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HOME REPORT
MICROBIAL DIVERSITY AND AIR QUALITY

Thank you for participating in our research study, "The Impact of Weatherization on Microbial Ecology and Human Health". Your contribution has been invaluable to our efforts to understand the relationships between weatherization, air quality, microbial ecology, and health. This report presents the data we gathered and our findings from your home. It starts by suggesting a way we think about health. It continues with a section on microbiomes and one on air quality.

HEALTH | The exterior *environment*, *buildings*, and *people* are useful ways to think about our health, both in general and in regards to air pollution. Air pollution poses a significant threat to health. According to the World Health Organization, more than four million premature deaths occur each year due to outdoor air pollution[1].

The *environment* is our yards, cities, and planet. While often thought of as out of our control, many actions reduce air pollution such as smog, pollens, wildfire smoke, and other substances that harm our health.

We spend almost all of our lives in *buildings*. Most of this time is in our homes. Building materials, furnishings, and appliances release and trap pollutants. Some materials can support the growth of microorganisms that release harmful spores or toxins, which is especially likely when there is moisture damage.

People (and other animals and plants) exchange gases and particles with the air through breathing, sweating, toileting, and even through shedding of skin cells. We also bring the outside inside on ourselves and

clothing. Furthermore, each of us makes daily decisions, such as opening and closing windows or driving to the store that affect the air quality of our homes or the community, or produce greenhouse gases that impact the whole planet's climate. Whether, how quickly, and how severely our health is affected by pollutants depends on many factors specific to each of us, such as the health of our immune system, how much exposure we've had, our activities, and our genetic makeup. Some of us are more vulnerable than others, including children, the elderly, and anyone with conditions such as asthma or heart disease.

The environment, buildings, and people are interconnected with both positive and negative implications for health. As an example, weatherization is an important strategy to reduce energy use. However, a tighter home is may be more likely to trap pollutants and increase moisture, especially during times when you are less likely to open windows. Ventilation helps but can make your inside air less healthy when outside air quality is poor.

There are many things you can do to improve the air quality in your community and reduce climate change:

- Set your thermostat lower in winter and higher in the summer (if you have air conditioning), and setback or turn off your heating and cooling systems at night and when you are gone from the home.
- If you use a wood-burning stove or fireplace insert, make sure it meets EPA design specifications, and burn only dry, seasoned wood.
- Walk, bike, use public transportation, or carpool. Combine driving trips such as shopping with work commutes.
- Buy plug-in or hybrid cars that do not pollute while waiting at stop lights and regenerate during braking.

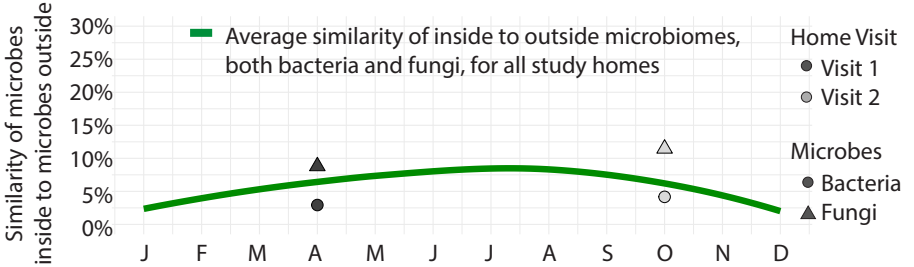
MICROBIOMES | Microbiomes are communities of microorganisms (or microbes), including bacteria, fungi, viruses, and others. When we study microbiomes we also think about it in terms of the environment, buildings, and people. The exterior environment is teeming with microbes, living on and in soil, plants, water, and air. The human microbiome is the collection of microbes that live in and on us. Built environment microbiomes are those that surround us in our buildings, being generally made up of exterior environmental and human- and pet-associated microbes. Our study is attempting to clarify how weatherization, an important strategy to reduce energy use and the carbon emissions that cause global climate change, affects these built environment microbes.

BACTERIA AND FUNGI

WHAT | We all live in intimate association with thousands of microorganisms; we share our bodies and our homes with these diverse communities of tiny life forms. Advancements made in sequencing technology have allowed this study to analyze microbial diversity in the context of air quality, health, and behavior. We report here on bacterial and fungal communities; we did not analyze other types of microorganisms.

WHAT DOES MY DATA SHOW | This graph shows how similar the microbial community inside your home was to the microbial community outside of your home. The green curve shows the average similarity of all the study homes. Your home's data is plotted with up to four points; if you have fewer than four points it means we could not find enough microbial cells in your home dust to analyze.

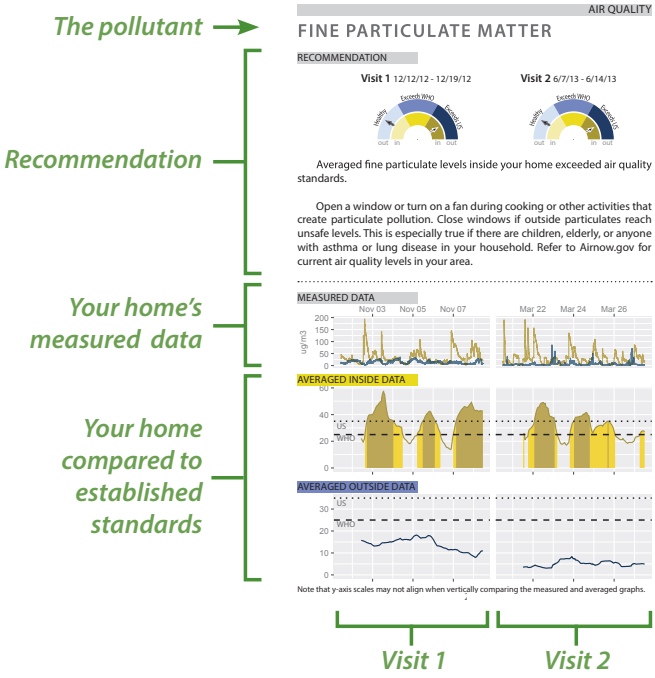
Human or animal occupants, indoor plants or compost, and window use or traffic between the indoors and outdoors can all affect the community of microbes that can be found indoors. Homes tend to have fewer "outdoor microbes" during the winter, and more during the summer.



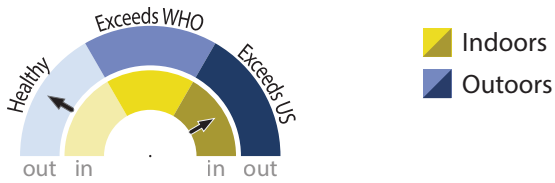
HEALTH | There is nothing inherently 'good' or 'bad' about most microbes; the microbiome data from this study helped us determine how similar the inside of your home is to the outside of your home. While no one has figured out what makes a microbiome "healthy" yet, there is some suggestion that diverse exposures can help train the immune system. Therefore, having outdoor microbes in your home may be good for you! However, we cannot draw any firm conclusions about the impact (good or bad) the diversity of the microbiome has on your health. We present this data solely to satisfy curiosities.

AIR QUALITY

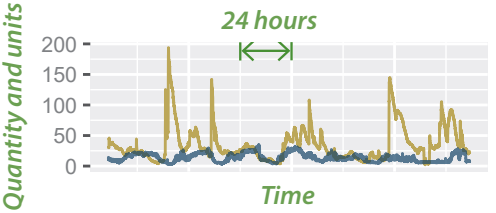
READING THE AIR QUALITY SECTION OF THIS REPORT | In the following sections we report on four pollutants measured at your home which can affect your health: radon, ozone, fine particulate matter (PM 2.5), and coarse particulate matter (PM 10). Each section includes our recommendations and analyses (as shown below) as well as important information on the pollutant—be sure to read both.



UNDERSTANDING THE RECOMMENDATIONS | The "speedometer", shown below, summarizes our findings on pollutant levels inside and outside your home (except radon which was measured only inside) for each visit we made. Our recommendations are based on what we learned about your house at both visits. The needle may point to the "Healthy" range, to the "Exceeds WHO" – the World Health Organizations' guidelines, or to the "Exceeds US" – which includes both the US standard or goal" and the WHO guideline.



UNDERSTANDING THE MEASURED DATA | Measured data is what we collected at your home. The graphs below show the quantity of the pollutant over time. Yellow represents the indoor data; blue is the outdoor data. The vertical white lines mark midnight of each day. Data was collected once per minute, with the exception of radon which was measured once every 3 hours.



UNDERSTANDING THE AVERAGED DATA | On the graph below, ozone and particulate matter are shown as a rolling average[5]. Radon is not shown as it is typically evaluated with a simple average over all the data collected. The potential for health impacts from these pollutants result from both how much of the pollutant is in the air and how long you are exposed to it. As specified in the US and WHO standards, these graphs show the data averaged over 8 (ozone) and 24-hour (particulate matter) rolling windows to identify time and intensity of exposure. The solid line represents the rolling average. The dashed horizontal lines indicate WHO and US standards, of which, the WHO's guidelines are more strict, meaning the WHO level is exceeded more frequently. The area below the curve is shaded when the averaged measurements are above the standard lines. Conclusions are limited by the short duration of the study; studies like this generally run over several years[2].

RADON

RECOMMENDATION

Visit 1 4/4/16 - 4/11/16

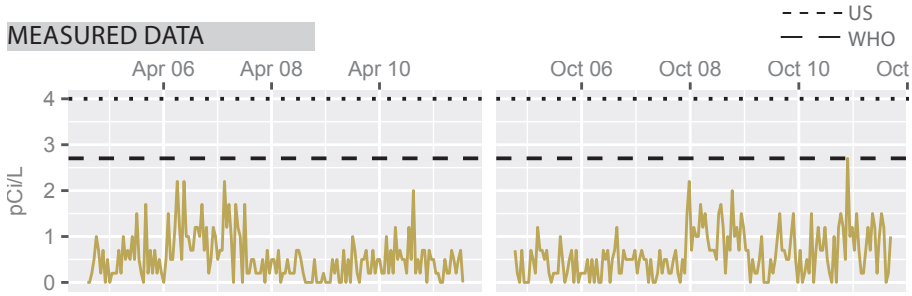
Averaged radon level = 0.5 pCi/L

Visit 2 10/4/16 - 10/11/16

Averaged radon level = 0.6 pCi/L

Averaged radon levels inside your home were acceptable

MEASURED DATA



Outside radon levels were not collected.

WHAT | Radon (Rn) is a radioactive gas classified as a Class A carcinogen. According to the EPA, radon is the second most frequent cause of lung cancer in the U.S. after cigarette smoking. Radon levels in homes vary throughout the day, from one day to the next, and from season to season, which is why it is recommended to perform a long term test if the short term test reveals unsafe radon levels. Radon concentrations are commonly expressed in picocuries per liter of air (pCi/L), where a picocurie is a measure of radioactivity [3].

HOW | Radon comes from the natural breakdown of uranium and thorium in soil, rock, and ground water, such as springs. Outdoor air has naturally occurring radon in it, but usually not at dangerous levels. Radon concentrations can build up indoors to much higher than outdoor levels if ventilation is poor. The main source of radon is the ground below the home. Radon can be drawn into a building and accumulate, especially in low areas such as basements and crawl spaces. Radon gets in through floor cracks, construction joints, gaps around service pipes, as well as the water supply. Increasing the tightness of your home by weatherizing it can potentially increase radon levels.

HEALTH | Exposure to radon causes lung cancer in non-smokers and smokers alike. For smokers the risk of lung cancer is significantly higher due to the combined effects of radon and smoking.

WHAT YOU CAN DO | Increasing ventilation by opening windows is the primary and easiest defense strategy against radon. More aggressive strategies include installing a soil depressurization system. Seal and caulk all openings in the ground floor. See pages 17-19 of the following document: www.epa.gov/sites/production/files/2014-08/documents/buildradonout.pdf

OZONE

RECOMMENDATION

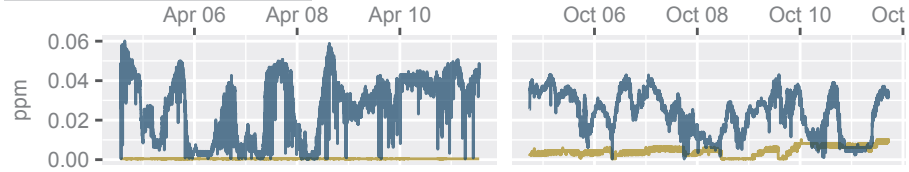
Visit 1 4/4/16 - 4/11/16

Visit 2 10/4/16 - 10/11/16

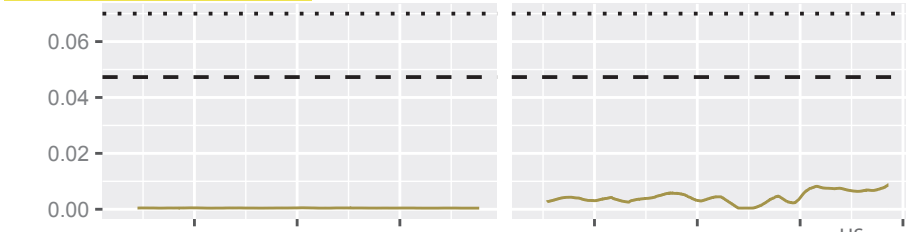
Averaged ozone levels outside your home exceeded air quality standards.

Close windows and stay indoors when ozone reaches unsafe levels. This is especially important if there are children, elderly, or anyone with asthma or lung disease in your household. Refer to Airnow.gov for current air quality levels in your area.

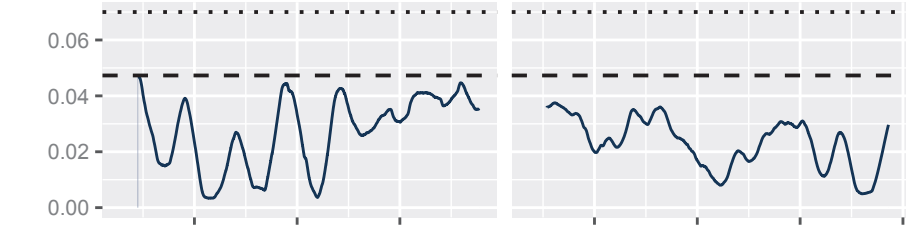
MEASURED DATA



AVERAGED INSIDE DATA



AVERAGED OUTSIDE DATA



Note: The y-axis scale increments may not be vertically consistent between graphs.

WHAT | Ozone (O_3) is a toxic, bluish gas with a distinctively pungent odor, reminiscent of chlorine. Ozone is naturally present in the stratosphere about 10 to 30 miles above the earth's surface. At these altitudes, it serves the beneficial role of filtering out much of the Sun's ultraviolet radiation. Ground-level ozone, on the other hand, is one of the biggest parts of smog and is harmful to your health. Ozone is measured in units of parts per million (ppm)[4].

HOW | Ozone is produced when pollutants from burning fossil fuels come in contact with sunlight. Weather conditions, local geography, and altitude also play a part in how ozone is formed. As ozone concentrations depend on sunlight, dangerous levels tend to occur following long periods of warmth and calm weather. Ozone forms in places far from where the pollution is actually emitted. As a result, ozone is often higher in rural than in urban areas.

HEALTH | Ozone can impair lung function and cause irritation to the respiratory tract. Those with asthma or lung disease will feel the effects of ozone at lower amounts and shorter periods of exposure than other people. Problems associated with ozone exposure include: coughing, higher risk of getting respiratory illness, and breathing difficulty during exercise.

WHAT YOU CAN DO | Stay indoors when dangerous levels of ozone are present. Refer to Airnow.gov for current air quality levels in your area. Close windows to prevent outdoor air from entering the home. Also avoid using chemical products such as paints or cleaning products that are made with smog-forming chemicals.

FINE PARTICULATE MATTER

RECOMMENDATION

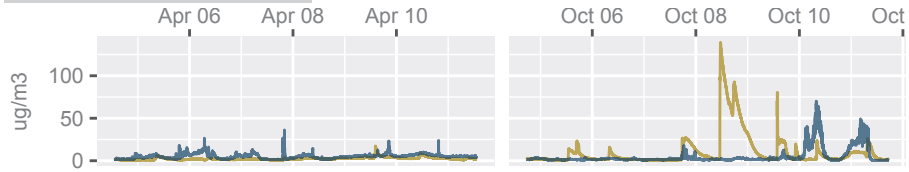
Visit 1 4/4/16 - 4/11/16

Visit 2 10/4/16 - 10/11/16

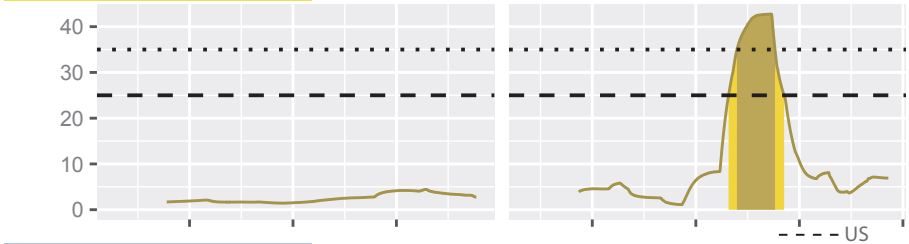
Averaged fine particulate levels inside your home exceeded air quality standards.

Open a window or turn on a fan during cooking or other activities that create particulate pollution. Close windows if outside particulates reach unsafe levels. This is especially true if there are children, elderly, or anyone with asthma or lung disease in your household. Refer to Airnow.gov for current air quality levels in your area.

MEASURED DATA



AVERAGED INSIDE DATA



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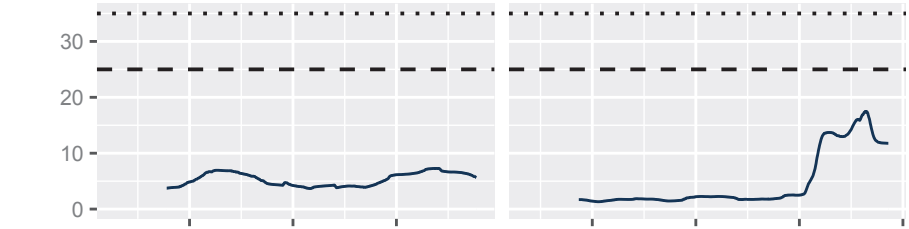


Note: The y-axis scale increments may not be vertically consistent between graphs.

COARSE PARTICULATE MATTER

RECOMMENDATION

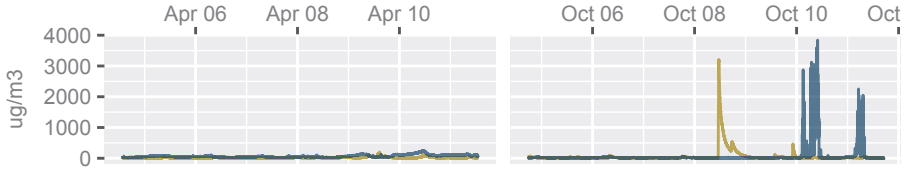
Visit 1 4/4/16 - 4/11/16

Visit 2 10/4/16 - 10/11/16

Averaged coarse particulate levels inside and outside your home exceeded air quality standards.

Open a window or turn on a fan during cooking or other activities that create particulate pollution. Close windows if outside particulates reach unsafe levels. This is especially true if there are children, elderly, or anyone with asthma or lung disease in your household. Refer to Airnow.gov for current air quality levels in your area.

MEASURED DATA



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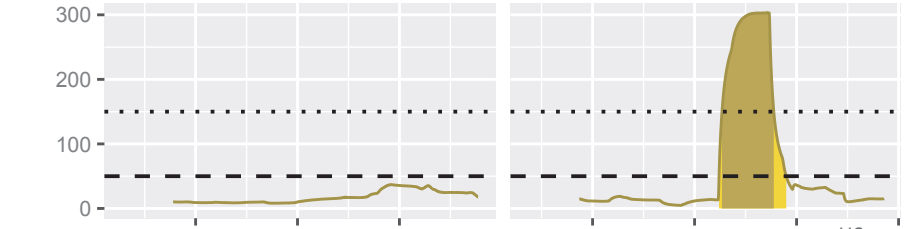

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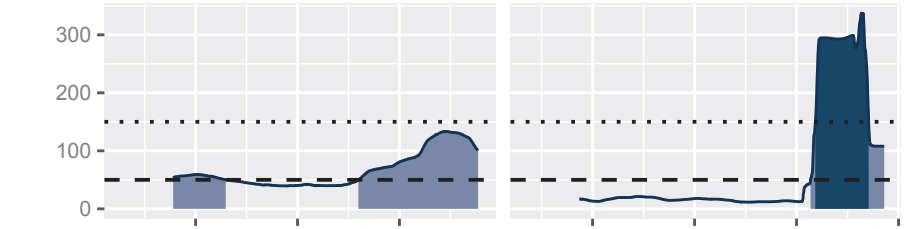


Note: The y-axis scale increments may not be vertically consistent between graphs.

PARTICULATE MATTER

WHAT | Particulate matter (also referred to as PM) is a mixture of solid and liquid particles suspended in the air. These particles vary in size and composition. We measured two size classes. Fine particles (PM 2.5) are less than 2.5 micrometers. Coarse particles (PM 10) are between 2.5 and 10 micrometers in diameter. These are all inhalable and can adversely impact health, particularly the heart and lungs. Particles larger than 10 micrometers may be irritating to your eyes, throat, and nose but are not considered as harmful.[4] Particulate matter is measured in units of micrograms per cubic meter ($\mu g/m^3$).

HOW | Particulate matter comes from outdoor and indoor sources. Outdoor particulates are commonly emitted from construction, agricultural, and industrial activities, coal burning, vehicle exhaust, road dust, and wildfires. Indoor particulates are generated through cooking, combustion activities (including burning of candles, use of fireplaces, use of unvented space heaters or kerosene heaters, cigarette smoking), and some hobbies, such as model making. Indoor particles can also be of biological origin including people, pets, mold, bacteria, and allergens. Fine particles, when encountered with sunlight, are the main cause of reduced visibility or haze. Particles can also be carried over long distances by wind and settle on the ground or water. Depending on the chemical composition of the particles this can have a variety of ecological effects including making lakes and rivers more acidic and changing the nutrient balance of soils. Over time, this can damage forests and farm crops and affect the diversity of terrestrial and aquatic ecosystems.

HEALTH | Particles less than 10 micrometers in diameter can penetrate deep into the lungs and enter the bloodstream. Breathing particulate matter can cause eye, nose, and throat irritation. It can also aggravate coronary and respiratory disease symptoms, therefore, those with heart or lung diseases, coronary artery disease, congestive heart failure, asthma, and chronic obstructive pulmonary disease (COPD) are at greater risk from particulate matter exposure. High exposure can lead to premature death in people with heart or lung disease. As with other air pollutants, particulate matter can be more hazardous to certain people, including children, the elderly, and people with heart or respiratory disease.

WHAT CAN YOU DO | When outside particulate levels are high, stay in as much as possible. Refer to Airnow.gov for current air quality levels in your area. Reduce or avoid outdoor activities and reduce indoor activities

that might increase particulate levels. This might include not using lawnmowers, burning trash or leaves, or using a fireplace. You can receive automatic air quality notifications from AirNow www.airnow.gov/index.cfm?action=topics.about_airnow to help you be proactive for better air quality. More information can be found at www.epa.gov/pm-pollution/particulate-matter-pm-basics.

For the health of your family and yourself, remember at all times to use adequate ventilation during cooking. Smoking outside and limiting use of fireplaces will improve indoor air quality. Also, regularly changing filters on central heating and cooling systems can help.

1. www.who.int/airpollution/en/

2. The World Health Organization (WHO) and US methods to evaluate ozone and particulate matter air quality first average the data over a number of hours and then calculate a statistic for a period of several years. The US standards can be found at the National Ambient Air Quality Standards: www.epa.gov/criteria-air-pollutants/naaqs-table. Since our visits were much shorter, we have adapted these methods to determine our level of concern. We perform the first step—averaging the data—but not the second step—calculating the long term statistic.

3. Radon is shown in units of picocuries per liter—pCi/L, a way of measuring radioactive decay. A picocurie is one trillionth of a Curie, or 2.22 radioactive decays per minute. The US action threshold is an average of at 4 pCi/L for a short term (2-90 days) test. The WHO's action level is an average of 2.7 pCi/L for a short term test. Radon is evaluated against the standards by calculating the mean, or average, of the measurements. For more information visit www.epa.gov/sites/production/files/2014-08/documents/buildradonout.pdf.

4. Ozone is measured in ppm or parts per million units. As an example, 1 ppm of ozone is the same as saying 1 gram of ozone in 1 million grams of air. The US has set the air quality standard for ozone as a 8-hour rolling average at 0.07 ppm. The WHO standard level is an 8-hr rolling average at 0.047 ppm. Ozone is produced when sunlight interacts with hydrocarbons and nitrogen oxides.

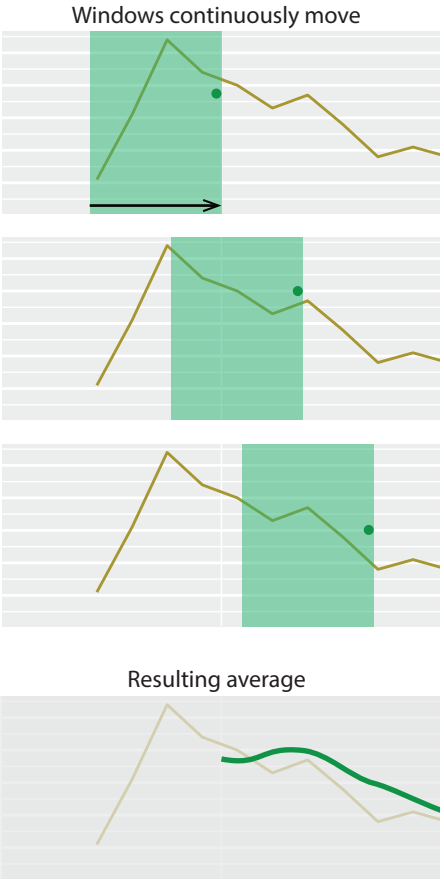
5. A rolling average is calculated by taking the arithmetic mean of a given set of values, and doing that for every time point in the data. For ozone this "rolling window" is 8 hours wide, and for particulate matter the window is 24 hours wide. The diagram on the facing page illustrates how a rolling average is continuously moving. The result is a data set in which each point is the average of the preceding 8 or 24 hour period. Note that our rolling average differs from the national standard in that we collected measurements every minute as opposed to the hourly measurements that the standards specify.

Short term episodic exposure is considered less hazardous at low levels. The averaging done to the data removes spikes that might otherwise give the appearance of being unhealthy. Generally when analyzing whether data is hazardous, more significance is given to long term (annual) averages. Nevertheless, the data we collected can help you identify patterns of

exposure that you might want to address.

The data for radon can be compared directly to the EPA and the WHO guidelines. These are shown as 2 dashed horizontal lines—the lower line is the WHO guideline and the upper line is the US standard. Our data is considered a short term test. Note also that we measured radon only inside your home.

Rolling Average



* In some cases one or more of the data sets may be missing or show holes. In some cases the quality of the data was not adequate and we excluded those points.

This report was a collaboration between the *University of Oregon, Biology and the Built Environment Center,* and the *Oregon Research Institute.*

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