Approaches for Effective Isolation Space Control to Minimize Airborne Transmission of Contaminants in Residential Homes

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Acknowledgement

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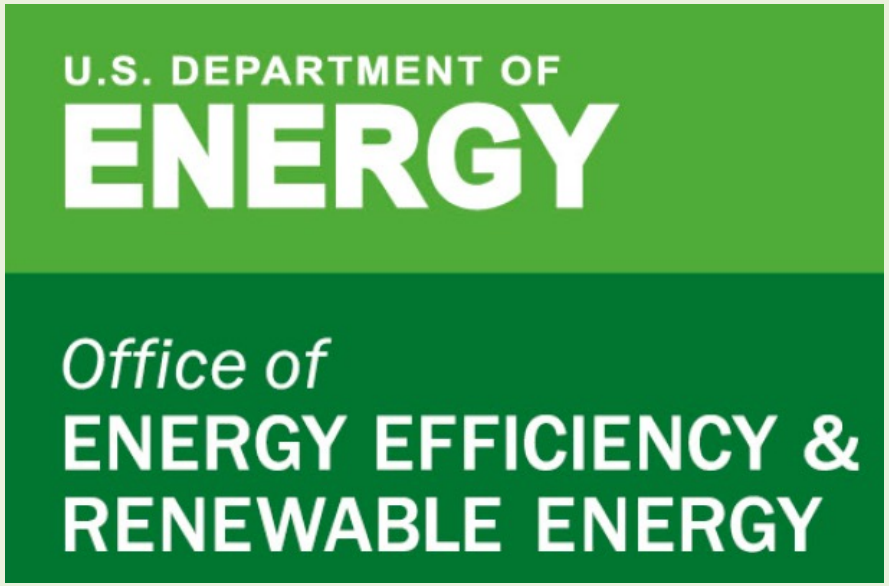


Background

- Both large and small respiratory droplets may contain virus, however, they are all **aerosols** because they can be inhaled directly from the air.
- Larger respiratory droplets fall to the ground (< 1 m) quickly while the smaller ones can remain suspended in the air and undergo long-range (> 2 m) transmission.
- Mitigation of aerosol-based transmission of the SARS-CoV-2 is critically important to protect occupants in shared indoor environments.

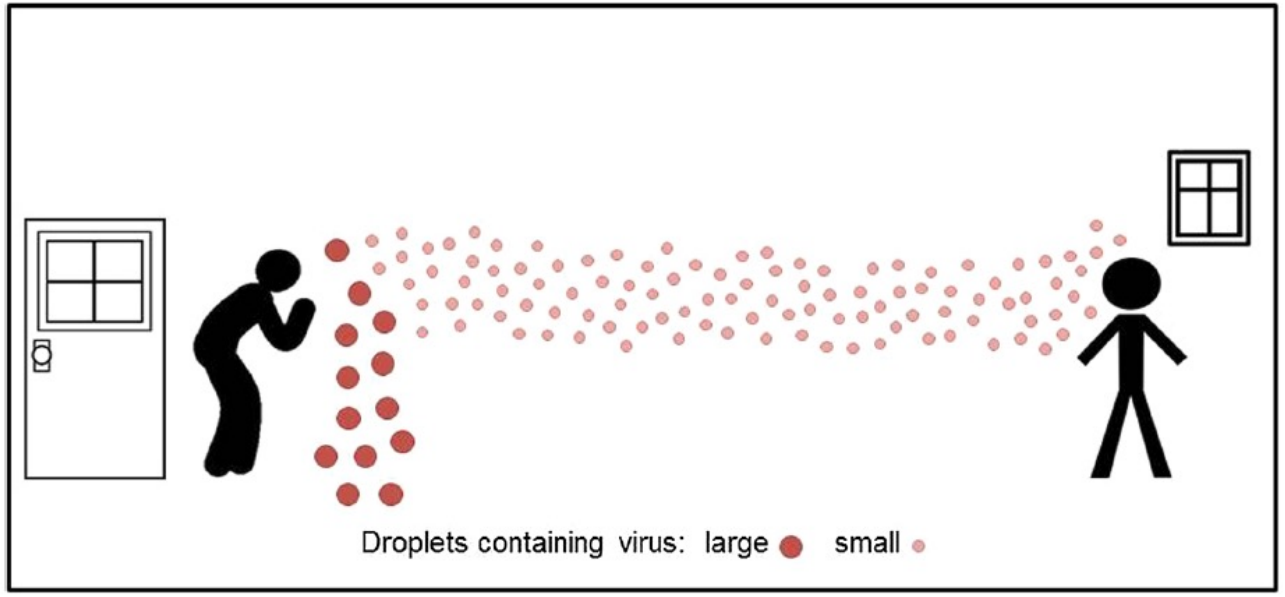


Fig. 1. Larger droplets deposit close to the emission point, while smaller ones can travel long distances in the air indoors (Morawska, L., & Cao, J. Airborne transmission of SARS-CoV-2: The world should face the reality. *Environment international*, 2020).

Background

- In the U.S., most health-care facilities use negative-pressure AIIRs for patients with airborne transmissible infections. However, **the concept of negative-pressure isolation zone for residential homes was yet to be explored**.

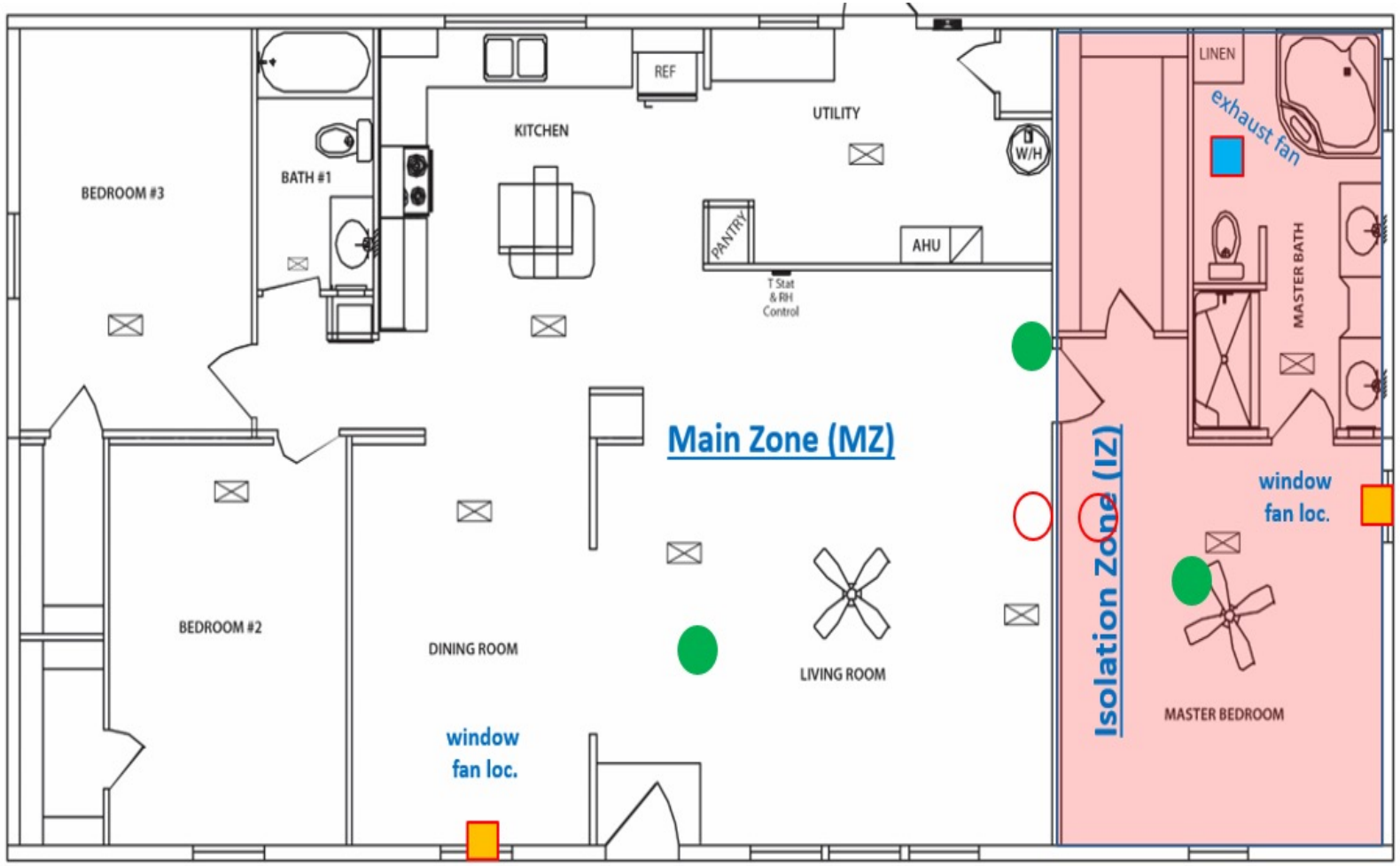
Study Objective

To test the effectiveness of various strategies to limit airborne transmission of infectious aerosols in a manufactured single-family laboratory house under various HVAC operating scenarios, intervention measures, and utilization of exhaust or window fans for pressure control.

Methods

- **Measurements**
  - Airtightness (house and zones)
  - Airflow (air moving fans)
  - Pressure differential (zone to zone, zone to outdoors)
  - Indoor and Outdoor Environmental Conditions (T, RH, wind, $PM_{2.5}$)
  - Aerosol particle containment effectiveness (tracer gas and $PM_{2.5}$)
- **Repeat measures for several different test configurations**
  - 17 test configurations
  - 2-3 trials per configuration

FSEC Manufactured Housing Lab



Air quality monitors Tracer gas (SF_6) measurement locations

- 1,620-ft^2 manufactured home with three bedrooms and two bathrooms
- Unvented and unconditioned crawl space, vented attic, wood frame wall construction
- House airtightness of 5 air changes per hour (ACH50) w.r.t. outdoors
- Master suite served as the isolation zone (IZ) for all tests
- Rest of the house served as the main zone (MZ)

Experimental Set-up in the Manufactured Housing Laboratory Isolation Space (Master Bedroom Suite)

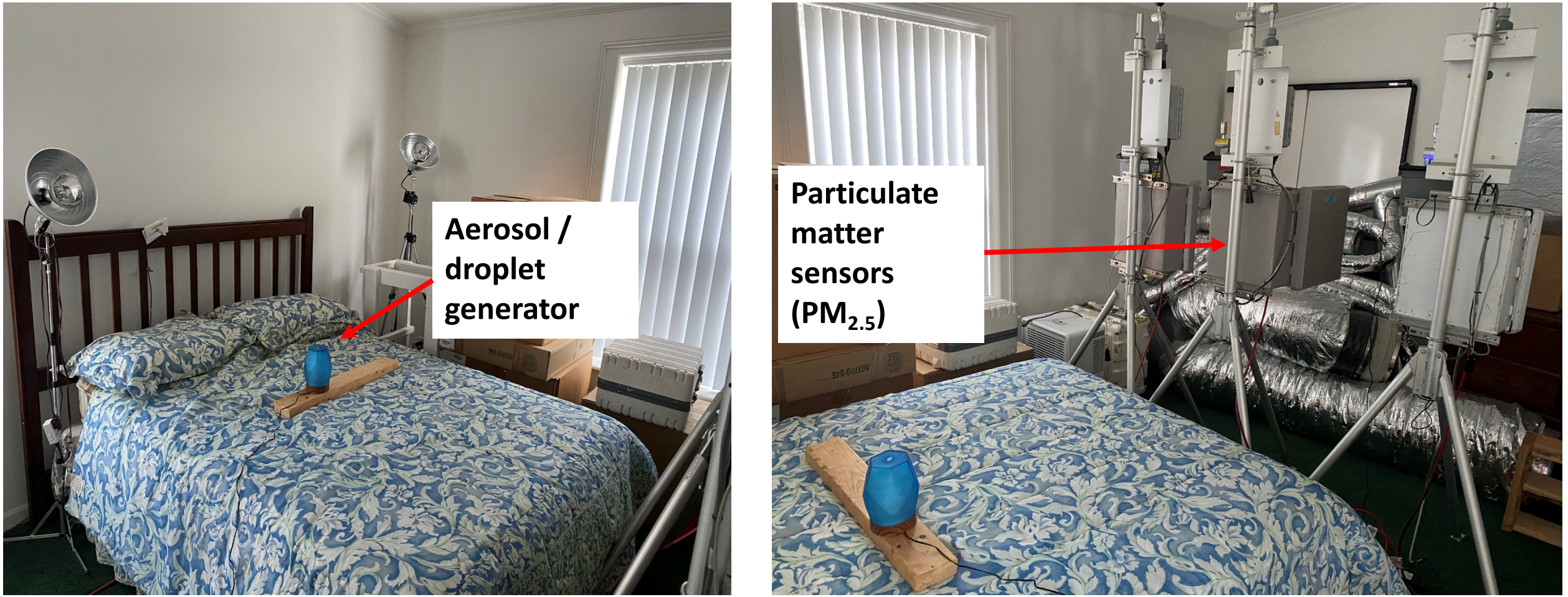


Fig. 3. Aerosol concentration measurements are taken in the isolation zone and in the main zone simultaneously.

Test Cases and Configurations

- **Developed based on various**
  - HVAC operating scenarios
  - intervention measures
  - utilization of **bathroom exhaust** or **window fans** for pressure control
- **Interventions involved**
  - closing the IZ door and/or
  - closing/opening IZ window(s)
  - sealing IZ supply (and return) air grilles
- **A total of 17 test scenarios developed and tested**
  - each test repeated two/three times

Test Cases and Configurations

a. An inexpensive window fan can aid with containment

b. Portable air conditioner can be used to aid with containment, and provide comfort to the isolation zone.

c. Window fan installed in the MZ providing outdoor air into the home. This strategy pressurizes the main zone, resulting in a lesser pressure in the closed-off IZ w.r.t. MZ, which helps with containment.

Fig. 4. Test photos from the MH Lab (a, b, c).

Results (Best and Worst Cases)

		IZ dP w.r.t. MZ (Pa)
Type	**Case #**	**Mean**
Best	4	-7.0
	5	-2.7
	6	-5.6
	17	-5.4
Worst	1	0.0
	2	-0.3
	8	-0.8
	11	2.0

In the best containment cases:

- ❑ IZ door and windows closed
- ❑ MZ windows closed
- ❑ Central heating/cooling ON
- ❑ IZ supply grilles sealed off
- ❑ Satisfactory dP values (mean) achieved either by using bath exhaust or window fan

In the worst containment cases:

- ❑ IZ door and/or window open
- ❑ Central heating/cooling ON and IZ supply grilles open while bath exhaust fan ON

Example (Baseline- Weak Containment)

Case 1

- IZ door open
- Bath exhaust fan NOT used
- Portable window fan NOT used
- Central heating/cooling ON
- IZ supply grilles open

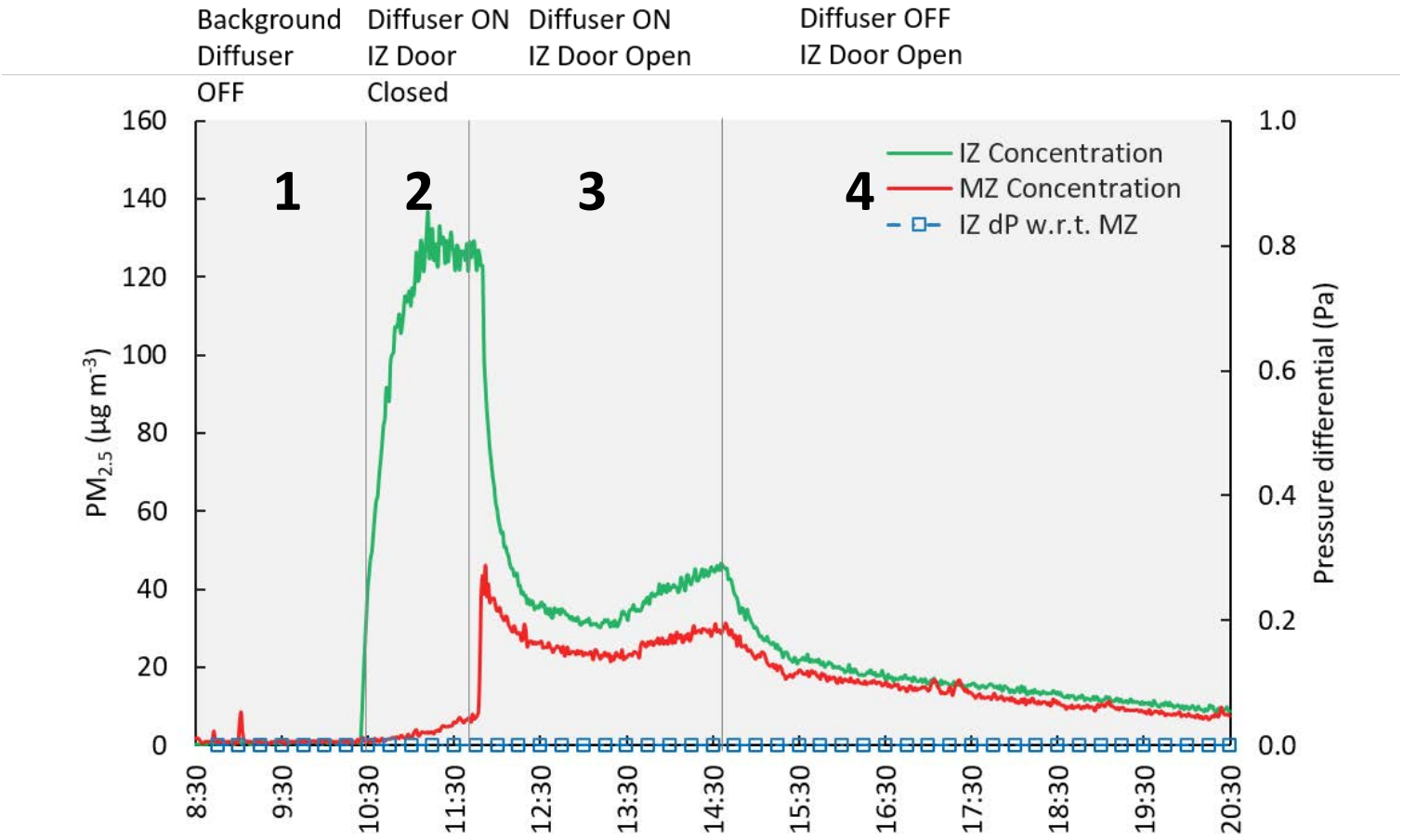


Fig. 8. Time-series of $PM_{2.5}$ for Case 1.

Example (Strong Containment)

Case 5

Depressurization in the IZ created by using the bath exhaust fan (high)

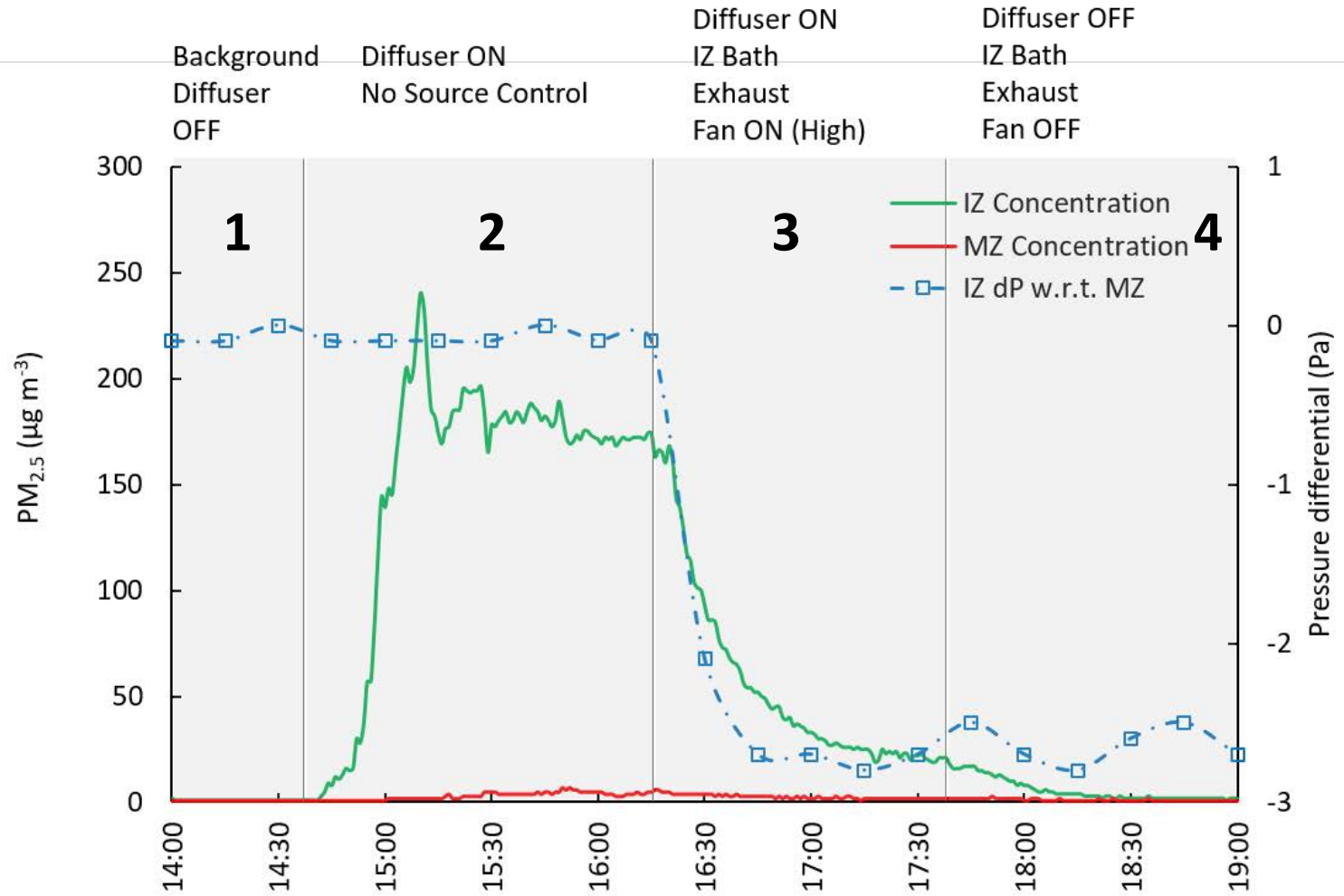


Fig. 6. Time-series of $PM_{2.5}$ for Case 5.

Summary

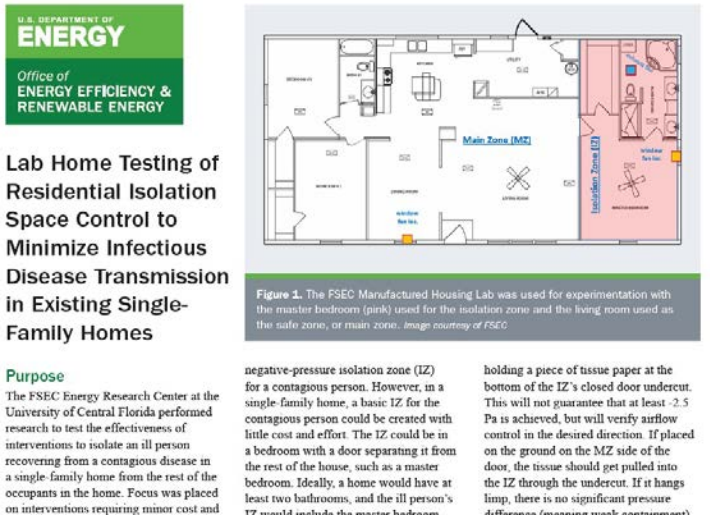
- This study focused solely on ways to limit airborne transmission.
- Four cases were identified as having the potential for strong containment, exhibiting adequate depressurization in the IZ (-2.7 to -7.0 Pa w.r.t. MZ)
- For two cases, depressurization was achieved using an IZ bathroom exhaust fan (required in-situ minimum airflow of 100 CFM) and a low-cost portable exhaust window fan (minimum airflow of 300 CFM), respectively.
- For the best cases, MZ to IZ door and all IZ windows remained closed at all times while all IZ supply grilles were sealed off.
- A room space heater or room air conditioner may be needed in the IZ as IZ thermal conditions are likely to become uncomfortable.

Recommendations

- Use recommended personal protective equipment and cleaning practices.
- Locate an infectious person in a room with a closeable door. Placing them in a master bedroom with direct access to a bathroom will help limit exposure if there is a second bathroom available to healthy occupants in the home.
- Air pathways between the IZ and MZ should be sealed. The IZ door should remain closed at all times, except for occasional opening/closing as would be needed to tend to an ill person.
- All heating and cooling supply (and return) air grilles should be sealed off in the IZ.
- The IZ should be kept at a lower air pressure than the MZ either by using an IZ bath exhaust fan and/or placing a window fan in the IZ window arranged to blow air from the IZ to outdoors. The window fan is more likely to produce greater containment than most existing bathroom fans and is available for under $40.

For More Details

Technical report:
https://www.nrel.gov/docs/fy21osti/79516.pdf



Fact sheet:
https://www.nrel.gov/docs/fy21osti/79519.pdf

https://www.mdpi.com/1660-4601/18/11/5880

Questions?

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