CU Boulder Indoor Air Quality Study

Personalized Final Report Sample

Executive Summary:

The purpose of this study is to analyze and inform you of your indoor air quality over a four-week testing period. Two sensors assessed the indoor air pollutant concentrations, a portable monitor tracked the indoor air quality throughout your daily activities while the stationary sensor assessed the air quality within your home. The following pollutant concentrations are measured by the sensors: fine particulate matter ($PM_{2.5}$), total volatile organic compounds (TVOCs), nitrogen oxides (NOx), and carbon dioxide (CO_2)**.**

During this study we observed that your nitrogen oxide, carbon dioxide, and particulate matter levels were found to be at acceptable levels according to WHO standards, however, TVOC levels in your home as well as your personal space exceeded the guideline limits few times during the study. Pollution exposure mitigation and recommendation are contained within this report.

Introduction

Thank you so much for participating in our study!

In this document, you will find information on the air quality of your personal environment, including data from both your home and your personal air quality sensors. In each section, you will find time series plots showing the daily average of a given pollutant and how your data compare to either World Health Organization (WHO) or The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) guidelines for that pollutant.

Additionally, we have included some personal mitigation strategies for each pollutant based on the measured concentration and certain information you provided us in your daily log. Further details on each pollutant can be found in the documents we provided you over email during the second half of the study, which includes background information, common sources, health effects, and general mitigation strategies.

We greatly appreciate your participation and hope that you will find the enclosed information helpful in understanding and improving the air quality of your surroundings.

1. Results and Personalized Recommendations

Calendar Plot- Daily Average							
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1:		7-Nov	8-Nov	9-Nov	10-Nov	11-Nov	12-Nov
PM 2.5 (µg/m³)		1.3	0.1	2.6	1.2	1.7	0.3
TVOC (ppb)		90	92	308	163	104	142
Week 2:	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov	18-Nov	19-Nov
PM 2.5 (µg/m³)	1.3	0.8	0.6	1.4	1.8	1.6	0.3
TVOC (ppb)	56	125	130	123	130	141	148
Week 3:	20-Nov	21-Nov	22-Nov	23-Nov	24-Nov	25-Nov	26-Nov
PM 2.5 (µg/m³)	0.5	1.2	0.2	5.2	2.4	4.8	2.0
TVOC (ppb)	186	90	101	220	103	183	140
Week 4:	27-Nov	28-Nov	29-Nov	30-Nov	1-Dec	2-Dec	3-Dec
PM 2.5 (µg/m³)	32.0	2.1	2.5	1.3	1.7	1.2	2.4
TVOC (ppb)	159	109	122	112	108	197	561
Week 4:	4-Dec	5-Dec					
PM 2.5 (µg/m³)	1.1	0.6					
TVOC (ppb)	159	51					

PM color key
Your Daily average is below the WHO **annual** average concentration guideline
Your Daily average is between WHO annual and 24-hour average concentration guideline
Your Daily average exceeds WHO 24-hour concentration guideline

VOC color key
Your Daily average is below the WHO target concentration
Your Daily average is above the WHO target concentration and is only advisable for short periods
Your Daily Average exceeds WHO TVOC level

Table 1. Calendar plot of daily average concentrations for $PM_{2.5}$ and TVOCs colored to indicate compliance with WHO guidelines.

In summary, the daily averaged $PM_{2.5}$ and TVOC levels inside your home were below the WHO guidelines except for two days when it exceeded the WHO limit. We encourage you to try to recall any particular activity that you may have partaken on these two days (November 27th and December 3rd) that may have caused these high levels and reach out to us so that we can guide you on how to reduce the exposure especially if you are planning to do that activity regularly over the current weeks.

In the next section, we will provide a daily time series for all the pollutants that were measured by both the indoor monitor (AirGradient) and the personal portable monitor (Atmotube) to compare these trends with the guideline limits and associated mitigation measures if needed.

Total Volatile Organic Compounds (TVOCs)

Total volatile organic compounds are a common class of pollutants emitted into the air as gases from certain solids or liquids, including many personal care products, cleaning supplies, automotive products, and other everyday products commonly found in homes. These compounds have many adverse health effects, including eye, nose and throat irritation, headaches, and fatigue.

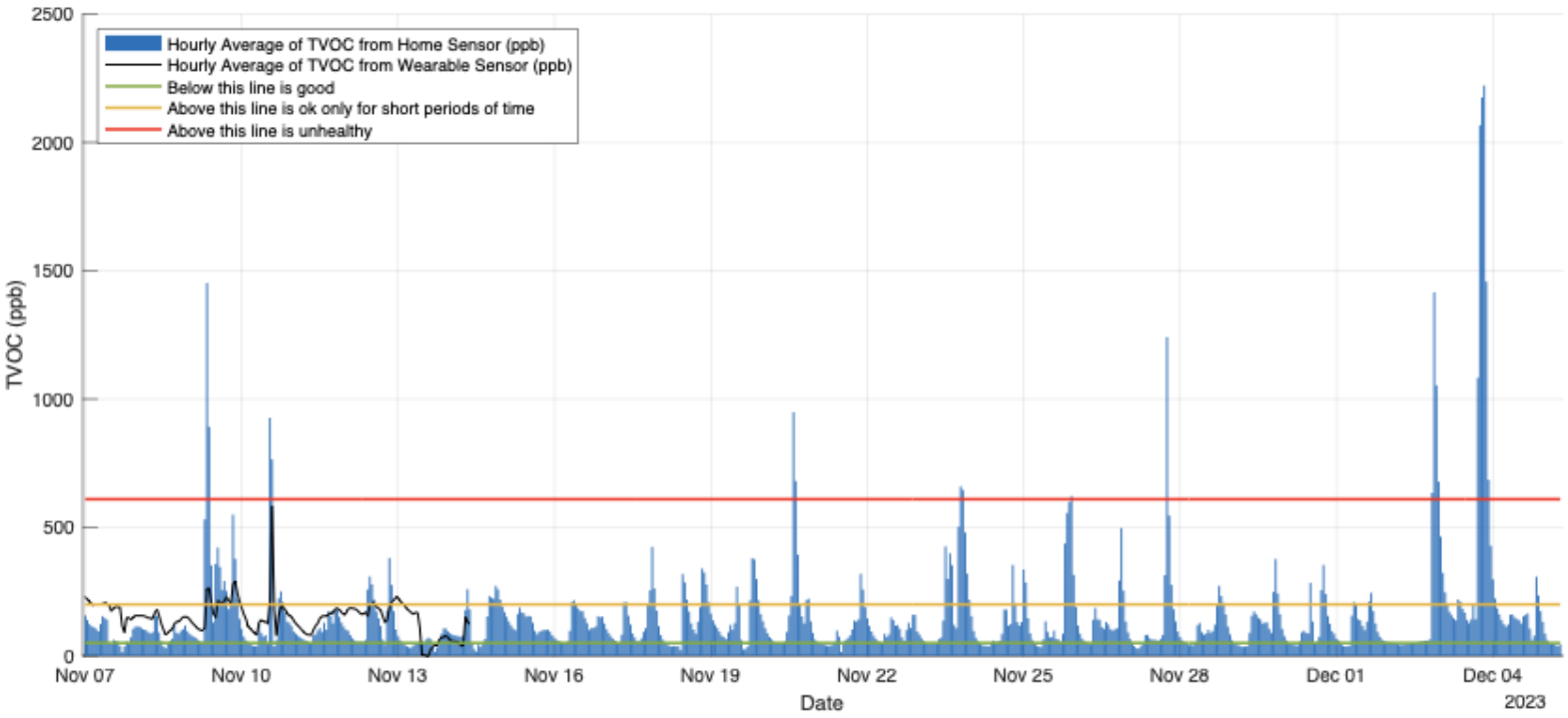

Figure 1: Time series plot of daily average exposure to volatile organic compounds from AirGradient and Atmotube Sensor Data.

The WHO Europe guidelines for indoor air quality considers any level of TVOC over 610 ppb for any amount of time as dangerous and a concentration of 200-610 ppb is permitted for temporary exposure**. The U.S. Environmental Protection Agency (EPA) suggests keeping TVOC levels as low as possible, typically below 500 ppb for good indoor air quality.** As shown above in Figure 2, your daily average exposure to total volatile organic compounds do not exceed the 610 ppb WHO guidelines on a 24-hour basis. However, your measured levels exceed the WHO 610 ppb guidelines 20 different times on an hourly basis. **Concentrations were also consistently in the temporarily acceptable 200-610 ppb range, which may be harmful**. Additionally, from Table 1 you can see most of your TVOC concentrations are considered acceptable for only short periods of time by the WHO guidelines. We recommend the below actions to reduce your exposure to elevated concentrations of TVOCs.

- **Implementing usage of air cleaners with activated carbon filters**.
- Reduce use of scented personal care products and use them in well-ventilated areas if necessary.
- Increasing ventilation of outdoor air by opening windows and doors if the outdoor AQI levels are low (You can use airnow.gov or the weather app in your phone to check the outdoor air quality).

Particulate Matter ($PM_{2.5}$)

Particulate matter is another common pollutant with several sources related to combustion activity whether occurring indoors or outdoors (indoor cooking, candle burning, outdoor emissions from traffic and industrial activity). They are small particles less than 2.5 micrometers in diameter (over 20 times smaller than the diameter of a human hair) and can cause adverse health effects as they are absorbed into your bloodstream through your lung barrier once breathed in.

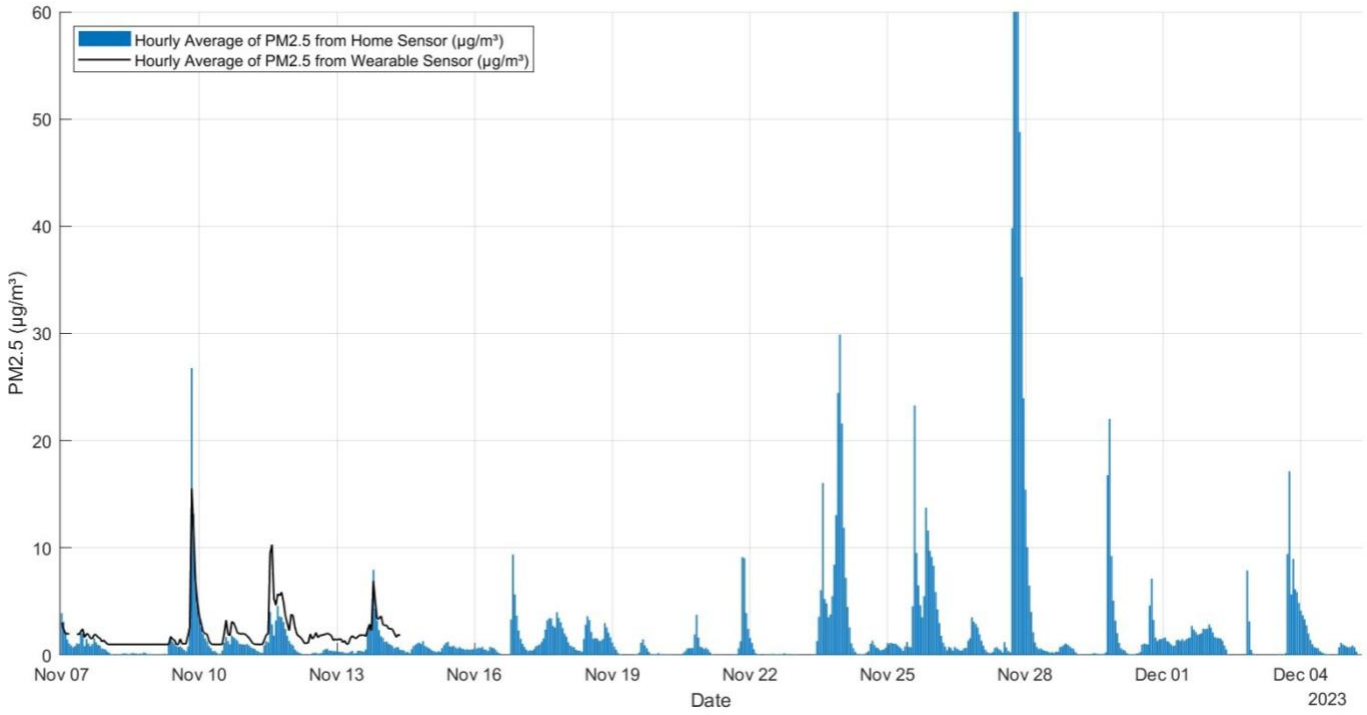

Figure 2: Time series plot of daily average exposure to particulate matter from AirGradient and Atmotube sensors.

Currently there is no guideline for $PM_{2.5}$ for less than 24 hours but we wanted to show you the hourly average in both your home as well as your personal space over the course of month. The idea behind this figure is to isolate any particular activity that could be attributed to these high levels of $PM_{2.5}$ and to guide you on how to manage your exposure from that activity if you will be doing that activity regularly over a long period of time.

For example, as per Table 1 above, your $PM_{2.5}$ levels generally range from 2.6 µg/m^3, which are considered acceptable concentration levels per the WHO guidelines, but one event occurred where your concentration spiked to 32.0 µg/m^3, which is outside of the 24-hour WHO guideline for $PM_{2.5}$. We encourage you to reach out to us if you can recall any particular event/activity that may have caused these high levels

For future reference, some actions you can continue to take part in to keep your home at these acceptable levels include:

- Monitor the outdoor air quality and keep windows closed to prevent outdoor pollutants from entering the home when outdoor air quality is bad.
- **Use an indoor air purifier if you are cooking in an enclosed kitchen space without the option of using the range hood that vents outdoors or keeping kitchen windows open** (Microwave range hoods are only meant to effectively trap grease particles and vent back to the kitchen space, so they won't be helpful to reduce PM levels associated with cooking).
    - Here is an EPA guide regarding how to use air cleaners indoors Guide to Air Cleaners in the Home (epa.gov).
    - Resources on how to build your own Do it yourself air portable air cleaner: CleanAirCrew, SJEQ-D
    - Please note that some commercial air cleaners use an electronic charge (ionizer) to eliminate PM. **It is important to note ionizers do produce ozone as a secondary byproduct that becomes problematic especially if you live in areas that already have high levels of ozone outdoors**.

Carbon Dioxide (CO2)

Carbon dioxide is the fourth most common gas in the atmosphere and primarily released indoors through the natural human breathing process and poorly vented combustion appliances. Carbon dioxide levels indoors can be used as an indicator of poor ventilation and certain levels of CO2 have been known to result in symptoms such as headaches, dizziness, fatigue, and nausea.

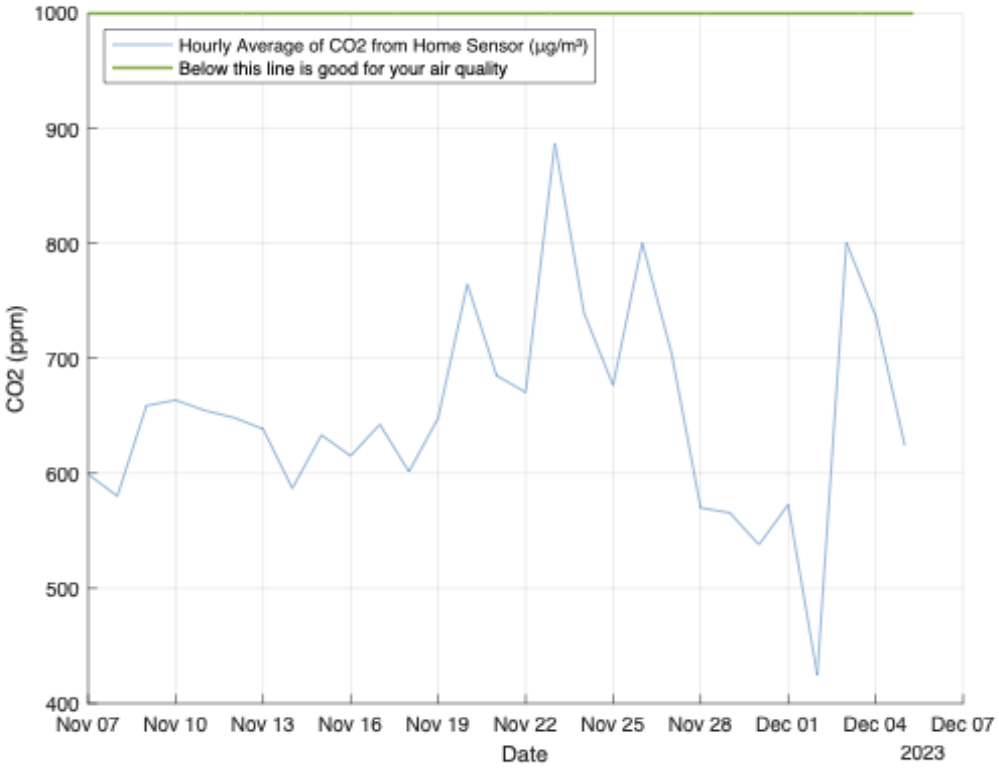

Figure 3: Time series plot of daily averaged carbon dioxide measurements.

The WHO does not give standards on CO_2 concentrations, but the American Society of Heating, Refrigeration and Air Conditioning Engineers recommend levels between 400-1000 parts per million (ppm) to maintain good air quality. Your daily average of CO_2 remained below the 1000 ppm recommendation over the entire course of the study, so CO_2 is not a concern in your home environment.

Nitrogen Oxides (NOx)

Nitrogen oxides are highly reactive gasses that form through the combustion process. Nitrogen oxides participate in the chemical reaction that creates ozone, a common outdoor air pollutant. Additionally, it can have health effects that include coughing, lung inflammation, asthma attacks, and in long-term exposure scenarios, lung cancer and respiratory infections.

The AirGradient sensor outputs an index of NOx instead of a concentration of NOx due to the sensitivity of the sensor to oxidizing gasses. The NOx index describes the current NOx condition in a room relative to the sensor's recent history and gives feedback, or a signal when it detects a difference in NOx levels. The index was built to help distinguish different events and user activities that may produce NOx. On the NOx index scale, the offset value is one, meaning if there is a detection of NOx compounds compared to the average level, the index will become greater than one to reflect this increase in NOx.

Your NOx index was one throughout the study, indicating there were no significant NOx gas concentration changes present in your home environment during the study.

However, if there is a continuous usage of any gas appliance on your home, NOx levels could still be consistently high throughout the day so please keep that in mind while interpretating these results.

Conclusion

Again, thank you so much for your time and effort over the course of this study. We hope that the information provided above has helped you gain a better understanding of the air quality of your surroundings and some methods for improvement. Lastly, please continue to reference the provided educational materials in prior emails regarding indoor air pollutants which contain detailed sources and mitigation techniques.

Appendix

Testing Methods

You were provided with two sensors that measured the indoor concentrations of pollutants and the environmental conditions of your surroundings. The Atmotube measured fine particulate matter ($PM_{2.5}$), total volatile organic compounds (TVOCs), humidity, and temperature. **Total volatile organic compounds (TVOC) are a similar term to volatile organic compounds and refer to the sum of all volatile organic compounds found in a given area.** They represent chemicals that are classified as VOCs but are used to simplify reporting from sensors. This device remained with you throughout the duration of the day which allowed for a quantitative record of the aforementioned pollutants and conditions during varying indoor environments.

In addition to the personal Atmotube monitor, you might have submitted to us an activity log to track your general activity throughout the day. This log helped highlight the environmental conditions specific to your location and identify trends among your daily routines. The AirGradient indoor air quality monitor measured the concentrations of NOx, $PM_{2.5}$, TVOC, CO_2, as well as the humidity and temperature. This device remained stationary within your home for the duration of the study.

Two weeks into the study you were provided with a set of mitigation tactics to implement into your everyday life to limit the pollutant concentrations. The intention of the mitigation techniques was to reduce exposure to indoor pollutants. Depending on the mitigation measures you chose to implement will help determine the trends noticed between the first half of the study and the second half.

DISCLAIMER: For the pollutant data, please note there is no standard for indoor air quality for personal residences; the data was compared to an outdoor standard instead. According to WHO Europe's indoor air quality guidelines, TVOC levels from 200 to 610 ppb are acceptable **for temporary exposure**. Anything over 610 ppm is considered a dangerous TVOC level. Current WHO guidelines state that annual average concentrations of $PM_{2.5}$ should not exceed 5 $\mu g/m^3$, while **24-hour average concentrations exposure** should not exceed 15 $\mu g/m^3$.

Additionally, the mitigations and recommendations should not be confused as health and medical advice. If you have any personal concerns regarding your health, please consult your medical practitioner for further consultation.

Please also note that although the data monitoring equipment provided was purchased new at the beginning of the study, due to the inherent limitations of these citizen science-based monitors, the data may not be completely accurate when compared to expensive research grade instruments. Therefore, these plots should be used only to make informed decisions regarding any personal mitigation strategies that could help you reduce your personal exposure to a given pollutant over the long run.

References

AirGradient output interpretations: Sensirion's NOx Index
ASHRAE: ASHRAE Position Document on Carbon Dioxide
WHO guidelines: WHO global air quality guidelines
A Comprehensive Guide on Volatile Organic Compounds (VOCs)
TVOC guidelines for Indoor Air Quality