0.02	0.10	0.95	82	100
Trichloroethylene	79-01-6	0.00	0.01	0.11	82	100

Note:
CAS - Chemical Abstracts Service number, VOC - Volatile organic compound

Table C5. Determination of non-cancer COPCs from all 2021 Timnath air sampling data

VOC	CAS	2021 Maximum (µg/m^3)	Chronic CV (µg/m^3)	Chronic CV * 0.1 (µg/m^3)*	CV source	Selected as Non-cancer Toxicity COPCs
Acetone	67-64-1	924.53	16,000	1,600	TCEQ, 2021	No
Benzene	71-43-2	28.58	4.5	0.45	TCEQ, 2021	Yes
Ethylbenzene	100-41-4	32.19	260	26	ATSDR, 2022	Yes
Isopropanol	67-63-0	107.67	210	21	EPA, 2021	Yes
Methyl Ethyl Ketone	78-93-3	38.96	5,000	500	ATSDR, 2022	No
Toluene	108-88-3	180.56	3,800	380	ATSDR, 2022	No
Xylene, m- + p-	108-38-3, 106-42-3	109.67	100	10	CDPHE, 2019c	Yes
Xylene, o-	95-47-6	29.97	100	10	CDPHE, 2019c	Yes
1,2,3-trimethylbenzene	526-73-8	3.96	60	6	CDPHE, 2019c	No
1,2,4-trimethylbenzene	95-63-6	18.13	60	6	CDPHE, 2019c	Yes
1,3,5-trimethylbenzene	108-67-8	4.63	60	6	CDPHE, 2019c	No
1,3-diethylbenzene	141-93-5	0.81	247	24.7	CDPHE, 2019c	No
1,4-diethylbenzene	105-05-5	3.08	247	24.7	CDPHE, 2019c	No
1-butene	106-98-9	3.76	5,278	527.8	CDPHE, 2019c	No
1-pentene	109-67-1	1.05	1,600	160	TCEQ, 2021	No
2,2,4-trimethylpentane	540-84-1	57.03	1,775	177.5	CDPHE, 2019c	No
2,3,4-trimethylpentane	565-75-3	23.05	1,775	177.5	CDPHE, 2019c	No
2,3-dimethylpentane	565-59-3	6.33	9,000	900	TCEQ, 2021	No
2,4-dimethylpentane	108-08-7	7.88	9,000	900	TCEQ, 2021	No
2-ethyltoluene	611-14-3	3.25	123	12.3	CDPHE, 2019c	No

2-methylheptane	592-27-8	8.74	1,775	177.5	CDPHE, 2019c	No
2-methylhexane	591-76-4	4.02	9,000	900	TCEQ, 2021	No
3-ethyltoluene	620-14-4	9.63	123	12.3	CDPHE, 2019c	No
3-methylheptane	589-81-1	6.90	1,775	177.5	CDPHE, 2019c	No
3-methylhexane	589-34-4	5.82	9,000	900	TCEQ, 2021	No
4-ethyltoluene	622-96-8	3.39	123	12.3	CDPHE, 2019c	No
Acetonitrile	75-05-8	4.92	60	6	ATSDR, 2022	No
c-2-butene	590-18-1	2.53	1,600	160	TCEQ, 2021	No
c-2-pentene	627-20-3	0.87	1,600	160	TCEQ, 2021	No
Cyclohexane	110-82-7	13.20	340	34	TCEQ, 2021	No
Cyclopentane	287-92-3	133.45	1,692	16.92	CDPHE, 2019c	Yes
Ethane	74-84-0	34.61	NA	NA	NA	NA
Ethene	74-85-1	95.43	6,081	608.1	CDPHE, 2019c	No
Ethyne	74-86-2	57.99	2,660	266	TCEQ, 2021	No
i-butane	75-28-5	4.70	23,772	2,377.2	CDPHE, 2019c	No
i-pentane	78-78-4	67.19	23,902	2,390.2	CDPHE, 2019c	No
i-propylbenzene	98-82-8	5.17	250	25	TCEQ, 2021	No
Isoprene	78-79-5	6.37	390	39	CDPHE, 2019c	No
Methane	74-82-8	1667.17	NA	NA	NA	NA
Methylcyclohexane	108-87-2	43.19	1,606	160.6	CDPHE, 2019c	No
n-butane	106-97-8	19.92	23,772	2,377.2	CDPHE, 2019c	No
n-decane	124-18-5	8.04	1,100	110	TCEQ, 2021	No
n-heptane	142-82-5	20.42	400	40	CDPHE, 2019c	No
n-hexane	110-54-3	128.62	670	67	TCEQ, 2021	Yes
n-nonane	111-84-2	3.87	20	2	CDPHE, 2019c	Yes
n-octane	111-65-9	11.17	1,775	177.5	CDPHE, 2019c	No
n-pentane	109-66-0	128.97	1,000	100	CDPHE, 2019c	Yes
n-propylbenzene	103-65-1	2.26	250	25	TCEQ, 2021	No
Propane	74-98-6	26.38	NA	NA	NA	NA
Propene (propylene)	115-07-1	32.62	3,000	300	CDPHE, 2019c	No
Styrene	100-42-5	16.10	470	47	TCEQ, 2021	No
t-2-butene	624-64-6	3.42	1,285	128.5	CDPHE, 2019c	No
t-2-pentene	646-04-8	1.30	1,600	160	TCEQ, 2021	No
Tetrachloroethylene	127-18-4	0.95	26	2.6	TCEQ, 2021	No
Trichloroethylene	79-01-6	0.11	54	5.4	TCEQ, 2021	No

Note:
CAS - Chemical Abstracts Service number, COPC – contaminant of potential concern, CV – comparison value, NA - not applicable, VOC - Volatile organic compound
*Non-cancer screening values were multiplied by 0.1 to account for potential impacts from multiple contaminants.
See References section for citations

Table C6. Selection of cancer COPCs from all 2021 Timnath air sampling data

VOC	CAS	2021 Maximum (µg/m³)	CV (µg/m³)	CV source	CV comments (per µg/m³)	Selected as Cancer Toxicity COPCs
Benzene	71-43-2	28.58	0.13-0.45	CDPHE, 2019c	IUR = 2.2-7.8E-6	Yes
Ethylbenzene	100-41-4	32.19	1.1	EPA, 2021	IUR = 2.5E-6	Yes
Isoprene	78-79-5	6.37	44.6	CDPHE, 2019c	IUR = 2.20E-8	No
Tetrachloroethylene	127-18-4	0.95	3.8	ATSDR, 2022	IUR = 2.6E-7	No
Trichloroethylene	79-01-6	0.11	0.21	ATSDR, 2022	IUR = 4.1E-6	No

Note:

CAS - Chemical Abstracts Service number, COPC – contaminant of potential concern, CV – comparison value, VOC - Volatile organic compound

See References section for citations

Table C7. Determination of odor COPCs from all 2021 Timnath air sampling data

VOC	CAS	2021 Maximum (µg/m³)	Minimum Odor CV (µg/m³)	Minimum Odor CV-10% (µg/m³)*	Minimum Odor CV source	Selected as Odor COPCs
Acetone	67-64-1	924.53	940	846	AIHA, 2013	Yes
Benzene	71-43-2	28.58	1,500	1,350	AIHA, 2013	No
Ethylbenzene	100-41-4	32.19	10	9	AIHA, 2013	Yes
Isopropanol	67-63-0	107.67	2,500	2,250	AIHA, 2013	No
Methyl Ethyl Ketone	78-93-3	38.96	210	189	AIHA, 2013	No
Toluene	108-88-3	180.56	80	72	AIHA, 2013	Yes
Xylene, m- + p-	108-38-3, 106-42-3	109.67	52	46.8	AIHA, 2013	Yes
Xylene, o-	95-47-6	29.97	52	46.8	AIHA, 2013	No
1,2,3-trimethylbenzene	526-73-8	3.96	30	27	AIHA, 2013	No
1,2,4-trimethylbenzene	95-63-6	18.13	30	27	AIHA, 2013	No
1,3,5-trimethylbenzene	108-67-8	4.63	30	27	AIHA, 2013	No
1,3-diethylbenzene	141-93-5	0.81	2.1	1.89	AIHA, 2013	No
1,4-diethylbenzene	105-05-5	3.08	2.1	1.89	AIHA, 2013	Yes
1-butene	106-98-9	3.76	830	747	AIHA, 2013	No
1-pentene	109-67-1	1.05	290	261	TCEQ, 2015a	No
2,2,4-trimethylpentane	540-84-1	57.03	3,100	2,790	AIHA, 2013	No
2,3,4-trimethylpentane	565-75-3	23.05	3,080	2,772	CDPHE, 2020c	No
2,3-dimethylpentane	565-59-3	6.33	1,700	1,530	AIHA, 2013	No
2,4-dimethylpentane	108-08-7	7.88	1,700	1,530	AIHA, 2013	No
2-ethyltoluene	611-14-3	3.25	NA	NA	NA	Yes
2-methylheptane	592-27-8	8.74	3,080	2,772	CDPHE, 2020c	No

2-methylhexane	591-76-4	4.02	1,700	1,530	AIHA, 2013	No
3-ethyltoluene	620-14-4	9.63	NA	NA	NA	Yes
3-methylheptane	589-81-1	6.90	3,080	2,772	CDPHE, 2020c	No
3-methylhexane	589-34-4	5.82	1,700	1,530	AIHA, 2013	No
4-ethyltoluene	622-96-8	3.39	NA	NA	NA	Yes
Acetonitrile	75-05-8	4.92	22,000	19,800	AIHA, 2013	No
c-2-butene	590-18-1	2.53	830	747	AIHA, 2013	No
c-2-pentene	627-20-3	0.87	545	491	CDPHE, 2020c	No
Cyclohexane	110-82-7	13.20	1,800	1,620	AIHA, 2013	No
Cyclopentane	287-92-3	133.45	NA	NA	NA	Yes
Ethane	74-84-0	34.61	25,000,000	22,500,000	AIHA, 2013	No
Ethene	74-85-1	95.43	20,000	18,000	AIHA, 2013	No
Ethyne	74-86-2	57.99	240,000	216,000	AIHA, 2013	No
i-butane	75-28-5	4.70	1,000	900	AIHA, 2013	No
i-pentane	78-78-4	67.19	3,800	3,420	AIHA, 2013	No
i-propylbenzene	98-82-8	5.17	25	22.5	EPA, 1992	No
Isoprene	78-79-5	6.37	130	117	AIHA, 2013	No
Methane	74-82-8	1667.17	1,900,000,000	1,710,000,000	AIHA, 2013	No
Methylcyclohexane	108-87-2	43.19	600	540	AIHA, 2013	No
n-butane	106-97-8	19.92	1,000	900	AIHA, 2013	No
n-decane	124-18-5	8.04	3,610	3,249	CDPHE, 2020c	No
n-heptane	142-82-5	20.42	1,700	1,530	AIHA, 2013	No
n-hexane	110-54-3	128.62	5,300	4,770	AIHA, 2013	No
n-nonane	111-84-2	3.87	12,000	10,800	AIHA, 2013	No
n-octane	111-65-9	11.17	3,100	2,790	AIHA, 2013	No
n-pentane	109-66-0	128.97	3,800	3,420	AIHA, 2013	No
n-propylbenzene	103-65-1	2.26	NA	NA	NA	Yes
Propane	74-98-6	26.38	2,700,000	2,430,000	AIHA, 2013	No
Propene (propylene)	115-07-1	32.62	17,300	15,570	AIHA, 2013	No
Styrene	100-42-5	16.10	12	10.8	AIHA, 2013	Yes
t-2-butene	624-64-6	3.42	830	747	AIHA, 2013	No
t-2-pentene	646-04-8	1.30	545	490.5	CDPHE, 2020c	No
Tetrachloroethylene	127-18-4	0.95	5,200	4,680	AIHA, 2013	No
Trichloroethylene	79-01-6	0.11	2,500	2,250	AIHA, 2013	No

Note:

CAS - Chemical Abstracts Service number, COPC – contaminant of potential concern, CV – comparison value, NA - not applicable, VOC - Volatile organic compound

*Odor screening values were reduced by 10% to account for potential masking or augmentation from multiple contaminants.

See References section for citations

Table C8. Summary of toxicity and odor COPCs

VOC	CAS	Non-cancer COPC	Cancer COPC	Odor COPC	Rationale
Acetone	67-64-1	.	.	COPC	Comparison to odor screening value
Benzene	71-43-2	COPC	COPC	.	Comparison to toxicity screening values
Ethylbenzene	100-41-4	COPC	COPC	COPC	Comparison to toxicity/odor screening values
Isopropanol	67-63-0	COPC	.	.	Comparison to toxicity screening value
Toluene	108-88-3	.	.	COPC	Comparison to odor screening value
Xylene, m- + p-	108-38-3, 106-42-3	COPC	.	COPC	Comparison to toxicity/odor screening values
Xylene, o-	95-47-6	COPC	.	.	Comparison to toxicity screening value
1,2,4-trimethylbenzene	95-63-6	COPC	.	.	Comparison to toxicity screening value
1,4-diethylbenzene	105-05-5	.	.	COPC	Comparison to odor screening value
2-ethyltoluene	611-14-3	.	.	COPC	Odor screening value unavailable
3-ethyltoluene	620-14-4	.	.	COPC	Odor screening value unavailable
4-ethyltoluene	622-96-8	.	.	COPC	Odor screening value unavailable
Cyclopentane	287-92-3	COPC	.	COPC	Comparison to toxicity screening value/Odor screening value unavailable
Ethane	74-84-0	COPC	.	.	Toxicity screening value unavailable
Methane	74-82-8	COPC	.	.	Toxicity screening value unavailable
n-hexane	110-54-3	COPC	.	.	Comparison to toxicity screening value
n-nonane	111-84-2	COPC	.	.	Comparison to toxicity screening value
n-pentane	109-66-0	COPC	.	.	Comparison to toxicity screening value
n-propylbenzene	103-65-1	.	.	COPC	Odor screening value unavailable
Propane	74-98-6	COPC	.	.	Toxicity screening value unavailable
Styrene	100-42-5	.	.	COPC	Comparison to odor screening value

Note:
CAS - Chemical Abstracts Service number, COPC – contaminant of potential concern, NA - not applicable, VOC - Volatile organic compound, “.” - empty cell

Appendix D. Exposure parameters, estimation of exposure concentration, and risk estimation

Identification of COPCs necessitates a refined exposure and risk estimation

COPCs were identified in toxicity screens, so more refined exposure calculations were used to estimate contaminant risks.

Estimation of exposure concentrations for different exposure durations (acute versus chronic) and scenarios (residential versus school)

Inhalation of VOCs was identified as the primary route of exposure and potential risk for people in the Timnath area. Two inhalation exposure durations (acute versus chronic) and two inhalation exposure environments (residential, school) were considered in this evaluation because residents have expressed health concerns for these specific scenarios. In general, the assumptions used to evaluate long-term residential exposures were 24 hours per day, 365 days per year, from birth to 33 years. The assumptions used to evaluate long-term risks to schoolchildren were 9 hours per day, 200 days per year over a period of 6 years. Nine hours in one day and 200 days per year were considered to be high end estimates of the time any child was likely to be at school. The National Center for Educational Statistics (NCES, 2018) and the Colorado Department of Education (CDE, 2018) have estimated that the minimum amount of instructional time per year was 160 days in Colorado. All of the exposure assumptions used in this evaluation are shown in Table D1. Exposures for school staff are likely between the residential and schoolchildren estimates since they do not spend 24 hours a day, 365 days per year at the school, but may work at the school for longer than five years.

The Exposure Concentration (EC) is a representative contaminant concentration in a population's exposure pathway. Different ECs were calculated for assessing risk under different conditions (Table C1). Maximum VOC concentrations were used as concentrations in air (CAs) for estimating acute exposures (Table C5). The 95% upper confidence level of the mean of weekly near-source data was used as a CA for chronic and cancer risks for each VOC (Table D4). Specifically, ECs were calculated based on the following equation where CA is the concentration in air (µg/m3), ET is the exposure time (hours/day), EF is the exposure frequency (days/year), ED is the exposure duration (years), and AT is the averaging time (hours).

$$\text{Exposure Concentration}_{scenario\text{-}i}\ (EC_{scenario\text{-}i}) = (CA * ET * EF * ED)/AT$$

Table D1. Exposure factors used in one-hour, one-day, chronic, and cancer exposure assessments

Risk Focus	Scenario	Exposure Time (ET; hours/day)	Exposure Frequency (EF; days/year)	Exposure Duration (ED; years)	Averaging Time (AT; hours)
Acute non-cancer	Residential: one hour	1	1	1	1
Acute non-cancer	School: one hour	1	1	1	1
Acute non-cancer	Residential: one day	24	1	1	24
Acute non-cancer	School: one day	9	1	1	24
Chronic non-cancer	Residential: 33 years	24	365	33	289,080
Chronic non-cancer	School: 6 years	9	200	6	52,560
Cancer	Residential: 33 years	24	365	33	683,280
Cancer	School: 6 years	9	200	6	683,280

Note:

ET - Exposure time, EF - Exposure frequency, ED - Exposure duration, AT - Averaging time

Acute non-cancer exposure concentrations and risk

Acute risks were evaluated using one exposure concentration (EC) per scenario for each COPC.

Exposure concentrations were then compared to toxicity reference values (TRV) to estimate the non-cancer hazard quotient (HQ) for inhalation of contaminants of potential concern:

$$Hazard\ Quotient_{copc-i}\ (HQ_{copc-i}) = EC_{scenario-i} / TRV_{copc-i},$$

where the TRV is referenced from CDPHE 2019b, 2019c, 2020b, or TCEQ 2021.

Hazard quotients for all the COPCs were then summed to get the aggregate hazard index:

$$Hazard\ Index_{scenario-i}\ (HI_{scenario-i}) = HQ_{copc1} + HQ_{copc2}... + HQ_{copc-n}$$

Chronic non-cancer exposure concentrations and risk

Near-source weekly data sets for each COPC were imported into ProUCL in order to determine and eliminate data outliers using two different methods, statistical outlier analysis and visual box plot analysis (Table D2). Both methods were used because the identification of statistical outliers might be masked in cases where more than one outlier was present. Box plot analysis identified outliers above and below the box. Both values correlated well with each other on the largest outliers. Elimination of outliers has been recommended prior to estimating descriptive statistics because of the potentially large effect it might have on calculated values (ProUCL, 2022; ITRC, 2021[2]).

[2] See References section for citations

Table D2. Table of COPCs and outlier analysis and removal

VOC	All Data	All Data Except Last Resident Data Point	All Data Except Weekly Background And Last Resident Data Samples	Total Weekly Data	Background Weekly Data	Near-source Weekly Data	SPOD Data	Resident Data
Benzene	OA - 28.5 @ 1% BP - 28.5, 16.5, 15.6, 12.4, 10.1, 6.3, 6.3, 3.8, 3.1, 2.9	OA - 28.5 @ 1% BP - 28.5, 16.5, 15.6, 12.4, 10.1, 6.39, 6.3, 3.8, 3.1, 2.9	OA - 28.5 @ 1% BP - 28.5, 16.5, 15.6, 12.4, 10.1, 6.39, 6.31, 3.8, 3.1, 2.9	OA - None BP - 0.65, 0.09	OA - 0.58, 0.09 @ 5% BP - 0.58, 0.098	OA - 0.65, 0.16 @ 5% BP - 0.65, 0.25, 0.16	OA - 28.5 @ 1% BP -28.5, 16.5, 15.6, 12.4, 10.1, 6.3, 6.3	OA - None BP - None
Ethylbenzene	OA - 32.1 @ 1% BP - 32.1, 26.9, 21.8, 19.4	OA - 32.1 @ 1% BP - 32.1, 26.9, 21.8, 19.4	OA - 32.1 @ 1% BP - 32.1, 26.9, 21.8	OA - None BP - None	OA - 0.3 @ 5% BP - 0.3	OA - None BP - None	OA - 32.1 @ 1% BP - 32.1, 26.9, 21.8	OA - None BP - None
Isopropanol	OA - 107.6 @ 5% BP - 107.6, 93.3, 91.6	OA - 107.6 @ 5% BP - 107.6, 93.3, 91.6	OA - 107.6 @ 5% BP - 107.6, 93.3, 91.6	OA - 5.8 @ 5% BP - 5.8, 2.3	OA - 5.8 @ 1% BP - 5.8	OA - 2.3 @ 5% BP - 2.3	OA - None BP - 107.6, 93.3, 91.6	OA - None BP - None
Xylene, m- + p-	OA - 109.6 @ 1% BP - 109.6, 01.6, 94.2, 74.8, 72.6	OA - 109.6 @ 1% BP - 109.6, 01.6, 94.2, 74.8, 72.6	OA - 109.6 @ 5% BP - 109.6, 101.6, 94.2, 74.8	OA - None BP - None	OA - 1.1 @ 1% BP - 1.1	OA - 1.2 @ 10% BP - None	OA - None BP - 109.6, 101.6, 94.2	OA - None BP - None
Xylene, o-	OA - 29.8 @ 1% BP - 29.8, 27.5, 25.7, 21.0, 19.8	OA - 29.8 @ 1% BP - 29.8, 27.5, 25.7, 21.0, 19.8	OA - 29.8 @ 5% BP - 29.8, 27.5, 25.7	OA - None BP - None	OA - 0.36 @ 5% BP - 0.36	OA - None BP - None	OA - None BP - 29.8, 27.5, 25.7	OA - None BP - None
1,2,4-trimethylbenzene	OA - 18.1 @ 1% BP - 18.1, 4.8, 1.3, 1.14, 1.13, 0.97, 0.95	OA - 18.1 @ 1% BP - 18.1, 4.8, 1.3, 1.14, 1.13, 0.97, 0.95	OA - 18.1 @ 1% BP - 18.1, 4.8, 1.3, 1.14, 1.13	OA - 0.29 @ 1% BP - 0.29, 0.13, 0.12	OA - 0.20 @ 5% BP - 0.20	OA - 0.29 @ 1% BP - 0.29	OA - 18.3 @ 1% BP - 18.1, 4.8	OA - None BP - None
Cyclopentane	OA - 133.5 @ 1% BP - 133.5, 3.8, 1.2, 0.73, 0.46	OA - 133.5 @ 1% BP - 133.5, 3.87, 1.29, 0.73, 0.46, 0.39	OA - 133.5 @ 1% BP - 133.5, 3.8, 1.2, 0.73, 0.46, 0.39	OA - None BP - 0.30, 0.29	OA - 0.30 @ 5% BP -0.30	OA - 0.29 @ 1%, 0.08 @ 10% BP - 0.29	OA - 133.4 @ 1% BP - 133.4, 3.8, 1.2, 0.73, 0.46, 0.39	OA - None BP - None
n-hexane	OA - 128.6 @ 1% BP - 128.6, 11.0, 3.6, 3.4, 2.6	OA - 128.6 @ 1% BP - 128.6, 11.0, 3.6, 3.4, 2.6	OA - 128.6 @ 1% BP - 128.6, 11.0, 3.6, 3.4, 2.6	OA - 2.04 @ 5% BP - 2.0, 0.87, 0.81	OA - 1.7 @ 5% BP - 1.7	OA - 2.0 @ 5% BP - 2.0	OA - 128.6 @ 1% BP - 128.6, 11.0, 3.6, 3.4	OA - None BP - None
n-nonane	OA - 3.86 @ 1% BP - 3.86, 3.85, 3.81, 3.2, 2.4, 0.838, 0.830, 0.81	OA - 3.86 @ 1% BP - 3.86, 3.85, 3.81, 3.2, 2.4, 0.838, 0.830, 0.81	OA - 3.86 @ 1% BP - 3.86, 3.85, 3.81, 3.2, 2.4, 0.838, 0.830, 0.81	OA - 0.39 @ 5% BP - 0.39, 0.33, 0.158, 0.150	OA - None BP -None	OA -None BP - 0.39, 0.33	OA - 3.86 @ 5% BP - 3.86, 3.85, 3.81, 3.2, 2.4	OA - None BP - 16.2, 0.04
n-pentane	OA - 128.9 @ 1% BP - 128.9, 15.3, 12.4, 7.6, 6.8, 5.3, 5.1, 4.7	OA - 128.9 @ 1% BP - 128.9, 15.3, 12.4, 7.6, 6.8, 5.3, 5.1, 4.7	OA - 128.9 @ 1% BP - 128.9, 15.3, 12.4, 7.6, 6.8, 5.3, 5.1	OA - 3.8 @ 5% BP - 3.8, 3.7	OA - 3.7 @ 1% BP - 3.7	OA - 3.8 @ 5% BP - 3.8	OA - 128.9 @ 1% BP - 128.9, 15.3, 12.4, 7.6, 6.8, 5.3, 5.1	OA - None BP - None

Note:
COPC – contaminant of potential concern, Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection, VOC - Volatile organic compound, Weekly - weekly automatic canister collection
OA – Outlier Analysis, Statistical Analysis
BP – Box Plot, Visual Analysis

Once outliers were removed, chronic risks were evaluated using one exposure concentration (EC) per scenario for each COPC.

Exposure concentrations were then compared to toxicity reference values to estimate the non-cancer hazard quotient (HQ) for inhalation of contaminants of potential concern:

$$Hazard\ Quotient_{copc-i}\ (HQ_{copc-i}) = EC_{scenario-i} / TRV_{copc-i},$$

where the TRV is referenced from CDPHE 2019b, 2019c, 2020b, or TCEQ 2021.

Hazard quotients for all the COPCs were then summed to get the aggregate hazard index:

$$Hazard\ Index_{scenario\text{-}i}\ (HI_{scenario\text{-}i}) = HQ_{copc\text{-}i} + HQ_{copc\text{-}i+1}\ldots + HQ_{copc\text{-}n}$$

The hazard index represents a conservative value that combines all non-cancer risks, regardless of mode or mechanisms of action or target tissues. This is thought to be conservative since it assumes additivity of effect, even in cases where the TRV toxicity endpoint might be based on different organs or processes.

Table D3. Descriptive statistics for COPCs from Timnath data sets after outlier removal (mean, geometric mean, maximum, 95% UCL; µg/m^3)

VOC	CAS	All Data	All Data Except Last Resident Data Point	All Data Except Weekly Background And Last Resident Data Samples
Benzene	71-43-2	Mean - 0.69 Geomean - 0.55 Maximum - 2.29 UCL - H - 0.82	Mean - 0.69 Geomean - 0.55 Maximum - 2.29 UCL - H - 0.83	Mean - 0.78 Geomean - 0.63 Maximum - 2.29 UCL - APG - 0.90
Ethylbenzene	100-41-4	Mean - 3.34 Median - 0.96 Maximum - 15.93 UCL - C - 5.43	Mean - 3.37 Median - 0.96 Maximum - 15.93 UCL - C - 5.48	Mean - 4.33 Geomean - 1.58 Maximum - 19.42 UCL - C - 6.92
Isopropanol	67-63-0	Mean - 17.35 Median - 8.23 Maximum - 78.79 UCL - KM - 39.31	Mean - 17.52 Median - 9.53 Maximum - 78.79 UCL - KM - 39.70	Mean - 20.94 Median - 16.00 Maximum - 78.79 UCL - KM - 46.15
Xylene, m- + p-	108-38-3, 106-42-3	Mean - 12.14 Median - 3.56 Maximum - 66.73 UCL - C - 19.92	Mean - 12.25 Geomean - 3.56 Maximum - 66.73 UCL - C - 20.12	Mean - 15.82 Geomean - 5.91 Maximum - 72.67 UCL - C - 25.56
Xylene, o-	95-47-6	Mean - 3.48 Median - 1.09 Maximum - 18.08 UCL - C - 5.68	Mean - 3.51 Geomean - 1.09 Maximum - 18.08 UCL - C - 5.73	Mean - 4.77 Geomean - 1.85 Maximum - 21.03 UCL - C - 7.68
1,2,4-trimethylbe nzene	95-63-6	Mean - 0.27 Geomean - 0.21 Maximum - 0.90 UCL - H - 0.33	Mean - 0.28 Geomean - 0.21 Maximum - 0.90 UCL - H - 0.33	Mean - 0.34 Geomean - 0.26 Maximum - 0.99 UCL - APG - 0.39
Cyclopentane	287-92-3	Mean - 0.14 Geomean - 0.12 Maximum - 0.34 UCL - S - 0.15	Mean - 0.14 Geomean - 0.12 Maximum - 0.30 UCL - S - 0.15	Mean - 0.14 Geomean - 0.11 Maximum - 0.34 UCL - S - 0.15
n-hexane	110-54-3	Mean - 0.83 Geomean - 0.68 Maximum - 2.29 UCL - APG - 0.94	Mean - 0.82 Geomean - 0.68 Maximum - 2.14 UCL - APG - 0.92	Mean - 0.84 Geomean - 0.68 Maximum - 2.28 UCL - APG - 0.97
n-nonane	111-84-2	Mean - 0.21 Geomean - 0.18 Maximum - 0.61 UCL - APG - 0.24	Mean - 0.22 Geomean - 0.19 Maximum - 0.61 UCL - APG - 0.24	Mean - 0.23 Geomean - 0.20 Maximum - 0.61 UCL - APG - 0.26
n-pentane	109-66-0	Mean - 1.79 Geomean - 1.55 Maximum - 3.92 UCL - S - 1.95	Mean - 1.81 Geomean - 1.58 Maximum - 3.92 UCL - S - 1.97	Mean - 1.83 Geomean - 1.56 Maximum - 4.80 UCL - S - 2.03

Note:

CAS - Chemical Abstracts Service number, COPC - contaminant of potential concern, VOC - Volatile organic compound
Resident - resident-initiated collection, Weekly - weekly automatic canister collection
UCL - upper confidence limit, 95-99% UCL - AG - 95% adjusted gamma UCL, APG - 95% approximate gamma UCL, C - 95% Chebyshev (Mean SD) UCL, H - H based statistics could result in unstable UCL values, K - 95% Km(t) UCL, KM - 99% KM (Chebyshev) UCL, S - 95% Student's-t UCL

Table D4. Descriptive Statistics for COPCs from Timnath data sets after outlier removal (mean, geometric mean, maximum, 95% UCL; µg/m^3)

VOC	CAS	All Weekly Data	Background Weekly Data	Near-source Weekly Data	SPOD Data	Resident Data
Benzene	71-43-2	Mean - 0.38 Geomean - 0.37 Maximum - 0.59 UCL - S - 0.41	Mean - 0.35 Geomean - 0.34 Maximum - 0.48 UCL - S - 0.39	Mean - 0.43 Geomean - 0.43 Maximum - 0.52 UCL - S - 0.46	Mean - 1.14 Geomean - 0.93 Maximum - 3.86 UCL - AG - 1.37	Mean - 0.29 Geomean - 0.25 Maximum - 0.59 UCL - S - 0.44
Ethylbenzene	100-41-4	Mean - 0.16 Geomean - 0.15 Maximum - 0.30 UCL - S - 0.18	Mean - 0.12 Geomean - 0.12 Maximum - 0.21 UCL - S - 0.14	Mean - 0.19 Geomean - 0.18 Maximum - 0.28 UCL - 0.22	Mean - 5.72 Geomean - 3.18 Maximum - 19.42 UCL - AG - 7.59	Mean - 3.06 Geomean - 1.21 Maximum - 8.35 UCL - S - 5.98
Isopropanol	67-63-0	Mean - 0.81 Median - 0.74 Maximum - 1.63 UCL - K - 0.89	Mean - 0.56 Median - 0.60 Maximum - 0.93 UCL - K - 0.63	Mean - 1.07 Median - 1.02 Maximum - 1.63 UCL - K - 1.19	Mean - 27.30 Median - 25.30 Maximum - 78.79 UCL - S - 32.37	Mean - 13.31 Median - 6.39 Maximum - 35.58 UCL - S - 25.78
Xylene, m- + p-	108-38-3, 106-42-3	Mean - 0.66 Geomean - 0.60 Maximum - 1.27 UCL - S - 0.74	Mean - 0.44 Geomean - 0.42 Maximum - 0.66 UCL - S - 0.50	Mean - 0.82 Geomean - 0.80 Maximum - 1.27 UCL - S - 0.92	Mean - 22.10 Geomean - 11.70 Maximum - 74.86 UCL - AG - 29.67	Mean - 11.45 Geomean - 5.16 Maximum - 27.88 UCL - S - 22.07
Xylene, o-	95-47-6	Mean - 0.20 Geomean - 0.19 Maximum - 0.37 UCL - S - 0.23	Mean - 0.15 Geomean - 0.14 Maximum - 0.21 UCL - S - 0.17	Mean - 0.25 Geomean - 0.24 Maximum - 0.35 UCL - S - 0.27	Mean - 6.30 Geomean - 3.54 Maximum - 21.03 UCL - AG - 8.33	Mean - 3.24 Geomean - 1.54 Maximum - 7.85 UCL - S - 6.22
1,2,4-trimethylbenzene	95-63-6	Mean - 0.13 Geomean - 0.13 Maximum - 0.21 UCL - S - 0.14	Mean - 0.12 Geomean - 0.11 Maximum - 0.15 UCL - S - 0.13	Mean - 0.14 Geomean - 0.14 Maximum - 0.21 UCL - S - 0.16	Mean - 0.46 Geomean - 0.37 Maximum - 1.30 UCL - AG - 0.55	Mean - 0.18 Geomean - 0.13 Maximum - 0.38 UCL - S - 0.31
Cyclopentane	287-92-3	Mean - 0.15 Geomean - 0.14 Maximum - 0.20 UCL - S - 0.16	Mean - 0.14 Geomean - 0.14 Maximum - 0.19 UCL - S - 0.16	Mean - 0.16 Geomean - 0.15 Maximum - 0.20 UCL - S - 0.17	Mean - 0.14 Geomean - 0.11 Maximum - 0.34 UCL - S - 0.16	Mean - 0.066 Geomean - 0.05 Maximum - 0.11 UCL - S - 0.10
n-hexane	110-54-3	Mean - 0.88 Geomean - 0.82 Maximum - 1.72 UCL - S - 0.98	Mean - 0.75 Geomean - 0.71 Maximum - 1.11 UCL - S - 0.85	Mean - 0.94 Geomean - 0.89 Maximum - 1.36 UCL -S - 1.09	Mean - 0.88 Geomean - 0.68 Maximum - 2.64 UCL - AG - 1.07	Mean - 0.35 Geomean - 0.30 Maximum - 0.57 UCL - S - 0.49
n-nonane	111-84-2	Mean - 0.16 Geomean - 0.15 Maximum - 0.28 UCL - S - 0.17	Mean - 0.16 Geomean - 0.15 Maximum - 0.22 UCL - S - 0.18	Mean - 0.16 Geomean - 0.15 Maximum - 0.28 UCL - S - 0.19	Mean - 0.30 Geomean - 0.25 Maximum - 0.84 UCL - AG - 0.36	Mean - 0.09 Geomean - 0.09 Maximum - 0.10 UCL - S - 0.10
n-pentane	109-66-0	Mean - 1.89 Geomean - 1.84 Maximum - 2.64 UCL - S - 2.03	Mean - 1.78 Geomean - 1.73 Maximum - 2.26 UCL - S - 1.97	Mean - 2.13 Geomean - 2.05 Maximum - 3.87 UCL -S - 2.44	Mean - 1.84 Geomean - 1.55 Maximum - 4.80 UCL - S - 2.10	Mean - 0.82 Geomean - 0.67 Maximum - 1.22 UCL - S - 1.18

Note:

CAS - Chemical Abstracts Service number, COPC - contaminant of potential concern, VOC - Volatile organic compound
Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection, Weekly - weekly automatic canister collection
UCL - upper confidence limit, 95-99% UCL - AG - 95% adjusted gamma UCL, APG - 95% approximate gamma UCL, C - 95% Chebyshev (Mean SD) UCL, H - H based statistics could result in unstable UCL values, K - 95% Km(t) UCL, KM - 99% KM (Chebyshev) UCL, S - 95% Student's-t UCL

Chronic cancer exposure concentrations and risk

Once outliers were removed, cancer risks were also evaluated using one exposure concentration (EC) per scenario for each COPC.

Exposure concentrations were then multiplied by inhalation unit risk (IUR) values for each COPC (benzene and ethylbenzene) to estimate cancer risk:

$$Cancer\ Risk_{copc\text{-}i}\ (CR_{copc\text{-}i}) = EC_{scenario\text{-}i} * IUR_{copc\text{-}i},$$

where the IUR was referenced from CDPHE 2019b, 2019c, 2020b, or TCEQ 2021.

Cancer risks for all the COPCs were then summed to get the aggregate cancer risk:

$$Aggregate\ Cancer\ Risk_{scenario\text{-}i} = CR_{copc\text{-}i} + CR_{copc\text{-}i+1} \ldots + CR_{copc\text{-}n}$$

As with the hazard index, the aggregate cancer risk is a conservative value that represents the combination of all cancer risks, regardless of cancer mode or mechanisms of action or target tissues. It is expected that truly additive risks would be based on cancers that affect the same mode or mechanism of activity, or at the very least the same target tissue.

Appendix E. Toxicological evaluation

The basic objective of a toxicological evaluation is to identify adverse effects that are associated with a contaminant and how the induction of these adverse effects depends on the route of exposure (oral, inhalation, dermal), duration of exposure (acute, subchronic, chronic or lifetime), and dose.

Contaminant-based adverse effects may be based on human evidence (primarily epidemiology) and/or animal evidence (toxicology) depending on the availability of data. Adverse effects can range from non-pathological effects (e.g. food consumption) to serious tissue pathologies or cancer.

It is important to note that some adverse effects experienced by humans such as dizziness, headaches, nausea, or numbness or tingling are important, but not assessed to any great extent in toxicological evaluations.

Non-cancer effects

Benzene

EPA's IRIS document for benzene (EPA, 2003a) notes that inhalation exposures to benzene can result in both hematoxicity and immunotoxicity. These are reportedly "the most sensitive indicators of noncancer toxicity in both humans and experimental animals." The bone marrow is the primary target organ and chronic exposure to benzene results in degradation of hematopoietic function (anemia, leukopenia, leukocytopenia, lymphocytopenia, thrombocytopenia, pancytopenia, and aplastic anemia). Neurotoxic and developmental effects have also been described following short-duration high concentration exposures. These effects are consistent with organic solvent exposure.

The one-hour and one-day acute (27 µg/m^3; 29 µg/m^3) and chronic (9.6 µg/m^3) non-cancer TRVs for benzene were selected from previous publications (CDPHE, 2019b/2019c; CDPHE 2020b[3]).

Ethylbenzene

EPA's IRIS document for ethylbenzene (EPA, 1991) and OEHHAs chronic toxicity summary (OEHHA, 2000) notes that inhalation exposures to ethylbenzene can result in developmental toxicity, hepatotoxicity, nephrotoxicity, and endocrine toxicity (pituitary gland, thyroid gland) in animals. Ethylbenzene is currently under re-development by the IRIS program.

The one-hour and one-day acute (86,000 µg/m^3; 22,000 µg/m^3) and chronic (260 µg/m^3) non-cancer TRVs for ethylbenzene were selected from previous publications (CDPHE, 2019b/2019c; CDPHE 2020b).

[3] See References section for citations

Isopropanol

EPA's PPRTV document for isopropanol (EPA, 2014) notes that inhalation exposures to isopropanol can result in hepatotoxicity, developmental toxicity, reproductive toxicity, gastrointestinal toxicity and changes in neurobehavioral activity in test animals. Increased relative liver weight was identified as a key pathology in EPA's derivation of an intermediate-duration toxicity value. Decreased testicular weight was identified as a key endpoint in EPA's derivation of a chronic duration toxicity value.

The one-day acute (7,000 $\mu g/m^3$) and chronic (200 $\mu g/m^3$) non-cancer TRVs for isopropanol were selected from a previous publication (CDPHE, 2019b).

M-p-o-xylene

EPA's IRIS document for xylene (EPA, 2003b) notes that inhalation exposures to xylenes can result in neurotoxicity and minor changes in serum chemistry and hematology in animals. Neurological endpoints used in the derivation of the TRV included impaired motor coordination and decreased sensitivity to pain. Additional animal and human effects of xylene have been reviewed in the ATSDR toxicological profile (ATSDR, 2007b) for xylene. Some of these effects involve the pulmonary, gastrointestinal, and hepatic systems.

The one-hour and one-day acute (22,000 $\mu g/m^3$; 8,700 $\mu g/m^3$) and chronic (100 $\mu g/m^3$) non-cancer TRVs for m-, p-, and o-xylene were selected from previous publications (CDPHE, 2019b/2019c; CDPHE, 2020b).

1,2,4-trimethylbenzene

EPA IRIS (EPA, 2016) and the Texas Commission on Environmental Quality (TCEQ, 2015b) note that inhalation to trimethylbenzenes can result in acute and chronic neurotoxicity in animals. Intermediate-duration adverse effects include decreased pain sensitivity and decreased neuromuscular coordination and function. Additional effects include pulmonary toxicity, hematotoxicity, and developmental toxicity. These effects occur at higher doses than neurological effects, however.

The one-hour and one-day acute (15,000 $\mu g/m^3$; 15,000 $\mu g/m^3$) and chronic (60 $\mu g/m^3$) non-cancer TRVs for 1,2,4-trimethylbenzene were selected from previous publications (CDPHE, 2019c; TCEQ, 2021).

Cyclopentane

EPA's IRIS document for cyclopentane (EPA, 2003c) notes that inhalation exposures to cyclopentane can result in developmental and reproductive toxicity in animals. Transient decreases in auditory and alerting response and neurological depression have also been reported during exposures to cyclopentane.

The one-hour and one-day acute (17,000 $\mu g/m^3$; 17,000 $\mu g/m^3$) and chronic (1,700 $\mu g/m^3$) non-cancer TRVs for cyclopentane were selected from previous publications (CDPHE, 2019c; TCEQ, 2021).

n-hexane

EPA's IRIS document for n-hexane (EPA, 2005) notes that inhalation exposures to n-hexane can result in neurotoxicity such as peripheral neuropathy in animals and humans. Peripheral neuropathy resulted in paralysis of the hind limbs in some studies.

The one-hour and one-day acute (19,000 µg/m^3; 19,000 µg/m^3) and chronic (700 µg/m^3) non-cancer TRVs for n-hexane were selected from previous publications (CDPHE, 2019c; CDPHE 2020b).

n-nonane

EPA's PPRTV document for n-nonane (EPA, 2009a) notes that inhalation exposures to n-nonane can result in transient clinical signs such as salivation, lacrimation, coordination loss, and fine tremors. Decreased body weight gain was also seen in some animals. Transient decrements in motor activity were also seen in animals following exposure in some studies.

The one-hour and one-day acute (16,000 µg/m^3; 16,000 µg/m^3) and chronic (20 µg/m^3) non-cancer TRVs for n-nonane were selected from previous publications (CDPHE, 2019c; CDPHE 2020b).

n-pentane

EPA's PPRTV document for n-pentane (EPA, 2009b) notes that inhalation exposures to n-pentane can result in transient changes to serum chemistry. Other effects might include eye, skin, and nasal irritation, drowsiness, narcosis, and peripheral neuropathy. High doses of n-pentane (>300,000 mg/m^3) have been reported to act as an anesthetic and asphyxiant. In general, pathological changes to the nervous system, developmental system, and general physiology have not been seen in animals following inhalation exposure to n-pentane.

The one-hour and one-day acute (200,000 µg/m^3; 200,000 µg/m^3) and chronic (1,000 µg/m^3) non-cancer TRVs for n-pentane were selected from previous publications (CDPHE, 2019c; CDPHE 2020b).

Cancer effects

Benzene

EPA, IARC, and the U.S. Department of Health and Human Services have concluded that benzene is a human carcinogen. The Department of Health and Human Services determined that benzene is a known carcinogen based on human evidence showing a causal relationship between exposure to benzene and cancer. IARC classified benzene in Group 1 (carcinogenic to humans) based on sufficient evidence in both humans and animals. EPA classified benzene in Category A (known human carcinogen) based on convincing evidence in humans supported by evidence from animal studies. Under EPA's consensus conclusion, benzene is a human carcinogen based on sufficient inhalation data in humans (EPA, 2003a). This is supported by animal evidence including oral studies. Human cancer induced by inhalation exposure to benzene is predominantly acute non-lymphocytic (myelocytic) leukemia. In animals, benzene is a multiple site carcinogen by both the inhalation and oral routes (ATSDR, 2007a).

EPA derived a range of inhalation unit risk (IUR) values of $2.2x10^{-6}$ per µg/m^3 and $7.8x10^{-6}$ per µg/m^3 for benzene based on human leukemia data. The high-end IUR was used in the estimation of cancer risks for this assessment. For cancer risks ranging from 1 x 10^{-4} to 1 x 10^{-6}, the corresponding exposure concentrations range from 45.5 to 0.455 µg/m^3 (IUR of $2.2x10^{-6}$ per µg/m^3) and 12.8 to 0.128 µg/m^3, (IUR of $7.8x10^{-6}$ per µg/m^3), respectively.

Ethylbenzene

Ethylbenzene is classified by IARC as a possible human carcinogen. These values are based on the incidence of kidney cancer (renal tubule adenoma or carcinoma) in male rats (OEHHA, 2007). EPA has classified ethylbenzene as a D, not classifiable as to human carcinogenicity (EPA, 1991).

The California Office of Environmental Health Hazard Assessment has adopted an inhalation unit risk (IUR) value for ethylbenzene of 2.5 x 10^{-6} per µg/m^3 (OEHHA, 2007) . For cancer risks ranging from 1 x 10^{-4} to 1 x 10^{-6}, the corresponding exposure concentrations range from 40 to 0.40 µg/m^3. The OEHHA IUR factor was used in this cancer risk assessment, but has not been evaluated formally by EPA or CDPHE.

Appendix F. Analytical summary for risk while attending school

Table F1. Acute hazard quotients and indices for maximum concentrations of COPC and school exposure scenarios.

COPC HQs (Maximum Level With Outliers Removed)	One-Hour Exposures (SPOD Samples)	One-Hour Exposures (Resident Samples)	One-Day Exposures (SPOD Samples)	One-Day Exposures (Resident Samples)	One-Hour Acute Health Guideline Value (µg/m³)	One-Day Acute Health Guideline Value (µg/m³)	Sources
Benzene	1.06	0.02	0.37	0.01	27	29	CDPHE (2019b/c), CDPHE (2020b)
Ethylbenzene	<0.01	<0.01	<0.01	<0.01	86,000	22,000	CDPHE (2019b/c), CDPHE (2020b)
Isopropanol	NA	NA	0.01	<0.01	NA	7,000	CDPHE (2019b)
Xylene, m- and p-	0.01	<0.01	<0.01	<0.01	22,000	8,700	CDPHE (2019b/c), CDPHE (2020b)
Xylene, o-	<0.01	<0.01	<0.01	<0.01	22,000	8,700	CDPHE (2019c), CDPHE (2020b)
1,2,4 trimethylbenzene	<0.01	<0.01	<0.01	<0.01	15,000	15,000	CDPHE (2019c), TCEQ (2021)
Cyclopentane	0.01	<0.01	<0.01	<0.01	17,000	17,000	CDPHE (2019c), TCEQ (2021)
n-hexane	0.01	<0.01	<0.01	<0.01	19,000	19,000	CDPHE (2019c), CDPHE (2020b)
n-nonane	<0.01	<0.01	<0.01	<0.01	16,000	16,000	CDPHE (2019c), CDPHE (2020b)
n-pentane	<0.01	<0.01	<0.01	<0.01	200,000	200,000	CDPHE (2019c), CDPHE (2020b)
Hazard Index (HI)	**1.08**	**0.02**	**0.39**	**0.01**	NA	NA	NA-

Note:
COPC - contaminant of potential concern, HI - Hazard Index, HQ - Hazard quotient, NA - not applicable, Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection
See References section for citations

Table F2. Chronic hazard quotients and hazard index for the 95% upper confidence level of concentrations of COPC and school exposure scenarios.

COPC HQs (95% Upper Confidence Level with Outliers Removed)	Weekly All	Weekly Upwind	Weekly Downwind	Chronic Health Guideline Value (µg/m³)	Sources
Benzene	0.01	0.01	0.01	9.6	CDPHE (2019c), CDPHE (2020b)
Ethylbenzene	<0.01	<0.01	<0.01	260	CDPHE (2020b)
Isopropanol	<0.01	<0.01	<0.01	200	CDPHE (2019b)

Xylene, m- and p-	<0.01	<0.01	<0.01	100	CDPHE (2019c), CDPHE (2020b)
Xylene, o-	<0.01	<0.01	<0.01	100	CDPHE (2019c), CDPHE (2020b)
1,2,4 trimethylbenzene	<0.01	<0.01	<0.01	60	CDPHE (2019c)
Cyclopentane	<0.01	<0.01	<0.01	1,700	CDPHE (2019c)
n-hexane	<0.01	<0.01	<0.01	700	CDPHE (2019c)
n-nonane	<0.01	<0.01	<0.01	20	CDPHE (2019c), CDPHE (2020b)
n-pentane	<0.01	<0.01	<0.01	1,000	CDPHE (2019c), CDPHE (2020b)
Hazard Index (HI)	**0.01**	**0.01**	**0.02**	NA	NA

Note:
COPC – contaminant of potential concern, HI - Hazard Index, HQ - Hazard Quotient, NA - not applicable, Weekly - weekly automatic canister collection
See References section for citations

Table F3. Cancer risk estimates for the 95% upper confidence level of concentrations of contaminants of potential concern and school exposure scenarios.

COPC Excess Risk (95% Upper Confidence Level with Outliers Removed)	All Weekly Data Points	Weekly Data (Upwind of Potential Source)	Weekly Data (Downwind of Potential Source)	SPOD data (Downwind of Potential Source)	Resident data (Downwind of Potential Source)
Benzene	5.10E-08	4.80E-08	5.63E-08	1.68E-07	5.41E-08
Ethylbenzene	7.23E-09	5.69E-09	8.54E-09	3.00E-07	2.36E-07
Combined Cancer Risk	**5.83E-08**	**5.36E-08**	**6.49E-08**	**4.68E-07**	**2.90E-07**

Note:
COPC – contaminant of potential concern, Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection, Weekly - weekly automatic canister collection

Appendix G. Analytical summary for risk while at home

Table G1. Acute hazard quotients and indices for maximum concentrations of contaminants of potential concern and residential exposure scenarios.

COPC HQs (Maximum Level With Outliers Removed)	One-Hour Exposures (SPOD Samples)	One-Hour Exposures (Resident Samples)	One-Day Exposures (SPOD Samples)	One-Day Exposures (Resident Samples)	One-Hour Acute Health Guideline Value (µg/m^3)	One-Day Acute Health Guideline Value (µg/m^3)	Sources
Benzene	1.06	0.02	0.99	0.02	27	29	CDPHE (2019b/c), CDPHE (2020b)
Ethylbenzene	<0.01	<0.01	<0.01	<0.01	86,000	22,000	CDPHE (2019b/c), CDPHE (2020b)
Isopropanol	NA	NA	0.02	0.01	NA	7,000	CDPHE, 2019b
Xylene, m- and p-	0.01	<0.01	0.01	<0.01	22,000	8,700	CDPHE (2019b/c), CDPHE (2020b)
Xylene, o-	<0.01	<0.01	<0.01	<0.01	22,000	8,700	CDPHE (2019c), CDPHE (2020b)
1,2,4 trimethylbenzene	<0.01	<0.01	<0.01	<0.01	15,000	15,000	CDPHE (2019c), TCEQ (2021)
Cyclopentane	0.01	<0.01	0.01	<0.01	17,000	17,000	CDPHE (2019c), TCEQ (2021)
n-hexane	0.01	<0.01	0.01	<0.01	19,000	19,000	CDPHE (2019c), CDPHE (2020b)
n-nonane	<0.01	<0.01	<0.01	<0.01	16,000	16,000	CDPHE (2019c), CDPHE (2020b)
n-pentane	<0.01	<0.01	<0.01	<0.01	200,000	200,000	CDPHE (2019c), CDPHE (2020b)
Hazard Index (HI)	**1.08**	**0.02**	**1.04**	**0.03**	NA	NA	NA

Note:
COPC - contaminant of potential concern, HQ - Hazard quotient, HI - Hazard Index, NA - not applicable, Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection
See References section for citations

Table G2. Chronic hazard quotients and hazard index for the 95% upper confidence level of concentrations of contaminants of potential concern and residential exposure scenarios.

COPC HQs (95% Upper Confidence Level with Outliers Removed)	Weekly All	Weekly Upwind	Weekly Downwind	Chronic Health Guideline Value (µg/m^3)	Sources
Benzene	0.04	0.04	0.05	9.6	CDPHE (2019c), CDPHE (2020b)
Ethylbenzene	<0.01	<0.01	<0.01	260	CDPHE (2020b)
Isopropanol	<0.01	<0.01	0.01	200	CDPHE (2019b)

Xylene, m- and p-	0.01	0.01	0.01	100	CDPHE (2019c), CDPHE (2020b)
Xylene, o-	<0.01	<0.01	<0.01	100	CDPHE (2019c), CDPHE (2020b)
1,2,4 trimethylbenzene	<0.01	<0.01	<0.01	60	CDPHE (2019c)
Cyclopentane	<0.01	<0.01	<0.01	1,700	CDPHE (2019c)
n-hexane	<0.01	<0.01	<0.01	700	CDPHE (2019c)
n-nonane	0.01	0.01	0.01	20	CDPHE (2019c), CDPHE (2020b)
n-pentane	<0.01	<0.01	<0.01	1,000	CDPHE (2019c), CDPHE (2020b)
Hazard Index (HI)	**0.07**	**0.07**	**0.08**	NA	NA

Note:

COPC – contaminant of potential concern, HI - Hazard Index, HQ - Hazard quotient, NA - not applicable, Weekly - weekly automatic canister collection
See References section for citations

Table G3. Cancer risk estimates for the 95% upper confidence level of concentrations of contaminants of potential concern and residential exposure scenarios.

COPC Excess Risk (95% Upper Confidence Level with Outliers Removed)	All Weekly Data Points	Weekly Data (Upwind of Potential Source)	Weekly Data (Downwind of Potential Source)	SPOD data (Downwind of Potential Source)	Resident data (Downwind of Potential Source)
Benzene	1.37E-06	1.28E-06	1.51E-06	4.51E-06	1.45E-06
Ethylbenzene	1.94E-07	1.52E-07	2.28E-07	8.03E-06	6.32E-06
Combined Cancer Risk	**1.56E-06**	**1.44E-06**	**1.74E-06**	**1.25E-05**	**7.77E-06**

Note:

COPC – contaminant of potential concern, Resident - resident-initiated collection, SPOD - SPOD-triggered canister collection, Weekly - weekly automatic canister collection

Appendix H. Statistical summary comparing near-source and "background" weekly samples

Table H1. Statistical comparison of weekly near-source and "background" samples

VOC	CAS	P Value (α=0.05)	Variance Equality	Is Near-Source Data Different from Background (data averages)?
Sum of all VOCs	NA	0.91	=	No
Average of all VOCs	NA	0.92	=	No
Acetone	67-64-1	0.15	=	No
Benzene	71-43-2	0.13	=	No
Ethylbenzene	100-41-4	0.03	=	Yes (0.189, 0.135)
Isopropanol	67-63-0	<0.01	NA	Yes (1.166, 0.971)
Methyl Ethyl Ketone	78-93-3	0.46	=	No
Toluene	108-88-3	0.10	=	No
Xylene, m- + p-	108-38-3, 106-42-3	<0.01	=	Yes (0.824, 0.491)
Xylene, o-	95-47-6	<0.01	=	Yes (0.245, 0.163)
1,2,3-trimethylbenzene	526-73-8	0.37	=	No
1,2,4-trimethylbenzene	95-63-6	0.09	=	No
1,3,5-trimethylbenzene	108-67-8	0.0	=	No
1,3-diethylbenzene	141-93-5	0.48	=	No
1,4-diethylbenzene	105-05-5	0.46	=	No
1-butene	106-98-9	0.13	=	No
1-pentene	109-67-1	0.38	=	No
2,2,4-trimethylpentane	540-84-1	0.36	=	No
2,3,4-trimethylpentane	565-75-3	0.31	=	No
2,3-dimethylpentane	565-59-3	0.26	=	No
2,4-dimethylpentane	108-08-7	0.21	≠	No
2-ethyltoluene	611-14-3	0.25	=	No
2-methylheptane	592-27-8	0.96	=	No
2-methylhexane	591-76-4	0.33	=	No
3-ethyltoluene	620-14-4	0.08	=	No
3-methylheptane	589-81-1	0.29	=	No
3-methylhexane	589-34-4	0.47	=	No
4-ethyltoluene	622-96-8	0.21	=	No

Acetonitrile	75-05-8	0.51	=	No
c-2-butene	590-18-1	0.22	=	No
c-2-pentene	627-20-3	0.36	=	No
Cyclohexane	110-82-7	0.36	=	No
Cyclopentane	287-92-3	0.50	=	No
Ethane	74-84-0	0.79	=	No
Ethene	74-85-1	0.62	=	No
Ethyne	74-86-2	0.70	=	No
i-butane	75-28-5	0.71	=	No
i-pentane	78-78-4	0.26	=	No
i-propylbenzene	98-82-8	0.26	=	No
Isoprene	78-79-5	0.23	≠	No
Methane	74-82-8	0.78	=	No
Methylcyclohexane	108-87-2	0.13	≠	No
n-butane	106-97-8	0.57	=	No
n-decane	124-18-5	0.52	≠	No
n-heptane	142-82-5	0.61	=	No
n-hexane	110-54-3	0.16	=	No
n-nonane	111-84-2	0.25	≠	No
n-octane	111-65-9	0.01	=	Yes (0.412, 0.240)
n-pentane	109-66-0	0.40	=	No
n-propylbenzene	103-65-1	0.08	=	No
Propane	74-98-6	0.82	=	No
Propene (propylene)	115-07-1	0.28	=	No
Styrene	100-42-5	0.26	=	No
t-2-butene	624-64-6	0.54	=	No
t-2-pentene	646-04-8	0.18	NA	No
Tetrachloroethylene	127-18-4	0.51	=	No
Trichloroethylene	79-01-6	0.50	=	No

Note:

CAS - Chemical Abstracts Service number, VOC - Volatile organic compound, "=" - equal variance, "≠" - unequal variance, NA - not applicable

Gray shading denotes examples in which "near-source" (e.g. near Alpine) VOC data compilations are statistically different from data collected from "background" locations.