



## **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. If you are the neighbor of some Portland industries, noticing VOC odors may require leaving your neighborhood entirely and then returning.

A human nose can usually detect VOCs but only a few times 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 concentrations. 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 Atmotube Plus (\$79 on Amazon) is sufficient to monitor your home and neighborhood. The Atmotube Plus 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 displayed on the app.

Portland Clean Air recommends the Atmotube Plus for low-cost TVOC monitoring because it uses the well-documented Sensirion SGPC3 gas sensor and it logs data. Data logging allows you to export tens of thousands of readings to graph long-term VOC exposure and make it possible to GIS map neighborhood VOC concentrations. We recommend the Temtop M10i only for low-cost formaldehyde monitoring because it has a Dart sensor and it logs data.

A GIS map of logged data from a bicycle-mounted monitor is the best way to document the source of a VOC problem and the extent of neighborhood exposure. The different concentrations of airborne VOCs form a bullseye on the GIS map. The source of the VOCs can be found at center of the bullseye at the highest concentration. Collecting data by bicycle requires a flashlight bike mount (two for \$10 on Amazon) or a Quad Lock handlebar bike mount and a Universal Adaptor (\$45 on Amazon) depending on the shape of your monitor. Each GIS map shows data collected on only one day but can include data collected from several devices on that day. Portland Clean Air charges \$50 for the first GIS 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.

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 determine the accuracy of these devices for ourselves.

Atmotube Plus 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. Atmotube Plus 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. Their sensors become slightly less accurate at higher VOC concentrations.

Some Portland industries emit a lot of formaldehyde, a dangerous carcinogen. The Temtop M10i (\$176 on Temtop website) is the only monitor we found that can both log data and has a Dart WZ-S sensor. The Dart WZ-S is the only low-cost sensor we found that can detect formaldehyde and is available in a commercially available monitor. Dart Sensors' stated accuracy is +/-10% or +/-30ppb, whichever is greater, obtained by an email response from the company. Dart Sensors told us their WZ-S sensor cannot report TVOC.

The only other low-cost VOC monitors we found that use a different TVOC sensor than Sensirion are made by Temtop. Temtop M10i use the Winson GM-402B MEMS sensor, information obtained by an email response from the company. The Winson sensor uses the same heated metal oxide sensor technology as Sensirion. Except in cases where we need to monitor for formaldehyde, we decided against buying the Temtop monitors because the Winson sensor datasheet does not include a value for its sensor's accuracy. Temtop M10i uses a Temtop laser sensor for particulate, we prefer the more the more widely used and extensively documented Plantower laser sensor for low-cost particulate monitoring.

### **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 the Aeroqual Series 900 Controller fitted with an 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). It 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 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 including formaldehyde and their airborne concentrations.

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

When bicycle monitoring with a low-cost device, two Summa canisters 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 fence-line 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 the 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 Atmotube 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 low-cost VOC monitors at their normal prices. We are also currently testing a Molekule using an Atmotube Plus, both purchased at full price.

For questions, or to volunteer or donate please email:  
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or call (503) 995-5453

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