Determining Airflows and VOC Source Strengths for an Occupied School

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BACKGROUND

- 15% of schools are located within 250 meters of a freeway.[1]
- Students are exposed to air pollutants with indoor and outdoor sources at near-roadway schools.
- We conducted a field study at Harriet Tubman Middle School (HTMS) in Portland, OR, USA.[2]
  - Adjacent to Interstate 5
  - Renovated to include advanced air cleaning systems (*Figure 1*)

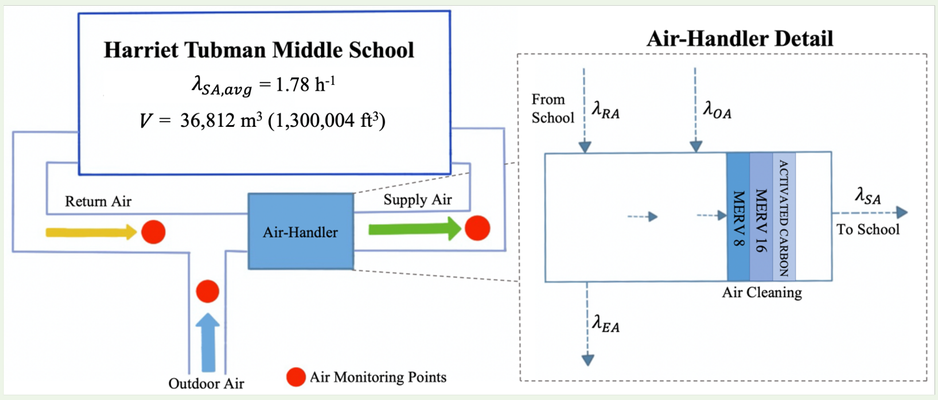

Figure 1: *Schematic of HTMS and renovated air handler*

METHODS

- We broadly characterized indoor and site outdoor air quality at HTMS.
  - Measurements made in return, outdoor, and supply air flows in AHU
  - VOCs measured using a PTR-ToF-MS instrument in the air handler
- We estimated site airflows through analysis of CO_2 trends.
  - Supply air flowrate backed out using CO_2 signals (*Figure 2*):

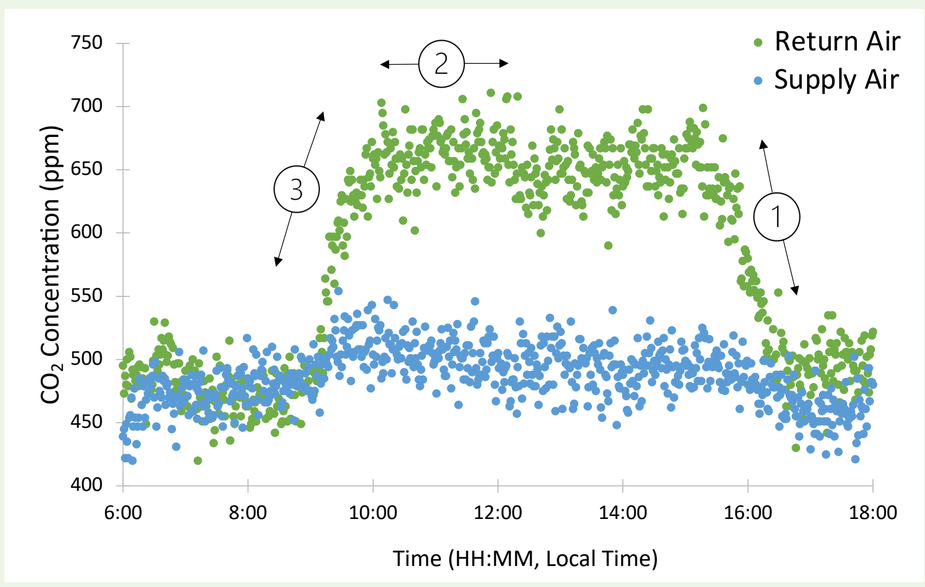

Figure 2: *Accumulation, steady-state, and decay period CO_2 analysis on 05/28/2019*

1. Decay period used to determine outdoor air flowrate
2. Outdoor air flowrate used during steady-state period to determine # of people present
3. # of people present used during accumulation period to determine supply air flowrate

- VOC source strengths were found with mass balances, e.g. mass emitted into the school:[3]

$$M = Q_{supply} \int_{t_0}^{t_1} \left(C_{return} - C_{supply}\right) dt + V \int_{t_0}^{t_1} dC_{return}$$

- Non-occupancy sources were accounted for by analyzing data on 05/27/19, a holiday.
- Source strengths were apportioned into four categories:
  - $E_{occupants}$: *Occupancy sources*
  - $E_{building}$: *Non-occupancy sources*
  - E_{supply}: *Supply air sources*
  - $E_{per\text{-}person}$: *Per-person emission rates*

RESULTS AND DISCUSSION

Airflows and Occupant Density

Table 1: *Average air flowrates and occupant density across 05/28/19, 05/29/19, and 05/31/19*

Outdoor Air Exchange Rate (h^{-1})	**Supply Air Change Rate** (h^{-1})	**Occupant Density** (# of people)
0.96	1.79	513

Source Apportionment

- A source apportionment was performed on 11 compounds associated with human activity and traffic-related air pollution to determine their origin within the near-roadway school (*Figure 3*).
  - Monoterpenes source is dominated by occupant contributions
    - The chemistry monoterpenes engage in can result in the generation of potentially harmful secondary products, including formaldehyde and secondary organic aerosols.
  - Benzene, which is associated with vehicle emissions, is mostly present due to supply air contributions.
    - Benzene is classified as a known human carcinogen.
    - Supply air source strengths of benzene would likely be much higher if not for the activated carbon scrubber present in the AHU.

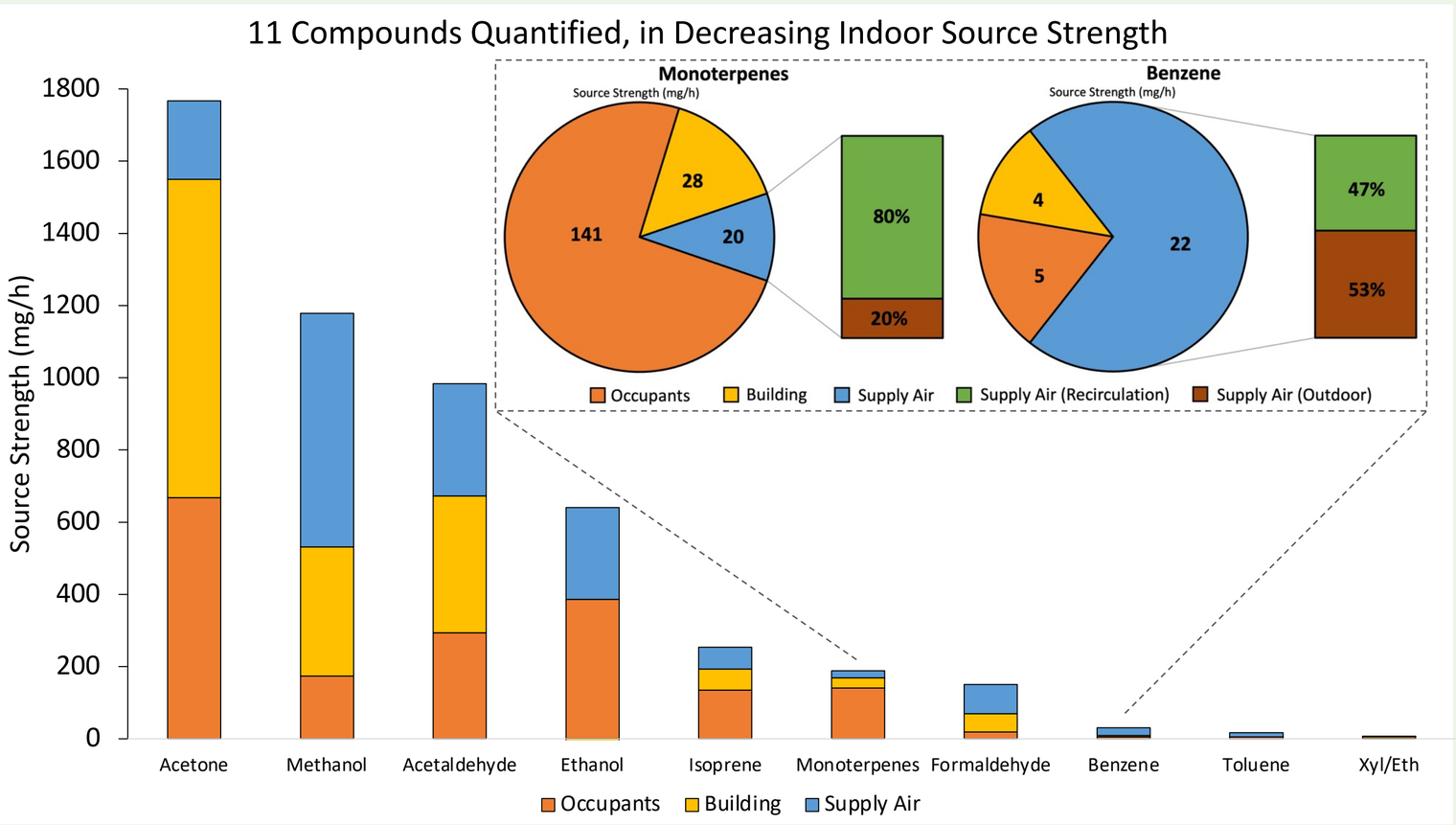

Figure 3: *Source apportionment of select compounds*

Per-Person Emission Rates

- Per-person emission rates were quantified, including compounds associated with human metabolism, and compared to literature (*Figure 4*):
  - VOC emissions from human metabolism (isoprene) may be higher due to eating and physical exercise activities inside the school.
  - Higher monoterpene emissions may be due to increased usage of scented personal care products.
  - Higher ethanol emission rates may be due to hand sanitizer and cleaning products used in the middle school environment.

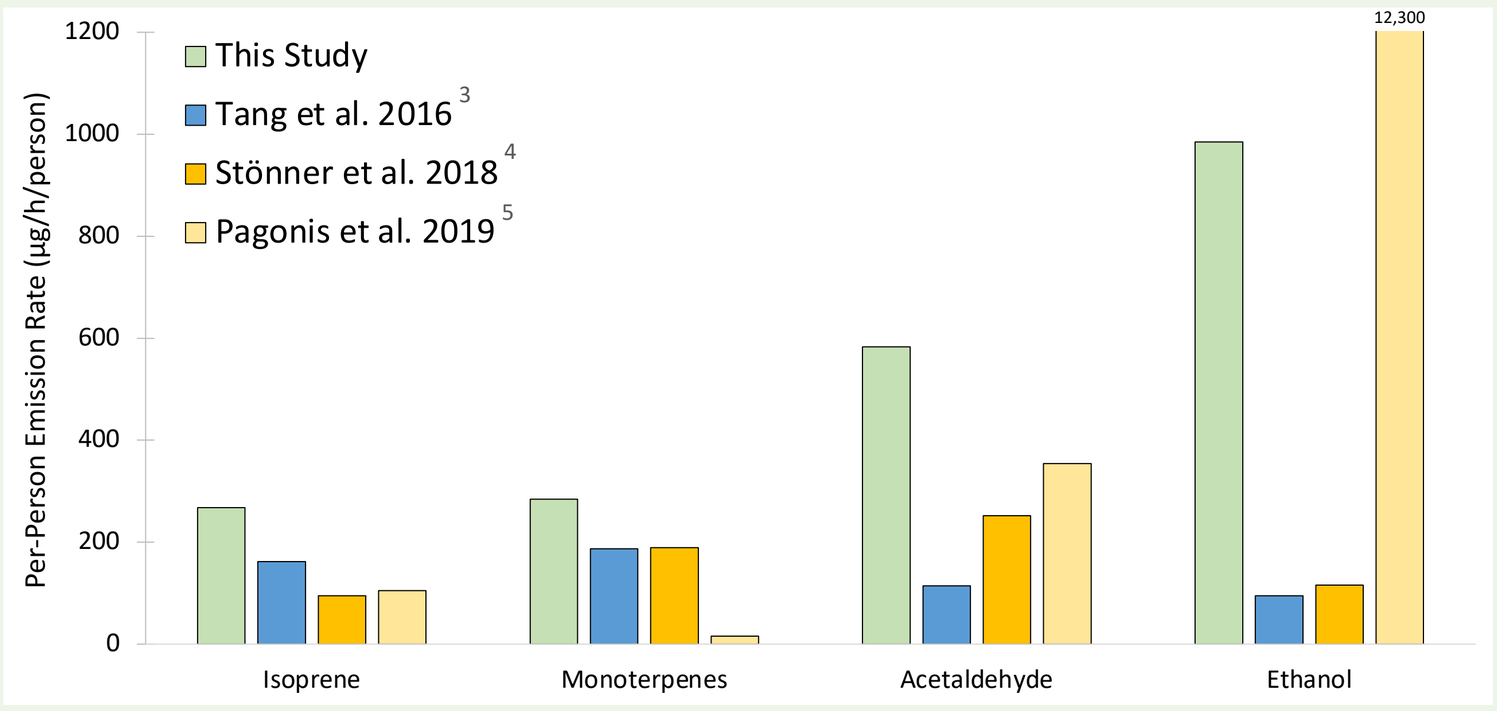

Figure 4: *Comparison of per-person emission rates to Tang et al. 2016[3], Stönner et al. 2019[4], and Pagonis et al. 2019[5]*

CONCLUSION

- New data concerning VOC source strengths to a building is presented here, which can enable the modeling of air pollution exposures in schools.
- HTMS is unique, in that it has the benefit of particle and gas-phase air cleaning systems—source strength results are likely to vary across buildings.
- Future studies in more buildings are critical for characterizing sources of pollution in environments that house susceptible populations, such as schools.

References: [1]Kingsley, S. L. *et al. J. Expo. Sci. Environ. Epidemiol.* (2014), [2]Gall, E. T. *Indoor and outdoor air quality at Harriet Tubman Middle School and the design of mitigation measures: Phase I report*. (2018), [3]Tang, X., Misztal, P. K., Nazaroff, W. W. & Goldstein, A. H. *Environ. Sci. Technol.* (2016), [4]Stönner, C., Edtbauer, A. & Williams, J. *Indoor Air* (2018), [5]Pagonis, D. *et al. Environ. Sci. Technol.* (2019)