Reducing Exposure to Air Pollution by Improving Indoor Air Quality

EPA Webinar - Clean Air Spaces
Indoor Air Pollution Mitigation

Challenge
Reduce exposure to US Dept. of State Employees and family members serving at high pollution posts.

Approach
Can’t control outdoor environment; investigate controlling indoor environment.

95% of the world’s population live in areas exceeding WHO’s Guideline
Indoor Air Pollution Mitigation

**Goal**
Attain USEPA 24-hr average of 35 µg/m³ (NAAQS)

**Factors**
- Pollution Concentration
- Duration of Exposure
- Breathing Rate
Indoor Air Pollution Mitigation

To do list

1. Reduce infiltration
   Tighten buildings to exclude infiltration of polluted air
   Minimize opening doors/windows and using exhaust fans

2. Filter indoor air
   Use centralized air filtration if available
   Use room air cleaners (RACs)
   Use vehicle cabin air filters

3. Minimize indoor sources
   Smoking
   Vacuuming
   Burning candles/incense
   Frying foods

4. Respiratory protection?
Indoor Air Pollution Mitigation

Tighten buildings to exclude infiltration of polluted air

Look for leaks around windows, doors, transoms, etc. and seal.

- Visually inspect for obvious openings
- Use smoke tubes to find leaks
- Thermal imaging is another option
Tighten buildings to exclude infiltration of polluted air

(continued)

- Perform blower door tests
- Goal is to achieve no more than 5 air changes per hour.
- Benefit: energy savings
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Minimize opening doors/windows and using exhaust fans
Indoor Air Pollution Mitigation

Use centralized air filtration if available

Preferably MERV 13 filters
Indoor Air Pollution Mitigation

Centralized air filtration

DustTrak Readings
Residence in Riyadh
March 2018

- EPA 24-hr PM2.5 Standard
- Indoors PM2.5, μ/m3
- Outdoors, PM2.5
- Outdoors, PM10

68% reduction in PM2.5
Indoor Air Pollution Mitigation

Use Room Air Cleaners (RACs)
Indoor Air Pollution Mitigation

Use room air cleaners (RACs) (continued)

How many are needed?

**Goal:** 4 room air changes per hour based on the Clean Air Delivery Rate

<table>
<thead>
<tr>
<th>Air Changes Per Hour</th>
<th>Minutes Required for Removal of Airborne Particles</th>
<th>99% Removal</th>
<th>99.9% Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>138</td>
<td>207</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>69</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>46</td>
<td>69</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>28</td>
<td>41</td>
<td></td>
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<tr>
<td>12</td>
<td>23</td>
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<td></td>
</tr>
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<td>18</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>14</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Indoor Air Pollution Mitigation

How many are needed?

Sizing a Room to Select an RAC

Example:

- Room Size: 12 ft x 12 ft x 10 ft high

- CADR: 240 CFM (use CADR for smoke)

- ACH: \[
\text{ACH} = \frac{\text{CADR in CFM} \times 60 \text{ min/hr}}{\text{Interior room volume (ft}^3\text{)}}
\]

- ACH: \[
\frac{240 \times 60}{12 \times 12 \times 10} = 10
\]
Indoor Air Pollution Mitigation

Chengdu Waterfront Apt.
March 4, 2013
No RACs in Use

~23% Less
Indoor Air Pollution Mitigation

Chengdu: Waterfront Apt
March 4, 2013
RACs In Use

BAM 1-Hour Average
Outdoor DustTrak
Indoor

76% Reduction!
Indoor Air Pollution Mitigation

PM2.5 Level Measured Using the Ambient Beta Attenuation Monitor (BAM) Outdoors, at Residence 1 (on the US Embassy Enclave), and at Residence 2 (off the Enclave*), US Embassy In New Delhi, India, January 30 - February 2, 2017

91% reduction in PM2.5 at Residence 1
80% reduction in PM2.5 in Residence 2
Indoor Air Pollution Mitigation

Improvising a Room Air Cleaner

If you're on a budget...

Source: https://tombuildsstuff.blogspot.com/2013/06/better-box-fan-air-purifier.html

Increase the filter area to decrease the effect of air resistance
Indoor Air Pollution Mitigation

Improvising a Room Air Cleaner
Kathmandu, May 2019

Test Chamber

DustTrak and Fan/Filter
Indoor Air Pollution Mitigation

Fan with Filter Test Results
(FPR 4 Filters)

Fan with Filter Test

PM2.5 (µg/m³)

Time


- Close windows/door; start fan
- Shut off fan; open windows

EPA 24 hr Standard  PM2.5 (µg/m³)
Indoor Air Pollution Mitigation

In-Vehicle Monitoring w/ Cabin Air Filtration
Chengdu, March 5, 2013 - Trip 1, CGR to Consulate

Change filter periodically: https://www.youtube.com/watch?v=bml8dletNbk
Indoor Air Pollution Mitigation

PM$_{2.5}$ and CO$_2$ Levels in Vehicle with Cabin Air Filters
Recirculating Ventilation
Kampala Uganda – July 2017
Indoor Air Pollution Mitigation

PM$_{2.5}$ and CO$_2$ Levels in Vehicle with Cabin Air Filters
Pass-Through Ventilation
Kampala Uganda – July 2017

![Graph showing PM$_{2.5}$ and CO$_2$ levels over time.]

Behind truck spewing black smoke

- PM$_{2.5}$
- CO$_2$
Indoor Air Pollution Mitigation

Vehicle Air Filtration

What

• High Efficiency Cabin Air Filters
• Do it yourself (Save $$)
### Indoor Air Pollution Mitigation

#### Respirators

**Should we use them?**

<table>
<thead>
<tr>
<th>MEDICALLY OK?</th>
<th>QUALITY RESPIRATOR?</th>
<th>GOOD FIT?</th>
</tr>
</thead>
</table>
| Lung, cardiac, or other medical conditions? If so, discuss respirator use with your health provider. | 1. NIOSH certified  
2. HEPA/N100, N99, or N95  
3. P2 or P3  
4. Other hallmarks or signs  
5. Holds mask in place (e.g., 2 straps) | • S, M, or L?  
• Try multiple brands & models  
• Test face seal  
• Facial hair, weight change +/- 20 lbs (9 kg), etc. affect fit  
• Get fit tested! |

#### WORN PROPERLY?

**When do you wear it?**
Minimize outdoor time & exertion if AQI > **200**

**Wearing procedures:**
1. Inspect filters, seal area, and straps.  
3. Dizzy or nauseous? Go indoors and remove the respirator. Seek medical attention.  
4. Remove and store respirator with care. See manufacturer’s instructions.  
5. Replace filter if misshapen, soiled, wet, or if end of filter life.

If air leaks around the respirator edges, adjust the panels on the face and the position of the straps along the sides of the head and make certain respirator edges fit snugly against face.
Indoor Air Pollution Mitigation

Respirators
Particulate Air Purifying

- Filtering Facepiece
  - Cost: ~$0.50 – $3.00

- Half-Face Elastomeric
  - Cost: ~$10 - $40
  - Plus ~$2-10 for filters

- Air Pollution Masks
  - Cost: ~$35-75
# Indoor Air Pollution Mitigation

## Respirators

**Fit and Seal Testing**

<table>
<thead>
<tr>
<th>Wearer/ Respirator</th>
<th>Unit Cost</th>
<th>NIOSH Approved?</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M Aura 9211 (disposable)</td>
<td>~$2.25</td>
<td>Yes</td>
<td>Fail</td>
</tr>
<tr>
<td>Vogmask® (reusable)</td>
<td>~$30</td>
<td>No</td>
<td>Fail</td>
</tr>
<tr>
<td>Vogmask® (reusable)</td>
<td>~$30</td>
<td>No</td>
<td>Pass</td>
</tr>
<tr>
<td>Honeywell Antipollution RY-D7051-DB2V-IND (disposable)</td>
<td>$2</td>
<td>No¹</td>
<td>2nd Pass</td>
</tr>
<tr>
<td>Vogmask® (reusable)</td>
<td>~$30</td>
<td>No</td>
<td>Fail</td>
</tr>
<tr>
<td>3M 8293 P100 Disposable Particulate</td>
<td>$9</td>
<td>Yes</td>
<td>Pass</td>
</tr>
<tr>
<td>Vogmask® (reusable)</td>
<td>~$30</td>
<td>No</td>
<td>Fail</td>
</tr>
</tbody>
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Indoor Air Pollution Mitigation - Summary Recommendations

• Seal residences
  ❑ Visual inspections
  ❑ Blower door testing

• Minimize the opening and closing of exterior doors and windows and use of exhaust fans in kitchens and bathrooms

• Be aware of and control indoor sources of air contaminants

• Use high efficiency air filters if there’s a central HVAC system

• Use RACs
  ❑ Recommend 4 air changes per hour. – easier to achieve in smaller rooms
  ❑ DIY RACs appear effective
  ❑ Run room air cleaners on the highest setting that noise is acceptable. Turn up to maximum when the room or residence is vacated.

• If you must travel, do so in a vehicle that preferably has a high-efficiency cabin air filter, keep windows closed, and don’t recirculate or carbon dioxide levels will quickly climb. Avoid following spewing trucks!

• Consider respirators but be cautious – you may not be getting great protection!