Protecting ourselves from wildfire smoke pollution

It's fairly obvious that, due to global warming, the extensive wildfires in the Canadian north are not a one-off event, but are likely to recur in future years, perhaps even more widely.

With wildfire smoke sweeping over our city, I set out to protect our household from the most damaging component of this pollution: the tiny PM2.5 particles. These are so small that they evade the body's natural air filtration and penetrate deep into our lungs, potentially causing a variety of health issues.

I found a partial solution, so to save you the research work, and in case you might want to do something similar, I've described in some detail what I learned and the steps that I took.

Monitoring and forecasting PM2.5 pollution
It's helpful to know how bad air pollution is at any time, indoors and out, to know what's ahead, and most important, to assess the effectiveness of countermeasures. Here are some tools.

Outdoor pollution:

- This website shows on a map the recent history and a 2-day forecast for wildfires in Canada and the resulting plumes of smoke.
- For residents of Ontario this government website tracks the pollutant levels in many cities, hour by hour: just select your location. For comparison, this chart shows the wakeup call we received in Ottawa on 7th June 2023 with PM2.5 levels over 500 µg/m3 – typical of a bad day in famously polluted cities like Beijing or New Delhi.

Indoor pollution:

- Air quality monitors like this and this provide a reliable and inexpensive way of tracking PM2.5 pollution levels, minute by minute, indoors or outdoors. These instruments allow you to see exactly what is going on in your own living space, how indoor pollution levels change according to outdoor conditions, and the effect of filtering the air.

Air filtration
Because air filters are expensive, there was a great deal of discussion during the pandemic about how to remove virus particles from the air cheaply. This resulted in the development of a very effective and low-cost DIY solution – the Corsi-Rosenthal box, named after the inventors. Happily, this device is also effective for removing PM2.5 particles (and some other pollutants).

The 'box' is essentially a cube made of high-grade 20" x 20" furnace filters, held together by duct tape, with a box fan taped to the top. It looks crude but works – in my opinion a rather brilliant example of engineering to meet a need in the most cost-effective manner possible.

On Wikipedia there is comprehensive information about the Corsi-Rosenthal box including detailed instructions on how to make one yourself. It's easy if you can work with duct tape without injuring yourself, you can probably manage.

A better alternative to the cube?
I've also come up with an alternative to the cube – I'll call it the flatpack – which is just as effective, significantly cheaper, simpler to build, and much more portable.

The genius of the cube is the use of multiple filters to increase the filter area, which reduces air resistance and therefore increases airflow. But a single 4" thick filter has about the same performance as the four 1" thick filters used in most cubes. This is because it has about the same filter surface area due to the much deeper pleats. I figured that a single 4" filter attached directly to the fan should have about the same performance as the cube. And it does.

The flatback that I built performs slightly better than my cube, moving about 10-15% more air, though this is likely due to differences in the filter material, rather than the design.

Here's what my two filters look like: the flatpack and the cube.

Costs
My cube cost **$180**, made up as follows: $115 for four high-grade (MERV-13) furnace filters, $57 for the Lasko 20" box fan, and $8 for 10 yards of duct tape. This is about one-tenth the cost of a commercial product of equivalent performance. The flatpack cost significantly less at **$102**, made up as follows: $42 for the filter (half of a $83 2-pack), $57 for the Lasko 20" box fan, and say $3 for a modest amount of duct tape.

If you wish to compare these with bought units, look for the CFM rating (cubic feet per minute) – or CADR (clean air delivery rate). CADR is just CFM adjusted for the efficiency of the filter in removing particles (e.g. 85% for MERV-13) filters. My calculations support the Wikipedia claim that these DIY filters cost about one-tenth of a bought unit of similar performance.

The cost of replacing filters is another factor. The replacement interval depends entirely on how much the filter is used, and how polluted the air. Eventually, the filter material will become loaded with particles, restricting the airflow and possibly reducing the percentage of particles captured. I expect mine to last a year or more since the filter will be in use only when there is significant smoke pollution. However, the key point is that I will know when they need to be replaced since the PM2.5 monitor will tell me when they are becoming less effective.

Results
These filters shift a lot of air! According to Wikipedia the cube shifts between 513 and 863 (CFM) depending on the fan speed and my measurements agree.

Because of this high capacity, one of these filters, with the fan running at full speed, will eliminate most of the pollution in an average room within 5-10 minutes. It will then easily maintain this level at the lowest speed when the fan hums unobtrusively. I find this scarcely noticeable and not loud enough to interfere with phone calls.

The flatpack version is so light and portable that it's easy to take it with you when you move to a different room, for example from the office to the kitchen. But I've found this unnecessary because the filter is quite effective at purifying the air throughout our home.

Provided that the forced-air furnace fan is kept running, the air purified in one room is moved throughout the house, diluting the polluted air that is gradually infiltrating from outside. I find that simply by leaving the filter fan running at medium speed in any room, the air pollution throughout our home drops significantly – to about 10% of the outside level. Only in the worst conditions, when the air outside is highly polluted, will we need to run the filter in the same room as us.

With these tools in place, although I'm no more optimistic than before about the future of our planet, at least I no longer have to worry about how my family is going to cope with one of the immediate impacts – onslaughts of wildfire smoke from the north.

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(editorial comment: The guidelines stipulate that $PM_{2.5}$ should not exceed 5 $\mu g/m^3$ annual mean, or 15 $\mu g/m^3$ 24-hour mean; and that PM_{10} should not exceed 15 $\mu g/m^3$ annual mean, or 45 $\mu g/m^3$ 24-hour mean.[2])

(This document is downloadable as a PDF here.)

For more information visit this CACOR web page: Protecting ourselves from wildfire smoke pollution - Canadian Association for the Club of Rome (canadiancor.com)