The ROCIS Initiative: How Buildings Can Protect Occupants From Outdoor Air Pollution

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ROCIS

The conventional approach to boosting Indoor Air Quality (IAQ) in buildings is to: 1) limit indoor sources of air pollution, and 2) exchange poor interior air with “fresh” outdoor air. But this strategy is based on the assumption that outdoor air is cleaner than interior air. What about buildings that are sited in areas with high levels of outdoor air pollution?

The ROCIS (Reducing Outdoor Contaminants in Indoor Spaces) Initiative aims to address this issue, with the mission to “reduce the impact of exterior environmental pollution in Southwestern Pennsylvania to improve healthy and energy efficient indoor environments where we live, work, and learn.” (ROCIS.ORG) The Initiative, funded by The Heinz Endowments, is a collaboration between the Pittsburgh area’s academic community, government agencies, and community organizations.

It is a two-pronged effort: 1) education, and 2) measurement and remediation (called the Low Cost Monitoring Project).

ROCIS Education Effort

The education phase of the project includes a series of stakeholder meetings, webinars, technical briefs, and two in-depth white papers (one for homes and another for commercial buildings) outlining ROCIS pollutants of interest, how these pollutants enter buildings, and the best approaches for protecting buildings against pollutant entry. (Fugler 2014)

Pollutants of interest includes particles, biological pollutants, heavy metals, semi-volatile organic compounds, volatile organic compounds, aldehydes, other chemical pollutants (hydrogen sulphide and pesticides), odours, explosive gases (methane), ozone, carbon monoxide, carbon dioxide, nitrogen compounds, and radioactive particles and gases.

According to ROCIS, external pollutants enter buildings through:

1) Infiltration: leaky building envelope, insufficiently filtered mechanical ventilation, and negative pressure created by HVAC equipment.
2) Spaces attached to the building: like attached garage, vented attic, or open crawlspace.
3) Track-in: soil and dust.
4) Water: organochloride compounds, VOCs, and radon in household water (municipal, well or spring).

The Initiative identifies the following best approaches to protecting buildings against pollutant entry:

1) Building envelope tightness.
2) Pressure boundaries.
3) Interior air circulation and filtration, both standalone and in-duct filters.
4) Cleanliness.
5) Water treatment.
6) Combination of the above approaches.

The researchers with ROCIS evaluate the effectiveness and cost of each remedial measure in Figure 1.

Remedial measure	Potential effectiveness	Cost	Degree of necessary occupant interaction	Maturity of technology (readily available?)	Comments
	All ratings are qualitatively low, medium, or high				
Tighten house envelope	High	High	Low	Medium	A tight house is 100% effective but will require mechanical ventilation (which will introduce outdoor pollutants)
Filtration of indoor air (or incoming air)	Medium (high at filter; medium in rest of house)	Medium	High (requires inspection, replacement, need to accept noise)	High (for particle reduction)	Almost always will be part of the solution
House pressurization	High	Medium	Medium	Low	This solution has not been extensively tested
Subslab depressurization for soil gases	High	Medium	Low	High	A specific pressure boundary solution
House cleanliness	Medium	Low	High	High	It takes diligence and the right tools
Water treatment for gaseous pollutants	Medium to high	High	Medium	High	

Figure 1: ROCIS Initiative summary of remedial measures to protect buildings from outdoor pollutants.

Notice that the top two strategies, tight house envelope and filtration of indoor air, are “high” and “medium” in potential effectiveness, respectively. Furthermore, for filtration, effectiveness is “high” at the filter. This is relevant for airtight buildings with HRVs with balanced ventilation, because all of the air supplied to these buildings passes through an HRV filter when the windows and doors are closed. So the potential effectiveness of filtration in airtight buildings with HRVs can reasonably assumed to be “high.”

Measurement and Remediation: Low Cost Monitoring Project

The measurement and remediation phase of the ROCIS Initiative, called the Low Cost Monitoring Project (LCMP), is ongoing and includes 74 homes in Western Pennsylvania to date. (Fanslow 2016) Low-cost air quality monitoring, both outdoors and indoors, is done with Dylos 1700 Air Quality monitors that measure small particle counts.

Both the author of this paper as well as colleague Laura Nettleton (of architecture firm Thoughtful Balance) are participants in the study. The following findings come from the LCMP report for Nettleton's home.

The overall finding of the LCMP so far is that indoor air quality suffers when outdoor particle counts go up. The relationship is not incredibly strong, but it is statistically significant. "As we look at homes in areas with increasingly higher particle levels, we expect indoor particles to reflect about 4.5% of the increases in outdoor particles," state the report's authors. The dark grey line in the graph below (Figure 2) illustrates that 4.5% relationship. The light grey line delineates where outdoor and indoor particle counts are equal. The small grey dots show LCMP participating homes. The large black dot shows Nettleton's home.

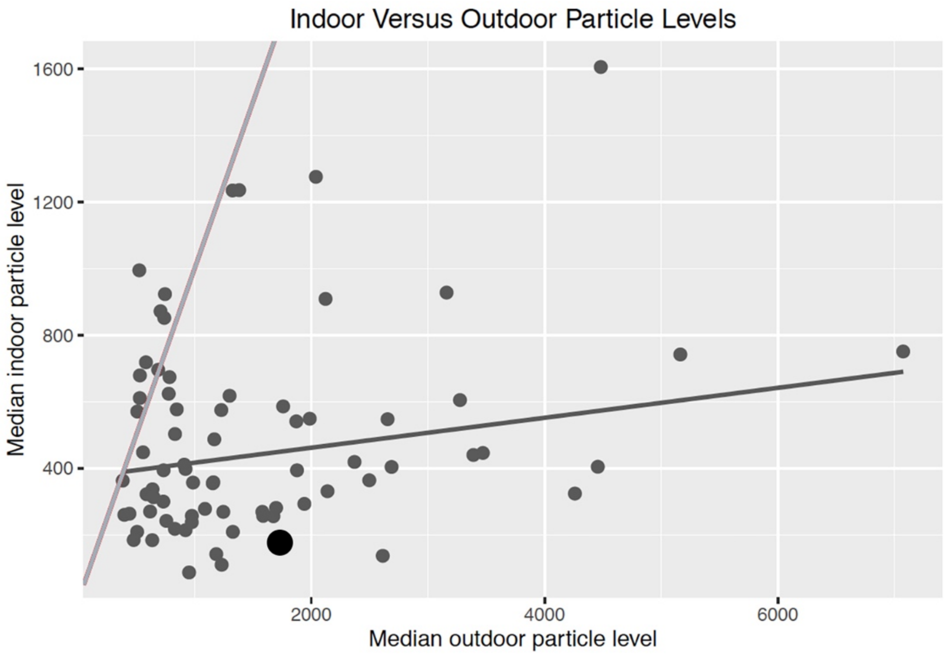

Figure 2: ROCIS measured relationship between indoor particle counts and outdoor particle counts, measured in particles per 1/100 of a cubic foot of air. Dark grey line shows 4.5% relationship between increases in outdoor particles and indoor particles. Light grey line delineates where outdoor and indoor particle counts are equal. Large black dot shows the readings for Nettleton's home.

At the beginning of the LCMP phase, Nettleton's home had the highest indoor particle count of the entire cohort, but the count plummeted after Nettleton's remediation efforts. (Figure 3) These remediation efforts included:

1) Use of a standalone MERV 13 filter taped over a floor fan (Figure 4) and run continuously.
2) Switch from tap water to distilled water in humidifier, followed by discontinued use of humidifier.
3) Cleaned furnace filter, then replaced HVAC system.
4) Switch from gas cooktop to induction cooktop.

These combined efforts made a significant impact on the particle count in Nettleton's home, making it one among the least polluted in the LCMP cohort after a few months.

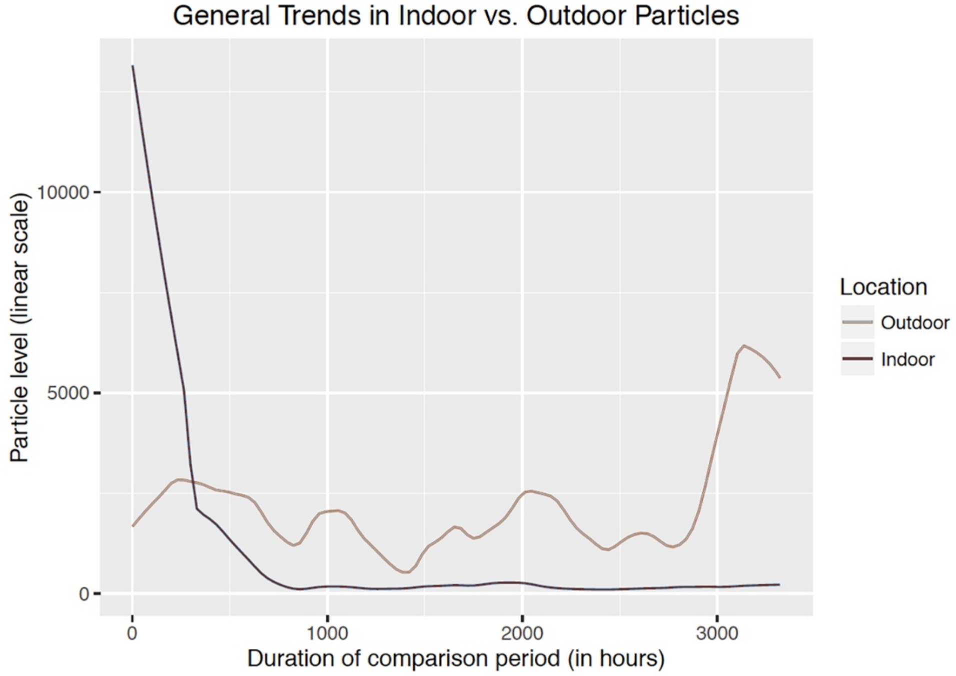

Figure 3: Comparison of the indoor and outdoor particle counts at Nettleton's home. The Dark grey line shows the interior particle counts, with their dramatic reduction corresponding to the remediation measures the Nettleton put into place, listed above.

Figure 4: Nettleton's standalone filter, made of a MERV 13 filter taped onto a floor fan.

Health Benefits of Airtightness and Filtered, Balanced Ventilation

Another North American study suggests that the airtightness plus HRV combination of Passive House brings significant health benefits to occupants compared to conventional buildings. The Canadian study (Leech 2004) compared telephone survey responses from a test group of 52 new R-2000 certified homes (with balanced HRV ventilation and airtightness of 1.5ACH5 – essentially "Passive House light" homes) and a control group of occupants of 53 new conventionally-built homes. Researchers administered the same health questionnaire to all home occupants twice, 12 months apart. This comparison revealed:

1) A statistically significant finding that R-2000 occupants were more likely than conventional home occupants to report improvement in throat irritation, cough, fatigue, and irritability.
2) A trend (though not quite statistically significant) toward R-2000 occupants being more likely than conventional home occupants to report improvement in runny nose, sneezing, wheeze, and headache.
3) No difference between R-2000 and conventional home occupants for symptoms that are unlikely to be related to indoor air quality, like nausea and diarrhoea.

Conclusion

These findings align well with the ROCIS Initiative's emphasis on airtightness and filtration measures and suggest that Passive House buildings are well-suited to shield building occupants from outdoor air pollution. The study also illustrates the importance of eliminating indoor pollutant sources in the first place. The consideration of kitchen exhaust and fuel supply options for cooking equipment become important health considerations. This conclusion has relevance beyond Western Pennsylvania of course, applying to any region of the world where outdoor air pollution is a problem.

While the ROCIS Initiative provides important insights into buildings' role in mitigating outdoor air pollution's impact on interior air, more study is needed to fully document how Passive House buildings perform in this regard.