Measuring indoor air quality across Austin, TX with consumer-grade sensors

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SUMMARY
We use consumer-grade sensors to measure four common indoor air pollutants and compare measurements between student-occupied dwellings and those from a vulnerable community. Results indicate that volatile organic compounds and particulate matter are higher in student homes while carbon monoxide and carbon dioxide concentrations are lower. These findings highlight the need for increased ventilation in vulnerable communities and that proximity to outdoor sources is less important than indoor sources when characterizing indoor air quality.

KEYWORDS
Low-Cost Sensors, Field Study

1 INTRODUCTION
Proper indoor air quality (IAQ) is paramount to the health of building occupants and is influenced by indoor and nearby outdoor sources in addition to building characteristics such as ventilation rate and age (Jones, 1999). IAQ in low-income, vulnerable communities is typically worse compared to more affluent regions primarily due to the proximity to significant outdoor pollutant sources such as heavily trafficked roadways, dumping sites, and industrial facilities (Adamkiewicz et al., 2012). In this study we compare the IAQ of student-occupied dwellings in central Austin, TX and measured in vulnerable communities in east Austin.

2 MATERIALS AND METHODS
We created the Building EnVironment and Occupancy (BEVO) Beacon which leverages multiple low-cost, consumer-grade sensors to measure four components of IAQ: carbon dioxide (CO_2), particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$), total volatile organic compounds (TVOCs), and carbon monoxide (CO). Fourteen of these devices were placed in students' bedrooms in central Austin during the summer of 2020 and allowed to operate for 11 weeks. Upon return, devices were post-calibrated in laboratory settings to correct readings with univariate, linear least-squares regression models unique to each sensor on each device. A subset of four of these devices were then deployed to living room spaces of families living in a vulnerable community in east Austin.

3 RESULTS
Figure 1 illustrates the distributions of IAQ measurements from each study. TVOC concentrations are typically higher in student dwellings while CO and CO_2 measurements are both higher for families in vulnerable communities. $PM_{2.5}$ concentrations are typically higher for the student population, but more instances of extreme measurements are registered for families. Table 1 further summarizes the IAQ measurements from both studies and includes p-values from Mood's Test to determine if the medians between distributions are equal. We opt for this test and to report percentiles since IAQ distributions are non-Gaussian.

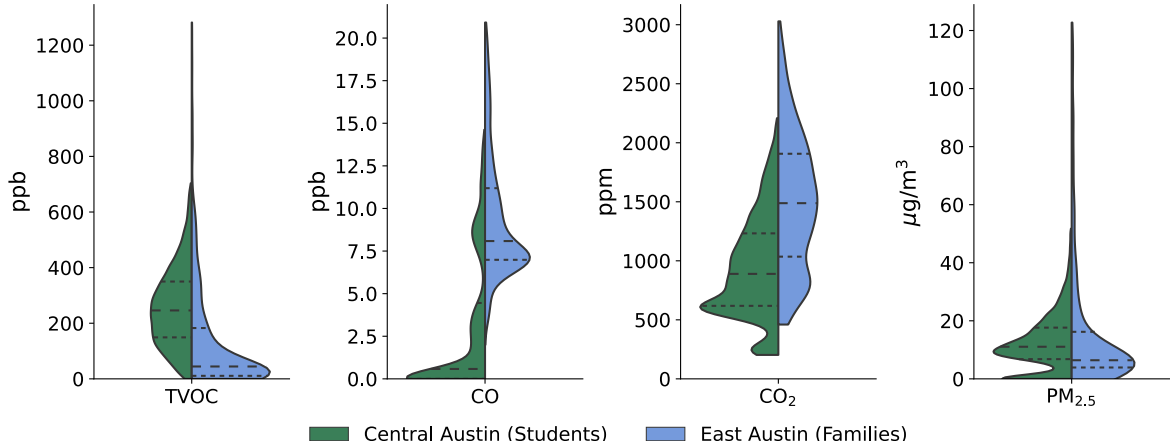

Figure 1. Comparison of hourly measured IAQ parameters between the student population in central Austin and the families living in east Austin. Dashed lines represent 25th, 50th, and 75th percentiles.

Table 1. Summary statistics of hourly IAQ measurements in central Austin versus east Austin

IAQ	Central Austin – Students				East Austin – Families				Mood's Test
Parameter	n	25th	Median	75th	n	25th	Median	75th	p-value
TVOC	16598	149.2	246.1	350.0	1846	10.9	44.5	182.7	**0.00**
CO	16225	0.0	0.6	4.5	1837	7.0	8.1	11.2	**0.00**
CO_2	15927	618.5	889.3	1232.6	1900	1035.2	1488.3	1906.9	**0.00**
$PM_{2.5}$	17268	6.8	11.1	17.6	1843	3.9	6.4	16.2	**0.00**

4 DISCUSSION

Interestingly, the TVOC and $PM_{2.5}$ concentrations are lower in east Austin despite the community's proximity to outdoor sources for both these pollutants. The difference in median CO concentrations between studies is significant and most likely a result of families who cook larger meals more frequently with gas-powered appliances. CO_2 concentrations are also markedly different because dwellings in east Austin are more densely occupied. Still these measurements indicate a need for increased ventilation and perhaps indicate other pollutants that we did not monitor are also elevated in east Austin relative to central Austin.

5 CONCLUSIONS

This study highlights the use of consumer-grade sensors for monitoring components of IAQ while also underscoring the need for vulnerable communities to be properly informed and protected from adverse effects associated with poor IAQ. Results also indicate that indoor sources are more relevant when characterizing IAQ than a home's proximity to outdoor sources.

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6 REFERENCES

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