Laboratory Safety Testing Protocol for Solvent Cabinets using Real-time Direct Reading Wireless Sensor for Measuring VOC Exposure

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(Laurent A. 2014)

Figure 1: Selection of relevant photographs indicative of the damage on the building No 5 (front of the building – inside laboratory room – collapse of the floor).

(William 2005)

(Kamm 2014)

(Purdie, Purdie et al. 2011)
(de Aquino, Zenkner et al. 2
(Schwerha 2007)

Statistics of Laboratory Workers

- 30% of researchers aware of major incidents in areas they work in
- 80% of people work alone in their lab weekly; 30% daily
- Academic Labs 10-100x more likely to have an accident than industry
- Only 12% of younger scientists said that safety was “paramount, and takes precedence over all other lab priorities”, compared with 36% of senior scientists.

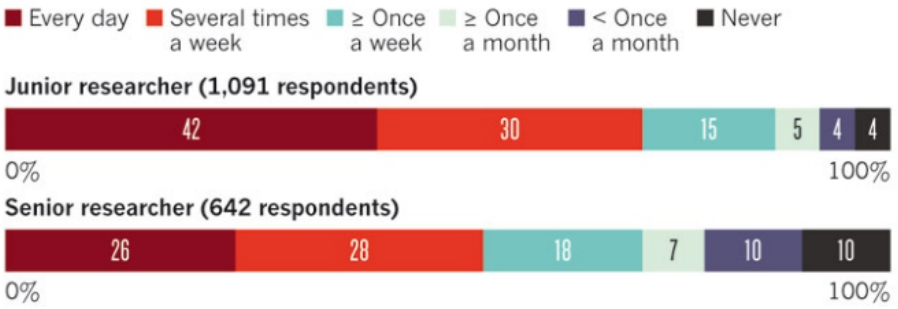
(Evans 2014) Nature 2013

A QUESTION OF SAFETY

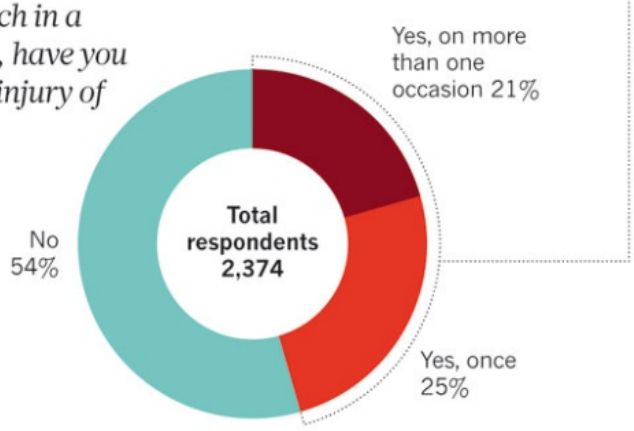
A survey of almost 2,400 scientists shows that although most believe their laboratories to be safe, about half have experienced injuries in the workplace. It also shows that junior and senior researchers have very different views of potentially hazardous practices.

1 *To what extent do you agree or disagree with the following statement? "I feel that my lab is a safe place to work."*

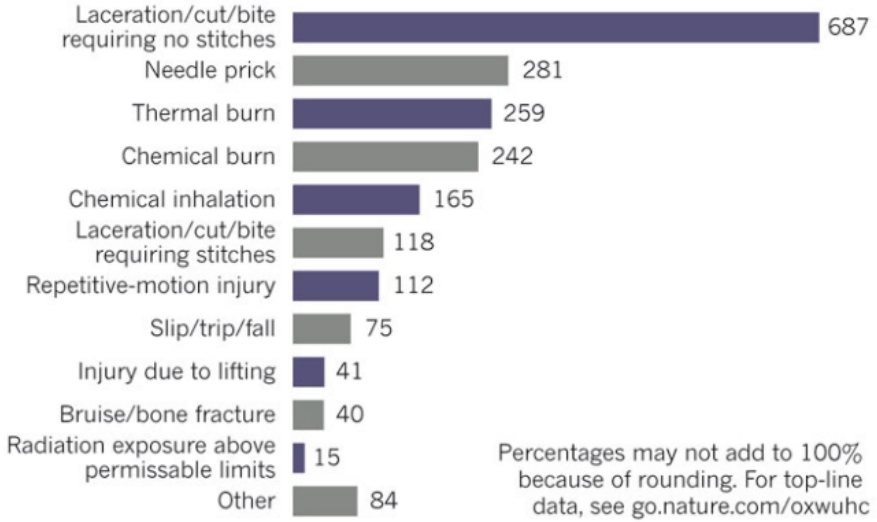
2 *In your lab, how frequently do people conduct experiments while working alone?*



3 *In the time that you've been conducting research in a laboratory setting, have you ever sustained an injury of any kind?*

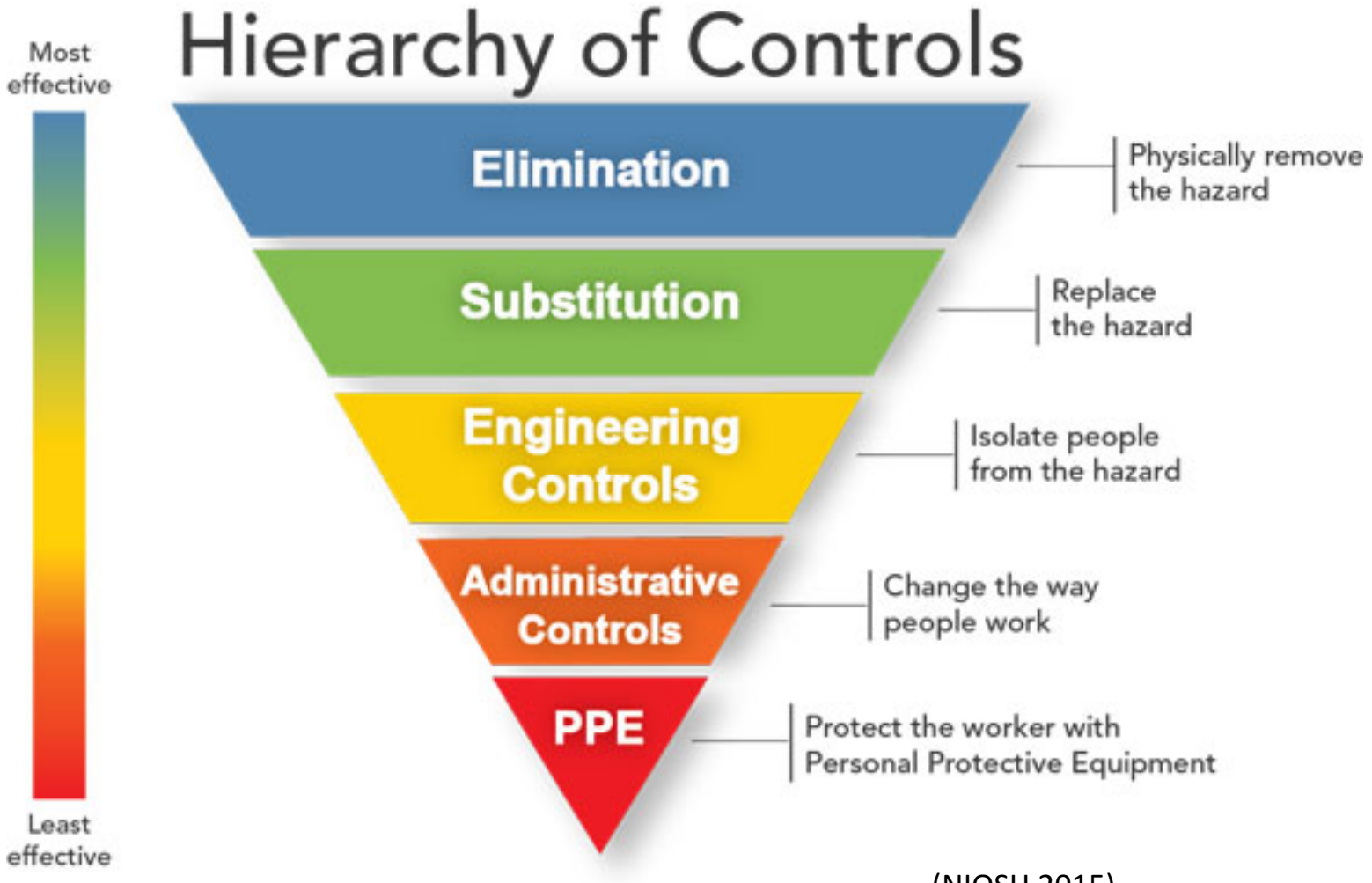


4 *What was the nature of your injury or injuries?*



Percentages may not add to 100% because of rounding. For top-line data, see go.nature.com/oxwuhc

SOURCE: Center for Laboratory Safety, UCLA/NPG/Bonamy Finch


Hierarchy of Controls
Most effective
Least effective
Elimination
Physically remove the hazard
Substitution
Replace the hazard
Engineering Controls
Isolate people from the hazard
Administrative Controls
Change the way people work
PPE
Protect the worker with Personal Protective Equipment

(NIOSH 2015)

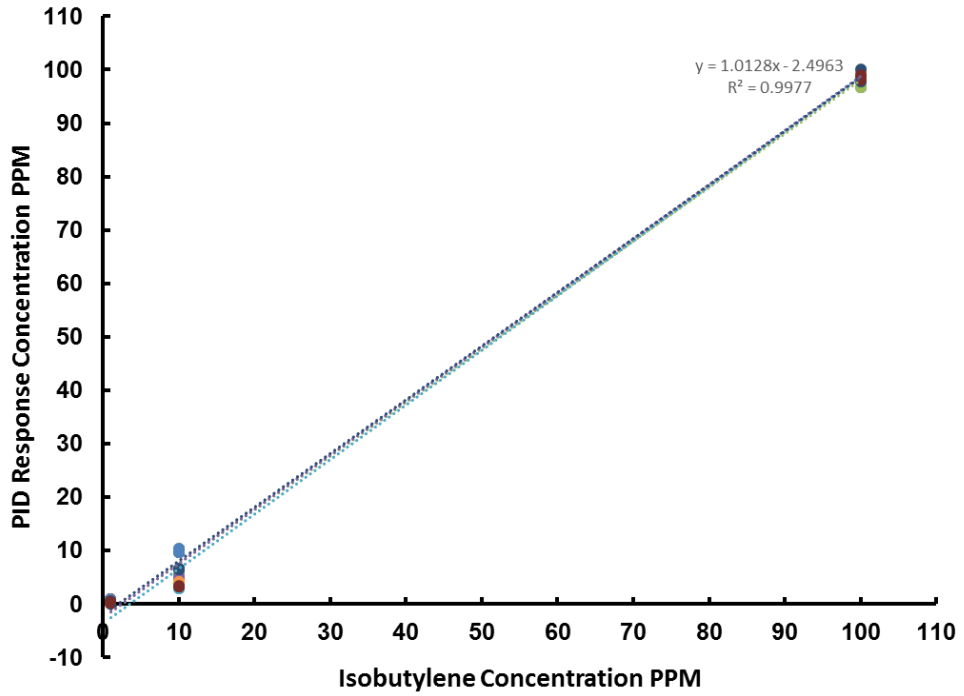
TOXI-RAE PIDS

Solvent Cabinet

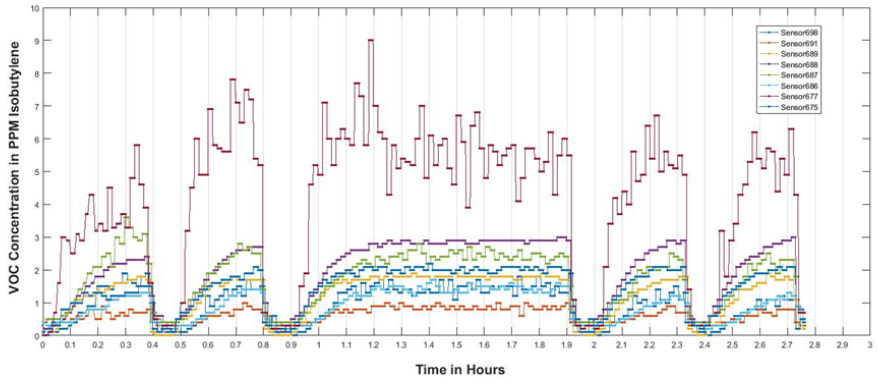
Calibration Table

Sensor	LOD	LOQ
1	2	6.1
2	1	2.5
3	4	12
4	3	8.8
5	3	9.5
6	3	10
7	4	11
8	3	9.1
Average	3	8.6

Calibration Curve



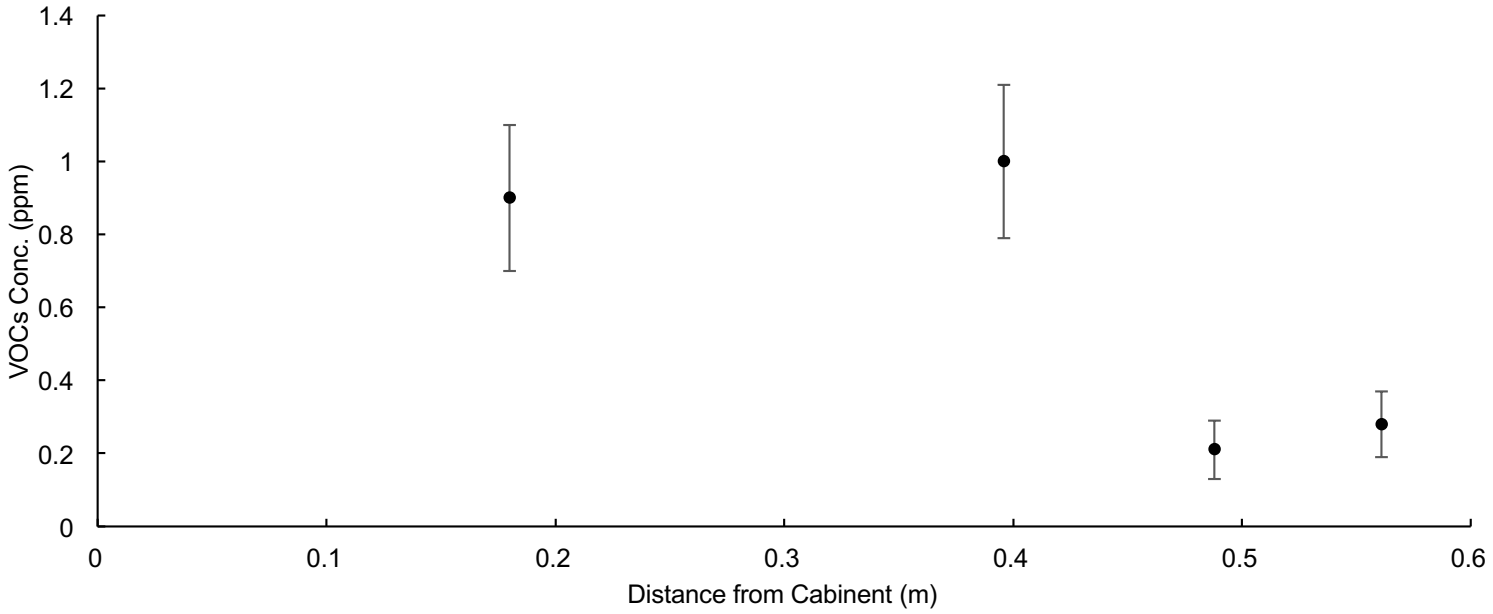
Experimental Graph



Highest concentration (ppm) at distributed locations within 8 different flammable storage cabinets.

Sensor Placement	Justrite27 S316	Justrite27 No ID	Eagle30 H420-F	Justrite27 LS315	Justrite27 LS313	Justrite30 No ID	under fume hood No ID	under fume hood No ID
TL	8.2	<3	3.9	14.0	<3	<3	4.6	30.3
TR	<3	<3	3.4	5.5	<3	<3	34.6	27.7
2L	4.7	<3	6.7	<3	<3	13.2 (TML)	NA	NA
2R	3.0	<3	5.6	<3	<3	10.1 (TMR)	NA	NA
3L	<3	<3	3.2	<3	<3	<3(BMR)	NA	NA
3R	3.7	<3	4.3	<3	<3	3.5(BML)	NA	NA
BL	<3	<3	4.7	<3	<3	<3	4.6	28.2
BR	<3	<3	7.5	<3	<3	<3	8.8	3.0
No of Bottles	104	16	45	33	23	22	22	22
Est. Vol. of Solvent	80L	2L	40L	50L	24L	40L	20L	20L
No. of shelves	5	4	5	4	4	2	2	2

Distance from the cabinet versus maximum VOCs concentration.



VOC compounds found in Flammable storage cabinet LS316 using the HAPSITE GC-MS.

Chemical	PEL (ppm)	STEL (ppm)	REL (ppm)
Acetone	1000	1000	250
Benzene	1	5	0.1
Dichloromethane	25	125	lfc
Ethyl Benzene	100	125	100
Methyl cyclohexane	500	not listed	400
Hexane	500	not listed	50
Xylene	100	150	100
Trichloroethylene	100	2	25
Tetrachloroethylene	100	not listed	lfc
Toluene	200	100	150

lfc= lowest feasible concentration

Efficacy of Engineering Control Measures

Sensor Placement	Flame Arrestor Clean (exhaust port)	Inlet Bung open	Inlet Bung Close Original	Air Flow Increase	Holes in Shelf
TL	8.2	12	18.5	13.3	15.6
TR	<3	<3	9.6	3.7	3.0
2L	4.7	9.6	7.5	<3	<3
2R	3.0	<3	<3	<3	3.3
3L	<3	<3	8.0	<3	<3
3R	3.7	<3	4.6	3.5	<3
BL	<3	<3	<3	<3	<3
BR	<3	<3	<3	<3	<3

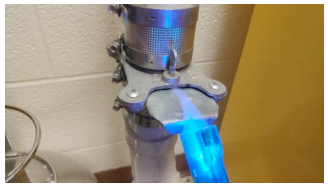


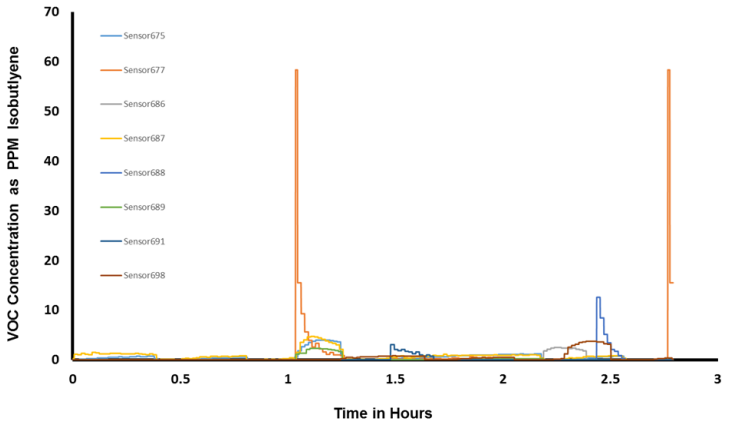
Figure 1. Vent tube valve.

Figure 2. The smoke is pulled through the cabinet door seal. Thus, room air also directly leaks into the cabinet through the door seals.

Figure 3. Debris accumulates on the flame arrestor filter that can restrict ventilation flow.

Figure 4. Cleaned flame arrestor.

Plastic Bottles



Effect of 3 variables on VOC concentrations in Flammable storage cabinet LS316

Three Variables			VOCs Inside Cabinet (ppm) – 8 internal locations							
1	2	3	TR	TL	BR	2L	3R	2R	BL	3L
Exhaust flow	Inlet Port	Teflon Tape Seal								
Closed	Closed	No	3.0	6.1	<3	3.6	3.2	<3	<3	<3
Closed	Closed	Yes	<3	<3	<3	<3	<3	<3	<3	<3
Closed	Open	No	5.3	10.1	<3	3.0	3.0	3.5	<3	3.0
Closed	Open	Yes	<3	<3	<3	<3	<3	<3	<3	<3
Open	Closed	No	3.0	5.7	<3	3.0	3.0	<3	<3	<3
Open	Closed	Yes	<3	<3	<3	<3	<3	<3	<3	<3
Open	Open	No	3.0	11.0	<3	<3	<3	3.0	<3	<3
Open	Open	Yes	<3	<3	<3	<3	<3	<3	<3	<3

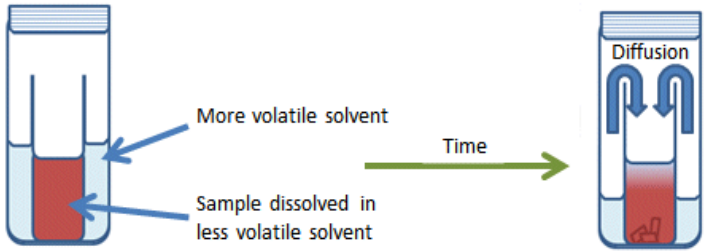
Note: The LOD was 3 ppm and LOQ was 10 ppm.

Conclusions

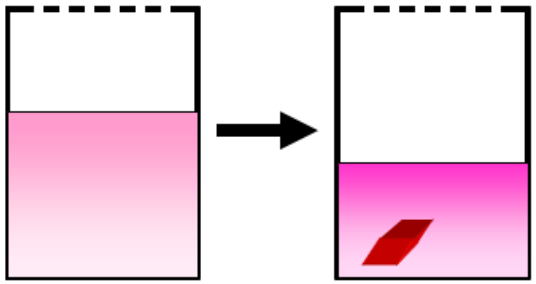
- The VOCs came from the chemical bottles stored in the cabinets.
- Factory sealed chemical bottles did not emit detectable VOCs. Once opened and recapped bottles emitted VOCs.
- Resealing with Teflon tape brought VOCs to non-detectable concentrations even with no ventilation of the cabinet.
- Cleaning the flame arrestor reduced the VOC concentration, thus flammable storage cabinets may require some maintenance.

Monitoring VOC generation during Crystallization

Vapor Diffusion



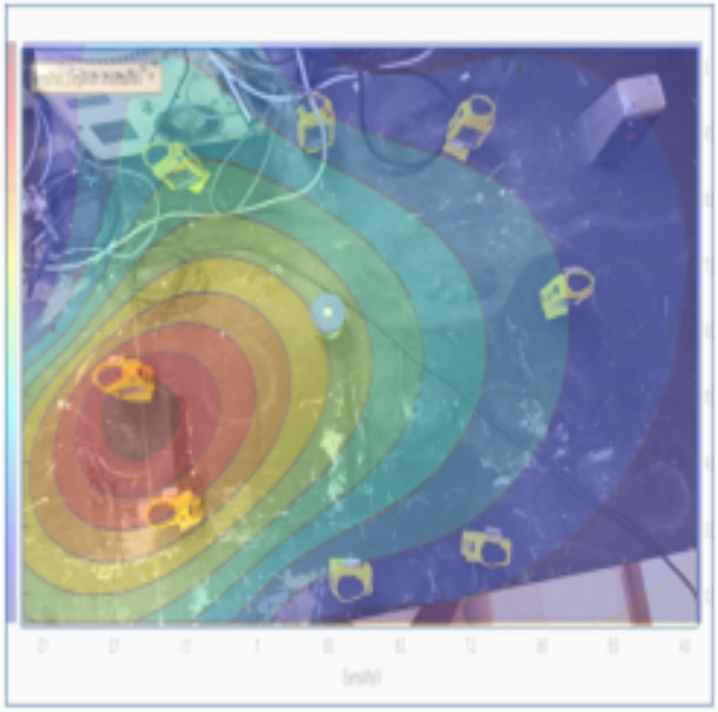
Evaporation



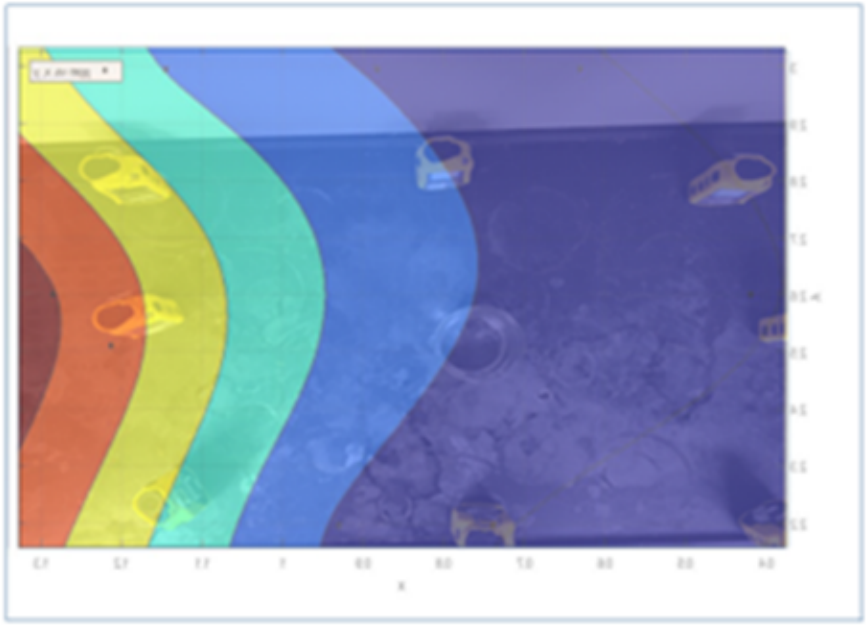
Methanol:acetone (1:1)

Circular Array

Contour Plot

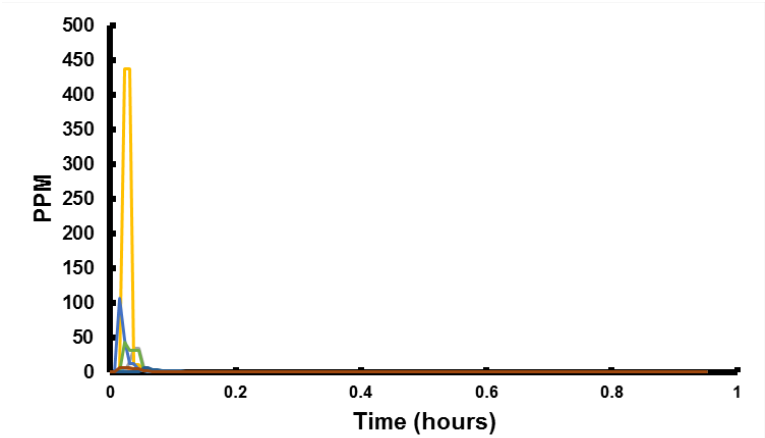


Vapor Diffusion

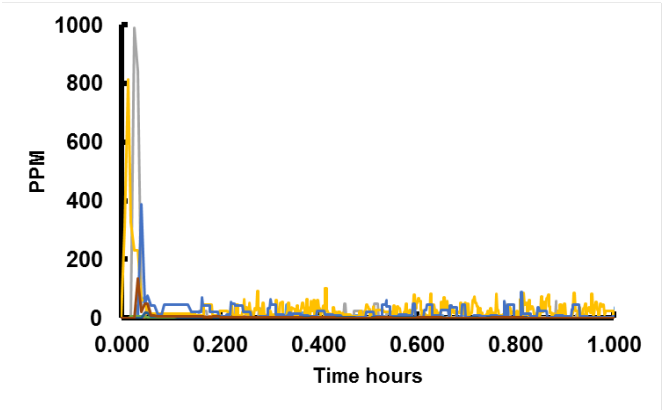


Evaporation

Time vs. PPM



Vapor Diffusion



Evaporation

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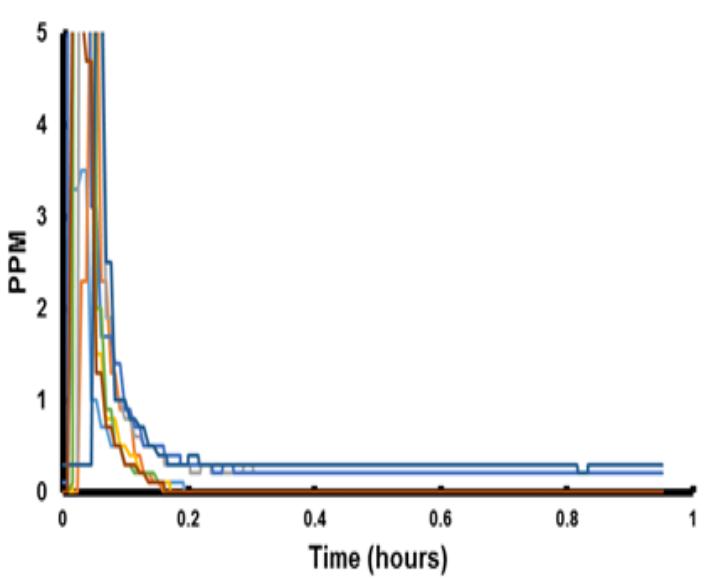
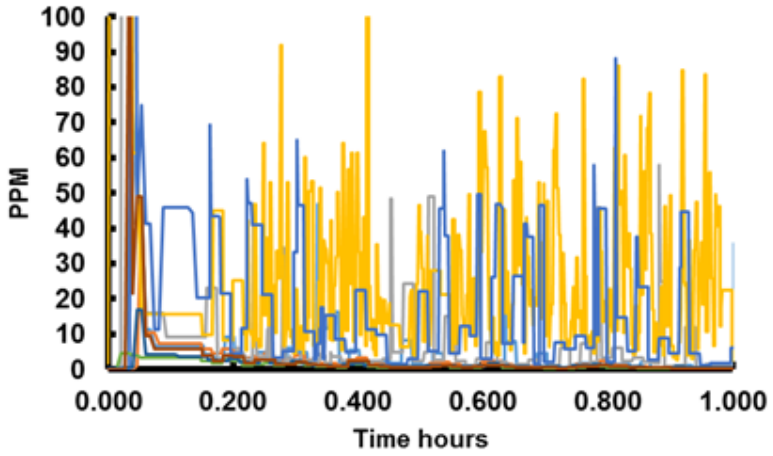
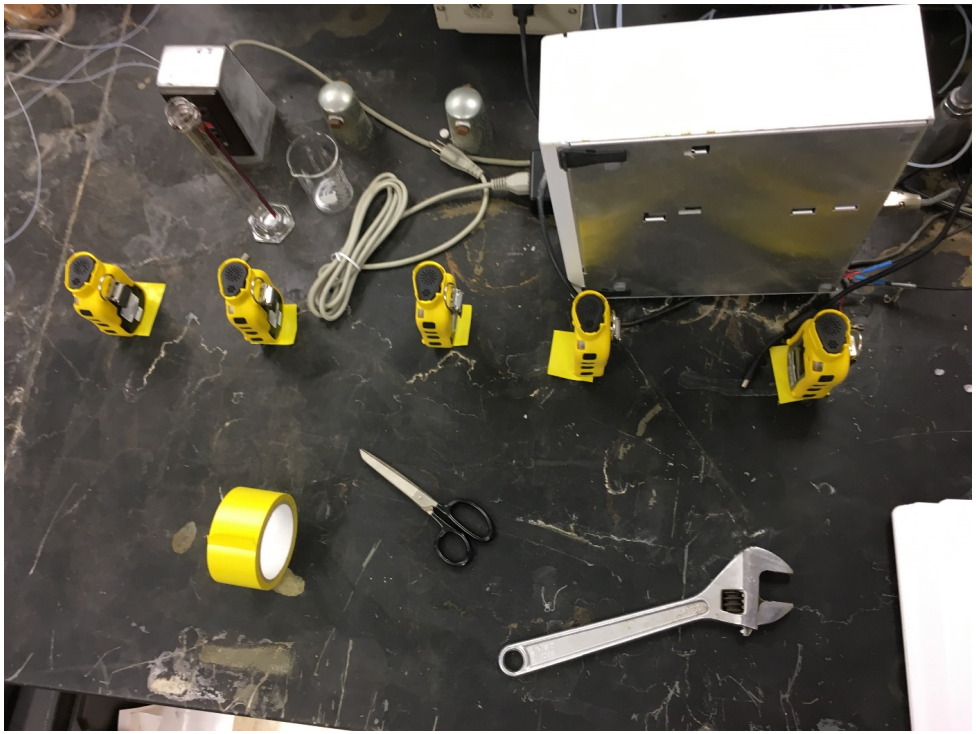


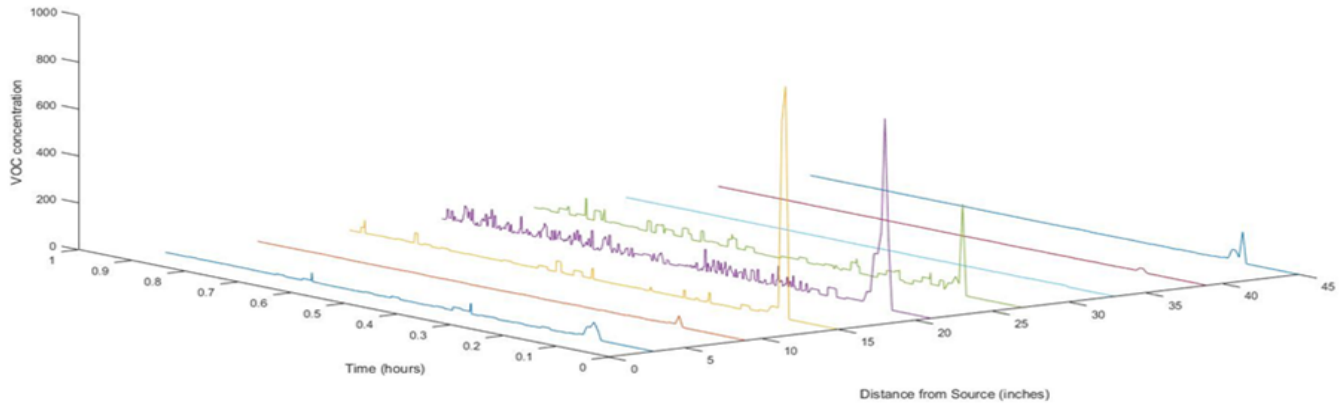
Vapor Diffusion



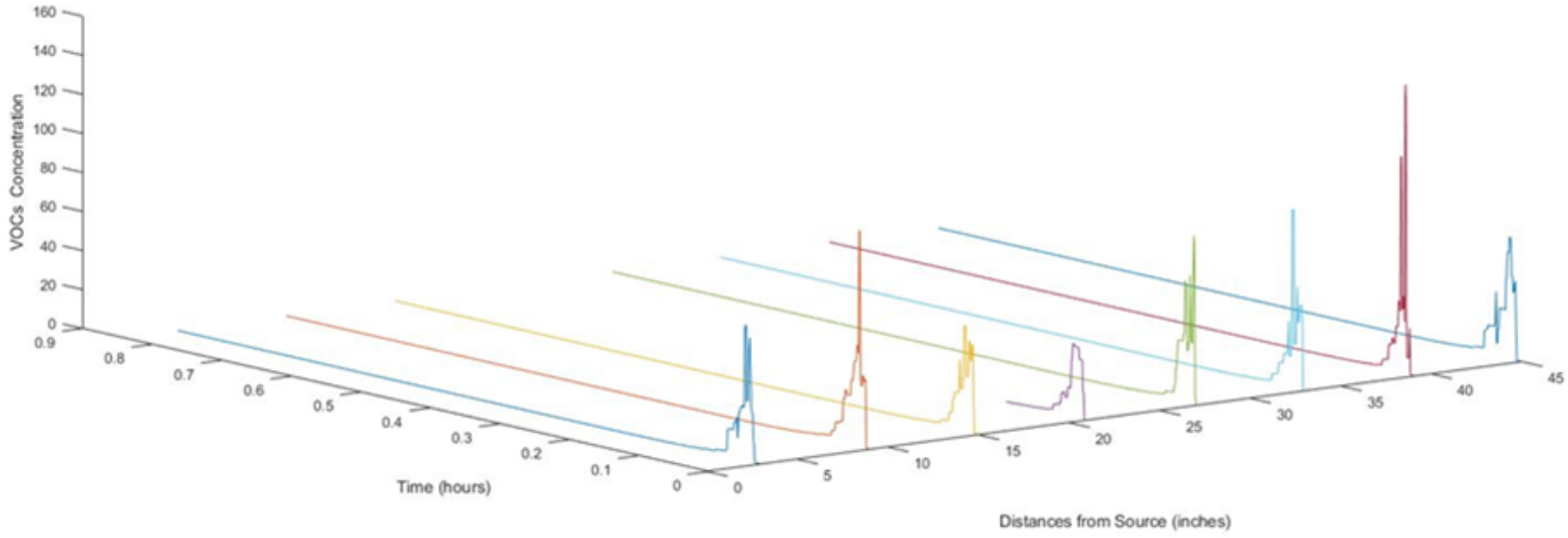
Evaporation



Linear Array Evaporation



Linear Array Vapor Diffusion



Conclusions

- We can successfully use a sensor array Monitoring VOC generation during Crystallization
- The vapor has a direction

Acknowledgements

- NIOSH
- LASSI funding