AIHA USGBC VOC PROJECT TEAM – FINAL REPORT
Approved by the AIHA Board: January 16, 2015

Introduction and Background

In March 2014, members of the American Industrial Hygiene Association (AIHA) Indoor Environmental Quality (IEQ) Committee and the U.S. Green Building Council (USGBC) Indoor Environmental Quality Technical Advisory Group (IEQ TAG) met by teleconference to discuss the Leadership in Energy and Environmental Design certification program version 4 (LEED v4) post-construction IEQ testing credit. Specifically, the attendees discussed the total volatile organic compounds (TVOCs) and target chemicals listed in LEED Building Design & Construction (BD&C) Credit: Indoor Air Quality Assessment - Table 1: Maximum Concentration Levels.

The IEQ TAG members and USGBC staff provided information and questions to the AIHA IEQ Committee members (see attached). In particular, there was discussion about the “Speciated VOCs” on the list. It was agreed that the AIHA IEQ Committee should conduct a review of the information and questions provided by USGBC, and that a report on the findings would be issued to the USGBC IEQ TAG.

At the AIHA IEQ Committee meeting convened in May 2014 at AIHce (San Antonio), the AIHA USGBC VOC Project Team was authorized to begin work. Shortly thereafter, the following AIHA members were selected for participation on the Project Team:

- Donald Weekes, CIH, InAIR Environmental Ltd., Project Team Chair
- Ed Stuber, CIH, Galson Laboratories
- Jeffrey Cooper, Bureau Veritas Laboratories
- Vincent Daliessio, CIH, EMSL Laboratories
- James Kenny, CIH, ESIS Laboratories
- David Kahane, CIH, Forensic Analytical Laboratories
- Raja Tannous, Berkeley Analytical Laboratories
- Catherine Bobenhausen, CIH, Vidaris Inc.

The Project Team teleconferenced three times to discuss the issues: in June, August, and September 2014. This report is based on the discussions that took place during these meetings, as well as the correspondence that occurred between Project Team members between meetings.

The focus of this paper is on the USGBC LEED v4 post-construction, IAQ sampling requirements, specifically for individual VOCs. This paper does not pertain to the conducting of indoor air quality (IAQ) investigations, or collection of VOC measurements, in occupied buildings.

Discussions

VOCs from the CREL List

The Project Team discussed in detail the recommended VOCs to be included on the final LEED IAQ maximum concentration level list. The discussion noted that the non-cancer chronic reference exposure levels (CRELs) on the LEED target chemical list originated with the California Department of Public Health (CPDH) document "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers Version 1.1," published in February 2010. Note that this CDPH publication has been periodically updated since 1990, when it was first published, with the CREL list adopted as part of the Standard Method document in 2004 and updated in 2010. Most likely, an update of this Standard Method will occur in the next few years.

In Section 1.1 of the CDPH document, the application of the Standard Method is stated:

> This method applies to any product category generally used within the envelope of an enclosed indoor environment. The method is applicable to products that can be tested whole or by representative sample in environmental chambers. This includes, as examples, paints, other architectural coatings and finishes, sealants, adhesives, wall coverings, floor coverings, acoustical ceilings, wood paneling, and wall and ceiling insulation used in public and commercial office buildings, schools, residences, and other building types.

Section 1.1.7 states:

> This method establishes performance criteria for specific chemicals of interest. These criteria are specifically for evaluating potential chronic health risks from inhalation exposures of vapor phase organic chemicals emitted by the products covered within the scope.

This method was established to test for and quantify the emissions of VOCs from building products in environmental testing chambers. The CRELs were adopted in this method to ensure that various building products would not contribute to levels above those established by California for chronic exposure, based on non-cancer endpoints, once the building product was installed or placed in the building. The method was not intended for use in the field, either for IAQ testing or to evaluate maximum concentration levels following construction of a building.

The CRELs are published periodically by the California Office of Environmental Health Hazard Assessment (OEHHA). The current OEHHA "Acute, 8-hour and Chronic Reference Exposure Level (REL)" list (June 2014) may be found at www.oehha.ca.gov/air/allrels.html.

Acute RELs are akin to “peak” or “short-term” levels associated with high concentrations for a brief period of time. OSHA has parallel limits for short-term episodes in short-term exposures in occupational settings. It appears that the OEHHA CRELs are more appropriate for evaluating post-construction conditions in a new building, on this admittedly conservative assumption: that levels will not diminish on the order of hours but will persist on the order of days to weeks and for some chemicals, such as formaldehyde, possibly longer, once the building is occupied.

The 2004 version of the CDPH document included all of the published CRELs. The 2010 version includes only those VOCs within the volatility range of n-pentane through n- heptadecane (C_5 – C_{17}) and low molecular weight aldehydes. The Project Team considers that it may be worthwhile to examine the 2004 list of all published CRELs to determine if there are other VOCs of interest that may impact indoor air quality in a new or reconstructed building. For example, acrolein and vinyl chloride are not on the current CDPH list. The Project Team believes that USGBC should review the 2004 CREL list of VOCs to determine if there are other chemicals that should be included for post-construction sampling. (Note that building product emission reports produced for compliance with the CDPH method also report California Proposition 65 and the California ARB List of Toxic Air Contaminant chemicals identified during the analysis.)

In the 2010 CDPH document, paragraph 4.2.3 states:

> Changes in the CREL list or values issued by OEHHA or in other references following the publication of this document do not automatically update these maximum allowable concentrations. The target CREL VOCs to be tested by this Standard Method and their maximum allowable concentrations shall continue to apply until these changes are published in a revised version of this document.

The Project Team expects that a future updated CDPH document will take into account updates to the OEHHA CREL list.

The OEHHA webpage also notes, “Chronic RELs are designed to address continuous exposures for up to a lifetime: the exposure metric used is the annual average exposure.”

In addition, CRELs are defined in the 2010 CDPH document as “inhalation concentrations to which the general population, including sensitive individuals, may be exposed for long periods (10 years or more) without the likelihood of serious adverse systemic effects (excluding cancer).”

These two statements tend to support a conservative use of the CRELs for LEED post-construction IAQ testing, where levels should be low enough that sensitive populations would not be affected. However, there is no scientific basis for the use, in post-construction IAQ testing, of a standard that is one-half of the CRELs, which are the current LEED v4 requirements. This requirement was developed for the chamber testing methodology with the assumption that other building products would also be emitting VOCs.

The CRELs are non-cancer, health-based maximum concentration levels for chronic exposure to specific VOCs. The EPA has similar reference concentrations (RfCs), which have been used to supplement the CRELs in some IAQ evaluations of offices and schools in California. An RfC is an estimate of a continuous inhalation exposure of people (including sensitive subgroups) that is likely to be without risk of deleterious effects during a lifetime. As far as the AIHA Project Team is aware, the CRELs and RfCs' are the only two sets of guidelines that have a toxicological basis for indoor air evaluations in the United States. The Agency for Toxic Substances and Disease Registry (ATSDR) has established minimal risk levels for screening at U.S. hazardous waste sites, but these levels are not applicable to indoor environments. The European Union, France, Germany, and Belgium have also established various VOC limits, which were not fully investigated by the Project Team as part of this evaluation.

<u>TVOCs and Target Chemical Maximum Concentration Levels</u>

The AIHA Project Team believes that a definition of total volatile organic compounds (TVOCs) that is generally accepted by all parties would be useful to those concerned with compliance with the LEED v4 IAQ post-construction requirements. Currently, there is no accepted definition for TVOCs by IAQ practitioners and those conducting post-construction IAQ sampling. This lack of a commonly accepted definition has resulted in significant differences in the reported TVOC measurements collected by practitioners, which in turn results in the inability to compare sampling and analytical data from one set of samples to another set.

The Project Team proposes using the following definition of TVOCs as the one that IAQ practitioners that will utilize when conducting post-construction, pre-occupancy sampling. This definition (slightly modified as underlined) comes from the California Standard Method document:

> TVOCs – Sum of the concentrations of all identified and unidentified VOCs <u>with retention times</u> between and including <u>those of</u> n-pentane through n-heptadecane (i.e., C_5 – C_{17}) as measured by the GC/MS TIC method and expressed as a toluene equivalent value.

The Project Team recommends that the USGBC IEQ TAG accept this definition and that this definition be incorporated into LEED v4 as it relates to post-construction IAQ measurements.

The Project Team discussed the LEED v4 Table 1 Maximum Concentration Levels. In particular, it considered the interaction between the maximum acceptable TVOC level and the maximum concentration levels set for the various target chemicals (VOCs) from the CDPH Standard Method v1.1, Table 4−1, with the exception of formaldehyde, which is addressed separately from the target chemicals list. It was noted that the maximum acceptable concentration levels for some of the VOCs are actually higher than the maximum acceptable TVOC level. For example, the maximum acceptable concentration for chlorobenzene is 1000 micrograms per cubic meter of air ($\mu g/m^3$), while the maximum acceptable concentration for TVOCs is 500 $\mu g/m^3$.

Although the maximum concentration levels for TVOCs and the target chemicals can be accurately quantified by proper sampling and analytical methods, the Project Team was of the opinion that these multiple maximum concentration levels may prove difficult to explain adequately to the contractors, construction mangers, and building owners that are responsible for meeting these levels. For example, the sampling results may fall within the maximum allowable TVOC level while the results for some of the specific target VOCs exceed their maximum concentration levels. Conversely, the maximum concentration levels for each of the target chemicals may be met while the TVOC maximum concentration level is exceeded.

The Project Team discussed the possibility of requiring a separate TVOC sample collection and analysis, either by real-time measurements or by lab analysis of a collected sample. The target VOC sample could be collected at the same time but not analyzed until the TVOC analysis is complete. The advantage of this requirement would be to determine whether the airborne concentrations of total VOCs were in compliance (i.e., less than 500 µg/m3) first prior to the analysis of any samples for the target chemicals. It is also likely that this requirement would result in lower overall lab analysis costs for the building in those circumstances when the TVOC airborne concentration does not meet the LEED v4 criteria. The Project Team recommends that the USGBC IEQ TAG consider allowing this staged approach.

In addition, the Project Team is interested in the basis for the setting of more stringent maximum concentration levels for healthcare facilities for TVOCs, total particulates, and formaldehyde.

<u>Potential Alternative VOCs Lists</u>

A discussion was also held by the Project Team on possible alternative lists of target chemicals as opposed to the target CREL VOC list in the LEED v4 post-construction IAQ sampling credit. Although there were brief discussions by the Project Team regarding specific VOC's and their inclusion on the CREL list, the Project Team did not review the maximum acceptable concentrations for the various VOC's due to a lack of a consensus on the specifics for each VOC and any changes to the CRELs for these VOC’s. However, the Project Team did consider one possible alternative to the target CREL VOC list, namely, the TO−15/TO−17 Calibration Standard for VOCs. One of the members of the Project Team completed a comparison of the two standards (see attached).

The advantage of the TO−15/TO−17 Calibration Standard for lab analysis is that these methods are well known in the field, having been used for a number of years for air sampling of indoor air as well as outdoor air. The TO−15/TO−17 list includes 65 VOCs as opposed to the 35 VOCs on the CREL list. The comparison found that 22 VOCs appeared on both lists.

The Project Team is not recommending a substitution of the TO−15/TO−17 VOC list for the current CREL list. The issue with the TO−15/TO−17 list is that many of the VOCs on the list do not have CRELs. We suggest that this list be further reviewed, and, where there are no CRELs, the guidance levels should be supplemented with EPA RfCs. Also, it was noted that most of the potential airborne VOCs in an indoor environment are captured by the TO−15/TO−17 method, which would facilitate a comparison of the TVOC level to the LEED v4 maximum concentration level.

The Project Team discussed cross-referencing the CREL VOC list to the TO−15/TO−17 list, the USEPA BASE study, and other current references (see references) for the purpose of potentially eliminating a large number of VOC's from the list of USGBC LEED v4 maximum acceptable concentrations for VOC's. The Project Team did review eliminating chemicals from the CREL VOC list that are uncommon in indoor air as evidenced by researchers and investigators. However, the Project Team decided that any reduced VOC list developed by AIHA for the purposes of use by USGBC in its LEED v4 post-construction testing would not have the scientific validation that the current CREL VOC list has achieved. Therefore, the Project Team decided not to pursue a review of each VOC on the list for the purpose of reducing the total number of VOCs.

The AIHA Project Team is recommending that the USGBC IEQ TAG continue to explore the option of reducing the current 35 target VOCs for LEED post-construction IAQ testing as listed in LEED v4 EQ Indoor Air Quality, Table 1. Specifically, the Project Team recommends that IAQ research studies be reviewed by the IEQ TAG in order to ensure that the VOC list is appropriate to new building conditions. This research (see references) may assist the IEQ TAG in its deliberations regarding future changes to the target VOC list.

Additional Analytical Methods

Based on the AIHA Project Team's review of the analytical methods listed in Table 1 in LEED v4 Credit EQ, the team recommends that the USGBC IEQ TAG consider adding additional allowable analytical methods to the list. In particular, the Project Team recommends:

- For formaldehyde: Add TO−15 to the acceptable analytical method list. Currently the analytical list consists of the following methods:

ASTM D5197; EPA TO-11, or EPA Compendium Method IP-6; ISO 16000-3. Formaldehyde is listed in the TO−15 method (see attached). The TO−15 analytical method is used currently by many of the industrial hygiene labs for formaldehyde concentrations in air. This method (TO−15) also tends to be less costly than other analytical methods as listed in LEED v4 EQ Credit – Indoor Air Quality Assessment, Table 1.

- For ozone: Add OSHA Method 214 to the acceptable analytical method list. Currently the analytical methods listed for ozone are: ASTM D4952−02; ISO 13964. The OSHA Method 214 is an analytical method used by many of the industrial hygiene labs for this contaminant. This method tends to be less costly than the other analytical methods currently listed by USGBC.

Each of these analytical methods (TO−15 and OSHA Method 214) can obtain analytical results at airborne concentrations well below the LEED IEQ maximum concentrations as listed in Table 1. The analytical sensitivity of these methods is sufficient to obtain these analytical results.

<u>Conclusions</u>

1. VOCs from the CREL List

   Based on its review of the applicable underlying documents, the AIHA Project Team accepts a “conservative” use of the CRELs for LEED post-construction IAQ testing, since the CREL levels are expected to be sufficiently low enough that sensitive populations would not be affected. However, the AIHA Project Team finds that there is no scientific basis for the use in post-construction IAQ testing of a standard that is one-half of the CRELs. Based on AIHA’s review, this “ one-half” factor was developed for chamber testing under the assumption that other building products would also be emitting. This assumption is not applicable to post-construction IAQ testing. The AIHA Project Team recommends that the USGBC IEQ TAG use the full CRELs as the maximum airborne concentration criteria in the LEED post-construction IAQ measurements.

2. TVOCs and Target Chemical Maximum Concentration Levels

   Based on its review, the AIHA Project Team recommends that the USGBC IEQ TAG accept the (slightly modified as underlined) TVOC definition promulgated by the California Standard Method document:

   TVOCs – Sum of the concentrations of all identified and unidentified VOCs <u>with retention times</u> between and including <u>those of</u> n-pentane through n-heptadecane (i.e., C_5 – C_{17}) as measured by the GC/MS TIC method and expressed as a toluene equivalent value.

The range identification will be based on DB−5 column or equivalent. All test methods approved may determine the column type. It is recommended that this definition be incorporated into LEED v4 as it relates to post-construction IAQ measurements.

The Project Team also suggests that the USGBC IEQ TAG consider the possibility of recommending TVOC sample collection either by real-time measurements or by lab analysis of a sample first prior to the analysis of samples for the target chemicals. The target chemical samples would be collected but not analyzed until the TVOC sample results are available. If the TVOC airborne concentrations do not meet the LEED v4 criterion of 500 $\mu g/m^3$ or less, then the target chemical samples would not be analyzed. If, on the other hand, the TVOC airborne levels meet the LEED v4 criteria, then the target chemical samples would be analyzed. The advantage of this recommendation would be to determine whether the total VOCs were in compliance prior to any analyses for the target chemicals. In addition, it may save laboratory costs for the client.

3. TVOCs Level for Health Care Facilities

The AIHA Project Team recommends that the USGBC IEQ TAG explain in LEED v4 the basis for health care facilities for the setting of a 200 $\mu g/m^3$ maximum concentration for TVOCs, a 16.3 parts per billion (ppb) maximum concentration for formaldehyde, and a 20 micrograms per cubic meter maximum concentration for total particulates. Currently, there does not appear to be any justification in LEED v4 for these reduced maximum concentrations for health care facilities. We recommend that an explanation be provided in the notes for this section of LEED v4.

4. Potential Alternative VOC List

The Project Team is not recommending a substitution of the TO−15/TO−17 VOC list for the current CREL list. The AIHA Project Team suggests that the USGBC IEQ TAG review the target contaminant list, and, where there are no CRELs, we recommend that the CRELs be supplemented with EPA RfCs.

The AIHA Project Team is recommending that the USGBC IEQ TAG continue to explore the option of reducing the current 35 target VOCs for LEED post-construction IAQ testing as listed in LEED v4 EQ Indoor Air Quality, Table 1. Specifically, the Project Team recommends that the IEQ TAG review the IAQ research to ensure that the VOC list is appropriate to new building conditions. This research (see references) may assist the IEQ TAG in its deliberations regarding future changes to the target VOC list.

5. Alternative Analytical Methods

The AIHA Project Team noted that most of the potential airborne VOCs in an indoor environment are captured by the TO−15/TO−17 method, which would facilitate a comparison of the TVOC level to the LEED v4 maximum concentration level. We recommend that the USGBC IEQ TAG consider adding additional allowable analytical methods to the list. In particular, the AIHA Project Team recommends that the following methods be added to the allowable analytical methods:

- For formaldehyde: Add TO−15 to the acceptable analytical method list. Currently the analytical list consists of the following methods: ASTM D5197; EPA TO−11, or EPA Compendium Method IP−6; ISO 16000−3. Formaldehyde is listed in the TO−15 method (see attached). The TO−15 analytical method is used currently by many of the industrial hygiene labs for formaldehyde concentrations in air. This method (TO−15) also tends to be less costly than other analytical methods as listed in LEED v4 EQ Credit – Indoor Air Quality Assessment, Table 1.

- For ozone: Add OSHA Method 214 to the acceptable analytical method list. Currently the analytical methods listed for ozone are: ASTM D4952−02; ISO 13964. The OSHA Method 214 is an analytical method used by many of the industrial hygiene labs for this contaminant. This method tends to be less costly than the other analytical methods currently listed by USGBC.

Each of these analytical methods (TO−15 and OSHA Method 214) can obtain analytical results at airborne concentrations well below the LEED IEQ maximum concentrations as listed in Table 1. The analytical sensitivity of these methods is sufficient to obtain these analytical results.

ATTACHMENTS

REFERENCES

1) Logue, J.M., P.N Price, M.H. Sherman, and Singer, B.C.: A method to estimate the chronic health impact of air pollutants in US residences. *Environ. Health Perspect. 120(2):* 216−222 (2012).

2) USEPA Method TO-15 Determination of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/Mass Spectrometry (GC/MS), USEPA Compendium of Methods for Toxic Organic Air Pollutants (1999).

3) Levin, H., and A.T. Hodgson: VOC Concentrations of Interest in North American Offices and Homes, *Proceedings Healthy Buildings 2006, Proceedings HB 2006, Healthy Buildings Creating a Healthy Indoor Environment for People*. 2006.

4) Levin, H., and A.T. Hodgson: Classification of Measured Indoor Volatile Organic Compounds Based on Noncancer Health and Comfort Considerations, LBNL Report (2003).

5) ECA (European Collaborative Action on Urban Air, Indoor Environment and Human Exposure) Report No. 18, Evaluation of VOC emissions from building products, Office for Official Publications of the European Communities, 1997 ISBN 92−828−0384−8. ECSC−EC−EAEC, Brussels – Luxembourg, 1997.

6) USGBC, Leadership in Energy and Environmental Design (LEED) certification program version 4 (LEED v4) Building Design & Construction (BD&C) Credit: Indoor Air Quality Assessment −Table 1: Maximum Concentration Levels, 2013.

TABLE 1
COMPARISON OF TO-15/TO-17 CALIBRATION STANDARD FOR VOCs AND LEED v4 TARGET VOCs (CDPH STD METHOD v1.1 TABLE 4.1)

	Chemical	CAS RN	Method TO-15/TO-17 Calibration Standard	CDPH v.1.1 Table 4-1	Comment
			µg/m³		
			(CREL)	(1/2 CREL)	
	TOTAL # OF CHEMICALS		*65*	*35*	
	ON BOTH LISTS		***22***		
	# WITH CRELs		*31*	*35*	
	# WITHOUT CRELS		*34*	*0*	
1	Acetone	67-64-1	x		
2	Acetaldehyde	75-07-0		70	
3	Acrolein	107-02-8	0.35		
4	**Benzene**	**71-43-2**	**3**	**30**	*In 2001, CREL was 60 µg/m³; currently 3 µg/m³*
5	Benzyl Chloride	100-44-7	x		
6	Bromoform	75-25-2	x		
7	Bromomethane	74-83-9	5		
8	Bromodichloromethane	75-27-4	x		
9	1,3-Butadiene	106-99-0	2		
10	2-Butanone (MEK)	78-93-3	x		
11	**Carbon Disulfide**	**75-15-0**	**800**	**400**	
12	**Carbon Tetrachloride**	**56-23-5**	**40**	**20**	
13	**Chlorobenzene**	**108-90-7**	**1,000**	**500**	
14	Chlorethane	75-00-3	30,000		
15	**Chloroform**	**67-66-3**	**300**	**150**	
16	Cyclohexane	110-82-7	x		
17	Chloromethane	74-87-3	x		
18	Dibromochloromethane	124-48-1	x		
19	1,2 Dibromoethane	106-93-4	0.8		
20	1,2-Dichlorobenzene	95-50-1	x		
21	1,3-Dichlorobenzene	541-73-1	x		
22	**1,4-Dichlorobenzene**	**106-46-7**	**800**	**400**	
23	1,1-Dichloroethane	75-34-3	x		
24	1,2-Dichloroethane	107-06-2	400		
25	**1,1-Dichlorethene**	**75-35-4**	**70**	**35**	
26	cis-1,2-Dichloroethene	156-59-2	x		
27	trans-1,2-Dichloroethene	156-60-5	x		
28	1,2-Dichloropropane	78-87-5	x		
29	cis-1,3-Dichloropropene	10061-01-5	x		
30	trans-1,3-Dichloropropene	10061-02-	x		
31	Dimethylformamide, N, N-	68-12-2		40	
32	**1,4-Dioxane**	**123-91-1**	**3,000**	**1,500**	
33	Epichlorohydrin	106-89-8		1.5	
34	Ethanol	64-17-5	x		
35	Ethyl Acetate	141-78-6	x		
36	**Ethyl Benzene**	**100-41-4**	**2,000**	**1,000**	
37	Ethylene Glycol	107-21-1		200	
38	Ethylene Glycol Monoethyl Ether	110-80-5		35	
39	Ethylene Glycol Monoethyl Ether	111-15-9		150	
40	Ethylene Glycol Monomethyl Ether	109-86-4		30	
41	Ethylene Glycol Monomethyl Ether	110-49-6		45	
42	Formaldehyde	50-00-0		16.5	
43	4-Ethyltoluene	622-96-8	x		
44	Halocarbon 11 (Trichlorofluoromethane	75-69-4	x		
45	Halocarbon 12	75-71-8	x		

46	Halocarbon 113(1,1,2-Trichlorotrifluoro	76-13-1	x		
47	Halocarbon 114 (1,2-Dichlorotetrafluor	76-14-2	x		
48	Heptane	142-82-5	x		
49	Hexachloro-1,3-butadiene	87-68-3	x		
50	**Hexane, N-**	**110-54-3**	**7,000**	**3,500**	
51	2-Hexanone (MBK)	591-78-6	x		
52	**Isophorone**	**78-59-1**	**2,000**	**1,000**	
53	4-Methyl-2-Pentanone (MIBK)	108-10-1	x		
54	**Methylene Chloride**	**75-09-2**	**400**	**200**	
55	Methyl methacrylate	80-62-6	x		
56	**Methyl-tert-Butylether (MTBE)**	**1634-04-4**	**8,000**	**4,000**	
57	**Naphthalene**	**91-20-3**	**9**	**4.5**	
58	Phenol	108-95-2		100	
59	Propylene Glycol Monomethyl Ether	107-98-2		3,500	
60	**2-Propanol**	**67-63-0**	**7,000**	**3,500**	
61	Propylene	115-07-1	3,000		
62	**Styrene**	**100-42-5**	**900**	**450**	
63	1,1,2,2-Tetrachloroethane	79-34-5	x		
64	**Tetrachloroethene**	**127-18-4**	**35**	**17.5**	
65	Tetrahydrofuran	109-99-9	x		
66	**Toluene**	**108-88-3**	**300**	**150**	
67	**1,1,1-Trichloroethane**	**71-55-6**	**1,000**	**500**	
68	1,1,2-Trichloroethane	79-00-5	x		
69	**Trichloroethene**	**79-01-6**	**600**	**300**	
70	1,2,4-Trichlorobenzene	120-82-1	x		
71	1,2,4-Trimethylbenzene	95-63-6	x		
72	1,3,5-Trimethylbenzene	108-67-8	x		
73	**Vinyl Acetate**	**108-05-4**	**200**	**100**	
74	Vinyl Chloride	75-01-4	x		
75	**o-Xylene**	**95-47-6**	**700**	**350**	
76	m-Xylene	108-38-3	"	"	
77	p-Xylene	106-42-3	"	"	

x = on list, no CREL " = all Xylenes combined for CREL

MEMO

March 7, 2014

AGENDA

Indoor Air Quality Testing for LEED

- Introductions
- Background on the three credits to be discussed
- Discussion
  - Cost
    - What is driving the cost? Number of samples? Types of contaminants?
  - Testing methods (see specific questions below)
    - Can we expand the list of test methods?
    - Should we limit the test methods?
    - How do we reconcile field tests with lab test methods, specifically how do we measure the SVOCs listed in Table 1.4 of the CDPH standard method in the field. We have heard that the duration of these tests can be upwards of 40 hours.
    - TVOC test method needed
- Additional questions
- Next steps

BACKGROUND:

The EQ section in LEED v4 was restructured to draw explicit connections between source control and design strategies and actual IAQ performance. The credits begin with ASHRAE 62.1 ventilation rates and end with IAQ testing. USGBC would like to incentivize project teams to think more in terms of actual performance in the building rather than prescriptive design.

The LEED v4 IAQ Assessment credit (previously called Construction IAQ Management Plan: before Occupancy in LEED 2009 was developed before the Indoor Air Quality Procedure Pilot Credit. The scope of the air quality option in the IAQ Assessment credit was expanded from previous versions of LEED to better match IAQP in ASHRAE 62.1 and the new emissions criteria for Low Emitting Materials. It also scored higher in the point weightings process, as a result.

Several project teams have had questions about the types of contaminants required to be tested for, the test methods listed in the credit, and the thresholds for contaminants.

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The table at the end of this document summarizes the air testing requirements for the Indoor Air Quality Assessment credit in LEED v4, Construction IAQ Management Plan: Before Occupancy credit in LEED 2009 and Pilot Credit 68: Indoor Air Quality Procedure.

The main differences for LEED v4 from LEED 2009 are:

- The addition of PM 2.5 and ozone in EPA nonattainment areas
- The target chemicals listed in CDPH Standard Method v1.1, Table 4-1 (based upon OEHHA CRELs)
- Additional test methods for formaldehyde and TVOCs were also added for LEED v4

EQ Pilot credit 68 is similar to LEED v4 but has the following differences:

- Higher max concentration for formaldehyde
- Does not include PM 10 or TVOCs
- Includes ammonia and carbon dioxide
- Max concentrations from target chemicals in CDPH are full CREL limits rather than ½ CREL as in LEED v4.
- Available testing methods for formaldehyde are not the same
  - EQpc68 allows ISO 16000-4 while LEED v4 allows EPA TO-11 and EPA comp. IP-6
  - Both allow ASTM D5197 and ISO 16000-3.
- Available test methods for PM 2.5 are not the same
  - LEEDv4 allows EPA comp. IP-10
  - Both allow ISO 7708
- Available test methods for target chemicals from CDPH are not the same
  - EQpc68 allows ISO 16017-1 and 16017-2
  - LEEDv4 allows EPA TO-1, TO-15, TO-17 and EPA comp. IP-1
  - Both allow 16000-3 and ISO 16000-6
- Available test methods for carbon monoxide are not the same
  - LEEDv4 allows EPA comp. IP-3
  - Both allow ISO 4224

QUESTIONS:

1. **Can we expand list of allowed test methods for LEED v4 and EQpc68?**
   - **a.** Allow projects to use test methods from EQpc68 for LEEDv4 and vice versa.
   - **b.** For formaldehyde, is it acceptable to use EPA TO-15?
   - **c.** For ozone, is a calorimetric test method acceptable?
   - **d.** Any others? Cost is the main limiting factor for this credit.

2. **Testing for the SVOCs listed in CPDH is proving difficult and costly for project teams.**
   - **a.** SVOC's require heat to drive them off. The heavier the compound (C18+) the more heat you need. How do you apply a chamber test to an indoor air sample? If following the method, you would have to heat up the room (100 degrees or more). If you heat up the room you drive off more VOC's which now allows you to fail your TVOC's.

The table below includes the sample volumes and sampling time required to achieve the LEED credit EQpc68 detection limits for epichlorohydrin, ethylene glycol monoethyl ether, ethylene glycol monomethyl ether, and ethylene glycol monomethyl ether acetate. The sampling times required to achieve the LEED credit EQpc68 detection limits for epichlorohydrin, ethylene glycol monoethyl ether, ethylene glycol monomethyl ether, and ethylene glycol monomethyl ether acetate range from 9.3 to 41.7 hours, which is not feasible using commercially available laboratory methods. (*Analytical methods used: NIOSH 1010 for epichlorohydrin, OSHA 53 for ethylene* glycol *monoethyl ether, NIOSH 1403 for ethylene glycol monomethyl ether, and NIOSH 1451 for ethylene glycol monomethyl ether acetate; sampling method: 226-01 & calibrated air sampling pump.*)

Contaminant	LEED credit EQpc68 Concentration Limit (μg/m³)	Analytical Method Limit of Quantitation (μg)	Sample Flow Rate (LPM)	Sample Volume Required (L)	Sampling Time Required (hours)
Epichlorohydrin	3	1.5	0.2	500	41.7
Ethylene glycol monoethyl ether	70	10	0.1	143	23.8
Ethylene glycol monomethyl ether	60	2	0.05	33.3	11.1
Ethylene glycol monomethyl ether acetate	90	10	0.2	111.1	9.3

b. Field sampling could potentially take days to complete rendering the method unusable. Furthermore, the allowable concentrations ranges of the CREL VOCs (1.5 -4,000 μg/m^3) are so large that it creates the need to calibrate well beyond the limits of a realistic calibration curve. A lab would have to develop multiple calibration curves and analyze multiple subsets of samples to meet the demands of the concentration ranges. Low detection limits aside, the amount of a calibration standard necessary to reach some of the higher allowable concentrations of the CREL VOCs would saturate and potentially damage an MS detector.

   The CDPH method appears to be intended for research environments or chamber testing rather than real world building testing. Sampling and calibration considerations aside, separation by gas chromatography is achieved by interactions between the individual chemical species comprising a sample and the chemical coating on the inside of the column. One of the most important interactions being the polarity of each compound in the sample with respect to the polarity of the chemical coating on the inside of the column. In other words, the polarities must be similar to achieve successful separations. Although there are other considerations, chromatography columns are primarily chosen based on the range of polarities encompassing the chemical species of interest. Most VOCs of concern our lab (and many other labs) routinely screens are in the non-polar to mid-polar range, while the CREL table contains some compounds that are considered polar to very polar. The compounds comprising Table 4.1 have such varying polarities that there is no single column that can separate all of them. The glycols are of particular concern. In order to resolve the entire compound list, a lab would essentially need two GCMS set-ups; one GCMS with a standard chromatography column for non to mid-range polarity VOCs and one GCMS with a column for very polar compounds. This would also mean duplicating sample collection and laboratory analyses.

Compound	Allowable Concentration (μg/m^3)	Volume Needed (L)	Time to Volume
Phenol	100	100	1,000 minutes (16.67 hours)
Epichlorohydrin	1.5	6,666.67	33,333.33 minutes (23.15 days)
Ethylene glycol monoethyl ether	35	285.71	1428.57 minutes (23.8 hours)
Ethylene glycol monoethyl ether	30	333.33	1666.67 minutes (27.78 hours)
Ethylene glycol monoethyl ether acetate	45	222.22	1111.11 minutes (18.52 hours)

3. **What methods are allowed for determining the TVOC values?**
   - The LEED v4 credit only specifies test methods for VOCs. There is no definition for TVOC or suggested calculation method for determining TVOC.
   - CDPH Standard Method v1.1 has Section 3.9.4 for TVOC method and defines TVOC as the sum of the concentrations of all identified and unidentified VOCs between and including n-pentane through n-heptadecane (i.e., C5 – C17) as measured by the GC/MS TIC method and expressed as a toluene equivalent value, and it requires the use of thermally desorbed, solid-phase sorption tubes for individual VOCs as well as TVOC (refer to EPA TO-1 and TO-17).

4. **Does LEED v4 require 4 hour sampling times or are the sampling times listed in the referenced test methods or is it up to project?**

Contaminant	Max concentration			Allowed test methods		
	LEED 2009	LEED v4	Pilot credit 68	LEED 2009	LEED v4	Pilot credit 68
Formaldehyde	27 ppb (16.3 ppb for HC)	27 ppb (16.3 ppb for HC)	33 ppb	EPA comp. IP-6, ISO 16000-3	EPA comp. IP-6, ISO 16000-3, ASTM D5197, EPA TO-11	ISO 16000-3, 4 ASTM D5197
Particulates-- PM 10	50 µg/m^3 (20 µg/m^3 for HC)	50 µg/m^3 (20 µg/m^3 for HC)	n/a	EPA comp. IP-10, ISO 7708	EPA comp. IP-10, ISO 7708	n/a
Particulates-- PM 2.5 (for all bldgs in EPA nonattainment areas, or local equiv.)	n/a	15 µg/m^3	15 µg/m^3	n/a	EPA comp. IP-10, ISO 7708	ISO 7708
Ozone (for bldgs in EPA nonattainment)	n/a	0.075 ppm	0.075 ppm	n/a	ASTM D5149-02 ISO 13964	ASTM D5149-02, ISO 13964
Total volatile organic compounds (TVOCs)	500 µg/m^3 (200 µg/m^3 for HC)	500 µg/m^3 (200 µg/m^3 for HC)	n/a	EPA comp. IP-1, ISO 16000-6	EPA comp. IP-1 ISO 16000-6, EPA TO-1, TO-15, TO-17	n/a
Speciated VOCs, except formaldehyde	n/a	Table 4-1 in CDPH	See chart below	n/a	ASTM D5197, EPA TO-1, TO-15,TO-17, EPA comp. IP-1, ISO 16000-3, 6	See chart below
4-Phenylcyclohexene (4-PCH)	6.5 µg/m^3	n/a	n/a	EPA comp. IP-1, ISO 16000-6	n/a	n/a
Carbon monoxide	9 ppm & <=2ppm above out.	9 ppm & <=2ppm above out.	9 ppm & <=2ppm above out.	EPA comp. IP-3, ISO 4224	EPA comp. IP-3, ISO 4224	ISO 4224
Ammonia	n/a	n/a	200 µg/m^3	n/a	n/a	NIOSH Manual of Analytical Methods
Carbon Dioxide	n/a	n/a	700 above outdoor (ppm)	n/a	n/a	EPA compendium infrared

Pilot Credit 68 VOCs

Contaminant Compound (CAS#)	Concentration Limit (µg/m3)	Test Method
Acetaldehyde 75-07-0	140	ISO 16017-1, 2; ISO 16000-3, 6; ASTM D6345-10
Benzene 71-43-2	60	
Carbon disulfide 75-15-0	800	
Carbon tetrachloride 56-23-5	40	
Chlorobenzene 108-90-7	1000	
Chloroform 67-66-3	300	
Dichlorobenzene (1,4-) 106-46-7	800	
Dichloroethylene (1,1) 75-35-4	70	
Dimethylformamide (N,N-) 68-12-2	80	
Dioxane (1,4-) 123-91-1	3000	
Epichlorohydrin 106-89-8	3	
Ethylbenzene 100-41-4	2000	
Ethylene glycol 107-21-1	400	
Ethylene glycol monoethyl ether 110-80-5	70	
Ethylene glycol monoethyl ether acetate 111-15-9	300	
Ethylene glycol monomethyl ether 109-86-4	60	
Ethylene glycol monomethyl ether acetate 110-49-6	90	
Formaldehyde 50-00-0	33	BS-ISO 16000-3, 4; ASTM D5197; BS ISO 16000-4

Hexane (n-) 110-54-3	7000	ISO 16017-1, 2; ISO 16000-3, 6; ASTM D6345-10
Isophorone 78-59-1	2000	
Isopropanol 67-63-00	7000	
Methyl chloroform 71-55-6	1000	
Methylene chloride 75-09-2	400	
Methyl t-butyl ether 1634-04-4	8000	
Naphthalene 91-20-3	9	
Phenol 108-95-2	200	
Propylene glycol monomethyl ether 107-98-2	7000	
Styrene 100-42-5	900	
Tetrachloroethylene 127-18-4	35	
Toluene 108-88-3	300	
Trichloroethylene 79-01-6	600	
Vinyl acetate 108-05-4	200	
Xylenes-total 108-38-3, 95-47-6, and 106-42-3	700	