MOLD, POLLEN AND OTHER CHEMICAL COMPOUNDS IN EFFLUENT AIR OF RESIDENTIAL HOMES

Brent E. Wholeben, Ph.D.
Director, Office of Research, Evaluation, and Policy Studies
Northern Illinois University

ABSTRACT

An investigation of the composition of effluent air – air emitted to the external environment from beneath residential dwellings – was conducted to determine emissions by type and amount. A total of 10 dwellings comprised the measured sample. However, only 8 dwellings elicited complete data due to obstacles encountered in physical structure of the research sites. All measurements were performed between August 24, 2006 and September 28, 2006, inclusive.

VARIABLES

Three (3) Variables were targeted for this study: (1) Biological: mold spores, pollen, and insect parts (2) Chemical: volatile organic compounds (VOC), measured in parts per billion by volume (PPBV) and micrograms per cubic meter of air (ug/m^3); and additional tentatively identified compounds (TIC) as validly and reliably present (detectable); (3) Physical: particle size and concentration, humidity, dew point, temperature, exhaust velocity.

ANALYSIS

Descriptive

Measures of spore, pollen, and other compounds, both inside and outside the radon mitigation system, are reported in terms of substance identity and 7 corresponding descriptive statistics:

1. Identity – name of the substance (spore, pollen, VOC, TIC) detected.
2. N – number of dwellings possessing a specific type of model or pollen spore.
3. Minimum – lowest spore count measured.
4. Maximum – highest spore count measured.
5. Mean – arithmetic average of spore count across possessing sites.
6. Standard Deviation – dispersion of measures across possessing sites, interpreted as a metric which, when added to and subtracted from the mean, provides a range of measure in which approximately ⅔ of the N measures would be found.
7. Skewness – metric that explains the shape of the distribution of measures across possessing sites, *i.e.* whether the distribution is symmetric or asymmetric.
8. Kurtosis – metric that explains the tendency of the distribution of measures across possessing sites to cluster about the mean, or alternative, to spread across several individual measures.

Relational

In addition to identity and descriptive statistics, further analysis of the interrelationships between measures within category (spore, pollen, VOC, TIC) was performed to examine the tendency of different types of compounds to be present in unison with other compounds. This analysis was completed using α=.05 as accepted sampling error (possibility of misinterpretation based upon inconsistent measurement).

The Pearson product-moment correlation coefficient is reported to identify the strength of the relationship between compounds. To interpret accurately the correlation coefficient (metric), simply square the metric listed in the correlation tables which are bolded, and that product (squared metric) denotes the percent of variability (standard deviation) in one compound that explains the variability in the corresponding compound (*i.e.* the higher the percent, the more closely aligned the 2 compounds).

ENVIRONMENTAL CONDITIONS

For warranty of disclosure, the following site-based environment conditions were present at the time of measurement:

- ✓ Calendar: 8/24/2006 – 9/28/2006
- ✓ Weather: variable
- ✓ Time of day: 1000-1100, with one dwelling measured at 1330
- ✓ Slab/sub-slab pressure differential: -.026 (average)
- ✓ Temperature (average)
  - Basement: 70.03°F
  - Atmosphere: 67.79°F
  - Discharge: 70.36°F
- ✓ Relative humidity (average)
  - Basement: 61.62%
  - Atmosphere: 68.86%
  - Discharge: 86.41%
- ✓ Barometric pressure (average)
  - Basement: 29.922
  - Atmosphere: 29.92
- ✓ Discharge velocity (feet per minute)
  - 1241.3 FM (average)
  - 530-1826 FM (range)

5 of the dwellings were occupied, the remaining 5 dwellings vacant. Square footage averaged 1281.6 square feet, with a range of 696-2198 square feet.

FINDINGS

Spore and Pollen Count

Count of spore and pollen were completed within (SPORE_IN) and without (SPORE_OUT) the site. A total of 24 different types of mold were targeted. Pollen, as well as total fungi and fibrous particulates were included in the analysis protocol, as were insect fragments.

The following table reports the descriptive statistics by spore type detected inside the radon mitigation system. Blanks in the table denoted those instances wherein spore type was not detected, or was undetectable.

SPORE_IN DETECTION

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
SPORE IN 01	2	79	79	79.00	.000	.	.
SPORE IN 02	3	79	158	105.33	45.611	1.732	.
SPORE IN 03	1	79	79	79.00	.	.	.
SPORE IN 04	4	79	869	414.75	331.267	1.007	1.829
SPORE IN 05	5	79	158	142.20	35.330	-2.236	5.000
SPORE IN 06	0						
SPORE IN 07	0						
SPORE IN 08	0						
SPORE IN 09	4	79	1030	376.00	440.746	1.873	3.580
SPORE IN 10	0						
SPORE IN 11	4	79	79	79.00	.000	.	.
SPORE IN 12	0						
SPORE IN 13	0						
SPORE IN 14	0						
SPORE IN 15	0						
SPORE IN 16	0						
SPORE IN 17	0						
SPORE IN 18 Rust	0						
SPORE IN 19	0						
SPORE IN 20	0						
SPORE IN 21	0						
SPORE IN 22 Torula	0						
SPORE IN 23	0						
SPORE IN 24	0						
SPORE IN 25 Total	10	0	1430	474.50	503.515	1.387	.746
SPORE IN 26 Fibrous	9	316	4030	1343.33	1109.105	2.044	4.991
SPORE IN 28 Insect	3	158	790	395.00	344.353	1.630	.
SPORE IN 29 Pollen	4	79	2130	710.25	961.762	1.820	3.322
SPORE IN 30	10	79	79	79.00	.000	.	.
SPORE IN 31 Skin	10	1	1	1.00	.000	.	.
SPORE IN 32	10	1	4	2.50	.850	.000	.107

Interrelationships between inside-site spore counts were computed where possible, given spore type detected and the suitability of sufficient data. The reader should limit their interpretation to only to those coefficients which are expressed in bold type (having an asterisks (*) following the correlation coefficient metric).

SPORE INTERRELATIONSHIPS

	Aspergillus/Pe	05 Basidiospores	09 Cladosporium	25 Total Fungi	26 Fibrous Particulate	28 Insect Fragment	29 Pollen	32 Background (1-5)
02 Alternaria	.(a)	.(a)	.(a)	1.000(*)	-.772	.(a)	.(a)	-
04		1.000(*)	.(a)	.766	-.490	.(a)	-	-.974(*)
05 Basidiospores			.(a)	.250	.193	.(a)	.(a)	.250
09 Cladosporium				.980(*)	-	1.000(*)	.(a)	-.808
25 Total Fungi					-.321	.729	-	-.513
26 Fibrous Particulate						.668	-	.476
28 Insect Fragment							.(a)	-.115
29 Pollen								.871

Likewise, spore and pollen outside of the dwelling were correspondingly measured and correlated, and are reported in the following detection and interrelationship tables.

SPORE OUT DETECTION

	N	MiN	Max	Mean	Std. Deviation	Skewness	Kurtosis
SPORE OUT 01	4	32	160	96.00	73.901	.000	-6.000
SPORE OUT 02	7	64	832	315.43	307.171	.857	-.751
SPORE OUT 03	10	32	3330	1311.60	1077.304	.832	.077
SPORE OUT 04	6	64	768	256.00	299.504	1.341	.359
SPORE OUT 05	10	192	3040	1098.60	949.150	1.070	.218
SPORE OUT 06	0						
SPORE OUT 07	2	32	128	80.00	67.882	.	.
SPORE OUT 08	0						
SPORE OUT 09	10	160	14000	4061.40	5084.889	1.428	.668
SPORE OUT 10	3	32	32	32.00	.000	.	.
SPORE OUT 11	6	32	192	112.00	69.374	.265	-2.214
SPORE OUT 12	1	64	64	64.00	.	.	.
SPORE OUT 13	8	32	224	100.00	67.205	.893	.077
SPORE OUT 14	0						
SPORE OUT 15	1	32	32	32.00	.	.	.
SPORE OUT 16	0						
SPORE OUT 17	5	32	96	51.20	28.622	1.258	.313
SPORE OUT 18 Rust	0						
SPORE OUT 19	0						
SPORE OUT 20	1	32	32	32.00	.	.	.
SPORE OUT 21	0						
SPORE OUT 22	2	32	32	32.00	.000	.	.
SPORE OUT 23	0						
SPORE OUT 24	0						
SPORE OUT 25	10	1020	18700	7106.00	5769.472	1.324	.913
SPORE OUT 26	8	32	352	196.00	114.023	.091	-1.357
SPORE OUT 27	7	32	192	91.43	59.663	.719	-.540
SPORE OUT 28	0						
SPORE OUT 29	5	32	192	102.40	82.830	.502	-3.215
SPORE OUT 30	10	32	32	32.00	.000	.	.
SPORE OUT 31 Skin	10	0	1	.90	.316	-3.162	10.000
SPORE OUT 32	10	1	2	1.60	.516	-.484	-2.277

SPORE_OUT INTERRELATIONSHIPS

	SPORE_OUT_02 Alternaria	OUT_03 Ascospor	OUT_04 Aspergillus/Penicil	OUT_05 Basidiosp	SPORE_OUT_09 Cladosporium	OUT_11 Epicoccu	OUT_13 Ganoder	OUT_17 Pithomyces/Ulocla	SPORE_OUT_25 Total Fungi	OUT_26 Fibrous Particulat	OUT_27 Hyphal	SPORE_OUT_29 Pollen	OUT_31 Skin Fragment	SPORE_OUT_32
ORE OUT 01	.492	.092	-	.852	.577	.866	.945	.(a)	.715	-	.707	-	.(a)	.(a)
ORE OUT 02		.076	.254	.202	.932(*)	-	-	-.522	.900(*)	.260	-	.369	.(a)	.132
ORE OUT 03			.937(*)	.065	-.053	.093	-	-.657	.166	-	-	.859	-	-
ORE OUT 04				-	.111	.899	.235	-.500	.596	-	-	.(a)	.(a)	-.66
ORE OUT 05					.256	-	.466	.932(*)	.411	-	.268	-	-	.219
ORE OUT 09						-	-	-.104	.962(*)	.153	.081	.241	.259	.449
ORE OUT 11							.550	-	-.065	.394	.328	-	.(a)	-.56
ORE OUT 13								.601	.057	-	.397	-	.216	.064
ORE OUT 17									-.001	-	.000	-	.(a)	.612
ORE OUT 25										-	.098	.261	.123	.305
ORE OUT 26											.280	.249	.(a)	.267
ORE OUT 27												-	.(a)	.439
ORE OUT 29													.(a)	.(a)
ORE OUT 31 Skin														.408

Volatile Organic Compounds

In addition to spore and pollen, volatile organic compounds (VOC) were targeted. With sufficient vapor pressure to vaporize and enter the atmosphere, VOC may contribute to air pollution.

A total of 69 volatile organic compounds were detected, as PPBV have reported in the table below. Please note that the order of the compounds was defined by the laboratory analysis report, and therefore does not imply any other foundation for interpretation. Measurements of VOC are expressed in both parts part per billion by volume (PPBV) and micrograms per cubic meter of air (ug/m^3).

VOC by PPBV DETECTION

	N	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
VOC PPBV 01	8	1.00	1.00	1.0000	.00000	.	.
VOC PPBV 02 Freon 1	8	.50	1.20	.6475	.25806	1.843	2.694
VOC PPBV 03 Freon	8	.50	.50	.5000	.00000	.	.
VOC PPBV 04	8	.50	.56	.5075	.02121	2.828	8.000
VOC PPBV 05 Vinyl	8	.50	.50	.5000	.00000	.	.
VOC PPBV 06 1.3-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 07	8	.50	.50	.5000	.00000	.	.
VOC PPBV 08	8	.50	.50	.5000	.00000	.	.
VOC PPBV 09 Ethanol	8	6.40	480.00	93.4250	160.66296	2.541	6.692
VOC PPBV 10	8	.50	.50	.5000	.00000	.	.
VOC PPBV 11 Freon 11	8	.50	1.50	.6250	.35355	2.828	8.000
VOC PPBV 12	5	2.00	100.00	24.4800	42.34084	2.204	4.883
VOC PPBV 13 Freon	8	.50	4.90	2.4250	1.76210	.654	-1.432
VOC PPBV 14 Acetone	8	4.40	140.00	30.8250	47.22635	2.254	5.034
VOC PPBV 15 1.1-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 16	8	.50	.50	.5000	.00000	.	.
VOC PPBV 17 Tertiary	8	.50	.50	.5000	.00000	.	.

VOC BY PPBV (CONT)		N	Min	Max	Mean	Std.	Skewness	Kurtosis
VOC PPBV 18		8	.50	.50	.5000	.00000	.	.
VOC PPBV 19	3-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 20	Carbon	8	.50	.61	.5138	.03889	2.828	8.000
VOC PPBV 21		7	1.50	1.50	1.5000	.00000	.	.
VOC PPBV 22		8	.50	.50	.5000	.00000	.	.
VOC PPBV 23	Methyl-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 24	trans-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 25	n-	8	.50	5.40	2.2250	1.93889	.933	-.548
VOC PPBV 26	1,1-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 27	Vinyl	8	.50	.50	.5000	.00000	.	.
VOC PPBV 28	2-	8	9.90	880.00	203.8625	323.91085	1.761	2.125
VOC PPBV 29	cis-1,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 30	Ethyl	8	.50	1.40	.6238	.31523	2.775	7.756
VOC PPBV 31		8	.50	1.10	.5750	.21213	2.828	8.000
VOC PPBV 32		8	4.60	1500.00	209.0375	522.80814	2.804	7.890
VOC PPBV 33	1,1,1-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 34		8	.50	.50	.5000	.00000	.	.
VOC PPBV 35	2,2,4-	8	.50	3.80	1.3588	1.21110	1.368	1.223
VOC PPBV 36	Carbon	8	.50	.50	.5000	.00000	.	.
VOC PPBV 37	n-	8	.50	2.30	1.1175	.77656	.851	-1.242
VOC PPBV 38	1,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 39	Benzene	8	.50	3.70	1.2875	1.07363	1.952	4.159
VOC PPBV 40		8	.50	.50	.5000	.00000	.	.
VOC PPBV 41	1,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 42		8	.50	.50	.5000	.00000	.	.
VOC PPBV 43	1,4-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 44	4-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 45	cis-1,3-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 46	Toluene	8	.89	12.00	5.1488	3.99723	.856	-.436
VOC PPBV 47	trans-1	8	.50	.50	.5000	.00000	.	.
VOC PPBV 48	1,1 ,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 49	2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 50		8	.50	.65	.5188	.05303	2.828	8.000
VOC PPBV 51		8	.50	.50	.5000	.00000	.	.
VOC PPBV 52	1,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 53		8	.50	.50	.5000	.00000	.	.
VOC PPBV 54		8	.50	2.70	.9950	.74516	2.083	4.737
VOC PPBV 55	Xylene	7	.50	9.80	3.6286	3.10683	1.452	2.559
VOC PPBV 56	Xylene	8	.50	3.40	1.1738	.97867	2.039	4.537
VOC PPBV 57	Styrene	8	.50	.61	.5138	.03889	2.828	8.000
VOC PPBV 58		8	.50	.50	.5000	.00000	.	.
VOC PPBV 59	1,1 ,2,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 60	4-	8	.50	2.50	1.1675	.70896	1.149	.257
VOC PPBV 61	1 ,3,5-	8	.50	.75	.5575	.10700	1.483	.277
VOC PPBV 62	2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 63	1 ,2,4-	8	.50	3.40	1.5463	.94879	1.119	.940
VOC PPBV 64	1,3-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 65	1,4-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 66	Benzyl	8	.50	.50	.5000	.00000	.	.
VOC PPBV 67	1 ,2-	8	.50	.50	.5000	.00000	.	.
VOC PPBV 68	1,2,4—	8	.50	.50	.5000	.00000	.	.
VOC PPBV 69		8	.50	.50	.5000	.00000	.	.

As was reported for spore and pollen detected, each of the statistical interrelationships between various VOC were calculated for interpretation. The reader is once again reminded to limit any interpretation to those correlation coefficients followed by an asterisk. Furthermore, correlation coefficients have been included in the table where sufficient date was available for such analyses. For readability and formatting purposes, correlation results have been split into two separate tables.

VOC_PPBV-1 INTERRELATIONSHIP

	04 Chlorometh ane	09 Ethanol	11 (Trichlorofl uorometha	12 Isopropyl alcohol(2- Propanol)	113(1,1 2- Trichlorotri	14 Acetone	25 n- Hexane	28 2- Butanone(MEK)	30 Ethyl acetate	31 Chloroform	32 Tetrahydrof uran
02 Freon 1	.364	.929(*)	-	.253	.426	.666	.876(*)	.212	.850(*)	.865(*)	.355
04 Chloromethane		.042	-	.997(*)	-	.934(*)	.557	.843(*)	-.159	-.143	.998(*)
09 Ethanol			-	-.124	.581	.387	.737(*)	-.068	.961(*)	.972(*)	.032
11 Freon 11				-.195	.568	-.206	-.047	-.184	-.043	-.143	-.152
12 Isopropyl alcohol(2-					-	.916(*)	.480	.999(*)	-.311	-.285	.997(*)
13 Freon 113(1,1 2-						.053	.369	-.197	.630	.568	-.152
14 Acetone							.792(*)	.784(*)	.197	.215	.933(*)
25 n-Hexane								.489	.663	.662	.561
28 2-Butanone(MEK)									-.225	-.204	.878(*)
30 Ethyl acetate										.995(*)	-.166
31 Chloroform											-.149

VOC_PPBV-2 INTERRELATIONSHIP

	35 2,2,4- Trimethylpe ntane (Isooctane)	37 n- Heptane	39 Benzene	46 Toluene	54 Ethylbenze ne	55 Xylene (para & meta)	56 Xylene (Ortho)	57 Styrene	60 4- Ethyltoluen e	61 1 ,3,5- Trimethylbe nzene	63 1 ,2,4-
Freon 1	.654	.816(*)	.617	.875(*)	.908(*)	.884(*)	.914(*)	.865(*)	.899(*)	.967(*)	.87
Chloromethane	.814(*)	.615	.908(*)	.490	.111	.124	.135	-.143	.417	.576	.32
Ethanol	.418	.659	.342	.756(*)	.930(*)	.882(*)	.927(*)	.972(*)	.838(*)	.832(*)	.85
Freon 11	-.287	-.285	-.033	.066	.057	.095	.052	-.143	.133	-.217	.15
Isopropyl alcohol(2-	.767	.520	.911(*)	.391	-.086	-.046	-.054	-.285	.296	.487	.15
Freon 113(1,1 2-	-.073	.103	.101	.448	.618	.587	.613	.568	.647	.369	.69
Acetone	.905(*)	.812(*)	.966(*)	.734(*)	.435	.439	.458	.215	.681	.826(*)	.59
n-Hexane	.840(*)	.938(*)	.843(*)	.983(*)	.852(*)	.874(*)	.869(*)	.662	.932(*)	.933(*)	.89
2-Butanone(MEK)	.649	.485	.778(*)	.381	-.017	-.009	.021	-.204	.270	.416	.18
Ethyl acetate	.254	.540	.191	.706	.939(*)	.896(*)	.933(*)	.995(*)	.780(*)	.712(*)	.81
Chloroform	.281	.563	.193	.693	.925(*)	.876(*)	.919(*)	1.000(*)	.759(*)	.727(*)	.78
Tetrahydrofuran	.810(*)	.612	.909(*)	.488	.101	.113	.126	-.149	.409	.569	.31
2,2,4-Trimethylpentane		.946(*)	.928(*)	.786(*)	.516	.512	.533	.281	.671	.797(*)	.61
n-Heptane			.842(*)	.901(*)	.744(*)	.741	.757(*)	.563	.808(*)	.892(*)	.77
Benzene				.799(*)	.477	.492	.500	.193	.719(*)	.789(*)	.64
Toluene					.893(*)	.925(*)	.906(*)	.693	.960(*)	.912(*)	.93
Ethylbenzene						.987(*)	.999(*)	.925(*)	.926(*)	.841(*)	.93
Xylene (para & meta)							.990(*)	.876(*)	.942(*)	.821(*)	.95
Xylene (Ortho)								.919(*)	.934(*)	.853(*)	.94
Styrene									.759(*)	.727(*)	.78
4-Ethyltoluene										.917(*)	.99
1 ,3,5-											.87

VOC as measured by ug/m^3 units – as contrasted with units of PPBV (above) – are listed in the following table.

VOC by ug/m^3 DETECTION

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
VOC UGM3 01	8	1.70	1.70	1.7000	.00000	.	.
VOC UGM3 02 Freon 1	8	2.50	5.80	3.1875	1.22175	1.843	2.663
VOC UGM3 03 Freon	8	3.50	3.50	3.5000	.00000	.	.
VOC UGM3 04	8	1.00	1.20	1.0250	.07071	2.828	8.000
VOC UGM3 05 Vinyl	8	1.30	1.30	1.3000	.00000	.	.
VOC UGM3 06 1,3-	8	1.10	1.10	1.1000	.00000	.	.
VOC UGM3 07	8	1.90	1.90	1.9000	.00000	.	.
VOC UGM3 08	8	1.30	1.30	1.3000	.00000	.	.
VOC UGM3 09	8	12.00	910.00	175.250	304.60783	2.565	6.802
VOC UGM3 10	8	2.20	2.20	2.2000	.00000	.	.
VOC UGM3 11 Freon	8	2.80	8.50	3.5125	2.01525	2.828	8.000
VOC UGM3 12	8	3.70	250.00	39.6500	85.34376	2.783	7.802
VOC UGM3 13 Freon	8	3.80	38.00	18.8375	13.63419	.646	-1.407
VOC UGM3 14	8	10.00	340.00	73.8750	114.38961	2.296	5.274
VOC UGM3 15 1,1-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 16	8	.84	.84	.8400	.00000	.	.
VOC UGM3 17	8	1.50	1.50	1.5000	.00000	.	.
VOC UGM3 18	8	2.20	2.20	2.2000	.00000	.	.
VOC UGM3 19 3-	4	1.60	1.60	1.6000	.00000	.	.
VOC UGM3 20 Carbon	8	1.60	1.90	1.6375	.10607	2.828	8.000
VOC UGM3 21	8	5.20	5.20	5.2000	.00000	.	.
VOC UGM3 22	8	1.10	1.10	1.1000	.00000	.	.
VOC UGM3 23	7	1.80	1.80	1.8000	.00000	.	.

VOC by ug/m^3 DETECTION (continued)

		N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
VOC UGM3 24	trans-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 25	n-	8	1.80	19.00	7.8375	6.75657	.925	-.530
VOC UGM3 26	1.1-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 27	Vinyl	8	1.80	1.80	1.8000	.00000	.	.
VOC UGM3 28	2-	8	29.00	2600.00	607.125	961.70228	1.737	1.977
VOC UGM3 29	cis-1.2-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 30	Ethyl	7	1.80	5.10	2.3143	1.23346	2.602	6.812
VOC UGM3 31		8	2.40	5.30	2.7625	1.02530	2.828	8.000
VOC UGM3 32		8	14.00	4400.00	612.125	1533.6933	2.806	7.900
VOC UGM3 33	1.1.1-	8	2.70	2.70	2.7000	.00000	.	.
VOC UGM3 34		8	1.70	1.70	1.7000	.00000	.	.
VOC UGM3 35	2.2.4-	8	2.30	18.00	6.3375	5.73335	1.406	1.406
VOC UGM3 36	Carbon	8	3.10	3.10	3.1000	.00000	.	.
VOC UGM3 37	n-	8	2.00	9.40	4.5500	3.20268	.866	-1.186
VOC UGM3 38	1.2-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 39		8	1.60	12.00	4.1250	3.48333	1.996	4.357
VOC UGM3 40		7	2.70	2.70	2.7000	.00000	.	.
VOC UGM3 41	1.2-	7	2.30	2.30	2.3000	.00000	.	.
VOC UGM3 42		8	3.30	3.30	3.3000	.00000	.	.
VOC UGM3 43	1.4-	7	1.80	1.80	1.8000	.00000	.	.
VOC UGM3 44	4-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 45	cis-1.3-	8	2.30	2.30	2.3000	.00000	.	.
VOC UGM3 46		7	3.40	38.00	15.7429	11.83214	1.140	1.321
VOC UGM3 47	trans-1	8	2.30	2.30	2.3000	.00000	.	.
VOC UGM3 48	1.1 .2-	8	2.70	2.70	2.7000	.00000	.	.
VOC UGM3 49	2-	8	2.00	2.00	2.0000	.00000	.	.
VOC UGM3 50		8	3.40	4.40	3.5250	.35355	2.828	8.000
VOC UGM3 51		8	4.30	4.30	4.3000	.00000	.	.
VOC UGM3 52	1.2-	8	3.80	3.80	3.8000	.00000	.	.
VOC UGM3 53		8	2.30	2.30	2.3000	.00000	.	.
VOC UGM3 54		8	2.20	12.00	4.4250	3.32727	2.045	4.558
VOC UGM3 55	Xylene	8	2.20	43.00	14.4750	13.11703	1.677	3.210
VOC UGM3 56	Xylene	8	2.20	15.00	5.1750	4.31633	2.040	4.562
VOC UGM3 57	Styrene	8	2.10	2.60	2.1625	.17678	2.828	8.000
VOC UGM3 58		8	5.20	5.20	5.2000	.00000	.	.
VOC UGM3 59	1.1	8	3.40	3.40	3.4000	.00000	.	.
VOC UGM3 60	4-	8	2.50	13.00	5.8000	3.65982	1.286	.901
VOC UGM3 61	1 .3.5-	8	2.50	3.70	2.7750	.51200	1.487	.302
VOC UGM3 62	2-	8	2.60	2.60	2.6000	.00000	.	.
VOC UGM3 63	1 .2.4-	8	2.50	17.00	7.6000	4.72259	1.197	1.238
VOC UGM3 64	1.3-	8	3.00	3.00	3.0000	.00000	.	.
VOC UGM3 65	1.4-	8	3.00	3.00	3.0000	.00000	.	.
VOC UGM3 66	Benzyl	8	3.70	37.00	7.8625	11.77333	2.828	8.000
VOC UGM3 67	1 .2-	8	3.00	3.00	3.0000	.00000	.	.
VOC UGM3 68	1.2.4—	8	3.70	3.70	3.7000	.00000	.	.
VOC UGM3 69		8	5.30	5.30	5.3000	.00000	.	.

As was done for PPBV units of VOC measure, statistical interrelationships between ug/m^3 units of VOC were calculated for interpretation. The reader is once again reminded to limit any interpretation to those correlation coefficients followed by an asterisk. Correlation coefficients are included in the table below only when sufficient data was available for such analyses. As done previously, for readability and formatting purposes, correlation results have been split into two separate tables.

VOC_UGM3-1 INTERRELATIONSHIPS

	04 Chlorometh	09 Ethanol	11 (Trichlorofl	12 Isopropyl alcohol(2-	13 113(1,1 2-Trichlorotri	14 Acetone	20 Carbon disulfide	25 n-Hexane	28 2-Butanone(MEK)	30 Ethyl acetate	31 Chloroform	32 Tetrahydrofuran
02 Freon 1	.3	.927	-	.352	.4	.656	.368	.881	.214	.848	.864	.360
04 Chloromethane		.033	-	.996	-	.940	1.000	.548	.837	-	-	.998
09 Ethanol			-	.026	.5	.363	.033	.737	-	.964	.975	.024
11 Freon 11				-	.5	-	-.143	-	-	-	-	-
12 Isopropyl					-	.931	.996(	.541	.826	-	-	.993
13 Freon 113(1,1						.044	-.143	.376	-	.628	.568	-
14 Acetone							.940(	.777	.786	.156	.198	.939
20 Carbon								.548	.837	-	-	.998
25 n-Hexane									.483	.671	.668	.553
28 2-										-	-	.871
30 Ethyl acetate											.996	-
31 Chloroform												-

VOC_UGM3-2 INTERRELATIONSHIPS

	33 2,2,4-Trimethylpentane (Isooctane)	37 n-Heptane	39 Benzene	46 Toluene	50 Tetrachloroethene	54 Ethylbenzene	55 Xylene (para & meta)	56 Xylene (Ortho)	57 Styrene	60 4-Ethyltoluene	61 1,3,5-Trimethylbenzene	62 1,2,4-
Freon 1	.642	.830(*)	.616	.781(*)	.368	.909(*)	.877(*)	.911(*)	.864(*)	.911(*)	.970(*)	.
ethane	.822(*)	.612	.913(*)	.829(*)	1.000(*)	.118	.139	.124	-.143	.364	.572	.
	.391	.665	.325	.493	.033	.927(*)	.887(*)	.926(*)	.975(*)	.859(*)	.830(*)	.
Freon 11	-.285	-.284	-.038	.233	-.143	.070	.139	.059	-.143	.132	-.217	.
opyl alcohol(2-	.801(*)	.589	.912(*)	.844(*)	.996(*)	.121	.148	.126	-.154	.381	.560	.
n 113(1,1 2-	-.088	.114	.095	.098	-.143	.625	.641	.615	.568	.667	.372	.
	.903(*)	.806(*)	.969(*)	.835(*)	.940(*)	.426	.437	.433	.198	.629	.813(*)	.
lisulfide	.822(*)	.612	.913(*)	.829(*)	1.000(*)	.118	.139	.124	-.143	.364	.572	.
e	.821(*)	.941(*)	.831(*)	.969(*)	.548	.858(*)	.879(*)	.868(*)	.668	.922(*)	.932(*)	.
one(MEK)	.649	.484	.785(*)	.733	.837(*)	-.014	.041	.008	-.205	.218	.409	.
etate	.280	.599	.170	.252	-.184	.938(*)	.904(*)	.937(*)	.996(*)	.809(*)	.708	.
rm	.258	.574	.183	.416	-.143	.920(*)	.879(*)	.920(*)	1.000(*)	.795(*)	.730(*)	.
rofuran	.817(*)	.610	.915(*)	.832(*)	.998(*)	.109	.134	.116	-.148	.357	.566	.
imethylpentane		.934(*)	.924(*)	.854(*)	.822(*)	.499	.514	.507	.258	.621	.781(*)	.
ne			.834(*)	.859(*)	.612	.751(*)	.756(*)	.760(*)	.574	.799(*)	.898(*)	.
				.938(*)	.913(*)	.471	.505	.480	.183	.669	.782(*)	.
					.829(*)	.920(*)	.913(*)	.939(*)	-.416	.922(*)	.829(*)	.
oroethene						.118	.139	.124	-.143	.364	.572	.
zene							.990(*)	.999(*)	.920(*)	.949(*)	.844(*)	.
para & meta)								.991(*)	.879(*)	.958(*)	.824(*)	.
Ortho)									.920(*)	.950(*)	.848(*)	.
										.795(*)	.730(*)	.
oluene											.910(*)	.
1 .3.5-												.
1 .2.4-												

Other Tentatively Identified Compounds

Each site produced an array of other detectable compounds which have been identified and listed in the following table.

TIC DETECTION

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
TIC RT 01 .alpha.-	3	26.57	26.57	26.5700	.00000	.	.
TIC RT 02 Acetic	1	23.51	23.51	23.5100	.	.	.
TIC RT 03	2	30.74	30.74	30.7400	.00000	.	.
TIC RT 04 Benzene.	1	27.44	27.44	27.4400	.	.	.
TIC RT 05 Butane	4	6.18	6.19	6.1875	.00500	-2.000	4.000
TIC RT 06 Butane. 2-	5	7.73	8.34	7.9660	.31477	.628	-3.212
TIC RT 07	1	28.56	28.56	28.5600	.	.	.
TIC RT 08	8	26.62	26.93	26.8513	.12833	-1.465	.268
TIC RT 09 Decane	1	27.11	27.11	27.1100	.	.	.
TIC RT 10	1	5.26	5.26	5.2600	.	.	.
TIC RT 11 Ethane.	3	5.25	5.62	5.3733	.21362	1.732	.
TIC RT 12 Ethane. 1-	1	5.73	5.73	5.7300	.	.	.
TIC RT 13 Hexanal	2	23.41	23.42	23.4150	.00707	.	.
TIC RT 14 Isobutane	2	5.73	6.14	5.9350	.28991	.	.
TIC RT 15 Limonene	8	28.70	28.80	28.7788	.04016	-1.608	1.077
TIC RT 16 Nonane	1	24.80	24.80	24.8000	.	.	.
TIC RT 17 Nonane. 3-	1	25.59	25.59	25.5900	.	.	.
TIC RT 18 Pentane	3	8.63	9.32	9.0667	.37978	-1.666	.
TIC RT 19 Pentane. 2-	3	12.13	12.32	12.1967	.10693	1.715	.
TIC RT 20 Pentane. 3-	2	13.08	13.08	13.0800	.00000	.	.
TIC RT 21 R-.alpha.-	2	26.28	26.57	26.4250	.20506	.	.
TIC RT 22 Undecane	3	29.15	29.16	29.1533	.00577	1.732	.

Available and sufficient data were present to calculate only the following interrelationships.

TIC_RT INTERRELATIONSHIPS

	08 Cyclohexanone	Ethane, 1,1-difluo	15 Limonene	18 Pentane	Pentane, 2-methy	21 R-.alpha.-Pinen	22 Undecane
06 Butane. 2-methyl-	-	1.000(*)	-.958(*)	1.000(*)	.999(*)	-	-
08 Cyclohexanone		-.999(*)	.993(*)	-.969	-.999(*)	1.000(*)	.(a)
11 Ethane. 1.1-			-	.(a)	1.000(*)	.(a)	.(a)
15 Limonene				-.925	-.999(*)	1.000(*)	.(a)
18 Pentane					1.000(*)	-	.(a)
19 Pentane. 2-						.(a)	-
21 R-.alpha.-Pinene							.(a)

Concentration levels for these TIC entities were as follows.

TIC_CONCENTATION DETECTION

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
TIC_CONC_01 .alpha.-	3	1	8	4.67	3.512	-.423	.
TIC_CONC_02 Acetic	1	2	2	2.00	.	.	.
TIC_CONC_03	2	2	3	2.50	.707	.	.
TIC_CONC_04 Benzene,	1	1	1	1.00	.	.	.
TIC_CONC_05 Butane	4	3	21	10.25	8.139	.892	-.675
TIC_CONC_06 Butane,	5	1	23	10.20	10.918	.531	-3.117
TIC_CONC_07	1	2	2	2.00	.	.	.
TIC_CONC_08	8	1	12	3.50	3.817	1.972	3.798
TIC_CONC_09 Decane	1	5	5	5.00	.	.	.
TIC_CONC_10	1	72	72	72.00	.	.	.
TIC_CONC_11 Ethane,	3	8	39	18.67	17.616	1.726	.
TIC_CONC_12 Ethane,	1	1	1	1.00	.	.	.
TIC_CONC_13 Hexanal	2	1	2	1.50	.707	.	.
TIC_CONC_14 Isobutane	2	16	24	20.00	5.657	.	.
TIC_CONC_15 Limonene	8	1	4	1.88	1.246	.895	-1.132
TIC_CONC_16 Nonane	1	6	6	6.00	.	.	.
TIC_CONC_17 Nonane,	1	3	3	3.00	.	.	.
TIC_CONC_18 Pentane	3	1	7	3.00	3.464	1.732	.
TIC_CONC_19 Pentane,	3	2	6	3.67	2.082	1.293	.
TIC_CONC_20 Pentane,	2	1	2	1.50	.707	.	.
TIC_CONC_21 R-	2	1	6	3.50	3.536	.	.
TIC_CONC_22	3	1	2	1.33	.577	1.732	.

Interrelationships between concentrations of TIC are reported as follows.

TIC_CONCENTRATION INTERRELATIONSHIPS

	05 Butane	Butane, 2-	08 Cyclohexanone	11 Ethane, 1,1-difluoro-	15 Limonene	18 Pentane	19 Pentane, 2-methyl-	22 Undecane
01 .alpha.-Pinene	.(a)	.(a)	.164	.(a)	.904	.(a)	.(a)	.(a)
05 Butane		-.463	-.351	1.000(*)	-.826	.(a)	1.000(*)	-.410
06 Butane, 2-methyl-			-.283	.976	.453	.569	.373	1.000(*)
08 Cyclohexanone				-.524	.375	-.115	.961	1.000(*)
11 Ethane, 1,1-difluoro-					-.524	.(a)	-1.000(*)	.(a)
15 Limonene						1.000(*)	.891	.756
18 Pentane							1.000(*)	.(a)
19 Pentane, 2-methyl-								1.000(*)

INTERRELATIONSHIPS

A variety of substances – mold fungi, pollen, and volatile organic compounds, as well as other compounds identified only tentatively – escape into the outside air from beneath residential dwellings via radon mitigation systems.

Generally, total fungi count is most influenced by the within level (sub slab of the dwelling) of *aspergillus/penicillium* (58.7% variance in total fungi count explained by presence and level of aspergillus/penicillium),

a

		U				
M		B		B	t	
1	C				.	.
	A	5			.	.

a D

M	R			
1	a		.	.

a P

although the most prevalent type of spore present within the dwelling was *basidiospores*. Additional analyses found that as the level of aspergillus/penicilium fluctuated, so also did basidiospores, respectively, and on a proportional linear scale (r=1.0, p=.000). Furthermore, the level of basidiospores interior to the radon mitigation system was significantly lower than the level of spores exterior (t=-3.121, df=4, p=.035).

							t	df	
P	B					0		4	
1	B								

No other spore entities were related to this phenomenon.

Utilizing the PPBV measures associated with various VOC, it was found that compounds tended to separate into 3 groups, membership in each depending upon statistical coexistence. Membership has been denoted by bolded values to the right of the various VOC entities in the following table.

p [a]

	1	2	3
[illegible]			
[illegible]			
[illegible]			
[illegible]	[illegible]		
[illegible]			
[illegible]			
C			
[illegible]			[illegible]
[illegible]	[illegible]		
[illegible] y			
[illegible]			
[illegible]			[illegible]
[illegible]	[illegible]		
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]		[illegible]	
[illegible]			
[illegible]			
[illegible]			
[illegible]			
[illegible]			

[illegible]
[illegible]
a [illegible]

Each of these 3 groups play an important role in understanding the VOC-based composition of interior dwelling air. The above model, although limited due to scant sample size (N=10), might explain as much as 97.495% of the underlying variability between and among VOC entities.

C			
1			
2			5
3	8		

[illegible]

Please note that a similar analysis utilizing VOC ug/m^3 units was not possible due to the instability of the data. Moreover, similar analysis of the TIC data was not possible due to sample size and data instability across the sample.

Particulate Emissions

Effluent discharge of particulates (EMIC) was measured in terms of 5 ranges of micron size (0.3-0.5; 0.5-0.7; .7-1.0; 1.0-3.0; 3.0-5.0). Correspondingly, extant particulate concentration was measured in the ambient air (AMIC) immediately external to the site.

Effluent Particulate Discharge by Size

Site	EMIC_0.3_0.5	EMIC_0.5_0.7	EMIC_0.7_1.0	EMIC_1.0_3.0	EMIC_3.0_5.0
1	1244800	139200	30400	34800	9200
2	8104000	1632800	676000	741600	311200
3	2900600	230400	46400	61200	38000
4	2904700	436800	104000	134600	85200
5	4054000	51000	130400	163200	361600
6	2234400	265200	60800	87200	37600
7	5867200	697600	143200	171600	115600
8	6735000	1045600	3256000	386400	248800
9	6497200	791600	214800	256800	228400
10	796800	101600	21808	40400	24400
Mean	**4133870**	**539180**	**468380.80**	**207780**	**146000**
Std Dev	2522047	506836	998132	216509	130242

Ambient Particulate Concentration by Size

Site	AMIC_0.3_0.5	AMIC_0.5_0.7	AMIC_0.7_1.0	AMIC_1.0_3.0	AMIC_3.0_5.0
1	5449600	188000	18000	13200	10800
2	8170600	175600	10000	13600	6400
3	7731200	1450400	280400	204000	17600
4	1476800	107600	16400	20000	4000
5	2888400	264000	40000	25600	51600
6	704800	27200	3200	4000	1600
7	4059200	161600	16800	5200	3600
8	474800	26000	3200	4800	5200
9	324000	19200	2800	5600	1600
10	220400	12000	1200	1200	1600
Mean	**3149980**	**243160**	**39200**	**29720**	**10400**
Std Dev	3071032	433062	85545	61731	15318

The difference between effluent and ambient particulate concentrations (DMIC) was calculated (EMIC-AMIC) by micron-size category. Positive differences depict that discharges were greater than extant in the surrounding environment, while negative differences depict that discharges were less than extant in the surrounding environment.

Particulate Concentration Differentials (E-A) by Size

Site	DMIC_0.3_0.5	DMIC_0.5_0.7	DMIC_0.7_1.0	DMIC_1.0_3.0	DMIC_3.0_5.0
1	-4204800	-48800	12400	21600	-1600
2	-66600	1457200	666000	728000	304800
3	-4830600	-1220000	-234000	-142800	20400
4	1427900	329200	87600	114600	81200
5	1165600	-213000	90400	137600	310000
6	1529600	238000	57600	83200	36000
7	1808000	536000	126400	166400	112000
8	6260200	1019600	3252800	381600	243600
9	6173200	772400	212000	251200	226800
10	576400	89600	20608	39200	22800
Mean	**983890**	**296020**	**429180.80**	**178060**	**135600**
Std Dev	3620556	736344	1017498	238216	123504

Hypothetically, positive discharge differences might be interpreted as an air pollution enabler. The preponderance of *enabling* conditions (82%) would suggest that significant air pollution might be extant based upon mitigation protocols.

Air Pollution Enablers

Site	MIC_0.3_0.5	MIC_0.5_0.7	MIC_0.7_1.0	MIC_1.0_3.0	MIC_3.0_5.0
1			ENABLING	ENABLING	
2		ENABLING	ENABLING	ENABLING	ENABLING
3					ENABLING
4	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING
5	ENABLING		ENABLING	ENABLING	ENABLING
6	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING
7	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING
8	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING
9	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING
10	ENABLING	ENABLING	ENABLING	ENABLING	ENABLING

As a final analysis, step-wise linear regression was employed to test for complex relationships between spore, VOC, and TIC measurements, and those of particulate emissions by size. The results of these analyses are summarized in the below table, wherein one (or more) entities were found to be predictive of the amount of particulate emission by size. The order of entities in those cells which have multiple contents signifies the strength (importance) of the entity in terms of predicting particulate size.

Relationship between Measured Substances and Particulate Emissions

Particulate (Microns)	SPORE (IN)	VOC PPBV	VOC UGM3	TIC
0.3-0.5	05 Basidiospores			18 Pentane
0.5-0.7	05 Basidiospores		30 Ethyl acetate 46 Toluene 43 1,4-Dioxane 66 Benzyl chloride	18 Pentane
0.7-1.0	04 Aspergillus/ Penicillium	12 Isopropyl alcohol (2-Propanol) 28 2-Butanone(MEK) 02 Freon 1 2 (Dichlorodifluoromethane) 37 n-Heptane	20 Carbon disulfide 30 Ethyl acetate 46 Toluene 01 Propylene 13 Freon 113(1,1 2-Trichlorotrifluoroethan	18 Pentane
10.-3.0	05 Basidiospores			18 Pentane
3.0-5.0	04 Aspergillus/ Penicillium			19 Pentane, 2-methyl-

RECOMMENDATION

It is recommended:

1. Replicate with a larger sample size of not less than 50 sites – in order to stabilize the data for more advanced statistical treatment.
2. Repeat the measurement protocol 3 times (4 trials total) over the course of 12 months –in order to isolate any seasonal differences as well as calibrate within-site variability.
3. Measure the presence of radon under variable fan mitigation, both pre- and post-mitigation – in order to study the relationship between mitigation and passive environmental effects.

ACKNOWLEDGEMENT

This project was supported by the SIRG 15 – IEMA SIRG Radon Mitigation System Project (2006).