Volatile organic compounds: neighborhood monitoring and home filtration

Volatile organic compounds (VOCs) are a group of thousands of chemicals containing carbon. Numerous Portland industries release dangerous VOCs into the air such as benzene, formaldehyde, toluene, and xylene which disperse into neighborhoods. These industrial sources of VOCs include oil refineries, tank farms, auto body painters, asphalt and fiberglass manufacturers, as well as their trucks and ships. Forest fire smoke also contains a lot of VOCs.

Short term health effects from VOCs may include:

- itchy eyes
- headaches
- fatigue
- breathing difficulties
- coughing
- burning eyes or throat
- nausea
- increased likelihood of asthma attacks

These symptoms often increase based on the frequency and duration of the exposure.

Long-term health effects from VOCs may include:

- persistent headaches
- dizziness or difficulty concentrating
- nausea
- breathing problems or lung cancer
- liver or kidney damage
- central nervous system conditions

VOCs often, but not always, are accompanied by an odor that people may recognize, such as scents related to paint, cleaning products, new cars, and petrochemicals.

Low-cost VOC monitoring

If you can smell VOCs outside your home regularly, then similar concentrations are present in your home as well. The human nose quickly desensitizes to odors over time (scent habituation is also known as olfactory fatigue or "nose blindness"), so people are unable to distinguish a particular scent for a prolonged time. To detect odors in your home, the United States Consumer Product Safety Commission recommends leaving your house for a few minutes and then reentering. For the neighbors of some industries, noticing VOC odors may require leaving your neighborhood entirely and then returning.

A human nose can usually detect VOCs but only to collect a few readings a day for data that may be considered too subjective when obtained by untrained volunteers. Vigor, a Portland shipbuilder, partially funded studies by University of Portland students and faculty to determine odors sources. In 2017 Vigor elected to end a $1 M waste treatment program in response to the results. Undergraduate students were trained in the ASTM E544-10 method to correctly sort ten unlabeled flasks of reference odorant 1-butanol and water from the lowest to highest concentration. To avoid olfactory fatigue, odor data was collected only three times per day — morning, midday, and evening; odors were sampled from 12/1/14 through 11/30/15 at 19 NE Portland locations.

VOC monitoring devices can record VOC sample data every two seconds without the need for special training. For most people concerned with VOC exposure, a low-cost device with a Sensirion SGPC3 gas sensor such as Flow 1 ($129 at plumelabs.com/en/flow/store/) is sufficient to monitor your home and neighborhood. The Flow 1 does not include a digital display of the data; instead, it uses Bluetooth to connect to a smartphone. Smartphone software shows the results in real time and records all data collected. This portable, battery powered monitor can be used to locate the source of airborne VOCs by walking or bicycling toward the area corresponding to higher total VOC (TVOC) numbers.

Flow 1 uses a Sensirion SGPC3 gas sensor, a heated metal oxide sensor located between two electrodes. Using high temperatures, the sensor creates oxygen ions that react with VOCs in the sample. These reactions change the electrical resistance between the electrodes, measuring the ambient gas concentration. Flow 1 takes a TVOC reading and logs the result every two seconds. Because humidity interferes with accuracy, it automatically

corrects the VOC reading based on its onboard humidity sensor. Sensirion's stated accuracy for 90% of its SGPC3 gas sensors are typically +/- 15%; 9% of its sensors are typically +/- 40%; and presumably 1% are worse than that, which we obtained from an information request to the company. The sensors become slightly less accurate at higher VOC concentrations.

The only other low-cost VOC monitors we found that uses a different TVOC sensor than Sensirion are made by Temtop. Temtop M10 ($90 on Temtop website) use the Winson GM-402B MEMS sensor. The Winson sensor uses the same heated metal oxide sensor technology as Sensirion. We decided against buying the Temtop M10 because the Winson sensor datasheet does not include a value for its sensor's accuracy. Temtop does not state that its' VOC monitors use a Winson VOC sensor on its website. We emailed Temtop and they responded with extensive documentation.

The Dart WZ-S is the only low-cost sensor we could find that can detect formaldehyde and is available in a commercially available monitor. The accuracy of the Dart sensor is unknown. The Temtop M10i ($176 on Temtop website) is the only monitor we can find that can both log data and has a Dart WZ-S sensor. However, the accuracy of its Winson TVOC sensor is unknown as explained above. Some Portland industries emit a lot of formaldehyde, so we purchased two lower-cost Hei Liang Air Quality Monitors ($60 on Amazon) which contain a Dart WZ-S sensor. Dart Sensors told us their WZ-S sensor cannot report TVOC. Hei Liang doesn't report which TVOC sensor they use, and they don't have a website so we couldn't contact them to ask; we also couldn't disassemble the device to check without damaging the case.

Accuracy compares the device to regulatory-grade VOC analysis such as gas chromatography–mass spectrometry (GC–MS). Oregon DEQ uses GC-MS for VOC analysis at two of their Portland air monitor sites. Air samples are gathered in Summa canisters and analyzed at the DEQ Lab. The DEQ Lab has agreed to allow us to colocate our low-cost VOC monitors at these sites so we can compare the accuracy of these devices for ourselves.

Portland Clean Air recommends the Flow 1 for low-cost TVOC monitoring because it uses the well-documented Sensirion sensor and it logs data. We recommend the Temtop M10i only for low-cost formaldehyde monitoring because it has a Dart sensor and its logs data. Data logging allows you to export collected data to graph long-term VOC exposure and to GIS map thousands of readings to show neighborhood VOC concentrations.

A GIS map of logged data from a bicycle mounted monitor can reveal the source of a VOC problem and the extent of neighborhood exposure. The emitter of the VOCs will be located at the center of the bullseye with the highest VOC concentration. This requires a flashlight bike mount (two for $10 on Amazon) or Quad Lock handlebar bike mount and Universal Adaptor ($45 on Amazon) depending on the shape of your monitor. Each bike map should have only one day of data collection which can include several devices collecting data on that day. Portland Clean Air charges $50 for the first map and $30 for each additional map.

Portland Clean Air assists graphing long-term data at no cost. For long-term monitoring, connect a low-cost VOC monitor with data logging to its own smartphone. Cellular service is not required. Used smartphones with Bluetooth are inexpensive and can be purchased at an electronics recycling site. A dedicated smartphone can store years of data.

Higher-cost VOC monitoring

Before the recent availability of inexpensive portable VOC monitors, the only choices were high-cost regulatory-grade instruments or VOC monitors such Aeroqual Series 900 Controller fitted with a Aeroqual VOC PID Sensor Head ($1,825 from GasSensing). This battery powered device can be bike mounted to collect data for GIS mapping but requires a wireless data logging kit (an additional $850 and $39/year from GasSensing). This device uses a photoionization detector (PID) in which high-energy photons break a small percentage of VOC molecules in the sample into positively charged ions. The ions produce an electric current which is measured and reported by the detector as a TVOC reading every ten minutes. PID sensors cannot measure formaldehyde, which

requires a different Aeroqual sensor. Aeroqual's accuracy is +/- 10% of the measured value obtained by a regulatory-grade instrument.

To obtain regulatory-grade VOC analysis of air samples from your area, EPA-certified labs lend portable Summa canisters and charge about $200 to analyze each sample. Summa canisters are spherical, six-liter, stainless steel containers about the size of a basketball and weigh about six pounds each. They have a nearly chemically inert interior surface manufactured for air sampling. Summa canister lab analysis can detect approximately 60 VOCs and their airborne concentrations.

Markes Easy-VOC ($840 for grab-sampler pump kit) charges about $100 to analyze each air sample. The equipment is easier to transport and the shipping the tiny samples costs less than Summa canisters. Easy-VOC can report hundreds of VOCS, a much wider range than Summa canisters, with similar accuracy. The device looks like a large syringe and can easily fit in a backpack. It stores samples in small stainless steel sorbent tubes which are mailed to the company for analysis.

When bicycle monitoring with a low-cost device, two Summa canister or Easy-VOC samples are required to detect which airborne VOCs are at the site and to determine their accurate concentration gradients. One sample is collected near the source of the emissions and a second sample is collected a few thousand feet away.

Another option for regulatory-grade accuracy, ideal for people living near refineries and tank farms, is an EPA 325 fenceline study. This study uses small stainless steel sorbent tubes that are left at the sample site for 28 days and then analyzed at a lab. Each sample costs $75 to report the results for just benzene. EPA 325 can be extended to additional VOCs of concern including 1,3-butadiene, toluene, ethyl benzene, xylenes, and other chemicals with known sampling rates. A single study may use as many as 20 to 30 sample sites. The cost for three rounds of 30 tubes in a three-month study, totaling 90 samples for a single VOC, is about $7000 through Beacon Labs in Maryland.

VOC home filtration

The only commercially available technologies for removing airborne VOCs from the home are activated carbon and photo electrochemical oxidation (PECO). While numerous home air purifiers contain small amounts of activated carbon, these amounts would be insufficient for people exposed to significant amounts of industrial airborne VOCs. There are air purifiers available that contain disposable cartridges with pounds of activated carbon. However, once the carbon becomes saturated, it must be replaced or the captured VOCs would be slowly released back into the indoor air. And, regularly replacing the carbon can be inconvenient and costly. If you can regularly smell VOCs outside your house, buying an air purifier with enough activated carbon would mean purchasing an expensive and bulky device.

The Molekule Air ($700 from Molekule website) can remove VOCs from the home using PECO. A filter surface coated with a catalyst such as titanium dioxide is irradiated with UV light, forming hydroxyl radicals which oxidize VOCs, converting them into carbon dioxide and water. While some air purifiers create harmful ozone, the Molekule air purifier does not – and it destroys a small amount of ozone already present in the air. The device is certified by the California Air Resources Board which requires that ozone emissions average less than 0.07 parts per million per eight hours. Portland Clean Air is now testing the Molekule Air using an Flow 1 at a site near the Linnton tank farms where neighbors often smell airborne VOCs.

Portland Clean Air has not been compensated in any way by companies mentioned in this report. We purchased Hei Liang Air's monitors for formaldehyde monitoring and Flow 1 for VOC monitoring at their normal prices. We are also currently testing a Molekule purchased at full price.

For questions, or to volunteer or donate please email:
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