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Survey of airborne organic compounds in residential communities near a natural gas compressor station: Response to community concern

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Abstract

Introduction: Natural gas compressor stations are located throughout the country and are used to maintain gas flow and ensure continuous distribution through the pipeline network. Compressor stations emit many air contaminants including volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). While the serious health effects associated with the inhalation of elevated pollutant levels are clear, the relationship between proximity to natural gas compressor stations and residential health effects is not well understood. Community members living near a natural gas compressor station in Eastern Ohio expressed concerns regarding their air quality; therefore, the objective of this study was to assess exposure to airborne organics in residential air near the compressor station.

Methods: Our team conducted a 24-hour air sampling campaign to assess outdoor and indoor air contaminant levels at 4 homes near the Williams Salem Compressor Station in Jefferson County, Ohio. Air quality was assessed using two techniques: 1) summa canisters to quantify VOC concentrations and 2) passive air samplers to evaluate a broader panel of VOCs and SVOCs.

Results: Among the three homes situated < 2 km from the compressor station, indoor benzene levels were 2–17 times greater than the Ohio Environmental Protection Agency (EPA)

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

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indoor standard due to vapor intrusion. Multiple other VOCs, including ethylbenzene, 1,2,4-trimethylbenzene, 1,2 dichloroethane, 1,3 butadiene, chloroform, and naphthalene also exceeded state standards for indoor concentrations. Several SVOCs were also detected inside and outside participants' homes, including benzene and naphthalene derivatives.

Conclusion: Our results validate the community members' concerns and necessitate a more comprehensive epidemiological investigation into the exposures associated with natural gas compressor stations and methods to mitigate elevated exposures.

Alarming levels of VOCS were detected inside of homes. Further research is needed to determine the source of VOC exposure and potential health effects.

Keywords

Volatile organic compounds; Semi-volatile organic compounds; Indoor air quality; Passive samplers; Natural gas compressor stations

Introduction

Natural gas production and use has increased in the United States over the past decade (Administration, U.S.E.I. 2020). Natural gas is extracted through conventional and unconventional methods such as hydraulic fracturing or "fracking". Once extracted, natural gas is transported from the production site to storage facilities and consumers across the nation by an elaborate system of more than 300,000 miles of pipeline and more than 1,400 compressor stations across the country (Administration, U.S.E.I. 2020). Compressor stations, also referred to as pumping stations, are located along the natural gas pipeline network to increase pressure to maintain gas flow and ensure continuous transportation of the natural gas through the pipeline. Depending on specific factors, such as the diameter of the pipeline and topography, compressor stations are typically located every 50 to 100 miles. Compressor stations have been identified as a major source of air pollutants (nitrogen dioxide, carbon monoxide, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), formaldehyde, and particulate matter) with levels often exceeding regulated standards (Macey et al., 2014).

The health hazards of elevated VOC exposure are well documented (Lee et al., 2010; Pappas et al., 2000; Agency, U.S.E.P. 2000; Registry, A.f.T.S.a.D. 2014, Filley et al., 2004; Loh et al., 2007) with adverse health effects including headaches, nausea (Lee et al., 2010), fatigue (Norbäck et al., 2017), skin and eye irritation (Agency, U.S.E.P. 2017), respiratory issues (Pappas et al., 2000), and central nervous system damage (Filley et al., 2004). However, there is limited information about exposure to air contaminants and resulting health effects in residents living near natural gas compressor stations. One recent ecological study evaluated county-level VOC emissions data across the US and identified that higher levels of total VOCs were reported around compressor stations (Hendryx and Luo, 2020). The emissions were also associated with greater age-adjusted mortality rates (Hendryx and Luo, 2020). A study in New York identified compressor stations as posing a significant public health risk due to toxic air emissions including VOCs (Russo and Carpenter, 2019). Even at low levels of exposure, benzene, a VOC and known carcinogen, has been repeatedly linked

with increased risk of developing blood disorders including nonlymphocytic leukemia, chronic non-lymphocytic leukemia and chronic lymphocytic leukemia (Society, 2016). Other VOCs such as 1,3 butadiene and ethylbenzene are associated with adverse health outcomes including respiratory effects, eye irritation, dizziness and fatigue (Agency, U.S.E.P. 2000; Registry, A.f.T.S.a.D. 2014). In addition, exposure to SVOCs, such as polycyclic aromatic hydrocarbons (PAHs), can pose high risks to acute and chronic health effects including impaired lung function, eye irritation, nausea, DNA, kidney, lung and liver damages, and cancers (Council, 2014). Several PAHs have often been detected near fracking-related activities, including compressor stations (Council, 2014; Luek and Gonsior, 2017). For example, naphthalene is one of the probable carcinogenic PAHs emitted at compressor stations. Exposure to naphthalene can lead to adverse health effects on immune system, reproductive, brain and nervous systems (Council, 2014; Registry, A.f.T.S.a.D. 2008).

Residents of Jefferson County in Eastern Ohio reached out to our research team with concerns about a nearby natural gas compressor station, the Williams Salem compressor station. These community members reported unsettling odors inside and outside of their homes and were concerned about the health impacts of the air quality. One resident remarked that on days in which the odor was very strong they would notice symptoms such as a burning in his/their nose and throat and debilitating headaches (Haberley, 2020). Another community member described eye irritation, breathing issues, nasal and throat dryness, fatigue, and excruciating headaches (Haberley, 2020, Haberley, 2020, Haberley, 2020). Our team responded to these concerns by developing a community-academic partnership with the objective of determining the concentration of VOCs and SVOCs on these properties.

Materials and methods

Study Design:

In August 2020 our team conducted a 24-hour air sampling campaign to assess outdoor and indoor airborne organics at 4 homes near the Williams Salem Compressor Station in Jefferson County. Air quality was assessed using two techniques: 1) summa canisters to quantify VOC concentrations and 2) passive air samplers to evaluate a broader panel of VOCs and SVOCs. Both air sampling devices were hung on a shepherd’s hook outside each home by our field team, away from known emission sources (i.e., vehicles). A second set of samplers was concurrently deployed inside each home on a table in the main room. During the sampling period residents were asked to continue their routine household activities. Samplers were deployed by a member of the field team between 7:00 AM and 10:00 AM on August 5, 2020. Samplers were collected in the same order as deployed on the morning of August 6, 2020 such that the total sampling time was 24 hours at each site. All samples were collected on the same day to ensure similar weather patterns across sites. Written consent was provided by residents prior to participation Approval for this study was received by the Institutional Review Board at the University of Kentucky.

Summa Canisters:

EPA recommended methods were used to measure VOCs, methane, and formaldehyde using summa canisters. An air flow controller was attached to each canister to monitor the sampling flow over the assessment period. Flow controllers were calibrated to a primary standard prior to each deployment. All canisters were batch certified by ALS Environmental before sample collection. Collected samples were immediately transported to ALS Environmental (Cincinnati, Ohio) for analysis of 62 VOCs, formaldehyde, and methane. VOCs were analyzed by EPA Method TO-15, methane was measured following NIOSH and OSHA methods using gas chromatography, and formaldehyde concentrations were assessed by OSHA Method 1007. The detection limits are detailed in the Supplemental Information Table 1. Twenty-four-hour average concentrations were calculated for all detected gases. Individual results from the summa canister sampling were shared with each participant followed by a phone call to discuss the results and any questions that arose.

FreshAir Clips:

FreshAir clips are passive samplers developed to assess exposure to VOCs and SVOCs. The design of these samplers has been previously described (Doherty et al., 2020). Briefly, airborne pollutants were captured using thin-film of polydimethylsiloxane (PDMS) which were custom fabricated as PDMS sorbent bars. PDMS absorbs compounds with a wide range of air-octanol portioning coefficients, including a broad array of pesticides, PAHs, VOCs, polybrominated diphenyl ethers (PBDEs), and phthalates (Lin et al., 2020; Koelmel et al., 2020). PDMS sorbent bars were housed in a PTFE chamber which was mounted in a magnetic clip. In this study, each PTFE chamber contained four pre-cleaned PDMS sorbent bars. PTFE chambers were wrapped with pre-baked aluminum foil and individually stored in air-tight 60 mL glass jars. These samplers were prepared by our team at Yale University and shipped overnight to the field team on the day prior to sample collection. The shipment included samplers for deployment with participants (n=8), field blanks (n=2), and transport blanks (n=6). Immediately prior to deployment at participants' home, a member of the field team mounted the PTFE chamber in a magnetic clip. At the end of the 24-h exposure assessment period, samplers were collected by a member of the field study team. The PTFE chamber was removed from each magnetic clip, wrapped with pre-baked aluminum foil, and individually stored in air-tight glass jar. All samplers were sent via cold-chain overnight shipment back to Yale for chemical analysis. Once received, PDMS sorbent bars were removed from each PTFE chamber and placed them back to air-tight glass storage vials using stainless steel forceps. Samples were stored at −20°C prior to analysis. PDMS sorbent bars samples were analyzed using a thermal desorption unit (TDU, Gerstel, Linthicum, MD, USA) coupled with a Q-Exactive Orbitrap mass spectrometer (Thermo-Fisher, Waltham, MA, USA). During analysis, thermally extracted analytes were first cryo-focused, then transferred to the GC column (TG-5SILMS, 20m x 0.25mm x 0.25 μm). Full scan electron ionization (EI) mass spectra (m/z 53.4 – 800) was recorded at an acquisition rate of 4Hz, at 60,000 resolution. The detailed method has been previously described (Koelmel et al., 2020). For this study, QCs and blanks (laboratory, field, and transport) were analyzed every 5 samples. Raw mass spectral data were analyzed using TraceFinder 4.1 (Thermo). A seven-point calibration curve (0 to 1000 pg/μL) was developed for each compound, then applied for quantification for a total of 71 compounds. All coefficients of determination (R^2)

were greater than 0.95. Peak integration was checked manually prior to data export. After chro-matographic peak-picking, blank feature filtering (BFF) was performed using field and transport blanks to remove compounds with high levels of background contaminations[35]. To compare indoor and outdoor airborne contaminant levels detected using the FreshAir clips, we conducted a fold change analysis using the mean concentration measured for each compound.

Questionnaire:

Each participant completed a brief questionnaire about their home characteristics during the sampling period, such as the use of tobacco inside the home, the operation of an air conditioner, propane heater and/or gas stove, and windows open or closed. Additionally, participants indicated if any products which emit odors/aerosols were used near the sampling devices such as air fresheners, candles, hair spray, perfume, paint, markers, disinfectants, adhesives, caulks, photographic solutions, kerosene, gasoline, fuel oil, farming equipment and/or lawn mowers.

Results

Three of the homes (Homes A-C) were within 2 km of the compressor station and the fourth home was approximately 16 km away (Home D) (Table 1). All homes were located northeast of the Williams Salem Compressor Station. During the sampling period the temperature ranged from 62°F to 82°F, the average wind speed was approximately 6 miles per hour and the wind direction was northwest. This data was captured by the Weather Forecast Office (WFO) located in Wheeling, West Virginia, approximately 30 miles from the participants' homes. Homes A – C were built between the 1930s and the 1960s. Home D is newer and was built in the 2000s. Home B was the only site to report that the windows were open during the sampling timeframe. A household member at Home C smoked inside during the sampling period. Numerous VOCs (n 25) were detected in Homes A, C and D using the summa canisters (Table 2). Seven VOCs were detected at levels that exceeded the state EPA indoor air standard due to vapor intrusion (Ohio EPA, 2021). Indoor benzene levels at Homes A, C, and D were 2 to 17 times greater than the Ohio EPA indoor standard (3.1 $\mu g/m^3$) (Ohio EPA, 2021); a maximum concentration of 55.2 $\mu g/m^3$ was measured at Home A. At Home A, indoor levels of 1,2,4- trimethylbenzene were 13 times greater than the state standard and levels of ethylbenzene were 5 times higher than the standard. Additionally, levels of chloroform and naphthalene were elevated (2.64 $\mu g/m^3$ and 2.20 $\mu g/m^3$, respectively) inside Home A. At Home C, the indoor levels of 1,3 butadiene and 1,2 dichloroethane both exceeded the indoor standards with concentrations of 7.50 $\mu g/m^3$ and 2.4 $\mu g/m^3$, respectively. VOCs, as measured using the summa canisters, were not detected at any of the outdoor sampling locations.

Seventeen airborne contaminants were detected using the FreshAir Clip (Fig. 1A) and included a nitroaromatic, isophorone, a haloether, seven PAHs, a phthalate, a chlorinated hydrocarbon, three organo-chlorine pesticides, a pyrethroid, and an organophosphate ester flame retardant. Like the summa canisters, indoor exposure levels collected with the FreshAir Clip were increased compared to outdoor samples. However, unlike the summa

canisters with which VOCs were below above detection limits outdoors (Table S1), quantifiable chemical exposures were measured outdoors using the FreshAir clips. Using these passive air samplers, similar profiles of airborne contaminants were measured inside and outside each home, including PAHs and nitro-aromatics (Fig. 1B). Indoor exposures were dominated by nitrobenzene, 2-methylnaphthalene, bis(2-chloro-1-methylethyl) ether, 2,4-dinitrotoluene, diethyl phthalate, and triphenyl phosphate (Fig. 1C). Four compounds were found to have significantly elevated levels outdoors (all PAHs) compared to indoor samples across all homes (Fig. 1C).

It is important to note that during this exposure assessment we asked residents to continue their typical routines. At Home B, windows were kept open for the 24-hour sampling period. Despite being less than 2 km from the compressor station, indoor levels of all VOCs evaluated using summa canisters were below detection limits (Table 2). Indoor concentrations of airborne contaminants measured with the FreshAir Clips at Home B were also lower than other homes tested (Fig. 1B).

Discussion

In our study, we detected 25 VOCs and 17 SVOCs inside the homes located near the Williams Salem Compressor Station in Jefferson County, Ohio. Of the VOCs detected, indoor air levels of benzene, 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,3-butadiene, chloroform, ethylbenzene, and naphthalene were particularly concerning, exceeding the state indoor standard. Detected SVOCs included benzene and naphthalene derivatives. Exposure to elevated concentrations of VOCs is associated with the symptoms reported by the community members, such as headaches, fatigue, respiratory issues, and nasal irritation (Pappas et al., 2000; Norbäck et al., 2017; Agency, U.S.E.P., 2017). Long-term exposure to the measured SVOCs is unclear. Furthermore, previous research has described associations among indoor exposure to VOCs at concentrations, comparable to those detected in our study, and health outcomes (Norback et al., 2017; Wickliffe et al., 2021).

According to the Agency of Toxic Substance and Disease Registry (ATSDR), benzene, toluene, ethylbenzene, and xylene (BTEX) are frequently emitted from natural gas compressor stations (Services, U.S.D.o.H.a.H., 2016). We observed levels of 1,2,4-trimethylbenzene and benzene that were more than ten times greater than the standard. Our results align with a previous exploratory study in New York which similarly described high levels of benzene, an established carcinogen (Society, 2016), near fracking activity and compressor stations (Macey et al., 2014). Low levels of ambient benzene exposure have been associated with hematologic malignancies such as T-cell lymphoma, follicular lymphoma, and myeloid dysplastic syndromes (Teras et al., 2019). Exposure to ambient benzene at levels similar to what was observed in our study have been associated with congenital disorders such as spina bifida in the offspring of exposed mothers (Lupo et al., 2010). There is no known threshold for benzene related health effects (Organization, W.H., 2010); therefore, reducing benzene levels to as low as possible is optimal for human health.

A study of compressor stations in New York reported outdoor air emissions of many of the same chemicals that were detected in our study, including 1,3 butadiene and naphthalene

(Russo and Carpenter, 2019). Acute inhalation exposure to 1,3-butadiene can lead to symptoms such as nasal and eye irritation, fatigue, headaches, and vertigo (Organization, W.H., 2012). Chronic exposure to the carcinogen has been linked with cardiovascular effects (Penn and Snyder, 2007), leukemia (Macaluso et al., 2021), and several other cancers (Organization, W.H. 2012). According to the US EPA, naphthalene has been classified as a possible human carcinogen. Health effects associated with exposure include cataracts, retinal damage, headache, nausea, gastrointestinal issues, and fatigue (US EPA 2020). Using county-level data, a recent study described associations between mortality rates and VOC emissions from compressor stations (Hendryx and Luo, 2020). While it is known that compressor stations emit VOCs and the literature is clear on the serious dangers associated with the inhalation of elevated VOC levels, the emission profiles of SVOCs and the human health impacts associated with these exposures from compressor stations is limited. In addition to environmental measures, further examination of the individual health impacts of exposure to these emissions would be insightful.

While outdoor contaminant levels were found using the passive air sampling technique, detected outdoor levels were lower compared to the concentrations measured indoors, even in the house where windows were kept open during assessment period. Following a similar trend, the summa canisters did not detect VOCs outside; VOC concentrations were only detected when sampling indoors. While more comprehensive sampling is necessary to determine the pathway of exposure, we hypothesize that the elevated indoor contaminant levels may be due to vapor intrusion, because measurements from assessed homes constantly showed elevated indoor levels of commonly found petroleum-related vapor intrusion contaminants (i.e., benzene) regardless of the age of buildings, and personal activities conducted during sampling. Furthermore, elevated levels indoors may be attributable to the poor ventilation. According to American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 62.2 (The American Society of Heating, R.a.A.-C.E., 2020), residential buildings typically receive 0.35 air changes per hour, which may result in accumulation of outdoor pollutants in the indoor space (Agency, U.S.E.P., 2020). To further explore this hypothesis, indoor air sampling should be conducted at varying levels throughout the home and ground water, soil, and/or sub-slab vapor data should be collected. Toluene/benzene (T/B) ratios have bene established to represent vehicle emissions. The indoor air T/B ratio at home D, located the furthest from the compressor station, was approximately 3:1 which may indicate vehicular emission as the source of exposure (Miller et al., 2011). More data is needed to investigate this pathway of exposure. As people spend most of their time inside (Owen et al., 2010), indoor air quality is a critical aspect of public health. The undetectable or near undetectable indoor levels of VOCs and SVOCs in Home B may be due to the open windows during the sampling period. This finding demonstrates the potential effectiveness of enhanced ventilation in reducing exposure (The American Society of Heating, R.a. A.-C.E., 2020, Agency, U.S.E.P., 2020, Godish and Spengler, 1996). Opening windows is feasible in mild to warm weather; however, extreme temperatures require an alternate solution to improve indoor air quality.

Despite compliance with EPA regulations (Haberley, 2020), our study detected elevated levels of airborne organics homes near the Williams Salem Compressor Station. Annual emission inventories assume a constant release of emission; however, monitoring studies

have demonstrated that emissions are episodic (Brown et al., 2015), released from scheduled or accidental “blowdowns”. These events occur when there is a buildup of pressure within the compressor and the gas is vented or flared directly into the air to depressurize and prevent a potential explosion. Since air emissions from compressor stations release transient high concentration plumes that are not captured by annual average concentration, future studies should conduct campaigns that allow for more comprehensive characterization of emissions.

Due to the rapid rise of natural gas and fracking technology coupled with the lack of transparency involved in the processes, many questions surround the potential public health impacts (Adgate et al., 2014, Fisher et al., 2018). Previous research demonstrates that residents living near fracking operations are more likely to experience stress and depression (Casey et al., 2018). Specifically, in Jefferson County, community members have also expressed concern surrounding their quality of life (Haberley, 2020). Future research should explore the impact of compressor stations on a variety of health outcomes including psychosocial factors.

In this study, the community members reported detecting odors and experiencing health effects since the addition of the nearby Williams Salem compressor station. We did not collect source data close to the compressor station since our exploratory study was designed to address the residents’ concerns by measuring VOC/SVOC concentrations at their homes. While many of the chemicals that we detected indoors naturally occur in petroleum and are associated with natural gas production, there are additional sources of indoor VOC/SVOC exposure such as paints, cleaners, furniture polish, detergents, pesticides, solvents, and tobacco smoke (Agency, U.S.E.P., 2017). To account for these potential exposures, we administered a questionnaire to each resident inquiring about the use of VOC/SVOC emitting products during the sampling timeframe. Future research would benefit from having a trained environmental technician inspect each home for additional sources of VOC/SVOC emissions. While this study did not capture source data and therefore cannot link the high levels of indoor VOC/SVOCs to the compressor station, the results validate the community members’ concerns and call for a more extensive epidemiological investigation. Additionally, while our study was prompted by antidotal reports of health effects, we did not capture health symptoms in this study. Our findings highlight the need for future epidemiologic research to thoroughly investigate these claims. Many previous studies have utilized aggregate exposure data (Russo and Carpenter, 2019, Macey et al., 2014, Hendryx and Luo, 2020, Koehler et al., 2018), limiting the ability to characterize specific individual-level exposures stemming from natural gas compressor stations. Future research should aim to fill this research gap by directly quantifying contaminant exposures at individual households. In this study, our comprehensive sampling methods, the summa canister and the passive Fresh Air sampler, enabled us to detect a broader range of airborne contaminants to characterize the range of emissions from compressor stations.

Natural gas activity is rapidly expanding, with more than 1,400 compressor stations across the US. Our study provides critical information not only to the residents but also to scientists, industry, and policy makers. Future research is needed to confirm the source of indoor air pollution. The growing energy demand and vastly expanding natural gas

infrastructure will continue to increase the number of homes located near compressor stations. Therefore, understanding the public health impacts associated with compressor stations needs to be a research priority.

Conclusions

An exploratory 24-hour air sampling campaign identified concerning levels of VOCs and SVOCs inside the homes of residents living near a natural gas compressor station. The results validate the community members' concerns and necessitate a more comprehensive epidemiological investigation into the exposures associated with natural gas compressor stations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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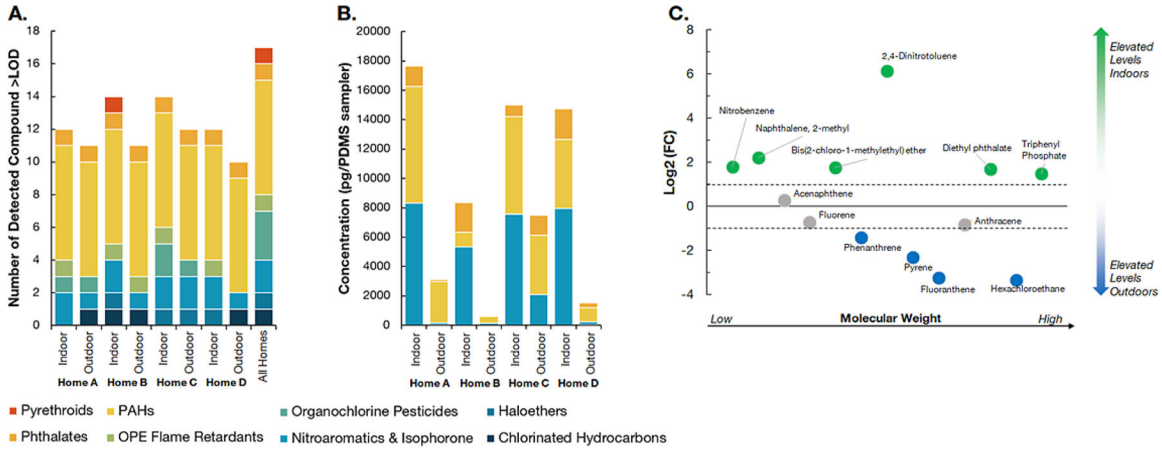

Fig. 1.

A) Number of chemicals detected by each FreshAir Clip sampler deployed at the four homes placed indoors and outdoors. B) Concentration of chemicals detected at the four study homes, indoors and outdoors. C) Comparison of indoor and outdoor exposures (fold change analysis, cut off = 2) using the mean concentrations across all sites.

Table 1

Characteristics of the homes included in the study.

Characteristic	Home A	Home B	Home C	Home D
Direction from the compressor station	NE	ENE	NNE	ENE
Distance from the Compressor station (km)	1.2	0.8	1.7	16.7
During the sampling period were the windows closed?	Yes	No	Yes	Yes
During the sampling period was the air conditioning on?	Yes	Yes	Yes	Yes
During the sampling period did anyone smoke in the home?	No	No	Yes	No
During the sampling period was a gas stove operated?	No	No	No	No
During the sampling period was a propane heater in operation?	No	No	No	No

Table 2

Detected VOC concentrations in 24-hour indoor air samples (μg/m^3).

Chemical	Home A	Home B	Home C	Home D	Ohio EPA Indoor Standard due to Vapor Intrusion
1,2,4-Trimethylbenzene	**99.2** *	ND	ND	2.7	7.3
1,2-Dichloroethane	ND	ND	**2.47** *	ND	0.94
1,3,5-Trimethylbenzene	30	ND	ND	ND	No standard
1,3-Butadiene	ND	ND	**7.50** *	ND	0.81
2-Butanone	ND	ND	7.73	ND	5200
2-Propanol	15.1	17.4	37.8	21	No standard
4-Ethyltoluene	18.7	ND	ND	ND	
4-Methyl-2-pentanone	ND	ND	ND	4.55	3100
Acetone	219	14.5	180	39.1	32000
Benzene	**55.2** *	ND	**7.16** *	**4.5** *	3.1
Chloroform	**2.64** *	ND	ND	ND	1.1
Chloromethane	ND	ND	9.37	ND	94
Cumene	5.16	ND	ND	ND	420
Cyclohexane	40.6	ND	ND	ND	6300
Dichlorodifluoromethane	ND	3.31	ND	2.67	No standard
Ethylbenzene	**54.3** *	ND	2.61	2.21	9.7
Heptane	74.8	ND	ND	ND	No standard
Hexane	195	ND	ND	2.93	730
m,p-Xylene	273	ND	9.42	9.68	1000
Naphthalene	**2.20** *	ND	ND	ND	0.72
o-Xylene	93.4	ND	ND	2.87	1000
Styrene	ND	ND	3.15	ND	1000
Toluene	376	ND	18.7	13.9	5200
Trichlorofluoromethane	35.2	3.03	2.87	ND	730
Formaldehyde (μg/sample)	ND	0.26	0.54	0.43	No Standard

* Indicates that the VOC value is greater than the Ohio EPA indoor standard; ND = Not Detected.