3040 Cornwallis Rd. PO Box 12194 Research Triangle Park, NC 27709
Telephone 919 541 6941 Fax 919 541 6936 www.rti.org

Office VOC Mixture Test Report

Manufacturer: Genesis
Product Name: Populated Catalyst Panel

RTI Report Number: A03230902

Test Laboratory:

RTI
3040 Cornwallis Road
Research Triangle Park, NC 27709
919-541-6941
mko@rti.org

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Operators: RP, KO, MM
Project Team: Kathleen Owen, Roger Pope, Jim Raymer, Michelle McCombs
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Office Mixture Test for Genesis
Populated Catalyst Panel

The objective of this test was to expose the Genesis air cleaner to a challenge containing a mixture of many common office environment gases and determine removal rates for the challenge compounds and production rates for aldehydes if any were produced. The unit was tested at air flowrates of 1200, 2000, and 2500 cfm (300, 500, and 625 fpm for this 24 x 24" unit).

The air cleaner, the Populated Catalyst Panel, was a UV PCO system and is shown in the attached figure. This unit was installed in RTI's ASHRAE 52.2 test rig with a light baffle upstream. This baffle was installed to prevent light from the unit interfering with the upstream sampling location. The baffle does not interfere with the working of the unit. The pressure drops reported for the unit were determined by subtracting the pressure drop of the baffle from the combined pressure drop during the tests.

Temperature and humidity were not controlled in the test rig itself but since the inlet air came from a temperature and humidity controlled room the result was steady conditions for the tests.

Temperature, Humidity, and Pressure Drop for the Three Test Runs

Airflow Rate (cfm)	Temp. (F)	Relative Humidity %	Pressure Drop (in. H_2O)
1200	72	42	0.22
2000	73	40	0.59
2500	73	41	0.92

Gas-phase air cleaners were installed upstream of the test section along with the particulate filters required for ASHRAE 52.2. These gas-phase air cleaners were intended to remove any contaminants from the inlet room air.

The Genesis Air Cleaner, the Populated Catalyst Panel, was installed in RTI's ASHRAE 52.2 test rig. With the unit installed, challenge injection OFF, and the rig on at 1200 cfm, the upstream and downstream were sampled for background levels. These background values applied to both the formaldehyde (separate test report) and the office mixture tests; however, the values are presented to show the low concentrations in the test rig but were not subtracted from the concentrations determined for the upstream and downstream samples in the data analysis.

The challenge concentration was produced by metering liquid through an HPLC pump into an approximately 75C heated chamber with 11.5 cfm nitrogen to vaporize the liquid completely before injecting it into the test rig. The resulting nitrogen/challenge gas stream is introduced into the rig through a multi-port manifold that ensures uniform distribution of the challenge. For this test, the mixture was based on one used by LBNL in a recent study (Hodgson et al., 2005). This mixture is described in detail following the description of the sampling procedure.

All sampling for the tests was done with simultaneous upstream and downstream samplers. For each case, 3 samplers each for carbonyls and volatile organic compounds (VOCs) were set up upstream and downstream.

To determine the upstream aldehyde and possible aldehyde byproducts at the expected low concentrations, carbonyl samples were collected onto silica tubes coated with dinitrophenyl hydrazine where they were adsorbed and derivatized to the corresponding dinitrophenyl hydrazones. Sampling flow rates were nominally 1 L/min for 30 minutes. Derivatized carbonyls were eluted from the tubes with acetonitrile and the extracts were analyzed using High Performace Liquid Chromatography with absorbance detection. Target analytes were quantified against a suite of standard compounds. Chromatograms were inspected visually for the detection of any non-target analytes. Each sample was analyzed for formaldehyde and likely byproducts present at or above the specified Detection Limits.

VOCs were sampled for one hour with a 6-L sample volume onto Carbotrap tubes. The sampling tubes gave the concentrations of the challenge compounds and the byproducts. The VOCs were collected onto a sorbent tube, again using constant flow pumps. Sorbent tubes were kept cold until analysis using thermal desorption GC/MS. Each sample was analyzed for the challenge compounds at or above the specified LODs using the response factor for toluene. The reproducibility of a toluene standard for a sorbent tube was acceptable. Additional peaks that could be byproducts were examined. Note that isopropanol and acetone coeluted on the column used for the analysis. This was considered acceptable as the concentration of each compound by itself was not critical to the issue of aldehyde production and the column and procedure worked well for the other compounds.

<u>Sample matrix </u>(repeated for each of the three flowrate)

	VOC/DNPH Upstream	VOC/DNPH Downstream	Carbonyl Upstream	Carbonyl Downstream
Backgrounds (only at 1200 cfm)	3	3	3	3
LBL Mixture Test	3	3	3	3

In addition we sampled with our ppbRAE (PID) to estimate the concentration of total VOCs and to monitor the stability. Since the PID can not discriminate between the compounds, this was not intended to determine the actual compound concentrations. During the test, the RAE showed the concentration to be steady within the limits of visually examining the readouts.

Once sampling was completed, new sampling tubes were installed and the airflow and mixture feedrate were changed. Then sampling was performed for the next set of conditions.

The Office Mixture is a mixture based on an LBNL test mixture. The requested challenge list is shown in Table 1. Note that the R-11 refrigerant in the LBNL study is not included in this test due to recycling and purchase issues; this was discussed with client before removing from the list. Since the LBNL study showed different concentrations for different runs, we modeled our study on data shown in their table 5 with a goal of being within the range of values shown in their study. The list of compounds with TLV, class, and molecular weight are shown in Table 1.

The data for these runs are shown in tables after the discussion. Data for each run, averages, and relative standard deviations are shown. Detection limits are shown for each compound.

To allow for comparison of concentrations found in the downstream air to the accepted safety limits, ACGIH TLVs and other recommended limits are shown for those compounds where they were readily available.

Statistical analysis of the data using a T-test for comparison of the upstream and downstream means at 95% confidence level ($\alpha = 0.05$) for each compound showed that the upstream and downstream concentrations can be considered the same for almost every case. Exceptions were noted in the 2500 cfm run where acetaldehyde and four of the VOCs decreased significantly and acetone increased. Since efficiencies were included as a goal for the project, these were calculated and are included in the data tables even where not statistically significant. The efficiencies were calculated as (upstream concentration – downstream concentration)/upstream concentration x 100%. Also, production rates of the compounds that show up in higher concentrations in the downstream than the upstream were calculated using the increase in concentration divided by the upstream concentration of isopropanol and acetone. These values are provided for informational purposes even though, in all but one case, they are actually statistically equivalent to no production.

In the examination of the chromatograms, multiple small peaks that were not in the challenge mixture were found. These peaks had retentions times and mass spectra that identified them as compounds including: 3-buten-2-one, 2-butanol, methyl cyclopentane, 1-hexene, benzene, butyl ester formic acid, 1-bromobutane, 2-methyl-4-methylene-hexane, 1-octene, and others. However, these small peaks were not further analyzed since they are likely to be insignificant and are outside the scope of the project.

In conclusion, the Office Mixture was introduced into the Genesis Populated Catalyst Panel Air Cleaner at three air flowrates. Sampling for aldehydes and volatile organics showed no statistically significant production of aldehydes or VOCs at the $\alpha = 0.05$ level except for a small increase in acetone at one flowrate.

REFERENCE

Hodgson, A.T., D.P. Sullivan, and W.J. Fisk. 2005. "Evaluation of Ultra-Violet Photocatalytic Oxidation (UVPCO) for Indoor Air Applications: Conversion of Volatile Organic Compounds at Low Part-per-Billion Concentrations. http://repositories.cdlib.org/lbnl/LBNL-58936.

The Genesis Populated Catalyst Panel as installed in the RTI test duct.

Table 1 Office VOC Mixture (based on LBNL Study*)

	TLV (ppm)	Class	MW	Detection Limit (ppb)**
Ethanol	1000	Alcohol	46.07	0.9
2-Propanol (Isopropanol)	400	Alcohol	60.10	0.7
1-Butanol	20	Alcohol	74.12	0.6
2-Ethyl-1-hexanol (Ethylhexanol)		Alcohol	130.23	0.3
Phenol	5	Alcohol	94.11	0.5
2-Butoxyethanol	25	Glycol ether	118.18	0.4
tert-Butyl methyl ether MTBE	40	Ether	88.15	0.5
2-Propanone (Acetone)	500	Ketone	58.08	0.8/0.7***
2-Butanone	200	Ketone	72.11	0.6
4-Methyl-2-pentanone MIBK	50	Ketone	100.16	0.4
Hexanal		Aldehyde	100.16	0.4
d-Limonene		Terpene HC	136.24	0.3
Toluene	50	Aromatic HC	92.14	0.5
m-Xylene	100	Aromatic HC	106.17	0.4
1,2,4-Trimethylbenzene (1,2,4-TMB)		Aromatic HC	120.20	0.4
n-Nonane	200	Alkane HC	128.26	0.3
n-Decane		Alkane HC	142.29	0.3
n-Undecane		Alkane HC	156.31	0.3
n-Dodecane		Alkane HC	170.34	0.3
Dichloromethane (DCM)	25	Halo HC	84.93	0.5
1,1,1-Trichloroethane (1,1,1-TCA)	350	Halo HC	133.41	0.3
Trichloroethene	50	Halo HC	131.39	0.3
Tetrachloroethene (PCE)	25	Halo HC	165.83	0.3
1,2-Dichlorobenzene (1,2-DCB)	25	Halo HC	147.00	0.3
Carbon disulfide (CS2)	10	Sulfide	76.14	0.6
Decamethylcyclopentasiloxane (D5)		Siloxane	370.78	0.1

*Trichlorofluoromethane (R-11) was included in the LBL study but not in this one.
**Note that the detection limit units are three orders of magnitude lower than the TLVs.
*** Carbonyl method, VOC method.

Background Sampling for Carbonyls+

	Upstream						Downstream						
Analyte	**#1**	**#2**	**#3**	**Average (ppb)**	**Confidence Interval***		**#1**	**#2**	**#3**	**Average (ppb)**	**Confidence Interval***		**Detection Limit (ppb)**
Formaldehyde	2.7	2.8	2.8	2.8	2.7	2.8	2.3	2.8	1.1	2.0	1.0	3.0	1.5
Acetaldehyde	3.9	4.0	4.3	4.1	3.8	4.3	4.0	3.9	2.1	3.3	2.1	4.5	1.0
Acetone	11.0	11.0	12.2	11.4	10.6	12.2	11.9	12.1	10.5	11.5	10.6	12.4	0.8
Acrolein	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.8
Proprionaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.8
Crotonaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.6
n-Butyraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.6
Benzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.4
iso-Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.5
Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.5
m-Tolualdehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.4
o,p-Tolualdehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.4
Hexanaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.4
2,5-Dimethylbenzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0			0.3

*for alpha=0.05

+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Office Mixture Test: Flow Rate 1200 cfm+

Analyte	Upstream #1	#2	#3	Average (ppb)	Confidence Interval*		Downstream #1	#2	#3	Average (ppb)	Confidence Interval*	
Formaldehyde	110	122	120	117	110	125	121	116	118	118	116	121
Acetaldehyde	4.5	6.2	5.5	5.4	4.5	6.4	7	5	5	5.7	4.7	6.7
Acetone	205	239	238	227	206	249	247	226	230	235	222	247
Acrolein	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Proprionaldehyde	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0		
Crotonaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Butyraldehyde	0.0	0.0	0.0	0.0			0.0	0.5	0.0	0.2	-0.2	0.5
Benzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
iso-Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
m-Tolualdehyde	27.9	31.9	32.9	30.9	27.9	33.8	37	31	30	32.6	28.4	36.9
o,p-Tolualdehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Hexanaldehyde	14.8	17.4	17.5	16.6	14.8	18.3	19	17	17	17.6	15.8	19.5
2,5-Dimethylbenzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Office Mixture Test: Flow Rate 2000 cfm+

Analyte	Upstream #1	#2	#3	Average (ppb)	Confidence Interval*		Downstream #1	#2	#3	Average (ppb)	Confidence Interval*	
Formaldehyde	25	29	28	27	25	29	26	26	26	26	25	26
Acetaldehyde	7.3	8.0	7.9	7.7	7.3	8.2	7.3	7.0	7.1	7.1	7.0	7.3
Acetone	277	317	317	304	278	329	278	264	264	269	259	278
Acrolein	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Proprionaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Crotonaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Butyraldehyde	0.3	0.0	0.0	0.1	-0.1	0.3	0.0	0.0	0.0	0.0		
Benzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
iso-Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Valeraldehyde	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0		
m-Tolualdehyde	37.8	41.9	42.6	40.8	37.8	43.8	37.6	38.6	38.8	38.3	37.6	39.1
o,p-Tolualdehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Hexanaldehyde	17.3	20.8	21.1	19.7	17.3	22.2	18.8	18.6	18.8	18.7	18.6	18.8
2,5-Dimethylbenzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Office Mixture Test: Flow Rate 2500 cfm+

Analyte	Upstream #1	Upstream #2	Upstream #3	Upstream Average (ppb)	Upstream Confidence Interval*		Downstream #1	Downstream #2	Downstream #3	Downstream Average (ppb)	Downstream Confidence Interval*	
Formaldehyde	23	23	23	23	23	23	22	23	23	23	22	23
Acetaldehyde	50	48	46	48	46	50	45	45	45	45	45	45
Acetone	265	274	282	274	265	283	289	303	291	294	286	303
Acrolein	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Proprionaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Crotonaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Butyraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Benzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
iso-Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Valeraldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
m-Tolualdehyde	40	43	43	42	40	44	42	45	42	43	41	45
o,p-Tolualdehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Hexanaldehyde	20	21	21	21	20	21	19	21	20	20	19	21
2,5-Dimethylbenzaldehyde	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		

*that the means are different
**for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Office Mix Test: Airflow 1200 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test+	Efficiency % *	Increase ppb of compound/ppb of acetone upstream*
Formaldehyde	117.3	118.4	no		0.005
Acetaldehyde	5.4	5.7	no		0.001
Acetone	227.3	234.5	no		0.032
Acrolein	0.0	0.0	no		
Proprionaldehyde	0.02	0.00	no	100	
Crotonaldehyde	0.0	0.0	no		
n-Butyraldehyde	0.0	0.2	no		0.001
Benzaldehyde	0.0	0.0	no		
iso-Valeraldehyde	0.0	0.0	no		
Valeraldehyde	0.0	0.0	no		
m-Tolualdehyde	30.9	32.6	no		0.008
o,p-Tolualdehyde	0.0	0.0	no		
Hexanaldehyde	16.6	17.6	no		0.005
2,5-Dimethylbenzaldehyde	0.0	0.0	no		

+ at $\alpha = 0.05$
* not statistically significant

Office Mix Test: Airflow 2000 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test+	Efficiency % *	Increase ppb of compound/ppb of acetone upstream*
Formaldehyde	27.2	25.9	no	5	
Acetaldehyde	7.7	7.1	no	8	
Acetone	303.7	268.7	no	12	
Acrolein	0.0	0.0	no		
Proprionaldehyde	0.0	0.0	no		
Crotonaldehyde	0.0	0.0	no		
n-Butyraldehyde	0.1	0.0	no	100	
Benzaldehyde	0.0	0.0	no		
iso-Valeraldehyde	0.0	0.0	no		
Valeraldehyde	0.0	0.0	no	100	
m-Tolualdehyde	40.8	38.3	no	6	
o,p-Tolualdehyde	0.0	0.0	no		
Hexanaldehyde	19.7	18.7	no	5	
2,5-Dimethylbenzaldehyde	0.0	0.0	no		

+ at $\alpha = 0.05$
* not statistically significant

Office Mix Test: Airflow 2500 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test+	Efficiency % *	Increase ppb of compound/ppb of acetone upstream**
Formaldehyde	23.2	22.6	no	2	
Acetaldehyde	48.0	45.0	yes	6	
Acetone	273.7	294.4	yes		0.075
Acrolein	0.0	0.0	no		
Proprionaldehyde	0.0	0.0	no		
Crotonaldehyde	0.0	0.0	no		
n-Butyraldehyde	0.0	0.0	no		
Benzaldehyde	0.0	0.0	no		
iso-Valeraldehyde	0.0	0.0	no		
Valeraldehyde	0.0	0.0	no		
m-Tolualdehyde	42.0	42.9	no		0.003
o,p-Tolualdehyde	0.0	0.0	no		
Hexanaldehyde	20.8	19.9	no	4	
2,5-Dimethylbenzaldehyde	0.0	0.0	no		

+ at $\alpha = 0.05$
* not statistically significant except for Acetaldehyde
** not statistically significant except for Acetone

Background Sampling for VOCs+

Analyte	Upstream #1	#2	#3	Average (ppb)	Confidence Interval*		Downstream #1	#2	#3	Average (ppb)	Confidence Interval*	
Ethanol	0.0	0.0	0.7	0.2	-0.2	0.7	0.4	0.3	2.8	1.1	-0.5	2.8
Isopropanol /Acetone	2.4	2.4	2.1	2.3	2.1	2.5	6.0	2.2	0.0	2.8	-0.7	6.2
Dichloromethane	0.0	0.0	0.0	0.0			0.0	0.6	0.0	0.2	-0.2	0.6
Carbon disulfide	1.6	0.0	0.0	0.5	-0.5	1.5	0.0	2.6	0.0	0.9	-0.8	2.6
MTBE (tert-Butyl-methyl ether)	0.0	0.0	0.0	0.0			0.0	0.8	0.0	0.3	-0.3	0.8
2-Butanone	0.2	0.2	0.0	0.1	0.0	0.3	0.2	0.2	0.1	0.2	0.1	0.2
1,1,1-Trichloroethane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
1-Butanol	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Trichloroethene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
MIBK (4-Methyl-2-pentanone)	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Toluene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Hexanal	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Tetrachloroethene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
m-Xylene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Nonane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
2-Butoxyethanol	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Phenol	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
1,2,4-Trimethylbenzene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Decane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
2-Ethyl-1-hexanol	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
d-Limonene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
1,2-Dichlorobenzene	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Undecane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
Decamethylcyclosiloxane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		
n-Dodecane	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0		

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Sampling for VOCs with Rig Airflow at 1200 cfm+

Analyte	Upstream #1	#2	#3	Average (ppb)	Confidence Interval*		Downstream #1	#2	#3	Average (ppb)	Confidence Interval*	
Ethanol	1.0	0.4	0.2	0.5	0.1	1.0	0.8	1.1	0.7	0.8	0.6	1.1
Isopropanol /Acetone	32.7	29.4	26.2	29.4	25.7	33.1	24.7	24.7	32.9	27.4	22.1	32.8
Dichloromethane	3.0	1.4	0.9	1.7	0.5	3.0	2.4	2.5	1.6	2.2	1.6	2.8
Carbon disulfide	1.7	1.3	1.1	1.4	1.0	1.7	1.6	2.3	1.2	1.7	1.1	2.3
MTBE (tert-Butyl-methyl ether)	21.3	25.1	21.4	22.6	20.1	25.1	20.4	19.5	24.8	21.6	18.4	24.7
2-Butanone	5.8	7.3	6.1	6.4	5.5	7.3	7.7	5.5	7.2	6.8	5.5	8.1
1,1,1-Trichloroethane	28.1	32.1	27.6	29.3	26.5	32.1	27.1	25.1	32.5	28.2	23.9	32.5
1-Butanol	7.2	9.9	8.6	8.6	7.0	10.1	7.7	7.6	10.0	8.4	6.9	10.0
Trichloroethene	6.5	8.5	7.3	7.4	6.3	8.6	6.7	6.8	7.4	7.0	6.5	7.4
MIBK (4-Methyl-2-pentanone)	17.7	23.8	20.4	20.7	17.2	24.1	19.0	11.7	23.8	18.2	11.3	25.1
Toluene	63.4	75.4	66.8	68.5	61.5	75.5	66.0	54.4	81.0	67.1	52.0	82.3
Hexanal	4.2	6.1	4.3	4.9	3.7	6.1	4.1	2.9	4.8	3.9	2.9	5.0
Tetrachloroethene	12.1	16.9	14.1	14.4	11.6	17.1	13.3	11.7	13.5	12.8	11.7	13.9
m-Xylene	27.3	41.2	35.6	34.7	26.8	42.6	32.6	24.9	36.6	31.4	24.7	38.1
n-Nonane	4.1	11.0	9.5	8.2	4.1	12.2	8.5	3.8	10.3	7.5	3.7	11.4
2-Butoxyethanol	9.6	14.8	12.3	12.2	9.3	15.2	9.8	6.8	10.3	9.0	6.8	11.1
Phenol	2.6	4.4	4.0	3.7	2.6	4.7	3.1	2.3	3.3	2.9	2.3	3.5
1,2,4-Trimethylbenzene	4.4	16.1	13.7	11.4	4.4	18.4	12.1	4.0	13.2	9.8	4.1	15.5
n-Decane	3.6	26.0	23.9	17.8	3.8	31.8	20.8	2.2	19.0	14.0	2.4	25.6
2-Ethyl-1-hexanol	9.7	18.4	15.7	14.6	9.6	19.7	14.2	10.2	17.1	13.8	9.9	17.8
d-Limonene	7.5	24.2	20.7	17.5	7.5	27.4	19.1	6.5	22.4	16.0	6.5	25.5
1,2-Dichlorobenzene	4.2	7.7	6.6	6.2	4.1	8.2	5.8	3.9	6.5	5.4	3.9	6.9
n-Undecane	0.5	7.6	16.5	8.2	-0.9	17.2	6.8	0.4	3.8	3.7	0.0	7.3
Decamethylcyclosiloxane	0.0	0.6	3.0	1.2	-0.6	3.0	0.5	0.0	1.6	0.7	-0.2	1.7
n-Dodecane	0.2	5.3	17.9	7.8	-2.5	18.1	4.7	0.5	3.0	2.8	0.4	5.2

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Sampling for VOCs with Rig Airflow at 2000 cfm+

Analyte	Upstream #1	Upstream #2	Upstream #3	Upstream Average (ppb)	Upstream Confidence Interval*		Downstream #1	Downstream #2	Downstream #3	Downstream Average (ppb)	Downstream Confidence Interval*	
Ethanol	na	1.0	1.7	1.4	0.7	2.1	1.3	1.1	0.6	1.0	0.6	1.4
Isopropanol /Acetone	na	19.2	28.6	23.9	14.7	33.1	22.3	18.4	18.8	19.8	17.4	22.3
Dichloromethane	na	1.6	2.6	2.1	1.1	3.1	2.1	1.4	1.2	1.6	1.0	2.1
Carbon disulfide	na	1.2	1.6	1.4	1.0	1.8	1.6	1.0	1.0	1.2	0.8	1.6
MTBE (tert-Butyl-methyl ether)	na	25.1	23.5	24.3	22.7	25.9	22.7	24.9	22.3	23.3	21.8	24.8
2-Butanone	na	7.2	6.4	6.8	5.9	7.7	6.6	45.4	7.8	19.9	-5.0	44.9
1,1,1-Trichloroethane	na	32.0	28.9	30.5	27.5	33.5	29.6	25.4	28.4	27.8	25.4	30.2
1-Butanol	na	9.8	9.5	9.7	9.4	9.9	8.9	8.3	8.7	8.6	8.2	9.0
Trichloroethene	na	8.7	7.3	8.0	6.6	9.3	7.6	6.4	6.9	7.0	6.3	7.6
MIBK (4-Methyl-2-pentanone)	na	24.4	22.6	23.5	21.7	25.3	21.8	20.3	21.3	21.2	20.3	22.0
Toluene	na	74.2	72.9	73.6	72.3	74.8	69.1	62.7	70.3	67.4	62.7	72.0
Hexanal	na	6.0	5.0	5.5	4.6	6.5	5.1	4.4	5.0	4.8	4.4	5.3
Tetrachloroethene	na	17.0	13.9	15.4	12.3	18.6	15.0	11.9	13.3	13.4	11.6	15.2
m-Xylene	na	42.3	36.6	39.5	33.9	45.0	37.8	31.8	34.9	34.9	31.5	38.3
n-Nonane	na	11.4	10.2	10.8	9.6	12.1	10.1	8.4	9.7	9.4	8.4	10.4
2-Butoxyethanol	na	15.0	11.2	13.1	9.3	16.9	12.0	11.6	12.8	12.1	11.4	12.8
Phenol	na	4.8	3.9	4.3	3.4	5.3	3.9	3.3	3.9	3.7	3.3	4.1
1,2,4-Trimethylbenzene	na	16.9	13.5	15.2	11.9	18.5	14.7	8.8	13.6	12.3	8.8	15.9
n-Decane	na	28.5	16.9	22.7	11.4	34.0	24.1	6.1	25.0	18.4	6.4	30.4
2-Ethyl-1-hexanol	na	19.5	17.5	18.5	16.5	20.5	16.7	14.3	16.8	15.9	14.3	17.5
d-Limonene	na	25.2	21.8	23.5	20.1	26.9	22.3	14.6	21.1	19.3	14.6	24.0
1,2-Dichlorobenzene	na	8.0	6.7	7.4	6.0	8.7	7.0	5.9	6.6	6.5	5.8	7.1
n-Undecane	na	12.7	3.4	8.0	-1.0	17.1	6.7	0.8	12.9	6.8	0.0	13.7
Decamethylcyclosiloxane	na	0.9	1.7	1.3	0.6	2.1	0.4	0.1	1.7	0.7	-0.3	1.7
n-Dodecane	na	8.6	3.0	5.8	0.3	11.3	4.1	0.7	10.8	5.2	-0.6	11.0

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Sampling for VOCs with Rig Airflow at 2500 cfm+

Analyte	Upstream #1	Upstream #2	Upstream #3	Upstream Average (ppb)	Upstream Confidence Interval*		Downstream #1	Downstream #2	Downstream #3	Downstream Average (ppb)	Downstream Confidence Interval*	
Ethanol	1.0	0.6	0.2	0.6	0.2	1.1	0.7	0.9	0.5	0.7	0.5	0.9
Isopropanol /Acetone	13.3	10.7	1.4	8.5	1.4	15.5	8.0	7.9	8.2	8.1	7.9	8.2
Dichloromethane	1.6	0.7	0.1	0.8	-0.1	1.7	0.8	1.0	0.8	0.8	0.7	1.0
Carbon disulfide	1.3	0.8	0.3	0.8	0.3	1.4	0.8	0.7	0.9	0.8	0.7	0.9
MTBE (tert-Butyl-methyl ether)	25.9	23.0	23.3	24.1	22.3	25.9	22.8	26.4	20.9	23.4	20.2	26.5
2-Butanone	37.5	6.8	26.8	23.7	6.1	41.3	29.2	55.6	5.4	30.1	1.7	58.4
1,1,1-Trichloroethane	31.3	29.2	27.1	29.2	26.8	31.6	28.0	25.4	26.5	26.6	25.2	28.1
1-Butanol	8.6	8.5	8.8	8.7	8.5	8.8	8.1	7.1	7.9	7.7	7.1	8.3
Trichloroethene	7.8	7.2	7.4	7.4	7.1	7.8	7.4	6.4	6.8	6.9	6.3	7.4
MIBK (4-Methyl-2-pentanone)	20.9	22.2	21.9	21.7	20.9	22.5	20.8	19.7	20.0	20.2	19.5	20.8
Toluene	73.6	72.3	67.1	71.0	67.1	74.8	65.7	62.9	65.8	64.8	62.9	66.7
Hexanal	4.9	5.0	6.1	5.3	4.6	6.1	5.1	5.1	4.3	4.9	4.3	5.4
Tetrachloroethene	15.3	13.8	14.2	14.4	13.5	15.4	14.5	12.6	13.2	13.4	12.3	14.5
m-Xylene	38.1	36.6	36.6	37.1	36.1	38.1	36.2	32.8	34.4	34.5	32.5	36.4
n-Nonane	10.3	10.0	6.4	8.9	6.5	11.4	10.1	9.2	9.4	9.6	9.0	10.1
2-Butoxyethanol	12.3	13.4	18.1	14.6	11.1	18.1	17.0	13.5	13.2	14.6	12.1	17.0
Phenol	4.4	4.2	5.0	4.6	4.1	5.0	4.7	4.5	3.8	4.4	3.8	4.9
1,2,4-Trimethylbenzene	14.5	13.5	5.3	11.1	5.4	16.8	15.9	12.4	12.3	13.5	11.2	15.9
n-Decane	23.1	18.1	4.7	15.3	4.5	26.1	25.1	19.4	13.5	19.3	12.8	25.9
2-Ethyl-1-hexanol	17.8	17.3	16.8	17.3	16.8	17.9	17.4	15.7	16.1	16.4	15.3	17.4
d-Limonene	23.0	21.6	11.2	18.6	11.3	25.9	22.3	19.4	19.8	20.5	18.7	22.3
1,2-Dichlorobenzene	6.9	6.8	6.5	6.7	6.5	7.0	7.0	6.2	6.4	6.5	6.0	7.0
n-Undecane	9.6	3.9	0.7	4.8	-0.3	9.8	8.0	4.9	2.1	5.0	1.7	8.3
Decamethylcyclosiloxane	1.5	0.3	0.0	0.6	-0.3	1.5	0.4	0.2	0.1	0.2	0.0	0.4
n-Dodecane	8.6	2.7	0.5	3.9	-0.8	8.6	3.8	2.5	1.1	2.5	0.9	4.0

*for alpha=0.05
+ 0.0 values are compounds that were not detected. Acrolein and crotonaldehyde are unstable on the DNPH sampler.

Office Mix Test: Airflow 1200 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test	Efficiency % *	Increase ppb of compound/ppb of IPA/acetone upstream*
Ethanol	0.5	0.8	no		0.010
Isopropanol /Acetone	29.4	27.4	no	7	
Dichloromethane	1.7	2.2	no		0.016
Carbon disulfide	1.4	1.7	no		0.011
MTBE (tert-Butyl-methyl ether)	22.6	21.6	no	5	
2-Butanone	6.4	6.8	no		0.013
1,1,1-Trichloroethane	29.3	28.2	no	4	
1-Butanol	8.6	8.4	no	2	
Trichloroethene	7.4	7.0	no	6	
MIBK (4-Methyl-2-pentanone)	20.7	18.2	no	12	
Toluene	68.5	67.1	no	2	
Hexanal	4.9	3.9	no	19	
Tetrachloroethene	14.4	12.8	no	11	
m-Xylene	34.7	31.4	no	10	
n-Nonane	8.2	7.5	no	8	
2-Butoxyethanol	12.2	9.0	no	27	
Phenol	3.7	2.9	no	22	
1,2,4-Trimethylbenzene	11.4	9.8	no	14	
n-Decane	17.8	14.0	no	21	
2-Ethyl-1-hexanol	14.6	13.8	no	5	
d-Limonene	17.5	16.0	no	8	
1,2-Dichlorobenzene	6.2	5.4	no	12	
n-Undecane	8.2	3.7	no	55	
Decamethylcyclosiloxane	1.2	0.7	no	40	
n-Dodecane	7.8	2.8	no	65	

*not statistically significant

Office Mix Test: Airflow 2000 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test	Efficiency % *	Increase ppb of compound/ppb of IPA/acetone upstream+
Ethanol	1.4	1.0	no	27	
Isopropanol /Acetone	23.9	19.8	no	17	
Dichloromethane	2.1	1.6	no	24	
Carbon disulfide	1.4	1.2	no	13	
MTBE (tert-Butyl-methyl ether)	24.3	23.3	no	4	
2-Butanone	6.8	19.9	no		
1,1,1-Trichloroethane	30.5	27.8	no	9	
1-Butanol	9.7	8.6	no	11	
Trichloroethene	8.0	7.0	no	13	
MIBK (4-Methyl-2-pentanone)	23.5	21.2	no	10	
Toluene	73.6	67.4	no	8	
Hexanal	5.5	4.8	no	13	
Tetrachloroethene	15.4	13.4	no	13	
m-Xylene	39.5	34.9	no	12	
n-Nonane	10.8	9.4	no	13	
2-Butoxyethanol	13.1	12.1	no	7	
Phenol	4.3	3.7	no	15	
1,2,4-Trimethylbenzene	15.2	12.3	no	19	
n-Decane	22.7	18.4	no	19	
2-Ethyl-1-hexanol	18.5	15.9	no	14	
d-Limonene	23.5	19.3	no	18	
1,2-Dichlorobenzene	7.4	6.5	no	12	
n-Undecane	8.0	6.8	no	15	
Decamethylcyclosiloxane	1.3	0.7	no	45	
n-Dodecane	5.8	5.2	no	10	

*not statistically significant

+no increases

Office Mix Test: Airflow 2500 cfm

Analyte	Upstream Average (ppb)	Downstream Average (ppb)	Statistically different by T-test	Efficiency % *	Increase ppb of compound/ppb of IPA/acetone upstream*
Ethanol	0.6	0.7	no		0.007
Isopropanol /Acetone	8.5	8.1	no	5	
Dichloromethane	0.8	0.8	no		0.005
Carbon disulfide	0.8	0.8	no	1	
MTBE (tert-Butyl-methyl ether)	24.1	23.4	no	3	
2-Butanone	23.7	30.1	no		0.749
1,1,1-Trichloroethane	29.2	26.6	no	9	
1-Butanol	8.7	7.7	yes	11	
Trichloroethene	7.4	6.9	no	8	
MIBK (4-Methyl-2-pentanone)	21.7	20.2	yes	7	
Toluene	71.0	64.8	no	9	
Hexanal	5.3	4.9	no	9	
Tetrachloroethene	14.4	13.4	no	7	
m-Xylene	37.1	34.5	yes	7	
n-Nonane	8.9	9.6	no		0.074
2-Butoxyethanol	14.6	14.6	no	0	
Phenol	4.6	4.4	no	4	
1,2,4-Trimethylbenzene	11.1	13.5	no		0.290
n-Decane	15.3	19.3	no		0.471
2-Ethyl-1-hexanol	17.3	16.4	yes	5	
d-Limonene	18.6	20.5	no		0.225
1,2-Dichlorobenzene	6.7	6.5	no	3	
n-Undecane	4.8	5.0	no		0.026
Decamethylcyclosiloxane	0.6	0.2	no	65	
n-Dodecane	3.9	2.5	no	37	

*not statistically significant, except as noted