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TECHNICAL MEMORANDUM

Updated: January 2024

Beacon Passive Samplers Reporting Concentration Data

Uptake Rate

In 2016, Beacon commissioned two consecutive studies at the Health and Safety Laboratory (HSL) in the United Kingdom. The studies set out to experimentally determine and validate the quantitative uptake rates of the Beacon Passive Sampler based on 7-day and 14-day sampling events, which are routine sampling periods used for passive soil gas investigations. Active pumped samplers (reference technique) and conventional, industry-standard, axial passive samplers were included in the studies.

The experiments were carried out in the HSL standard atmosphere generator based upon procedures described in ISO 6145-4:2004. HSL is an internationally recognized center of excellence for VOC sampling, and their methods for the determination of hazardous substances (MDHS) are the source of most of the published uptake rates in the relevant international standard methods (e.g., ISO 16017-2).[1]

Quantitative uptake rates for 13 key chlorinated and aromatic VOCs were determined and verified for the Beacon Passive Sampler for 7- and 14-day exposure periods. In this six-replicate study, the devices showed excellent performance with great linearity and reproducibility. In addition, the uptake rates were within the 0.1 to 1.0 ml/min range, which was confirmed to be the recommended range when sampling for soil gas, as described in the federally funded study ESTCP Report ER-200830.[2] These findings confirmed that the Beacon Passive Sampler is an ideal device for quantitative, time-weighted-average (TWA) concentration determination for the compounds targeted in the study, as well as compounds of similar molecular weight and/or volatility, for both air and soil gas sampling.

Per the requirements of ISO 16017-2, the mass measured (ng) by a passive sampler is converted to a concentration by dividing the mass (ng) by the sampler uptake rate (ml/min) and the sampling period (min), which is then multiplied by a value of 1,000 to convert ng/ml to ug/m^3.

The equation used to calculate the time-weighted average concentrations is provided below.

$$C = \frac{1000 \times M}{U \times t}$$

Where:
- C = concentration (ug/m^3)
- M = mass (ng)
- U = uptake rate (ml/min)
- t = sampling time (minutes)

The compounds included in the uptake rate study are provided in **Table 1**, which also provides the validated uptake rates.

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Table 1: Compounds with Validated Uptake Rates

COMPOUND	Uptake Rate (ml/min)
Vinyl Chloride	0.81
1,1-Dichloroethene	0.33
trans-1,2-Dichloroethene	0.44
1,1-Dichloroethane	0.85
cis-1,2-Dichloroethene	0.53
1,2-Dichloroethane	0.56
1,1,1-Trichloroethane	1.05
Benzene	0.53
Trichloroethene	0.33
Toluene	0.40
Tetrachloroethene	0.41
Ethylbenzene	0.85
o-Xylene	0.88

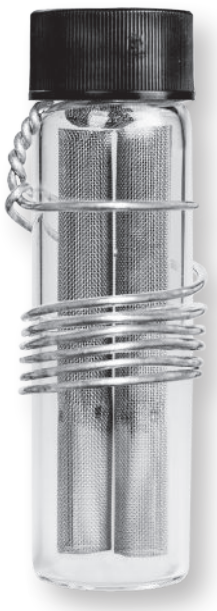
Graham's Law of gas diffusion is used to calculate the uptake rate for target VOCs that were not included in the uptake rate study. Graham's law states that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight. In the HSL study, Beacon included a broad range of VOCs from vinyl chloride to o-xylene in order to determine the uptake rates for a wide range of compounds and be able to better estimate uptake rates for other target VOCs. The equation used to calculate the uptake rates based on Graham's Law is provided below:

$$U_C = \frac{U_k}{\sqrt{\frac{MW_C}{MW_k}}}$$

Where:
- U_c = Uptake rate calculated from known uptake rate (ml/min)
- U_k = known uptake rate from study (ml/min)
- MW_c = Molecular weight of compound with calculated uptake rate (g/mol)
- MW_k = Molecular weight of compound with known uptake rate (g/mol)

Table 2 on the following page provides the known and calculated uptake rates for the list of compounds that are in Beacon's standard list of compounds targeted with EPA Method 8260C or TO-17. Table 2 also provides the molecular weights in g/mol for each of the compounds. The compounds from the uptake rate study used to calculate the other target VOCs were chosen based on similar molecular weights and chemical properties. Note that the calculated uptake rates for the TPH fractions is based on the average uptake rates calculated for each of the individual alkanes within the reported range (e.g., TPH C4-C9 is based on the average of the calculated uptake rates for pentane, hexane, heptane, octane, & nonane).

Table 3 provides the limit of quantitation (LOQ) for each of the compounds in the standard compound list based on 1, 3, 7, and 14 day sampling periods. The LOQ is at or above the low point of the initial calibration curve to ensure data reported are defensible. In addition, results less than the LOQ but greater than the limit of detection (LOD) may be reported as estimates and qualified with a "J" to achieve lower reporting limits. LODs for each compound are provided in **Table 4** ■



The Beacon Passive Soil Gas Sampler

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Table 2: Uptake Rates for Standard Target Compound List

COMPOUND	Uptake Rate (ml/min)	Compound with known uptake rate used to calculate estimated uptake rate	Molecular Weight (g/mol)
Vinyl Chloride	0.81		62.5
1,1-Dichloroethene	0.33		97
Methylene Chloride	0.35	1,1 Dichloroethene	84.9
1,1,2-Trichlorotrifluoroethane (Fr.113)	0.89	1,1,1-Trichloroethane	187.38
trans-1,2-Dichloroethene	0.44		96.95
Methyl-t-butyl ether	0.50	Benzene	88.17
1,1-Dichloroethane	0.85		99
cis-1,2-Dichloroethene	0.53		96.95
Chloroform	0.35	Trichloroethene	119
1,2-Dichloroethane	0.56		99
1,1,1-Trichloroethane	1.05		133.4
Carbon Tetrachloride	0.43	Tetrachloroethene	153.84
Benzene	0.53		78.11
Trichloroethene	0.33		131.4
1,4-Dioxane	0.41	Toluene	88.11
1,1,2-Trichloroethane	0.33	Trichloroethene	133.4
Toluene	0.40		92
1,2-Dibromoethane (EDB)	0.39	Tetrachloroethene	187.9
Tetrachloroethene	0.41		165.8
1,1,1,2-Tetrachloroethane	0.41	Tetrachloroethene	167.85
Chlorobenzene	0.85	o-Xylene	112.6
Ethylbenzene	0.85		106
p & m-Xylene	0.88	o-Xylene	106.2
o-Xylene	0.88		106.2
1,2,3-Trichloropropane	0.75	o-Xylene	147.43
Isopropylbenzene	0.83	o-Xylene	120.19
1,3,5-Trimethylbenzene	0.83	o-Xylene	120.2
1,2,4-Trimethylbenzene	0.83	o-Xylene	120.2
1,3-Dichlorobenzene	0.75	o-Xylene	147
1,4-Dichlorobenzene	0.75	o-Xylene	147
1,2-Dichlorobenzene	0.75	o-Xylene	147
1,2,4-Trichlorobenzene	0.39	Tetrachloroethene	181.46
Naphthalene	0.80	o-Xylene	128.16
1,2,3-Trichlorobenzene	0.39	Tetrachloroethene	181.45
2-Methylnaphthalene	0.76	o-Xylene	142.2
TPH C5-C8	0.59	Based on the average of the uptake rates calculated for individual alkanes	
TPH C9-C15	0.69		

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Table 3: Limits of Quantitation (LOQs) based on Exposure Periods and Third Party Validated Uptake Rates

COMPOUND	CAS	Uptake Rate (ml/min)	1 Day LOQ (ug/m3)	3 Days LOQ (ug/m3)	7 Days LOQ (ug/m3)	14 Days LOQ (ug/m3)
Vinyl Chloride	75-01-4	0.81	8.57	2.86	1.22	0.61
1,1-Dichloroethene	75-35-4	0.33	21.04	7.01	3.01	1.50
Methylene Chloride	75-09-2	0.35	19.84	6.61	2.83	1.42
1,1,2-Trichlorotrifluoroethane (Fr.113)	76-13-1	0.89	7.80	2.60	1.11	0.56
trans-1,2-Dichloroethene	156-60-5	0.44	15.78	5.26	2.25	1.13
Methyl-t-butyl ether	1634-04-4	0.50	34.72	11.57	4.96	2.48
1,1-Dichloroethane	75-34-3	0.85	8.17	2.72	1.17	0.58
cis-1,2-Dichloroethene	156-59-2	0.53	13.10	4.37	1.87	0.94
Chloroform	67-66-3	0.35	19.84	6.61	2.83	1.42
1,2-Dichloroethane	107-06-2	0.56	12.40	4.13	1.77	0.89
1,1,1-Trichloroethane	71-55-6	1.05	6.61	2.20	0.94	0.47
Carbon Tetrachloride	56-23-5	0.43	16.32	5.44	2.33	1.17
Benzene	71-43-2	0.53	32.76	10.92	4.68	2.34
Trichloroethene	79-01-6	0.33	21.04	7.01	3.01	1.50
1,4-Dioxane	123-91-1	0.41	16.94	5.65	2.42	1.21
1,1,2-Trichloroethane	79-00-5	0.33	21.04	7.01	3.01	1.50
Toluene	108-88-3	0.40	43.40	14.47	6.20	3.10
1,2-Dibromoethane (EDB)	106-93-4	0.39	18.03	6.01	2.58	1.29
Tetrachloroethene	127-18-4	0.41	16.94	5.65	2.42	1.21
1,1,1,2-Tetrachloroethane	630-20-6	0.41	17.04	5.68	2.43	1.22
Chlorobenzene	108-90-7	0.85	8.17	2.72	1.17	0.58
Ethylbenzene	100-41-4	0.85	20.42	6.81	2.92	1.46
p & m-Xylene	108-38-3	0.88	19.73	6.58	2.82	1.41
o-Xylene	95-47-6	0.88	19.73	6.58	2.82	1.41
1,2,3-Trichloropropane	96-18-4	0.75	9.26	3.09	1.32	0.66
Isopropylbenzene	98-82-8	0.83	20.92	6.97	2.99	1.49
1,3,5-Trimethylbenzene	108-67-8	0.83	20.92	6.97	2.99	1.49
1,2,4-Trimethylbenzene	95-63-6	0.83	20.92	6.97	2.99	1.49
1,3-Dichlorobenzene	541-73-1	0.75	9.26	3.09	1.32	0.66
1,4-Dichlorobenzene	106-46-7	0.75	9.26	3.09	1.32	0.66
1,2-Dichlorobenzene	95-50-1	0.75	9.26	3.09	1.32	0.66
1,2,4-Trichlorobenzene	120-82-1	0.39	17.72	5.91	2.53	1.27
Naphthalene	91-20-3	0.80	8.68	2.89	1.24	0.62
1,2,3-Trichlorobenzene	87-61-6	0.39	17.72	5.91	2.53	1.27
2-Methylnaphthalene	91-57-6	0.76	9.14	3.05	1.31	0.65
TPH C5-C8		0.59	5,874	1,958	839	420
TPH C9-C15		0.69	5,032	1,677	719	359

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Table 4: Limits of Detection (LODs) based on Exposure Periods and Third Party Validated Uptake Rates

COMPOUND	CAS	Uptake Rate (ml/min)	1 Day LOD (ug/m3)	3 Days LOD (ug/m3)	7 Days LOD (ug/m3)	14 Days LOD (ug/m3)
Vinyl Chloride	75-01-4	0.81	4.29	1.43	0.61	0.31
1,1-Dichloroethene	75-35-4	0.33	10.52	3.51	1.50	0.75
Methylene Chloride	75-09-2	0.35	9.92	3.31	1.42	0.71
1,1,2-Trichlorotrifluoroethane (Fr.113)	76-13-1	0.89	3.90	1.30	0.56	0.28
trans-1,2-Dichloroethene	156-60-5	0.44	7.89	2.63	1.13	0.56
Methyl-t-butyl ether	1634-04-4	0.50	13.89	4.63	1.98	0.99
1,1-Dichloroethane	75-34-3	0.85	4.08	1.36	0.58	0.29
cis-1,2-Dichloroethene	156-59-2	0.53	6.55	2.18	0.94	0.47
Chloroform	67-66-3	0.35	9.92	3.31	1.42	0.71
1,2-Dichloroethane	107-06-2	0.56	6.20	2.07	0.89	0.44
1,1,1-Trichloroethane	71-55-6	1.05	3.31	1.10	0.47	0.24
Carbon Tetrachloride	56-23-5	0.43	8.16	2.72	1.17	0.58
Benzene	71-43-2	0.53	13.10	4.37	1.87	0.94
Trichloroethene	79-01-6	0.33	10.52	3.51	1.50	0.75
1,4-Dioxane	123-91-1	0.41	8.47	2.82	1.21	0.60
1,1,2-Trichloroethane	79-00-5	0.33	10.52	3.51	1.50	0.75
Toluene	108-88-3	0.40	17.36	5.79	2.48	1.24
1,2-Dibromoethane (EDB)	106-93-4	0.39	9.02	3.01	1.29	0.64
Tetrachloroethene	127-18-4	0.41	8.47	2.82	1.21	0.60
1,1,1,2-Tetrachloroethane	630-20-6	0.41	8.52	2.84	1.22	0.61
Chlorobenzene	108-90-7	0.85	4.08	1.36	0.58	0.29
Ethylbenzene	100-41-4	0.85	8.17	2.72	1.17	0.58
p & m-Xylene	108-38-3	0.88	7.89	2.63	1.13	0.56
o-Xylene	95-47-6	0.88	7.89	2.63	1.13	0.56
1,2,3-Trichloropropane	96-18-4	0.75	4.63	1.54	0.66	0.33
Isopropylbenzene	98-82-8	0.83	8.37	2.79	1.20	0.60
1,3,5-Trimethylbenzene	108-67-8	0.83	8.37	2.79	1.20	0.60
1,2,4-Trimethylbenzene	95-63-6	0.83	8.37	2.79	1.20	0.60
1,3-Dichlorobenzene	541-73-1	0.75	4.63	1.54	0.66	0.33
1,4-Dichlorobenzene	106-46-7	0.75	4.63	1.54	0.66	0.33
1,2-Dichlorobenzene	95-50-1	0.75	4.63	1.54	0.66	0.33
1,2,4-Trichlorobenzene	120-82-1	0.39	8.86	2.95	1.27	0.63
Naphthalene	91-20-3	0.80	4.34	1.45	0.62	0.31
1,2,3-Trichlorobenzene	87-61-6	0.39	8.86	2.95	1.27	0.63
2-Methylnaphthalene	91-57-6	0.76	4.57	1.52	0.65	0.33
TPH C5-C8		0.59	5,874	1,958	839	420
TPH C9-C15		0.69	5,032	1,677	719	359

[1] ISO 16017-2, Indoor, ambient and workplace air – Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography – Part 2: Diffusive Sampling, 2003.
[2] ESTCP Project ER-200830, Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling, July 2014.