

VOLATILE ORGANIC COMPOUND DETECTION

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ABSTRACT. This research was conducted to see whether Volatile Organic Compounds (VOCs) are present in Abigale's apartment after Abigale and Abigale's guests experienced intense symptoms: Dizziness, Nausea, Drowsiness, Breathlessness, Blurred Vision, Confusion, and Agitation; and if VOCs are present, what is the cause. A *MiniRae3000* 11.7eV PhotoIonization Detector (PID) was used to establish a baseline level of VOC gases. While using the PID, it was found that the VOC makeup of the air was 0.0 Parts Per Million (*ppm*) over 2 hours. Then the electric heaters that were expected to be releasing VOC gases were turned on. An increase of 1.1*ppm* over 15 hours was measured. To verify the results, the PID was taken out into the hallway where it quickly read 0.0*ppm*, and then returned to the apartment to see the PID read 0.8*ppm*. These findings lead one to conclude that VOC gases are present in Abigale's apartment, and they are likely being created by the electric heaters.

1. INTRODUCTION

After Abigale and Abigale's guests experienced intense symptoms: Dizziness, Nausea, Drowsiness, Breathlessness, Blurred Vision, Confusion, and Agitation, it became clear that there is a dangerous gas in the air. To quantify this understanding, we used a *MiniRae3000* 11.7eV (Append.4) PhotoIonization Detector (PID) to determine the VOC content in the air in various situations.

According to the Occupational Safety and Health Administration (OSHA) worker exposure is measured by a Permissible Exposure Limit (PEL) specific to the regulatory limit for a certain material. While PELs have not been updated since 1970, they are still used with support from more up to date measurement systems like the California Division of Occupational Safety and Health Administration (Cal/OSHA) Permissible Exposure Limits (PELs), not to be confused with OSHA PELs, and National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs)(1). The OSHA PEL is calculated by taking the Time Weighted Average (TWA) over a workday, typically 8 hours. Cal/OSHA PELs can have a specified TWA over a 8 hour workday, short-term exposure limit (STEL), and a Ceiling (C) that cannot be exceeded for any amount of time. NIOSH RELs are similar to Cal/OSHA PELs, considering they can have a specified TWA, STEL, and C, but the TWA is for 10 hours. The difficulty with VOC materials is the wide variety, there are some VOC materials like Maleic Anhydride that OSHA designates a 1*ppm* TWA, (Cal/OSHA) designates a 0.1 PEL TWA on and then other materials like Acetaldehyde that have an OSHA 200*ppm* TWA, and a (Cal/OSHA) 25*ppm* C (2). The tricky part is the fact that they are all measured on the same scale, without the ability to differentiate with a PID.

A PID is still a useful tool for testing ideas since it can detect the presence of over 700 VOC gases. While it is nice to identify exactly the source of the problem, determining that there is a problem at all is more important. Initially it was believed that the symptoms were being caused by carbon monoxide gases, but after a visit from the fire department determined that there were no carbon monoxide gases present and symptoms were still being experienced by Abigale and Abigale's guests proved that this was not the case. This led to further analysis and deeper prying to understand what was causing the symptoms. It is known that heating up paint causes VOC gases to be released, and the experienced symptoms line up with the EPA's specified health effects (3). With the baseboard heater's radiator fins covered in paint (4), it was a natural step to test if the heaters were the cause of the symptoms.

2. METHODOLOGY

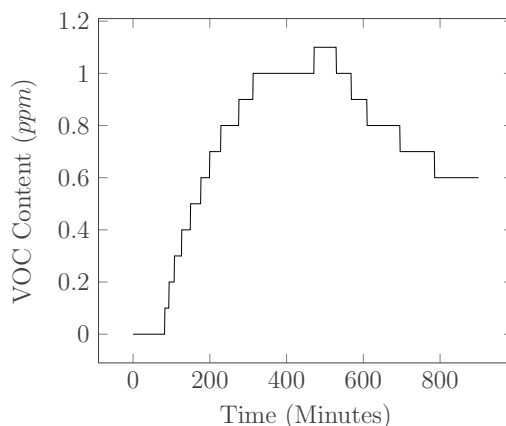
To determine the cause of the symptoms, we needed to reduce the situation to a simple baseline form. From there we would be able to see how the environment reacted in various ways:

- (1) To establish a baseline in Abigale's Apartment, all the windows were opened for 18 hours, fans were placed in a pushing and pulling orientation to circulate air, two air purifiers were left running on the highest setting, and extra care was taken to make sure that no items were in contact with the baseboard heaters. The baseboard heaters were then turned off at the circuit breaker.
- (2) To conduct the first test, the windows were closed, and the air purifiers were turned off. The PID was positioned in a central location about three feet above the ground on a table. The PID checked the air for VOCs every 5 seconds for 2 hours.
- (3) For the second test, the first test's data was interpreted, and then the baseboard heaters were turned on. The PID checked the air every 5 seconds for 15 hours.
- (4) To verify findings, after the second test concluded the PID was taken outside of Abigale's apartment and after it stabilized, the PID was returned to the apartment to make sure the result was consistent with what was found in the second test.

3. RESULTS

3.1. Baseline. To establish the baseline for later testing the PID recorded data for 2 hours in a central location. The PID did not detect any VOC in the air during this test. See Ref. 4 for raw data.

3.2. Heater Test. Over 15 hours the PID recorded data. It took 83 minutes for VOC content to be identified, but between minute 83 and 472 the VOC content rose to 1.1ppm and maintained this peak until minute 530. The VOC content dropped from the peak to 0.6ppm between minute 530 and 786. This is illustrated below:



Make note that the VOC content is rising faster than it is falling. This could mean that the VOC content is not being removed as fast as it is being released into the room. The VOC content took 67 minutes to rise from 0.0ppm to 0.5ppm while it took 163 minutes to rise from 0.5ppm to 1.0ppm . This could mean that the VOC content increases fastest just after the heater switches on. In a real-world case where the baseboard heater is being switched on and off by the thermostat it is likely that more VOC content is being released into the air. Moreover, the VOC content lingers longer than it takes to introduce it to the environment, this could create a turnstile effect where the VOC content never returns to 0.0ppm . See Ref. 4 for more details.

3.3. Verification. To verify the integrity of the results, the PID was removed from Abigale’s apartment until it zeroed out. The PID was returned to Abigale’s apartment where it read 0.8ppm which is consistent with the findings at the end of the heater test. The PID read 0.8ppm in ~ 4 seconds, which is consistent with the device’s specified reaction time. See Ref. 4 for more details.

4. CONCLUSION

It is likely that VOC gases are being introduced into Abigale’s apartment from the electric baseboard heaters. While there are other factors that could be considered for introducing VOC gases into Abigale’s apartment, these can mostly be excluded since the baseline was established over 2 hours, and the first VOC gases from the heater were detected after 87 minutes. This means that if there was another source of VOC gases, it would have been detected during the baseline test. It is important to consider that the danger of VOC gases is constant, and without fresh airflow the gases will likely continue to increase. While there were substantial detectable levels of VOC gases in 87 minutes, it is likely that over the course of months while Abigale was running the heat, VOC gases were being introduced the whole time. This is important because even if VOC levels are not at an immediate evacuation level, over time their effects compound and can be nearly as bad; if not worse than experiencing a concentrated dose of VOC gases. The symptoms that Abigale and Abigale’s guests experienced are consistent with common VOC poisoning symptoms (3). It seems that more likely than not, that the VOC gases

from the baseboard heaters caused the adverse symptoms Abigale and Abigale's guests experienced.

REFERENCES

1. Permissible exposure limits - annotated tables. Occupational Safety and Health Administration. (n.d.). <https://www.osha.gov/annotated-pels>
2. Permissible exposure limits – osha annotated table Z-1. Occupational Safety and Health Administration. (n.d.-b). <https://www.osha.gov/annotated-pels/table-z-1>
3. Environmental Protection Agency. (2023, August 15). Volatile Organic Compounds' Impact on Indoor Air Quality. EPA. <https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality> <https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality>
4. VOC resources. VOC. (n.d.). <https://starlitmantis.com/VOC.html>

5. APPENDIX

5.A. Further Reading.

- (1) <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8700805/>
- (2) <https://www.health.state.mn.us/communities/environment/air/toxins/voc.htm>
- (3) <https://www.dhs.gov/publication/handheld-photoionization-detectors>
- (4) <https://www.rae-gasmonitors.com/xyxy-minirae-3000-plus.html>

5.B. Key Data Points. Heater Test 3.2:

Increasing *ppm*:

Date/Time	Minute	VOC(<i>ppm</i>)
1/22/24 22:31	83	0.1
1/22/24 22:42	94	0.2
1/22/24 22:56	108	0.3
1/22/24 23:15	127	0.4
1/22/24 23:38	150	0.5
1/23/24 00:05	177	0.6
1/23/24 00:28	200	0.7
1/23/24 00:57	229	0.8
1/23/24 01:44	276	0.9
1/23/24 02:21	221	1.0
1/23/24 05:00	472	1.1

Decreasing *ppm*:

Date/Time	Minute	VOC(<i>ppm</i>)
1/23/24 05:58	530	1.0
1/23/24 06:37	569	0.9
1/23/24 07:18	610	0.8
1/23/24 08:44	696	0.7
1/23/24 10:14	786	0.6