Regulatory Update: Ventilation and IAQ Strategies

Marwa Zaatari, PhD
enVerid Systems
January 15, 2020
Agenda

- The challenge
- What is new and proposed in 62.1 – 2019?
  - VRP
  - IAQP
- LEED Indoor air Quality Procedure
- Electronic Air Cleaners
Poor IAQ

Emission

Energy

Ventilation

Dallas-Fort Worth Grade F for ozone

90% of our time indoors
ASHRAE Standard 62.1
ASHRAE Standard 62.1 Overview

- ASHRAE Std. 62.1: Ventilation Rate Procedure (VRP)
  - PRESCRIPTIVE

- ASHRAE Std. 62.1: Indoor Air Quality Procedure (IAQP) – since 1979*
  - PERFORMANCE-BASED
  - Energy conservation
  - Less outdoor air pollution
What is new in 62.1 – VRP?
VRP – 2019
Ventilation Efficiency

- Elimination of Table 6.2.5.2 System Ventilation Efficiency
- Replacing with two new equations based on diversity

\[ E_v = 0.88 \times D + 0.22 \text{ for } D < 0.60 \ (6.2.5.3.1A) \]
\[ E_v = 0.75 \text{ for } D \geq 0.60 \ (6.2.5.3.1B) \]

No changes to Appendix A method
• Published in 2019: when the engineer is in doubt of the indoor/outdoor pollutants sources
→ the engineer must use IAQP + air cleaning.

→ Acknowledging that the ventilation rate procedure is inferior to the Indoor Air Quality procedure in terms of risk on the engineer/IAQP

6.2.2.1.2 Source Strengths. The Ventilation Rate Procedure minimum rates are based on contaminant sources and source strengths that are typical for the listed occupancy categories. Where unusual sources are expected, the additional ventilation or air cleaning required shall be calculated using Section 6.3.6 of the IAQ procedure or criteria established by the Environmental Health and Safety (EHS) professional responsible to the owner.
• Accuracy = ±75 ppm at 600 and 1000 ppm

• Sensors shall be factory calibrated

• Sensors shall be certified that they don’t require calibration not more frequently than 5 years

• Sensor failure controls

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Addendum al to 62.1-2016

Add new Section 6.2.7.1.3 as shown. Renumber the existing sections as appropriate.

6.2.7.1.3. Where CO₂ sensors are used for DCV, the CO₂ sensors shall be certified by the manufacturer to be accurate within plus or minus 75 ppm at a 600 ppm and 1000 ppm concentration when measured at sea level at 25°C. Sensors shall be factory calibrated and certified by the manufacturer to require calibration not more frequently than once every 5 years. Upon detection of sensor failure, the system shall provide a signal that resets the ventilation system to supply the required minimum quantity of outdoor air \( P_{m} \) to the breathing zone for the design zone population \( P_{d} \).
VRP – 2019
Simplified Ventilation Rate for existing buildings

- Simplified Ventilation Rate Table for Existing Buildings

\[ V_{\text{target}} = \sum_{\text{all zones}} A_z \times R_x \]  \hspace{1cm} \text{(D2)}

where

\[ A_z = \text{zone floor area, the net occupiable floor area of the ventilation zone, ft}^2 \ (\text{m}^2) \]

\[ R_x = \text{outdoor airflow rate required per unit area as determined from Table D2} \]

<table>
<thead>
<tr>
<th>Educational Facilities</th>
<th>Outdoor Air Rate ( R_x )</th>
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<tbody>
<tr>
<td>Classroom (ages 5-8)</td>
<td>0.65</td>
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<tr>
<td>Classroom (age 9 plus)</td>
<td>0.82</td>
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<tr>
<td>Computer lab</td>
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<tr>
<td>Media center</td>
<td>0.65</td>
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<tr>
<td>Music/theater/dance</td>
<td>0.72</td>
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<tr>
<td>Multi-use assembly</td>
<td>1.42</td>
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<tr>
<td>General</td>
<td></td>
</tr>
<tr>
<td>Conference/meeting</td>
<td>0.44</td>
</tr>
<tr>
<td>Corridors</td>
<td>0.11</td>
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<tr>
<td>Office Buildings</td>
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<tr>
<td>Breakrooms</td>
<td>0.65</td>
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<tr>
<td>Main entry lobbies</td>
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<tr>
<td>Occupable storage rooms for dry materials</td>
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<tr>
<td>Office space</td>
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<tr>
<td>Reception areas</td>
<td>0.37</td>
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<tr>
<td>Telephone/data entry</td>
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<td>Public Assembly Spaces</td>
<td></td>
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<tr>
<td>Libraries</td>
<td>0.30</td>
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<td>Outpatient Facilities</td>
<td>Animal Facilities</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------------------------------</td>
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<tr>
<td><strong>Outpatient health care facilities</strong></td>
<td><strong>Animal procedure room</strong></td>
</tr>
<tr>
<td>General examination room</td>
<td><strong>Animal exam room</strong></td>
</tr>
<tr>
<td>Psychiatric examination room</td>
<td>(static cages)</td>
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<tr>
<td>Psychiatric consultation room</td>
<td>(ventilated cages)</td>
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<tr>
<td>Psychiatric group room</td>
<td>Large-animal holding room</td>
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<tr>
<td>Psychiatric seclusion room</td>
<td>Animal imaging</td>
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<tr>
<td>Birthing room</td>
<td>(MRI/CT/PET)</td>
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<tr>
<td>Urgent care examination room</td>
<td>Animal operating rooms</td>
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<td>Urgent care treatment room</td>
<td>Animal postoperative</td>
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<tr>
<td>Urgent care triage room</td>
<td>recovery room</td>
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<tr>
<td>Urgent care observation room</td>
<td>Animal preparation rooms</td>
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<tr>
<td>Physical therapy individual room</td>
<td>Animal surgery scrub</td>
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<td>Physical therapy exercise area</td>
<td>Necropsy</td>
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<td>Physical therapeutic pool area</td>
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<tr>
<td>Speech therapy room</td>
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<td>Prosthetics and orthotics room</td>
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<tr>
<td>Dental operatory</td>
<td></td>
</tr>
<tr>
<td>Other dental treatment areas</td>
<td></td>
</tr>
<tr>
<td>Class 1 imaging rooms</td>
<td></td>
</tr>
</tbody>
</table>
What is proposed in 62.1 - IAQP?
What is proposed in ASHRAE IAQP 2019/2020?

Performance-based Approach

Minimize the risk on the engineer behalf

Make requirement more stringent towards air cleaning

Make key requirement more prescriptive

IAQP = Indoor Air Quality Procedure + air cleaning

- Define the requirements for design
- Specify lab tests to get efficiency
- Specify that the use of EAC is not allowed if they produce detectable by-products
- Concentration limit, no by-product generation value, etc.
The IAQP allows compliance based on:

1. Objective Evaluation (contaminants concentrations)
2. Subjective Evaluation (survey)

- Contaminants and/or mixtures, sources, and emissions
- Concentration limits
- Identify air cleaning solution and efficiency
- Use mass balance equation

- Locations at breathing level
- EPA methods
The IAQP allows compliance based on:

1. Objective Evaluation (contaminants concentrations)
2. Subjective Evaluation (survey)

**Design**
- Not Defined
  - Contaminants and/or mixtures, sources, and emissions

**Verification**
- LEED
  - IAQ Testing
  - Not Defined
  - Survey
  - Locations at breathing level
  - EPA methods

**IAQ Testing**
- Survey
- Design
- Verification
- IAQP Methodology - 2016
IAQP Methodology - Proposed

**Design**
- Contaminants and/or mixtures, sources, and emissions
- Concentration limits
- Identify air cleaning solution and efficiency
- Use mass balance equation

**Verification**
- IAQ Testing
- Survey
What is new in 2019?

Contaminants and mixtures, sources, and emissions

2016

Proposed

**New terminology:**
Design Compounds, PM$_{2.5}$

**Defined:**
Design Compounds, PM$_{2.5}$

Proposed

**Not defined**

Design Compounds, PM$_{2.5}$

*Defined:*
Mixtures of concern

---

*Design compounds (DCs)*: commonly encountered chemical compounds found in the indoor environment that have the potential to reduce acceptability of the air.

*Particulate Matter 2.5 (PM$_{2.5}$)*: particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers.
What is new in 2019?

Contaminants and mixtures, sources, and emissions

2016

Proposed

New terminology:
Design Compounds, PM$_{2.5}$

Defined:
Design Compounds, PM$_{2.5}$

Defined:
Mixtures of concern

IAQP Methodology - Proposed

Compound or PM$_{2.5}$
- Acetaldehyde
- Acetone
- Benzene
- Dichloromethane
- Formaldehyde
- Naphthalene
- Phenol
- Tetrachloroethylene
- Toluene
- 1,1,1-trichloroethane
- Xylene, total
- Carbon monoxide
- PM$_{1.5}$
- Ozone
- Ammonia
(presence of animals)
IAQP Methodology - Proposed

Design

Contaminants and/or mixtures, sources, and emissions → Concentration limits → Identify air cleaning solution and efficiency → Use mass balance equation

Verification

IAQ Testing + Survey
IAQP Methodology - Proposed

Concentration limits

2016

Not defined

Proposed

Defined:

Concentration limits and
cognizant authority

<table>
<thead>
<tr>
<th>Compound or PM$_{2.5}$</th>
<th>Cognizant Authority</th>
<th>Design Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>Cal EPA CREL (June 2016)</td>
<td>140 ug/m$^3$</td>
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<tr>
<td>Acetone</td>
<td>AgBB LCI</td>
<td>1,200 ug/m$^3$</td>
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<tr>
<td>Benzene</td>
<td>Cal EPA CREL (June 2016)</td>
<td>3 ug/m$^3$</td>
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<tr>
<td>Dichloromethane</td>
<td>Cal EPA CREL (June 2016)</td>
<td>400 ug/m$^3$</td>
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<td>Formaldehyde</td>
<td>Cal EPA CREL (2004)</td>
<td>33 ug/m$^3$</td>
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<tr>
<td>Naphthalene</td>
<td>Cal EPA CREL (June 2016)</td>
<td>9 ug/m$^3$</td>
</tr>
<tr>
<td>Phenol</td>
<td>AgBB LCI</td>
<td>10 ug/m$^3$</td>
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<tr>
<td>Tetrachloroethylene</td>
<td>Cal EPA CREL (June 2016)</td>
<td>35 ug/m$^3$</td>
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<tr>
<td>Toluene</td>
<td>Cal EPA CREL (June 2016)</td>
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<tr>
<td>1,1,1-trichloroethane</td>
<td>Cal EPA CREL (June 2016)</td>
<td>1000 ug/m$^3$</td>
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<tr>
<td>Xylene, total</td>
<td>AgBB LCI</td>
<td>500 ug/m$^3$</td>
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<tr>
<td>Carbon monoxide</td>
<td>USEPA NAAQS</td>
<td>9 ppm</td>
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<tr>
<td>PM$_{2.5}$</td>
<td>USEPA NAAQS (annual mean)</td>
<td>12 ug/m$^3$</td>
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<tr>
<td>Ozone</td>
<td>USEPA NAAQS</td>
<td>70 ppb</td>
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<tr>
<td>Ammonia</td>
<td>Cal EPA CREL (June 2016)</td>
<td>200 ug/m$^3$</td>
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</tbody>
</table>
IAQP Methodology - Proposed

**Design**
- Contaminants and/or mixtures, sources, and emissions
- Concentration limits
- Identify air cleaning solution and efficiency
- Use mass balance equation

**Verification**
- IAQ Testing
- Survey
What is new in 2019?

Identify air cleaning solution and efficiency

Proposed

**Defined:**
- Air Cleaning

**Defined:**
- Gaseous scrubbers
- Documentation

**Defined:**
- Gaseous scrubbers
- Requirements

1) Particle filters
   - MERV
   - ASHRAE Standard 52.2, ISO

2) Gaseous scrubbers
   - Efficiency
   - ASHRAE Standard 145.2, ISO, or third party test
   - No by products: ozone and formaldehyde

\[ V_{oz} = \frac{N - E_{z}RV}{E_{f}C_{bz}} \times \frac{E_{f}}{E_{z}(C_{bz} - C_{o})} \]
Summary of ASHRAE Testing Standards

- **Standard 145.2**
  - Tests for: VOCs, aldehydes, ozone, basic and acidic gases

- **Standard 52.2**
  - Applies to filters
  - Tests for: particle filtration
Sorbent-based Air Cleaning Performance

Example: Ozone test data from RTI:

- Efficiency = 70%
- By-product VOCs and ozone concentrations = 0 ppb
IAQP Methodology - Proposed

**Design**
- Contaminants and/or mixtures, sources, and emissions
- Concentration limits
- Identify air cleaning solution and efficiency
- Use mass balance equation

**Verification**
- IAQ Testing
- Survey
IAQP: Objective Evaluation Steps

Mass Balance Analysis

Outside Concentration, \( C_0 \)

\[ V_d C_{bz} = N dt - \left( V_{ot} C_0 dt \right) - \left( Q_{HLR} E_f C_{bz} dt \right) \]
IAQP Use Cases

- Outdoor air is non-attainment for NAAQS or polluted
- Buildings with existing capacity limitations / Densification (aging of HVAC equipment, re-purpose of the space, adding more people)
- New buildings with limited HVAC capacity (e.g., geothermal projects)
- Identified COC concentrations are high, requiring additional ventilation
- Building is located in cold or hot/humid climates
- LEED buildings
Summary

• James has a 200 sf office
• What ventilation is required?
  • Appendix F  \(200 \times 0.15 = 30\) cfm
  • Appendix L  \(200 \times 0.11 = 22\) cfm
  • Vbz  Equation 6.2.2.1  \(1 \times 5 + 0.06 \times 200 = 17\) cfm
  • Vot = 17 cfm  (Assume \(Ez = 1\))
  • Personal Ventilation  \(Vot = (1 \times 5)/1.5 + 0.06 \times 200 = 15.3\) cfm
  • Dynamic Reset?
    When James is not present during working hours \(Vot = 12\) cfm
• Natural Ventilation?  One window or two must be open depending
• IAQP?  \(Vot = 5\) cfm  Assuming building sources are managed to below limits
Graph of Mechanical Ventilation, Vot

ASHRAE Standard 62.1

Outside Air CFM

Appendix F | Appendix L | VRP | Personal Ventilation | Dynamic Reset | IAQP + Air Cleaning

0 | 10 | 15 | 20 | 25 | 30 | 35
What is new in LEED?

Indoor Air Quality Procedure (IAQP)
## The Challenge

<table>
<thead>
<tr>
<th><strong>Energy &amp; Atmosphere (EA)</strong></th>
<th><strong>Indoor Environmental Quality (EQ)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce energy consumption associated with buildings / building systems</td>
<td>Indoor Air Quality directly impacts: occupant well-being and productivity</td>
</tr>
<tr>
<td>Holistic approach to energy conservation</td>
<td>Reduces liability for building designs and owners.</td>
</tr>
<tr>
<td>Reduce economic harms associated with excessive energy use</td>
<td>Positively influence the way people learn, work, and live.</td>
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</tbody>
</table>
LEED - Pilot Credit PC124 – v3, v4, v4.1

Published in April 2018:

LEED BD+C: New Construction | v4 - LEED v4
Performance-based indoor air quality design and assessment
Possible 7 points

Intent
To contribute to the comfort and well-being of building occupants by minimizing indoor air quality problems associated with construction and renovation and establishing minimum standards for indoor air quality (IAQ). To provide awareness of baseline indoor air contaminant levels to support indoor air quality management.

Requirements
Tier 1: Contaminant-based IAQ design (1 point)
Comply with the following two requirements:
1. Design the building so that during occupancy, the indoor air does not exceed the concentrations for the specified...
Pilot Credit PC124

Earning Points

**PC124, New construction**

- + 6 points → IEQ
- 4 - 8 points → Energy

Total = +12 points

<table>
<thead>
<tr>
<th>Indoor Environmental Quality</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Y</strong></td>
<td><strong>Prereq</strong></td>
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<tr>
<td><strong>Y</strong></td>
<td><strong>Prereq</strong></td>
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<tr>
<td>Credit</td>
<td>Enhanced Indoor Air Quality Strategies</td>
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<tr>
<td>Credit</td>
<td>Low-Emitting Materials</td>
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<tr>
<td>Credit</td>
<td>Construction Indoor Air Quality Management Plan</td>
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<tr>
<td>Credit</td>
<td>Indoor Air Quality Assessment</td>
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<tr>
<td>Credit</td>
<td>Thermal Comfort</td>
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<td>Quality Views</td>
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<td>Acoustic Performance</td>
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<tr>
<td><strong>Y</strong></td>
<td><strong>Credit</strong></td>
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</tbody>
</table>
Electronic Air Cleaners
Electronic Air Cleaners

- Lots of names:
  - Photocatalytic Oxidation (PCO)
  - Photocatalytic Activation
  - Ionization
  - Bi-polar ionization (BPI)
  - Needlepoint ionization
  - Plasma
  - Ozone generator
  - Activated Oxygen
  - Surface irradition
  - High voltage coronas
  - Hydroxlation
  - Precipitators

- But the mechanism is always the same:
  1. Apply high energy to air
  2. Creates new, highly reactive chemical species
  3. Species react with contaminants & particles

- Why so many names?
  - No industry rules for product names
  - Each vendor wants to appear different
Electronic Air Cleaners

“Ionization” tubes in supply air duct

Energy applied to air breaks down molecules and creates ions

Ions are blown into space to chemically react with molecular contaminants and/or react with particles to increase their weight so they drop below breathing zone.
Produce ions called Reactive Oxygen Species (ROS, or radicals) and ozone:

- Superoxide anion radical: $\text{O}_2 + e^- \rightarrow \cdot\text{O}_2^-$
- Hydrogen peroxide: $2\text{H}^+ + \cdot\text{O}_2^- + \cdot\text{O}_2^- \rightarrow \text{H}_2\text{O}_2 + \text{O}_2$
- Hydroxyl radical: $\text{H}_2\text{O}_2 + e^- \rightarrow \text{HO}^- + \cdot\text{OH}$
- Ozone: $\text{O}_2 + \text{O} \rightarrow \text{O}_3$

Ozone and ROS cause:
- Respiratory disease
- Cancer
- Auto-immune disease
Chemistry Fact #2: Indiscriminate & Unpredictable Reactions

*Electronic Air Cleaners*

- **Good**: $\text{H}_2\text{O} + \text{CO}_2$
- **Bad**: New radical
- **Bad**: Harmless contaminant into harmful one (alcohol + ion oxidation $\rightarrow$ aldehyde)
- **Bad**: Oxygen turned into ozone
Chemistry Fact #3: Not all contaminants addressed

**Electronic Air Cleaners**

**VOCs with low reactivity (“aromatics”)**
- Ions/radicals cannot chemically react with these VOCs
- Includes common indoor VOCs such as benzene, toluene, xylenes

**Carbon dioxide**
- Not addressed. CO₂ proven to impact productivity and cognitive performance

**Formaldehyde**
- Some products create formaldehyde, generally as a reaction byproduct
Chemistry Fact #4: Measuring Efficiency is Difficult

Electronic Air Cleaners

1. Efficiency changes over distance from cleaner
2. Where to measure Before & After?
3. Different mix of contaminants = different chemical reactions = different cleaning efficiency results
Numerous studies show electronic air cleaners do not work or are hazardous


Example Study: CDC found electronic ionizers produce ozone

<table>
<thead>
<tr>
<th>Device</th>
<th>Company</th>
<th>Technology</th>
<th>Background Concentration (ppb)</th>
<th>Unit Concentration (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanobreeze, Unit #2</td>
<td>NanoTwin Technologies</td>
<td>Photocatalytic Oxidation</td>
<td>6.9</td>
<td>10.3</td>
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<td>Prototype</td>
<td>ActiveTec</td>
<td>ActivePure Technology (H₂O₂)</td>
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<td>AirOCare, Ser No 0033, with screen</td>
<td>AirOCare</td>
<td>Reactive Oxygen Species</td>
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<td>88.5</td>
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<td>Reactive Oxygen Species</td>
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<td>AirOCare, Ser No 0034, with screen</td>
<td>AirOCare</td>
<td>Reactive Oxygen Species</td>
<td>3.4</td>
<td>115.5</td>
</tr>
</tbody>
</table>
| AirOCare, Ser No 0034, no screen | AirOCare                | Reactive Oxygen Species    | 3.4                           | 82.5                     

Ozone Levels (> 50ppb is harmful)

EVALUATION OF MITIGATION STRATEGIES FOR REDUCING FORMALDEHYDE CONCENTRATIONS IN UNOCCUPIED FEDERAL EMERGENCY MANAGEMENT AGENCY-OWNED TRAVEL TRAILERS

Michael G. Gressel, PhD, CSP
Lynn Wilder, MSHyg, CIH

Division of Environmental Hazards and Health Effects
National Center for Environmental Health
Centers for Disease Control and Prevention
Example study: CARB found electronic air cleaners can increase VOCs, formaldehyde, and/or ozone

### Evaluation of Pollutant Emissions from Portable Air Cleaners

#### Draft Final Report: Contract No. 10-320

Prepared for the California Air Resources Board and the California Environmental Protection Agency Research Division

PO Box 2815
Sacramento CA 95812

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<table>
<thead>
<tr>
<th>Table 5.4.4: Pollutant concentration change $\Delta C$ (µg m$^{-3}$) in Scenario 2 based on results from Phase 2. Negative changes (concentration reductions) are shown in black, and positive changes (increases in concentration) are shown in red</th>
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<table>
<thead>
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<th>PAC1</th>
<th>PAC2</th>
<th>PAC3</th>
<th>PAC4</th>
<th>PAC5</th>
<th>PAC6</th>
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<td>ozone</td>
<td>-</td>
<td>-</td>
<td>22 - 191</td>
<td>0.6 – 5.5</td>
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**TOTAL VOCs** | -528 | 213 | -553 | -1086 | 661 | 895 | -422

*The compounds listed in italics were not present in the challenge mixture.*
Example study, NY department of health

Report of Bureau of Toxic Substance Assessment Testing the AtmosAir Bi-Polar Ionization Product at the Glens Falls High School, Glens Falls, NY on February

Results Published in 2018 in ASHRAE Journal:

1. The average indoor ozone concentrations more than doubled when the corona discharge was on.

2. The concentrations of the aldehydes and acetone increased when the corona discharge was operating.

3. Ultrafine particles counts increased following the deployment of limonene in the classroom.
Thank you!