

# 經濟部標準檢驗局 106 年度 委 辨 計 畫 執 行 總 報 告

案號: 1D161051125-143

標案名稱: 含揮發性有害物質之生活用品風險 模擬研究計畫

執行期間:自簽約日起至106年11月30日止

委辦單位:經濟部標準檢驗局

執行單位:國立臺灣大學

- 地 址:臺北市羅斯福路四段一號
- 電 話:02-33668267
- 傳 真: 02-33668267

中華民國 106 年 11 月

																E	E							く正	与习	こく														
壹	`	目	標	分	析	Ē,	••			•	 •		•		•		•	•••	•		•	•••	•		•••	•	 ••		•	 •••	•	••		• •	•	•••	••			. 2
貳	•	辨	理	依	き		•••		• •	•	 •		•		•		•	•••	•		•	•••	•		•••	• •	 •••		•	 •••	•	••		• •	•	•••	•••			. 4
參	`	執	行	方	式		•••		• •	•			•		•		•	•••	•		•	••	•		•••	•	 ••		•	 •••	•				•	•••			•	29
肆	`	執	行	成	、果	2	••	•••	• •	•	 •	•••	•	•••	•	•••	•	••	•	• •	•	••	•		••	•	 ••	•••	•	 •••	•	••		• •	••	•••	••		•	35
伍	•	經	費	使	用	分	析	•		•	 •	•••	•	•••	•		•	•••	•	•••	•	••	•		•••	•	 •••		•	 •••	• •	•••	•••	•••	•	•••	•••	•••	•	94
陸	•	成	效	評	估	•	•••	•••	• •	•	 •		•	•••	•		•	••	•	••	•	••	•		••	•	 ••	•••	•	 ••	• •	••	• •	• •	••	•••	•••		•	94
柒	•	建	議	事	項	•	•••		•••	•	 •	•••	•		•		•	•••	•	•••	•	••	•		•••	• •	 •••	•••	•	 •••	• •	•••	•••	• •	•	•••	•••		•	95
挒	•	參	考	文	獻	•	•••		•••	•	 •	•••	•		•		•	•••	•	•••	•	••	•		•••	• •	 •••	•••	•	 •••	• •	•••	•••	• •	•	•••	•••		1	09
玖	•	附	錄		•••	•				•			•					•••							•••		 		•	 •••					•				1	13

## 壹、目標分析

1.1 前言

為掌握國際間對於含揮發性有害物質之風險參數資訊,並透過運 用國際認可之模式進行風險模擬,以研析含揮發性有害物質生活用品 風險值,作為標準檢驗局(以下簡稱標準局)未來制定生活用品相關國 家標準參考。因此,本計畫將參考105年所建構的『生活用品之風險 評估架構』,以國際認可之模式進行模擬,包括貝式統計、馬可夫鏈 蒙地卡羅模式等,評估國人生活用品中揮發性有害物質之甲醛,建構 台灣本土暴露情境資料。

本計畫預計從國際資料庫中彙整出生活用品具有揮發性化學物質的毒 理資料文獻,研析模擬暴露程式所需的本土參數,根據產品所含化學物質 類型及消費者可能的暴露途徑,綜合評估產品潛在產生之健康風險,並與 前揭推估之暴露量與風險值進行我國與歐、美、日、中等國家之比較分析。 最後,產出風險評估報告與符合 WTO 技術性貿易障礙協定(Technical Barriers to Trade, TBT)之標準建議值,期協助標準局建構妥適之國家標 準,執行以科學數據為基礎的風險管理與政策建議,減少爭議同時提高標 準的合理性。

1.2 本計畫預計執行下列工作項目:

(1) 貝式統計與馬可夫鏈蒙地卡羅模式等進行模擬,取得國人攝入參數。

(2)研析標準局權責之含揮發性物質生活用品,應用前揭參數推估成人之暴 露量 95%信賴區間。

(3) 進行綜合性風險評估,研析我國含揮發性有害物質生活用品風險值。

(4) 蒐集歐盟、日本、美國、中國大陸四國含揮發性有害物質生活用品之風 險資訊,並與前揭推估之暴露量與風險值進行比較分析。

(5) 提出符合世界性貿易組織技術性貿易障礙協定(WTO/TBT)之修訂含揮發 性有害物質生活用品國家標準,標準值及可行性分析與政策建議。

(6) 至少召開2場專家會議。

同時建構適合日常用品之使用評估模式與參數,本研究團隊將應用既有認證 的推估方式,推估甲醛之暴露情形與暴露量,並參考國內已有之參數或建構適合 本國使用之推估參數,以貝氏統計蒙地卡羅馬可夫鏈方法求得參數降低其不確定 性。研究結果除了呈現風險之外,亦會分析其管制標準是否需加嚴及國外目前的 管制情形,並對此甲醛之危害影響,做詳細的探討與分析,以提供標準局做為參 考方針。

## 貳、辦理依據

由於本計畫名稱之「揮發性有害物質」在國內現行法規中並無相關定義,因 此根據字義可將其詮釋為同時具有揮發性且對人體可造成危害之化學物質,依據 毒理學的觀點,化學物質對人體造成之健康不良效應或毒性與人體暴露化學物質 之劑量有關,故所有的化學物質均可視為具有對人體造成健康危害之特性,而具 揮發性之化學物質中又以有機物廣為應用於商品原料及產品中,因此本計畫名稱 所指之揮發性有害物質會以揮發性有機化合物(Volatile Organic Compound, VOC)作為後續討論與評估的對象。

2.1 國內揮發性有機化合物(Volatile Organic Compounds, VOC)現況

VOC 在人類生活的環境中無所不在,無論是自然生態的生成或是人為的製造 生產都是釋放 VOC 的來源,自然界中最大的 VOC 釋放源來自於植物且以異戊二烯 為主要排放的物質(Lerdau and Keller 1997)。人為的 VOC 釋放源除了由人類日 常生活所需的清潔產品、冷媒、化石燃料、塗料、有機溶劑之外,也會透過工廠 於商品的製造過程中溢散或排放到自然環境中,因此既然無法避免民眾暴露到 VOC,只能透過政府的管理政策來降低民眾暴露 VOC 的機會與劑量。

關於室外空氣品質的部分,我國為了防制空氣污染,維護國民健康、生活環 境,以提高生活品質由行政院環境保護署(簡稱,環保署)於中華民國102年1月 3日環署空字第1020000990號令修正之「揮發性有機物空氣污染管制及排放標 準」中定義 VOC 為「指在一大氣壓下,測量所得初始沸點在攝氏二百五十度以下 有機化合物之空氣污染物總稱。但不包括甲烷、一氧化碳、二氧化碳、二硫化碳、 碳酸、碳酸鹽、碳酸銨、氰化物或硫氰化物等化合物。」,其中又依據不同之業 別、設施、污染物項目或區域規定其排放濃度值或排放削減率以達到 VOC 減量管 制的目地。

室內空氣品質的部分,環保署依室內空氣品質管理法於中華民國 101 年 11

月23日環署空字第1010106229號令發布之「室內空氣品質標準」中,有甲醛與 總揮發性有機化合物2項VOC相關標準值,其中總揮發性有機化合物為:12種 揮發性有機物之總和,其項目分別有苯(Benzene)、四氯化碳(Carbon tetrachloride)、氯仿(三氯甲烷)(Chloroform)、1,2-二氯苯(1,2-Dichlorobenzene)、1,4-二氯苯(1,4-Dichlorobenzene)、二氯甲烷 (Dichloromethane)、乙苯(Ethyl Benzene)、苯乙烯(Styrene)、四氯乙烯 (Tetrachloroethylene)、三氯乙烯(Trichloroethylene)、甲苯(Toluene)及二 甲苯(對、間、鄰)(Xylenes)共計12種化合物。而甲醛與總揮發性有機化合物 之標準值以一小時值定之分別為0.08 ppm 與0.56 ppm,一小時值是指一小時內 各測值之算術平均值或一小時累計採樣之測值。

我國 CNS16000-6:2016 參考世界衛生組織(World Health Organization, WHO)針對室內空氣品質將所有揮發性有機化合物依不同沸點區分為半揮發性有 機化合物(Semi-Volatile Organic Compound, SVOC)、揮發性有機化合物 (Volatile Organic Compound, VOC)和高揮發性有機化合物(Very Volatile Organic Compound, VVOC),其對應之定義如下:

1. SVOC: 沸點介於(240 °C ~ 260 °C)至(380 °C ~ 400 °C)間之有機化合物。

VOC: 沸點介於(50 °C ~ 100 °C)至(240 °C ~ 260 °C)間之有機化合物。

3. VVOC: 沸點介於 < 0 °C 至(50 °C ~ 100 °C)間之有機化合物。

而國際間對於 VOC 也有不同的定義,美國環保署(United States Environmental Protection Agency, US EPA)以化學物質之光化學反應性作為 標準,定義除了被 US EPA 認定為可忽略光化學反應性之有機物外,其他任何能 參與大氣光化學反應之含碳化合物(不包括一氧化碳,二氧化碳,碳酸,金屬碳 化物或碳酸鹽和碳酸銨)為 VOC。

國內室內與室外空氣中 VOC 濃度的分析方法有環境檢驗所(簡稱,環檢所)與 標準局2個公告單位,下表為國內於分析空氣中 VOC 濃度的公告方法,環檢所主

5

要是針對室外空氣和製程設備中之空氣公告之分析方法,而標準局公告的分析方法則是以室內空氣(包含車輛之內部空氣)為分析對象之分析方法。「室內空氣品 質標準」中 VOC 限值的分析方法以環檢所公告之「空氣中揮發性有機化合物檢測 方法-不銹鋼採樣筒/氣相層析質譜儀法」為主,而甲醛則以「空氣中氣態之醛 類化合物檢驗方法-以 DNPH 衍生物之高效能液相層析測定法」分析之(行政院環 境保護署 2017)。

公告單位	公告分析方法	方法编號
環檢所	排放管道中六價鉻檢測方法	NIEA A308.10C
環檢所	空氣中揮發性有機化合物檢測方法-不銹	NIEA A715.15B
	鋼採樣筒/氣相層析質譜儀法	
環檢所	排放管道中氣態有機化合物檢測方法-採	NIEA A722.75B
	樣袋採樣/氣相層析火焰離子化偵測法	
環檢所	廢水處理池逸散揮發性有機化合物採樣方	NIEA A739.70B
	法	
環檢所	空氣中總揮發性有機化合物檢測方法一不	NIEA A732.10C
	銹鋼採樣筒/火焰離子化偵測法	
環檢所	揮發性有機物洩漏測定方法一火焰離子化	NIEA A706.73C
	偵測法	
環檢所	非甲烷有機氣體排放量測定方法(以碳為	NIEA A718.10C
	基準)	
環檢所	空氣中氣態之醛類化合物檢驗方法一以	NIEA A705.12C
	DNPH 衍生物之高效能液相層析測定法	
環檢所	排放管道中甲醛標準檢測方法-4-胺基-	NIEA A724.72B
	3-胼基-5-硫醇基-1,2,4-三唑比色法	
標準局	道路車輛內部空氣-第1部:整車試驗室	CNS 15676-1 Q1008-1
	- 車廂內部揮發性有機化合物測定法	

表 2.1、我國空氣中 VOC 濃度的公告分析方法表

標準局	室內空氣-第3部:甲醛與其他羰基化合	CNS 16000-3 Q1007-3
	物之測定-主動採樣法	
標準局	室內空氣-第4部:甲醛之測定-擴散採	CNS 16000-4 Q1007-4
	樣法	
標準局	室內空氣-第5部:揮發性有機化合物	CNS 16000-5 Q1007-5
	(VOCs)採樣策略	

VOC 是室外重要的空氣污染物之一,VOC 通常分為兩類:甲烷或非甲烷碳氫 化合物(Non-Methane Hydrocarbons, NMHCs)。甲烷為造成全球暖化的溫室氣體; 而非甲烷類 VOC,如:苯、甲苯、乙苯及二甲苯等化學物質。VOCs 同時與臭氧及 光化學煙霧的生成有著密不可分的關係。VOC 對人體具有刺激性和毒性等健康不 良效應,部分揮發性有機化合物會形成可吸入的懸浮微粒,容易引起眼睛不適、 呼吸道疾病和增加哮喘病發機率,揮發性有機化合物的存在也會引起人體免疫失 調,影響中樞神經系統功能,使人體出現頭暈、頭痛、嗜睡、無力、胸悶等症狀, 甚至可能影響消化系統,出現食欲不振、噁心等,嚴重時可能損傷肝臟和造血系 統。因此對於生活環境中 VOC 可能造成的危害必須進一步的研究與探討。

2.2 生活用品中之揮發性有機化合物

室內 VOC 的來源除了部分由室外 VOC 所提供之外,其餘來源則是由日常會接 觸到之生活用品以及室內裝潢材料釋放到室內空氣的環境中。生活用品種類繁多 且其中包含之 VOC 會隨著商品原料、用途而有所不同,因此國際間亦有差異,下 列回顧國際間生活用品中 VOC 的相關規範:

美國環保署制定之國家揮發性有機化合物排放標準(40 CFR Part 59 Subpart C: National Volatile Organic Compound Emission Standards)中規 定了消費用品 VOC 的限量(如下圖),其中包含的消費用品有:空氣清新劑、汽車

擋風玻璃清洗液、浴室和瓷磚清潔劑、化油器清潔劑、除塵清潔劑、引擎除油劑、 織物保護劑、地板拋光劑(臘)、殺蟲劑、洗衣精、去光水、烤箱清潔劑、刮鬍膏 等均屬於消耗用品的規定範圍。此標準以不同使用狀態、用途有不同之限量規定 如:液態、固態、氣膠、爬蟲類殺蟲劑、跳蚤殺蟲劑、飛蟲殺蟲劑。

歐盟在 2013 年提出應用最低人體效應濃度值(Lowest concentrations of interest, EU-LCI)的概念對建築產品於室內排放之健康評估的調和架構,LCI 的 概念由歐洲合作行動(European Collaborative Action, ECA) 中 "室內空氣質 量及其對人類的影響"提出,最初的考量是用於評估地板材料排放的最佳方法。 LCI 值被定義為"根據最佳專業判斷結果,污染物於室內環境中對人體有一定影 響的最低濃度"。歐盟通過科學團隊按安全等級劃分出職業接觸限值,同時還考 慮到更多的毒性資料,LCI 值的概念在德國建材健康評估委員會(AgBB)和法國食 品、環境和職業健康與安全局(ANSES)中被採納且用於發展建築產品中 VOC 排放 的健康相關評估。

Product category	VOC content limit (weight- percent VOC)
Air fresheners:	
Single-phase	70
Double-phase	30
Liquids/pump sprays	18
Solids/gels	3
Automotive windshield washer fluid	35
Bathroom and tile cleaners:	
Aerosols	7
All other forms	5
Carburetor and choke cleaners	75
Cooking sprays—aerosol	18
Dusting aids:	
Aerosols	35
All other forms	7
Engine degreasers	75
Fabric protectants	75
Floor polishes/waxes:	
Products for flexible flooring mate- rials	7
Products for nonresilient flooring	10
Wood floor wax	90
Eurniture maintenance products-aerosol	25
General purpose cleaners	10
Glass cleaners:	
Aerosols	12
All other forms	8
Hairsprays	80
Hair mousses	16
Hair Styling gels	6
Household adhesives:	-
Aerosols	75
Contact	80
Construction and panel	40
General purpose	10
Structural waterproof	15
Insecticides:	
Crawling bug	40
Flea and tick	25
Flving bug	35
Foggers	45
l awn and Garden	20
Laundry prewash:	20
Aerosols/solids	22
All other forms	5
Laundry starch products	5
Nail polish removers	85
Oven cleaners:	
Aerosols/pump	8
Liquids	5
Shaving creams	5

圖 2.1、美國消費產品之 VOC 排放量表(資料來源: 40 CFR Part 59 Subpart C)

歐盟每年 12 月更新 EU-LCI 值,目前最新的版本為 2016 年 12 月更新的版本,歐盟將 EU-LCI 值分成 4 類清單,分別為:已同意物質清單、資料不足物質清單、主要清單和工作中清單。目前主要清單將 VOC 分為 12 大類,有芳香烴、 飽和脂肪烴、萜烯、脂肪醇、芳香醇、二醇類、醛類、酮類、酸類、酯類、氯化 碳氫化合物和其他,共計有111項不同之 VOC 列入已同意之物質清單(詳見附錄 一)。

生活用品中之甲醛為最常見之 VOC,在室溫下甲醛為無色具刺激性味道之液 體,甲醛來源除了抽煙、燃燒行為外,主要來源為使用尿素甲醛樹脂或酚甲醛樹 脂作為黏著劑之木製產品,如粒狀板、中密度纖維板、合板 、樹酯、接著劑、 地毯,同時亦用以製造尿素甲醛泡綿絕緣材料(urea formaldehyde foam insulation)(Hines, 1993),由於木材資源日漸貧乏,需求量大,所以木材之利 用也講求物盡其用,遂發展出許多加工材板,如合板、粒狀板等,而其於生產過 程中會使用尿素甲醛樹脂、酚甲醛樹脂等當膠合劑及塗料;而這些膠合劑在製造 完成後及使用過程中均會釋放甲醛,而導致室內環境中甲醛濃度累積。

建築材料中之甲醛是目前廣泛管制之生活用品,國內建築法規已訂定室內裝 修材質的使用規範,限制揮發性較高或是成分中含有危害性高的揮發性有機化合 物之材質使用、製造與進口。世界許多國家已建立相關建材分級,如:日本 JAS(日 本農業標準)將住宅建材分為F1-F4、澳洲和紐西蘭分為 Super E0-E3、芬蘭建材 逸散等級、歐盟生活用品逸散分級、國內綠建材相關評估制度。

國內內政部建築研究所於 93 年起委託財團法人台灣建築中心辦理綠建材標 章評定作業,執行揮發性有機化合物及甲醛逸散率之評定、健康綠建材標章核發 及建置本土綠建材標章資料庫,而環保署於 94 年公告室內空氣品質建議值,起 初建議室內甲醛容許濃度值為 0.1 ppm,環保署已於 101 年 11 月 23 日發布之室 內空氣品質標準公告,甲醛的室內容許標準為 0.08 ppm(一小時值),研究文獻 指出國際間針對室內空氣品質中甲醛的建議管制值,可了解各國在不同暴露情境 下對於甲醛之管制值,作為與我國對照之參考。

10

country	year issued	v	alue	comments
Australia	1982226	0.1 ppm	$120 \ \mu g \ m^{-3}$	short-duration
	2006227	0.08 ppm	$100 \ \mu g \ m^{-3}$	
Canada	1987220	0.1 ppm	$120 \ \mu g \ m^{-3}$	action level
	1987	0.05 ppm	$60 \ \mu g \ m^{-3}$	target level
	200522	0.1 ppm	$123 \ \mu g \ m^{-3}$	1 h
	2005	0.04 ppm	$50 \ \mu g \ m^{-3}$	8 h
China	2003225	0.08 ppm	$100 \ \mu g \ m^{-3}$	1 h average
Denmark	1990207		$0.15 \text{ mg m}^{-3}$	
Finland	2001209		$30 \ \mu g \ m^{-3}$	S1
			$50 \ \mu g \ m^{-3}$	<u>\$2</u>
			$100 \ \mu g \ m^{-3}$	\$3
France	2008213		50 ug m <sup>-3</sup>	2 h (proposed)
1 milee	2000		$10 \ \mu g \ m^{-3}$	long-term exposure (proposed
Germany	1977216	0.1 ppm	10 118 111	iong term experime (proposed
Singapore	1996224	0.1 ppm	$120 \ \mu g \ m^{-3}$	8 h
Hong Kong	1999	0.025 ppm	$30 \mu g \mathrm{m}^{-3}$	level 1 (8 h)
Hong Hong		0.081 ppm	$100 \ \mu g \ m^{-3}$	level 2 (8 h)
		0.3 ppm	$370 \ \mu g \ m^{-3}$	level 3 (8 h)
	2003221	0.025 ppm	$30 \ \mu g \ m^{-3}$	excellent
		0.081 ppm	$100 \ \mu g \ m^{-3}$	good
Japan	1997223	0.08 ppm	$100 \ \mu g \ m^{-3}$	0.5 h
Korea	2004222	0.1 ppm	$120 \ \mu g \ m^{-3}$	8 h
Norway	1990210	0.05 ppm	$60 \ \mu g \ m^{-3}$	24 h average
	1999211	0.05 ppm	$100 \ \mu g \ m^{-3}$	30 min average
Sweden	2000	0.08 ppm	$100 \ \mu g \ m^{-3}$	adopted from WHO
Poland	1996215	0.04 ppm	$50 \mu g m^{-3}$	category A: 24 h
, online		0.08 ppm	$100 \ \mu g \ m^{-3}$	category B: 8-10 h
U.K.	2004 <sup>208</sup>	FF	$100 \ \mu g \ m^{-3}$	0.5 h
USA (California)	1991217	0.1 ppm	$120 \ \mu g \ m^{-3}$	action level
con (cuntoning)		0.05 ppm	$60 \mu g m^{-3}$	target level (ALARA) <sup>a</sup>
	1999 <sup>203</sup>	0.076 ppm	$94 \ \mu g \ m^{-3}$	1 h (acute REL) <sup>b</sup>
	2004219	0.027 ppm	$33 \mu g m^{-3}$	8 h (interim REL)
	2005218	0.002 ppm	$3 \mu g m^{-3}$	annual average (chronic REL)
WHO	1987228	0.08 ppm	$100 \ \mu g \ m^{-3}$	0.5 h average

#### 表 2.2、國際室內空氣品質甲醛管制值

資料出處:"Formaldehyde in the indoor environment." Chemical Reviews 110, no. 4 (2010): 2536-2572

各種建築與裝潢材料或日用品之甲醛逸散率(µg/m³/日),從窗簾幾乎不逸 散(0-7)、地毯(0-65)、衣服(35-570),到硬木合板(1500-3400)、中密度纖維板 (17,600 到 55,000)等,不同材質逸散率差異甚大(Godish 1991, 吳佩芝與李俊 璋,2000)。

種類	甲醛逸散率 µg/m³/day
中密度纖維板	17,600 - 55,000
硬木合板	1,500 - 34,000
密集板	2,000 - 2,500
尿素甲醛泡麵絕緣材料	1, 200 - 19, 200
軟木合板	240 - 720

表 2.3 、建築與裝潢材料或日用品甲醛逸散率(µg/m³/日)(Godish, 1991)

種類	甲醛逸散率 μg/m³/day
紙製品	260 - 680
玻璃纖維製品	400 - 470
衣服	35 - 570
彈性地板	<240
地毯	0 - 65
窗簾物品	0 - 7

國際間對於室內使用建築材料所釋出之揮發性有機化合物,已制定其標準、 檢測方法與其產品分級,下表為適用板材類別之國內外揮發性有機化合物逸散檢 測標準。

表	2.	4	•	板材	中	揮發	性有	'機イ	七合	物逸	散	檢測	國際標準	Ē
---	----	---	---	----	---	----	----	-----	----	----	---	----	------	---

國家	標準	試驗方法	Class	值	備註
台灣	CNS 1349	玻璃乾燥	F3	1.5 mg/L	
	普通合板	器法	F2	0.5 mg/L	
	CNS 2215		F1	0.3 mg/L	
	粒片板				
	CNS 9909				
	中密度纖				
	維板				
日本	JIS A 5908	JISA 1460	F☆☆	1.5 mg/L	
	JIS A 5905	玻璃乾燥	$F \cancel{C} \cancel{C} \cancel{C} \cancel{C} \cancel{C} \cancel{C} \cancel{C} \cancel{C}$	0.5 mg/L	
		器法	$F \Leftrightarrow \Leftrightarrow \Leftrightarrow \Leftrightarrow \Leftrightarrow$	0.3 mg/L	
美國/加拿	ANSI	ASTM	PB粒片版	0.09 ppm	
大	A208.1-	E1333	MDF 中密度	0.11 ppm	
	2009 • ANSI		纖維板		
	A208. 2-		HWPW 硬質	0.05ppm	
	2009				

			合板		
歐洲	EN13986	EN-171-1	E1	$\leq$ 0.1 ppm	PB, MDF, P
			E2	>0.1 ppm	W
		EN120	E1	$\leq$ 8mg/100g	PB, MDF, P
			E2	$\leq$ 30mg/100g	W
		EN-171-2	E1	≤ 3.5	PW 合板
				$mg/m^2 \cdot h$	
			E2	$\leq$ 8 mg/m <sup>2</sup> ·h	
中國	GB18580-	GB18580	E1	$\leq$ 1.5 mg/L	膠合板標
	2001	(9-11L)	E2	$\leq$ 5 mg/L	准。
					E2須經表
					面裝飾
		GB18580	E1	$\leq$ 1.5 mg/L	膠合板標
		(40L)	E2	$\leq$ 5 mg/L	准。
					E2須經表
					面裝飾
		GB18580	E1	$\leq 9$	粒片版、
		(穿孔萃		mg/100mg	中密度纖
		取)	E2	$\leq 30$	維板標
				mg/100mg	準。E2 須
					經表面修
					飾

2.3 揮發性有機化合物之健康風險評估

風險分析主要可以分為三大主軸:風險評估、風險管理與風險溝通,其中風 險評估則為風險分析的核心,風險評估是建立在科學數據的基礎上,提供風險管 理制定的客觀性參考值。風險與危害是兩種不同概念,有危害並不必然會發生, 而風險則是一種未發生的事前機率預測。因此,在執行風險評估時,為求謹慎, 需考慮使用現有可得之相關科學數據,並考慮現有知識上未能確認的不確定因子 以及變異性,最終能使評估出的結果更能回饋風險管理的需求,並追求評估之精 準度,以不低估風險為原則,進行精準而保守的風險評估。

WHO 針對化學性之健康風險評估分為四大步驟:有害物質鑑定(Hazard identification)、暴露評估(Exposure assessment)、劑量反應關係評估(Dose-response assessment)及風險特性(Risk characteristic)。



圖 2.2、健康風險評估架構

韓國曾對消費用品進行 VOC 之量化健康風險評估的研究(Lim, Shin et al. 2014),研究中消費用品分為玩具、鞋、鞋油、皮革、清潔劑、鉛筆、修正液、標 記筆、膠水、膠帶、空氣清新劑、殺蟲劑、洗滌劑、油氈和壁紙等 30 個不同類 別商品,而 VOC 的分析項目為苯、甲苯、乙苯和二甲苯共 4 項。研究中已分析消 費用品中 4 項 VOC 的濃度作為暴露濃度之參數,並以點估計的方式估算致癌風險 (苯)與非致癌風險(甲苯、乙苯和二甲苯)。結果顯示,苯於修正液中估算之的致 癌風險最高(0 - 3.2×10<sup>-5</sup>),膠水(0 - 7.2×10<sup>-6</sup>)次之。非致癌效應的部分甲苯、 乙苯和二甲苯在標記筆中之 HI 分別為 7.2×10<sup>-2</sup>、37.5、15.5 為各項用品中最高, 其次甲苯於自粘壁紙中的 HI 為 1.0×10<sup>-2</sup>,而鞋油中乙苯和二甲苯的 HI 為 0.23 與0.036 是次高之用品類別。討論中提到由於並非所有消費用品全都分析到 VOC, 因此本研究以最差情境的前提評估個別 VOC 之健康風險,未來需要進一步研究整 體性暴露 VOC 的健康風險評估。

Lefebvre 分析個人護理產品以及化妝品中甲醛的呼吸暴露評估(Lefebvre, Meuling et al. 2012),分析的生活用品包括洗髮乳、沐浴露、身體乳液、面部 保濕、粉底、髮型凝膠、除臭劑和護髮素等,研究中分析使用前與使用後之室內 空氣中甲醛濃度之差異以估算消費者在使用生活產品後之呼吸暴露劑量,研究結 果指出上述生活用品的類別對於消費者暴露室內空氣中甲醛並無明顯的差異,並 認為上述生活用品中甲醛釋放量是可忽略的風險。

國內生活用品健康風險評估的相關研究僅於國立台灣科技大學研究團隊(秦 偉庭 2009)以櫥櫃類家具評估於室內揮發性有機化合物之健康風險評估之研究, 研究中以全尺寸環控艙測試法 ASTM D6670-01)檢測木製櫥櫃類家具之 VOC 濃度 之逸散衰減量測,並由逸散衰減模式推估室內空間中由木製櫥櫃類家具之逸散濃 度與速率,以探討室內櫥櫃類家具產生之危害指數(HI)與致癌風險。研究結果指 出 BTEX 非致癌性之平均危害指數未超過危害標準(HI = 0.0002<1),甲醛之致 癌風險則是皆超過可接受之健康風險 1×10<sup>-6</sup> (Cancer Risk = 9.901×10<sup>-5</sup> ~ 6.536×10<sup>-4</sup>),傳統建材之衣櫃與書櫃中甲醛之致癌風險(Cancer Risk =6.536×10<sup>-4</sup>) 最高。

相同研究團隊之另一項研究(陳智揚 2009)以甲殼素添加劑抑制建材中甲醛 溢散量之量化健康風險研究,針對尿素甲醛接著劑與聚醋酸乙烯酯接著劑兩種接 著劑添加不同比例之甲殼素,並使用小尺寸環境控制箱系統進行不同種類接著劑 逸散甲醛量之實驗,而以逸散甲醛量之分析結果估算之其致癌風險範圍在 4.55×10<sup>-4</sup>~ 8.27×10<sup>-5</sup>之間亦大於可接受之健康風險。

本計畫希望以個別揮發性化學物質為對象進行生活用品中之健康風險評估, 以利標準局未來制(修)定國內相關標準時可參考之健康風險資訊,因此於投標建 議書中已將預評估之化學物質設定為甲醛外,也會對常見之揮發性化學物質如苯、 乙苯、二甲苯等評估健康風險,而進行模擬評估的生活用品以家具為評估對象。 健康風險評估中會因為不同的評估項目或化學物質,而有不同之暴露情境或評估 方法,而本計畫則希望以家具中甲醛為範本建構制定標準時的健康風險評估資訊, 以利未來應用至不同之 VOC 或是不同之生活用品標準制定時的參考資訊。因此甲 醛之有害物質鑑定資訊如入下:

甲醛基本資料 (Inchem, 2009):

中文名稱:甲醛

英文名稱:Formaldehyde, Methanal, Methylene oxide, Oxymethylene, Methylaldehyde, Oxomthane, Formic aldehyde

分子式:HCHO

分子量: 30.03g/mol

CAS. NO : 50-00-0

物質性狀:無色氣體具有刺鼻、窒息之強烈辛辣味、沸點-19.5℃、熔點-92℃、 蒸氣壓 6.3Kpa (at 38℃)、密度 1.067 kg/m<sup>3</sup>、易溶於水、甲醛氣體在常溫下 易溶於水、酒精,及其他極性溶劑中。

毒理資料:

動物實驗數據

以10隻雄性F344大鼠為一組,暴露於0,0.7,2.0,5.9,10.5或14.5ppm
 (0,0.84,2.4,7.1,12.6或17.4mg/m<sup>3</sup>)的甲醛6小時/天,5天/週,共4
 天或11週。結果對老鼠鼻孔的組織病理有影響。

2. 以 32 隻雄性 F344 大鼠為一組,暴露於 0,0.3,2.17 或 14.85ppm (0,0.36,2.6或 17.8mg/m<sup>3</sup>) 之甲醛 6 小時/天,5 天/週,長達 28 個月。結果對 老鼠鼻孔的組織病理有影響。(Inchem, 2009)

3. 以甲醛蒸氣 15ppm 處理雄的查理士河大白鼠(Charles River CD rats) 或雄的 C57BL6/F1 小鼠,發現大白鼠比小白鼠抵抗力強。產生的症狀包括潮氣 容積(Tidal Volume; TV「為在一定活動時,每一次吸氣呼氣的量,其波形如 同潮汐,故稱之。」)變少,呼吸速率降低,二氧化碳產生量及體溫亦降低。 (台灣環保署,2009)

4. 以天竺鼠做實驗時發現其對甲醛敏感界限是 0.5 mg/m<sup>3</sup>。詳細分析發現只 有 B 淋巴球改變, T 淋巴球不受影響。當劑量加至 3 mg/m<sup>3</sup>時,所有的老鼠皆 受影響。其 T 淋巴球數降低,而 B 淋巴球則增加。

5. 懷孕的大白鼠受到 1mg/m<sup>3</sup> 甲醛處理後對其所懷的小鼠無太大的影響。僅有 維他命 C 含量低,體重較重,其 DNA 減少, RNA 增加等現象。

6. 動物吸入甲醛後立刻產生很嚴重的呼吸道及眼睛傷害,形成肺水腫或出血。 在大白鼠的肝臟及腎臟會有充血,血管附近水腫的現象。而這些症狀在皮下注 射甲醛亦會出現。如果動物在受甲醛處理未死亡者,通常在 2-3 天即可康復。
7. 在大白鼠或其他動物身上,低量的甲醛(低於 1 ppm)或中等劑量(10-50 ppm)可造成眼睛及呼吸系統的刺激傷害。高劑量甲醛(超過 100 ppm)會導 致唾液流出、嘔吐、陣痛、呼吸困難及死亡。

體內吸收、分布、代謝與排泄(ADME):

EMEA 無甲醛體內代謝與排泄相關資訊(EMEA, 2007)。根據 ATSDR 甲醛可由吸 入、飲食或皮膚接觸進入體內。甲醛由飲食進入體內時,很快被人體吸收。一 旦被吸收,甲醛即迅速被分解,通常被分解成甲酸鹽類後,經由尿液排出體外。 甲醛也可以分解成二氧化碳,經由呼吸道排出體外。(ATSDR, 2007)

非致癌性健康不良效應

急毒性:食入甲醛會導致人類口腔與腸胃道黏膜產生潰瘍,並且會引起全身性 的過敏反應或是局部性的過敏性皮膚炎。甲醛對於眼睛、皮膚與呼吸道有刺激 性。

免疫系統:流行病學研究指出暴露甲醛會影響免疫系統,主要是產生過敏反應; 研究指出吸入甲醛可能引起氣喘,而以皮膚接觸暴露到甲醛則會產生接觸性 皮膚炎。

基因毒性:根據職業暴露甲醛的工人研究調查,發現甲醛對口腔與鼻腔黏膜細胞產生基因毒性。

致癌性健康不良效應

甲醛可能造成鼻咽癌,因此國際癌症研究中心(IARC)將甲醛分類為致癌物類 別第一級(Group):判斷甲醛對人體及實驗動物有足夠證據的致癌性。(IARC, 2009)

其餘 VOC 之毒理資料如下表所示,分別蒐集 VOC 之致癌分類、人類相關毒理資料 和動物相關毒理資料以供參考。

中文名稱	英文名稱	C A S N O	IARC 致癌 分類	人類相關毒理資料	動物相關毒理資料
苯	Benzene	71-43-2	1(人致物)為類癌)	<ul> <li>急毒性:         <ol> <li>1.吸入暴露苯, 產生的神經系統症狀 包括嗜睡,頭暈,頭暈,頭暈, 有,神誌不清。大量 食入苯可能導致嘔 吐,頭暈,和抽搐</li> <li>2.暴露於液體和 蒸魚會刺激皮膚,眼 睛,和上呼吸道。皮 膚接觸可能造成紅腫 和水泡。</li> <li>3.根據人的血液 學影響,苯在人類血 液的 RfC為 0.03</li> <li>ng/n3,該 RFC 估計是 一個經由人群的連續 的吸入暴露(包括敏 感的群體)測試得 到。</li> </ol> </li> <li>慢性毒性:</li> </ul>	<ul> <li>急毒性:從大鼠,小 鼠,兔子和豬的急性 暴露試驗已經證明苯 有低的吸入急性毒, 從食入暴露產生中度 急毒性,並從皮膚接 觸性毒性:</li> <li>慢性毒性:</li> <li>在動物中,慢性 吸入和口服暴露在人類中 看到的是同樣的效 果。 1.大鼠,豬, 兔子暴露於 80-88 ppm的苯,一天7小 時,連續暴露 30-40 週,發現曲細精管退 化和睾丸重量增加, 大鼠暴露於 1.6或 9.4 ppm的苯四個</li> </ul>

1. 長期吸入苯導 月	1,發現動情週期的
致人的血液紊亂,特 改	<b>、變,但對他們以後</b>
別是影響骨髓,造成 的	的生育或產仔數沒有
再生障礙性貧血(為 景	۶響。(IARC,1972)
急性非淋巴細胞性白	2. 大鼠經過 5~8
血病的危險因子),失 小	、時/天,5天/星
血過多,並損害免疫 期	月,暴露劑量44和
系統(由於血液中抗 4)	7ppm下,出現中等
體水平改變和白血細 程	星度的白細胞減少
胞損失)。 症	E。在暴露劑量 15-
長期接觸苯通常是由 31	lppm 下則無發現異
於吸入蒸氣或皮膚接 狀	···而大鼠暴露50
觸。 長期暴露對中 p	)pm,暴露週期8
樞神經系統和胃腸道 小	、時/天,5天/星期
(頭痛,食慾不振, 下	、在第756小時,
嗜睡,精神緊張,和 發	我大鼠白細胞數量
蒼白),但中毒主要表 湖	<b>认</b> 少,粒細胞活性下
現是再生障礙性貧 降	肾隨中紅細胞前
血。(Hardman, 题	區物數量上升。
1996) (	ACGIH, 5th ed.
2. 義大利製鞋工 C	incinnati,1986)
人暴露於油墨和膠水	
中濃度約 200-500	
ppm 的苯, 白血病發	
生率為1/1,000。	
(Vigliani EC,	
1976)	
3. 針對 147 個工	
作人員(聘用10年)	

				進行血液學調查,暴 露於高苯含量下 (320-470 ppm)。最 常見症狀是血小板減 少(62%),其次是貧 血(35%)和白細胞 減少(32%),全血細 胞減少(21%)。之後 三個月不再暴露,其 中120個工人血液 指標正常,一個工人 死亡。(Savilahti M,1956)	
こ 苯	Ethylbenzene	100-41-4	2B(	<ul> <li>&gt; 急性暴露:</li> <li>1. 呼吸效應,如喉嚨發炎 和胸部收縮,刺激眼睛 和對神經系統的影響, 如頭暈。(USEPA: Hazard Summary- Created in April 1992; Revised in January 2000)</li> <li>&gt; 慢性毒性:         <ol> <li>1.長時間暴露在 乙苯蒸氣下,可能會 導致功能紊亂,增加</li> </ol> </li> </ul>	<ul> <li>急毒性:</li> <li>動物研究已經報導</li> <li>急性吸入乙苯對中樞神經系統(CNS)的毒性和對肺、肝、腎的影響。2.研究報告發現大鼠急性吸入和食入暴露乙苯造成中程度毒性。</li> <li>慢性毒性:大鼠, 兔,豬和猴子暴露濃度400-2200 ppm,7 ~8小時/天,一週5天,連續6個月,結</li> </ul>

		深反射,刺激上呼吸	果發現,豬,兔,猴
		道,血液系統異常	並沒有受到影響,只
		(尤其是白細胞和淋	有大鼠暴露
		巴細胞增多)	400ppm186 天發現肝
		2. 暴露在 200ppm	和腎的平均重量少量
		濃度下會導致眼睛發	增加。
		炎。暴露 100 ppm 連	
		續8小時引起人體的	
		刺激性反應。	
		(Cleland, 1977)	
		3. 一個 20 年的職	
		業暴露研究,並無肝	
		毒性產生(ATSDR:	
		Toxicological	
		Profile for	
		Ethylbenzene ,	
		1999)	

						$\triangleright$	大鼠急性暴露劑量
							1000, 1500, and
							2000 ppm 對二甲苯四
							小時,發現血清中谷
							丙轉氨酶(GPT)、穀
				$\succ$	16 位男性吸入暴露於		草轉氨酶 (GOT)、葡
					70ppm 下四小時,再		萄糖-6 - 磷酸(脫氫
					簡單反應測試還有短		酶(G-6-PDH)、異檸
					暫記憶測試皆無影		檬酸脫氫酶 (ICD)、
					響。(OH 45240-		乳酸脫氫酶(LDH)、
					1634 , 2007)		穀胱甘肽還原酶和
			3(無	$\succ$	三個女性暴露 100ppm		5'-核苷酸酶在血清中
141	4-)		法判		對二甲苯,1至7.5		的濃度隨暴露劑量上
對	xy l er	1	宗为		小時/天連續5天,對		升而增加。反應急性
— Н	ne	06 - 4	<b>大</b> ¬>		腦電圖,誘發電位,		肝細胞損傷。
甲	р-ху	$2^{-3}$	人烈		或認知能力皆無明顯		(Hayes, 1991)
本	lene		致癌		影響,但經常發生頭		公母 Sprague-Dawley
			物)		痛頭暈症狀。相比之		大鼠各20隻灌食暴露
					下,四名男性在相同		0, 100, 200,
					的曝露條件下暴露達		800 mg/kg-day 連續
					150 ppm 的對二甲		90天,在四種劑量
					苯,並沒有增加頭痛		下,公鼠存活率
					或頭暈的情形。(DHHS		20/20, 19/20,
					ATSDR • 2007)		17/20,和16/20,
							母鼠存活率 20/20,
							18/20, 18/20, 和
							17/20,死亡率在高劑
							量組是呈現顯著,體
							重的增加在高劑量組

						並無顯著,但高劑量
						母鼠的食物攝取量則
						有顯著較高,在血液
						學或臨床化學參數,
						眼科檢查,或器官重
						量則無發現顯著影
						響,病理組織學檢查
						也未見異常。
					$\blacktriangleright$	基因毒性:1.沙門式
						菌 Ames 試驗,代謝活
						性(大鼠,肝,S9),
						劑量 3.3-200
						UG/PLATE,結果呈陰
						性。(NCI/NTP TR-
						327 Y86)2.沙門式菌
						Ames 試驗,代謝活性
						(大鼠,肝,S9),劑
						量 1-1000
						UG/PLATE,結果呈陰
						性。(SHIMIZU,
						1985)
				▶ 人體急性吸入暴露於	$\checkmark$	SPRAGUE-DAWLEY 雌大
			2B(	800ppm 連續三小時,		鼠吸入暴露,劑量
菜			對人	發現眼睛和喉嚨發		0; 25; 50; 100;
7	sty	100-	類懷	炎,增加鼻腔黏膜分		200; 300 PPM , —
」、「」	rene	-42-5	疑為	泌,嗜睡,眩暈。測		週四小時,一週五
μ»τ		5	致癌	試結束後,輕微的肌		天,連續52週,發現
			物)	肉無力,伴有慣性和		乳腺惡性腫瘤。但同
				抑鬱。2.10 名年齡		樣的暴露情形在雄大

				20-41 歲工 露苯乙烯 體變異增力	- 人職業暴 , 發現染色 no。	A	<ul> <li>鼠沒有發生。</li> <li>(CONTI,B,1988)</li> <li>致基因突變:結果大</li> <li>多是陰性,但有一沙</li> <li>門氏菌 AMES 試驗,</li> <li>針對 TA1535</li> <li>STRAIN,代謝活性</li> <li>RAT,LIVER,S-9,</li> <li>AROCLOR 1254,結果</li> <li>呈陽性。</li> </ul>
鄰 二 甲 苯	2-XYLENE	95-47-6	3(法定人致物無判為類癌)	<ul> <li>暴露 1000 苯產生嚴重         應,暴露         甲苯產生乙         狀,暴露         甲苯無觀         (Verschu         83)         </li> </ul>	opm 鄰二甲 重毒性反 300ppm 鄰二 不舒服的徵 100ppm 鄰二 客到不適。 eren,19		Sprague-Dawley 大鼠 (每組 12 隻公鼠)六 小時暴露之 LC50 為 4330 ppm (95% 信賴 區間 4247-4432 ppm),根據報告,中 毒反應有肌張力低下 和嗜睡,存活的大鼠 在 14 天後犧牲並無發 現肉眼可見的肺肝腎 病變。(WHO,1997) Sprague-Dawley 大鼠 (每組六隻公鼠)暴 露 0 到 2000 ppm鄰 二甲苯,每天暴露六 小時,連續三天,在 暴露後 18 天內犧牲, 發現有暴露之大鼠腦 下丘兒茶酚胺有顯著

			增加,前腦多巴胺顯
			著減少。(WHO,
			1997)
		$\blacktriangleright$	亞慢性研究:15 隻公
			鼠每天吸入暴露 3500
			ppm8 個小時,連續 1
			或 6 週,發現各組肝
			重量增加。
		$\succ$	慢性研究:大鼠暴露
			鄰二甲苯 1,096 ppm
			連續一年,肝臟的電
			子顯微鏡檢查發現內
			質網的擴散,在線粒
			體只有輕微的影響以
			及發現過氧化物酶數
			量增加。(DHHS
			ATSDR • 2007)
		1	

2.4 揮發性有機化合物之室內空間模擬模式

本計畫所使用的模式係參考美國環保署於 2012 年所建立之甲醛室內空氣模擬模 式-合板家具第二版(FIAM-pwp v2.0)搭配蒙地卡羅模擬統計的混合法(Hybrid)。 其他國家單位發展的室內空氣品質模式還有如美國環保署發展的室內空氣品質 及吸入暴露模式(Indoor Air Quality and Inhalation Exposure, IAQX v.1.1), 以及加拿大全國研究委員會(National Research Council of Canada, NRCC)建 立的室內空氣逸散模式(Indoor Air Quality Emission Simulation Tool, IA-QUEST v.1.1)。後二模式較適合評估空間中有機揮發性物質的短期變化,但其所 使用的經驗模式必須有實際材料的逸散數據擬合得到的係數才能拿來做濃度預 測。FIAM-pwp v2.0 是一個考慮到板材中由於尿素甲醛樹脂所釋放的甲醛會隨著 溫溼度提高影響尿素甲醛水解速率而影響甲醛逸散速率的情形,以及隨著時間在 空間因沉降而衰退的變化情形,因此適合用來評估板材的甲醛濃度變化。然原模 式的限制在於只能模擬單一種空間、換氣率、溫溼度時的濃度變化,無法考慮到 人生活於不同環境的情境不確定性。因此本計畫參考 CNS 31010 風險管理-風險 評鑑技術中在選擇風險評鑑工具時,考慮的統計方法:馬可夫分析、蒙地卡羅分 析與貝式統計進行評估。蒙地卡羅模擬可以評估在廣泛的範圍情況中(情境),不 確定性對系統的效應,以定量量測系統可能的後果範圍,以及在此範圍的數值的 相對頻率。貝式統計法可用於將已知的資訊(先驗者或稱事前分布)與後續的量測 (後驗者或稱事後分布)結合建立整體機率,得以修正蒙地卡羅機率分布設定之不 確定性。此兩模式在風險評估(Risk evaluation)的過程中被認為是極適合 (Strongly applicable)的工具,貝式統計對於風險分析(Risk analysis)中的後 果(Consequence)分析也是極適合的工具。

模式	本計畫模式	FIAM-pwp	IAQX v.1.1	IA-QUEST		
		v2. 0		v. 1. 1		
使用的原理	決定論-質量	決定論-質量	經驗模式	經驗模式-冪		
	平衡模式搭	平衡模式	階至多階衰	次法則、三段		
	配蒙地卡羅	(Determinis	退模型、幂次	模型或高峰		
	模擬統計	tic)	法则等	模 型		
	(Hybrid)		(Empirical)	(Empirical)		
適合的化學	甲醛	甲醛	VOCs, O3, PM	VOCs		
物質						
特色	假設房間完	已經由實驗	需以實驗蒐	已經由實驗		

表 2.4 比較本計畫所使用之模式與其他國家發展之室內空氣模式

27

	美混合、穩定	得到各種材	集各種材料	蒐集各種材
	逸散。可模擬	料的傳遞係	的 VOC 逸散資	料的 VOC 逸散
	物理環境的	數與原始逸	料,獲得模式	資料,獲得模
	變化如何影	散速率。	所需係數。可	式所需係數。
	響濃度。	假設房間完	評估不同時	可評估不同
		美混合、穩定	間時的換氣	時間時的換
		逸散。需要評	率影響濃度	氣率影響濃
		估换氣與逸	的變化	度的變化
		散速率		
溫溼度校正	是	是	否	否
吸附效應	是	是	是	否
(sink)				
時間	長期可(年)	長期可(年)	適合短期	適合短期
			(天)	(天)
區域	單一或雙區	單一或雙區	單一到多區	單一區域

後續健康風險評估步驟之暴露評估、劑量反應關係評估及風險特性化之計算公式、 模擬參數與參考資料等詳細介紹於研究成果的部分呈現。

## **參、執行方式**

3.1 計畫組織及人力

本計畫內擔任之具體工作性質、項目及相關各項目計畫人員職責詳述如下:

- 計畫主持人負責下列工作:(1)計畫之執行與品保計畫成果、(2)工作協調
   聯繫及進度追蹤、(3)計畫執行程序擬定、(4)成果報告整理及簡報;
- 專案計畫助理教授負責下列工作:(1)建構多介質模式參數資料。(2)多 介質模式模擬。(3)報告撰寫;
- 兼任研究助理負責下列工作:(1) 蒐集各國健康風險評估資料、(2) 翻譯
   各國健康風險評估資料、(3)報告撰寫。



圖 3.1 計畫執行人員組織

#### 3.2 人力配置

計畫主持人、檢驗主管及專業技術人員等之配置情形,相關之資歷及 分工如表 3.1 所示:

編號	姓名	職稱	<b>最高</b> 學歷	主要經歷	職級	參與計畫工作項目	投入 月數
1	莊育權	計畫主持	博士	(1)台大職衛所	研究	(1)計畫之執行與品保計	9.5
		人		專案計畫助	員級	畫成果	個月
				理教授		(2) 工作協調聯繫及進度	
				(2)台大職位所		追蹤	
				博士後研究		(3)計畫執行程序擬定	
				員		(4)成果報告整理及簡報	
2	陳鑫昌	專案計畫	博士	(1)基龍米克斯	研究	(1)建構多介質模式參數	9.5
		助理教授		生物科技股	員級	資料	個月
				份公司實驗		(2)多介質模式模擬	
				室主任		(3)報告撰寫	
				(2)台大職衛所			
				博士後研究			
				員			
3	黄紹組	兼任研究	碩士	(1)台大職衛所	研究	(1)蒐集各國健康風險評	9.5
		助理		博士生	助理	估資料	個月
				(2) 台大職衛所	級	(2)翻譯各國健康風險評	
				碩士		估資料	
						(3)報告撰寫	

表 3.1 計畫人力配置表

## 3.3 工作進度

## 計畫工作進度表如表 3.2 所示:

工作内容項月	月次	1	2	3	4	5	6	7	8	9	10
	月份	2	3	4	5	6	7	8	9	10	11
(一)運用國際認了	可之模式										
包括貝式統計與,	馬可夫鏈	5	5	5	5	5	5	5	5		
蒙地卡羅模式等進	<b>赴行模擬</b> ,				-						
取得風險評估之重	夏要參數,					А					
以建構適用我國	生活用品										
之風險評估之攝入	係數										
(二)研析有關標:	準局權責										
之含揮發性物質生	活用品,					2	2	2	2	2	
應考慮及管制之暴	露量,並										
應用前揭參數推住	估各不同							D			
情境下之暴露量											
(三)基於暴露量	與現有之										
毒理資訊進行綜合	合性風險					2	2	2	2	2	
評估,以研析我國	適用之含										
揮發性有害物質。	生活用品							E			
風險值											
(四)蒐集國際(至	少包含歐										
盟、日本、美國、	中國大陸					2	2	2	2	2	
等)含揮發性有害	物質生活										
用品之風險資訊,	並與前揭									Г	
推估之暴露量與	虱險值進										
行比較分析											

表 3.2 計畫工作進度表

工作内灾值日	月次	1	2	3	4	5	6	7	8	9	10
工作内谷项日	月份	2	3	4	5	6	7	8	9	10	11
(五)提出符合世,	界性貿易										
組織技術性貿易[	障礙協定									5	5
之制修訂含揮發	性有害物										╸■■
質生活用品國家	標準之可									G	
行性分析與政策建	き議										
(六)第1次專家會	諸				2.5	2.5					
						В					
(七)繳交期中進度	E報告						5				
							C				
(八)第2次專家會	▶→議									2.5	2.5
											Η
(九)繳交期末成果	长報告										5
											т
石山山市田山一〇	1										1
損定進度系積白分	下比	5	10	15	22.5	36	52	63	74	87.5	100
(%)											
已達成進度累積百	「分比(%)	5	10	15	22.5	36	52	63	74	87.5	100
■■Ⅰ預定進	度			■ 已分	完成進	医度					

# 3.4 進度查核點說明

查

核

點

進度查核如表 3.3 所示:

時 間	工作進度說明	實際完成進度
	● 運用國際認可之模式包	● 已完成家具中甲酉
	括貝式統計與馬可夫鏈	入係數參數。
	蒙地卡羅模式等進行模	
D6年6月	擬,取得風險評估之重	
	要參數,以建構適用我	
	國生活用品之風險評估	

表 3.3 計畫進度查核表

編			
號			
		● 運用國際認可之模式包	● 已完成家具中甲醛之攝
		括貝式統計與馬可夫鏈	入係數參數。
		蒙地卡羅模式等進行模	
A	106年6月	擬,取得風險評估之重	
		要參數,以建構適用我	
		國生活用品之風險評估	
		之攝入係數	
		● 第一場專家會議	● 已於6月29日假台灣大學
В	106年6月		工衛大樓711會議室召開
			第1次專家會議。
C	106 年 7 日	● 完成計畫期中報告	● 已於7月20日繳交期中報
U	100 平 1 万		告初稿
		● 研析有關標準局權責之含	● 已完成各國標準之板材中
		揮發性物質生活用品,應	甲醛釋出量之暴露劑量。
D	106年8月	考慮及管制之暴露量,並	
		應用前揭參數推估各不同	
		情境下之暴露量	
		● 基於暴露量與現有之毒理	● 完成比較我國之家具板材
E	106年8月	資訊進行綜合性風險評	中甲醛之致癌健康風險。
		估,以研析我國適用之含	
E	106年8月	資訊進行綜合性風險評 估,以研析我國適用之含	中甲醛之致癌健康風險。

查 核 點 編 號	時間	工作進度說明	實際完成進度
		揮發性有害物質生活用品 風險值	
F	106 年 10 月	<ul> <li>蒐集國際(至少包含歐 盟、日本、美國、中國 大陸等)含揮發性有害 物質生活用品之風險資 訊,並與前揭推估之暴 露量與風險值進行比較 分析。</li> </ul>	<ul> <li>完成比較歐盟、日本、</li> <li>美國、中國大陸之家具</li> <li>中甲醛之致癌健康風</li> <li>險。</li> </ul>
G	106年10 月	<ul> <li>提出符合世界性貿易組織 技術性貿易障礙協定之制 修訂含揮發性有害物質生 活用品國家標準之可行性 分析與政策建議</li> </ul>	<ul> <li>已根據VOC之健康風險評 估之結果提出含揮發性有 害物質生活用品國家標準 之建議。</li> </ul>
H	106 年 11 月	● 第二場專家會議	<ul> <li>已於11月28日假台灣大學</li> <li>工衛大樓710會議室召開</li> <li>第2次專家會議。</li> </ul>
Ι	106年11 月	● 完成計畫成果末報告	<ul> <li>已於11月29日繳交成果末 報告初稿。</li> </ul>

## 肆、執行成果

4-1 家具中甲醛之健康風險模擬模式

4-1-1 模式建立

4-1-1.1 初始甲醛濃度在單一空間內的穩態模式

模式是由 Matthews(Matthews, Hawthorne et al. 1983)與其同事在 1983 年所提出,能夠模擬單一空間甲醛的穩態濃度。此模式需要假設其空間為均勻混 合、只有單一排放源、且無甲醛損失(沉降或滲透)。

在穩態,甲醛在單一空間的濃度可以下列公式4.1表示:

[甲醛室內濃度] = [甲醛室外濃度] + 甲醛單位面積逸散率 × 表面積/(換氣率 × 體積) 式 4.1

單位:

甲醛室內濃度: mg/m<sup>3</sup>

甲醛室外濃度: mg/m<sup>3</sup>

甲醛單位面積逸散率: mg/m<sup>2</sup>·h

表面積:m<sup>2</sup>

換氣率:h-1

體積:m<sup>3</sup>

4-1-1.2 溫度與濕度校正模式(USEPA 2012)

前模型可以估計的是在原始標準測量條件(溫度23或25°C;濕度45或50%)時的穩態原始濃度,經過溫溼度校正模式之後可以校正至輸入的環境溫度與濕度時的穩態濃度。

温度的校正模式如公式 2.2:

[校正後濃度] = [原始濃度] 
$$e^{\left[R\left(\frac{1}{R^{halle}}-\frac{1}{R^{halle}}\right)\right]}$$
式 4.2
R: 溫度調整係數

單位:

溫度: K

濕度的校正模式如公式 4.3

[校正後濃度] = 
$$\frac{[溫度校正後的濃度]}{1 + A(原始濕度 - 環境濕度)}$$
式 4.3

A: 濕度調整係數

單位:

濕度: %

將以上兩公式結合可用下列式 4.4 表示原始濃度與調整後濃度的關係:

溫溼度結合校正因子 = 
$$\frac{e^{[R\left(\frac{1}{\frac{\pi}{\beta \# \mathbb{Z}} e^{-\frac{1}{\frac{\pi}{\beta} \# \mathbb{Z}} e^{-\frac{1}{\frac{\pi}{\beta}}}\right)]}}}{1 + A(\beta \# \mathbb{Z} e^{-\frac{\pi}{3}} + \frac{\pi}{3} + \frac{\pi}{3})}$$
式 4.5

對於溫度及濕度校正係數的設定會在下章說明

4-1-1.3 室內濃度的衰減

假設隨著時間,由上述模型計算的初始室內甲醛濃度會隨著各種來源和滲入、 甲醛的逐漸耗盡而降低。 假設初始值隨時間的減少遵循一次指數衰退,表示如 下列式 4.6:

甲醛於時間 t 的濃度只考慮從板材釋放的濃度,不考慮背景濃度值。

k: 一次衰退模式的速率常數(years<sup>-1</sup>)

t: 時間(years)

常數 k 的設定是由室內甲醛濃度半衰期做計算。若半衰期設定為 1.5 年,則 常數 k 為 0.462。對於半衰期的設定會在下章說明

4-1-2 暴露評估與風險特性化

4-1-2.1 計算 50 年累積濃度值

可藉由將式 4.6 積分求得一累積 50 年的甲醛濃度值如以下式 4.7:

$$[50 年累積甲醛濃度] = \frac{(1 - e^{-50k}) \times [甲醛溫溼度校正濃度]}{k}$$
式 4.7

單位: mg/m<sup>3</sup>·50 years

4-1-2.2 終身每人每日暴露量(LADD)

終身每人每日甲醛暴露量(LADD)可以下列公式 4.8 計算:

$$LADD = \frac{\left[ \text{PER} \overset{\circ}{\text{E}} \right] \times \text{PER} \times \text{Respine to the second se$$

單位:

LADD: mg/kg/day

甲醛濃度: mg/m<sup>3</sup>

呼吸率: m³/year

暴露時間:year

體重:kg

壽命: days

[甲醛 50 年累積濃度] = [甲醛濃度] × 暴露時間(50 年),帶入公式 4.8 後可得式 4.9

$$LADD = \frac{\left[ P \overrightarrow{W} 50 \notin R \overrightarrow{R} \overrightarrow{R} \overrightarrow{R} \overrightarrow{R} \right] \times \mathscr{P} \mathscr{P} \mathscr{P} \mathscr{P} \mathscr{P} \mathscr{P}}{\underline{m}} \underbrace{1}{\underline{m}} \underbrace{1}{\underline{m}$$

關於呼吸率、體重及壽命的設定在下章說明

4-1-2.3 計算致癌風險

甲醛之致癌斜率因子=0.021 (mg/kg/day)<sup>-1</sup>

另一個方法計算致癌風險是用加拿大健康局所設定的甲醛單位致癌風險,乘 以甲醛的調整濃度(EC)來計算致癌風險,單位致癌風險的是將體重及呼吸率直接 與致癌斜率因子一起考慮,可得到一般人暴露於每濃度單位致癌物質會導致癌症 的機率。

加拿大健康局建議的單位致癌風險:

單位致癌風險 = 致癌斜率因子 × 呼吸率/(體重 × 1000) 式 4.12 呼吸率: 20 m<sup>3</sup>/day 體重:60 kg 甲醛單位致癌風險= 6 × 10<sup>-6</sup> (μg/m<sup>3</sup>)<sup>-1</sup>

EC = [甲醛濃度] × 暴露時間 × 暴露頻率 × 暴露期間/壽命 式 4.13

單位:

暴露時間:h/day

暴露頻率:day/year

暴露期間:years

關於致癌斜率因子的設定會在下章說明

4-1-2.4 不確定分析-蒙地卡羅模擬

在風險評估過程中,最大的弱點在已知數據不足及有許多未知數存在,而此 等未知數均需進行各種假設,故在推測模式中各種假設是否合理(合於現有知識 及推理),乃是風險度評估正確與否最重要一環。由於在風險評估過程中所使用 之各種參數或模擬模式大多存在不確定性。而不確定性之來源如數據本身的變異、 模擬模式或暴露參數的不確定性,因而影響風險估計的不確定性和變異性。風險 的不確定性及變異性可以用數值分析的方法蒙地卡羅模擬法(Monte Carlo simulation)。使用蒙地卡羅模擬法進行不確定性分析,可以經由累積分布函數 描述機率性風險的分布,以呈現毒性物質可能產生風險的平均數、中位數(如第 50 百分位)及上限值(第 95 百分位)。以下針對蒙地卡羅模擬(Monte Carlo Simulation)進行介紹:

模擬係為針對某一假設環境條件與過程,將各種情境予以複製呈現之方法, 在已知的流程架構下,藉由參數之變更即可模擬系統之反應與變化程度。蒙地卡 羅模擬多應用於產生已知或假定機率分布之隨機亂數,並將此一符合特定機率分 布的亂數帶入模式中予以運算,以求得因參數變化而反應出的變異性,所造成輸 出結果之變化情形。

在不同暴露介質之下的暴露劑量推估與健康風險評估模式中,使用了大量的 參數資料,然而在模式中所使用的參數值,大都是各項研究結果的平均值或單一 測量值,但對於整個族群而言,這些參數存在有一定的變異特徵與機率分布情形, 若是將這些參數的變異性予以忽略,則無法真正瞭解推估結果的不確定性為何。 蒙地卡羅模擬法可解決具有特定機率分布的隨機變數問題,以求得一客觀之模擬 結果。

蒙地卡羅模擬法能處理非線性及非常態分配的參數組合,特別是一些難以進 行估算的非線性預測,只要假設合理,並依據蒙地卡羅理論,便能將參數的分布 情形精確呈現出來。另外也可處理不對稱等非常態分配和極端狀況等特殊情形。

4-1-2.5 敏感度分析

敏感度分析會顯示每個假設參數對特定預測數值的影響。預測對假設的整體 敏感度是由兩個因素組合而成:

1. 預測對假設的模型敏感度

2. 假設的不確定性

敏感度分析提供下列主要優點:

可以得知哪些假設對預測的影響最大,以縮短調整估計所需要的時間。
 可以得知哪些假設對預測的影響最小,因此可將其略過或捨棄。

40

4-1-3 產品攝取係數(PiF)

產品攝取係數的概念是由 Jolliet et al. (Jolliet, Ernstoff et al. 2015)所提出,意義是呈現出一個化學物在產品中最後能被人類暴露到的比例, 這個方法能夠一致性的比較使用這些產品時在不同化學與產品的結合、暴露時間、 暴露途徑以及其他產品生命循環的暴露。係數能夠在生命週期與影響評估的狀態 之間提供清楚的介面,計算出使用產品的整體暴露劑量,並且能夠回推在產品中 最大可接受的化學物質濃度。產品攝取係數的公式如下:

對於含甲醛產品的 PiF 參數設定會於下章說明

4-2、家具甲醛風險評估參數設定

## 4-2-1 標準方法下的單位表面逸散速率

以逸散試驗箱法(Chamber)標準方法(如 ASTM-E1333、ASTM D 6007-02、EN 717-1) 檢驗板材時能得到特定溫溼度、換氣率下穩態(steady state)的甲醛濃度,我們將以此濃度以下列公式換算穩態的甲醛單位表面逸散速率。

$$[ \Psi \vec{E} \vec{E} \vec{E} ] = \frac{ \vec{\mu} \vec{L} \cdot \vec{L$$

註: 可將表面積與腔體體積以產品負載因子(product loading ratio)代替,單 位為 $m^2/m^3$ 

單位:

- 甲醛濃度: mg/m<sup>3</sup>
- 單位表面逸散速率: mg/m<sup>2</sup>·hr

表面積: m<sup>2</sup>

通氣率:h-1

腔體體積: m<sup>3</sup>

4-2-2 標準的轉換:

4-2-2.1 台灣/日本轉換至美國標準: 以台灣 CNS 標準中(CNS 1349 普通合板、 CNS 2215 粒片板、CNS 9909 中密度纖維板)對於甲醛的標準為F3(1.5 mg/L)、F2(0.5 mg/L)以及F1(0.3 mg/L)。 分別估計若有板材剛好在這些標準時,在美國 ASTM-E1333 的標準 方法下可測得的甲醛濃度為何。 轉換公式:

粒片板

× [CNS 標準方法之標準濃度(mg/L)]

中密度纖維板

[ASTM E1333 標準方法濃度(ppm)]

= -0.039 + 0.161 式 4.17

× [CNS 標準方法之標準濃度(mg/L)]

1 ppm= 1.23 mg/m<sup>3</sup>

依據文獻: Que et al. (2013) (Que, Wang et al. 2013)等人使用 六家不同廠商的粒片板及三家不同廠商的中密度纖維板分別以日本 玻璃乾燥器標準方法(JIS A 1460-2001)以及美國大型逸散試驗箱方 法(ASTME1333-10)量測甲醛濃度。由於台灣 CNS 標準方法係參考日本 之標準方法,在粒片板的轉換公式是採用其於大型逸散試驗箱腔室方 法條件(換氣率=0.5、負載率=0.43)的相關線性曲線,其相關係數 R<sup>2</sup>為 0.946。而中密度纖維板的轉換公式是採用其於大型逸散試驗箱方法 (換氣率=0.5、負載率= 0.13)的相關線性曲線,其相關係數 R<sup>2</sup>為 0.995。

材料/等級	F3	F2	F1
粒片板	0.7103	0.1310	0. 0151
中密度纖維板	0.2491	0.0510	0.0114

轉換後甲醛濃度 (mg/m<sup>3</sup>):

材料/等級	F3	F2	F1
粒片板	0.834	0.154	0.018
中密度纖維板	0.950	0.195	0.044

帶入公式 4.15 後得到的穩態甲醛單位面積逸散率(mg/m<sup>2</sup>·hr)為:

4-2-2.2 歐洲標準: 歐規的標準為以 EN 171-1 逸散試驗箱標準方法設 定 E1 等級( $\leq 0.1$  ppm (0.124 mg/m<sup>3</sup>))及 E2 等級(> 0.1 ppm),不須 另外轉換成逸散試驗箱的條件。但若以 EN 171-2 氣體分析法訂定 E1 等級(3.5 mg/m<sup>2</sup>·hr)及 E2 等級(8 mg/m<sup>2</sup>·hr),則以目前文獻上的轉 換數據,必須先將 EN 171-2 標準方法的數據轉換成 EN 120 穿孔萃取 (Perafator)法的濃度,再轉換成 EN 171-1 的濃度。而 EN 120 穿孔萃 取法的濃度訂定為 E1 等級( $\leq 8$  mg/100g),則需轉至 EN 171-1 的濃 度。

轉換公式:

EN 171-2 轉換 EN 120

粒片板:

[EN 171-2 標準方法濃度]

= -0.23 + 0.15 × [EN 120 標準方法濃度(mg/100g)] 式 4.18

中密度纖維板:

[EN 171-2 標準方法濃度]

= -0.96 + 0.38 × [EN 120 標準方法濃度(mg/100g)] 式 4.19

EN 120 轉換 EN 171-1

= 0.005 + 0.012 × [EN 120 標準方法濃度(mg/100g)] 式 4.20

依據文獻: Salem et al. (2013) (Salem, Zeidler et al. 2013)等 人以歐洲雲杉製備的粒片板與中密度纖維板,分別以標準方法 EN 171-1、EN 171-2、EN 120 進行量測。EN 171-1 方法有 3 個測試、EN 171-2 及 EN 120 有 36 個測試。在粒片板的相關性上,其線性曲線的相關係 數 R<sup>2</sup>為 0.93,而在中密度纖維板上其線性曲線的相關係數 R<sup>2</sup>為 0.77。 至於 EN120 與 EN171-1 間的方法轉換則是參考 Risholm-Sundman et al. (2007) (Risholm-sundman, Larsen et al. 2007)等人以粒片板與中 密度纖維板比較 EN 120、EN 171-1、與日本 JIS A1460 進行量測,合 併 JISA 1460 方法分別與 EN 120 及 EN 171 的線性曲線所得到的關係 曲線(Salem, Böhm et al. 2011)。

轉換至 EN 171-1 逸散試驗箱法後甲醛濃度 (mg/m<sup>3</sup>):

材料/標準	EN 171-1;	EN 120;	EN 171-2;	EN 171-2;
與等級	E1/E2	E1/E2	E1	E2
粒片板	0.124	0.101	0.303	0.663
中密度纖維板	0.124	0.101	0.146	0.29

帶入公式 4.15 後得到的穩態甲醛單位面積逸散率(mg/m<sup>2</sup>·hr)為:

材料/標準	EN171-1;	EN120;	EN171-2;	EN171-2;
與等級	E1/E2	E1/E2	E1	E2
粒片板	0.124	0.101	0.303	0.663
中密度纖維板	0.124	0.101	0.146	0.29

註:由於 EN171-1 標準方法的通氣率與負載率都是1,因此濃度與逸散率值相同

4-2-2.3 中國標準:包含 GB18580 (9-11L)以及 GB18580(40L),此兩者 採用玻璃乾燥器法,主要測試對象為膠合板,以此標準方法設定 E1 等 級( $\leq 1.5 \text{ mg/L}$ )及 E2 等級( $\leq 5 \text{ mg/L}$ )。另外有 GB18580 穿孔萃取 (Perafator),主要測試對象為粒片板及中密度纖維板等,以此標準設 定 E1( $\leq 9 \text{ mg}/100$ g)及 E2 ( $\leq 30 \text{ mg}/100$ g)。E1 標準可直接使用於室 內、而 E2 必須先以表面處理後才能使用於室內。轉換上必須將兩標準 方法轉換至 GB18580 逸散試驗箱法所得到的濃度。

轉換公式:

GB18580 玻璃乾燥器法 9-11L 轉換至 GB18580 逸散試驗箱法:

[逸散試驗箱法濃度] = -0.011 + 0.149 × [玻璃乾燥器法(9-11L)濃度] 式 4.21

GB18580 玻璃乾燥器法 40L 轉換至 GB18580 逸散試驗箱法:

[逸散試驗箱法濃度] = 0.025e<sup>0.282×[玻璃乾燥器法濃度(40L)]</sup>式 4.22

GB18580 穿孔萃取法轉換至 GB18580 逸散試驗箱法:

[逸散試驗箱法濃度] = 0.059 + 0.021 × [穿孔萃取法濃度] 式 4.23

依據文獻: Song et al. (2015) (Song, Cao et al. 2015) 等人以 五種不同材料(中密度纖維板、粒片板、擋板、實木複合板及強化地板) 分別以四種國家方法測試(9-11L、40L 玻璃乾燥器、穿孔萃取、逸散試 驗箱法)。得到的關係轉換公式(逸散試驗箱法 vs 9-11L、40L、穿孔萃 取)相關係數 R<sup>2</sup>分別為 0.909、0.949 及 0.84。

轉換至 GB18580 逸散試驗箱法後甲醛濃度 (mg/m³):

材料/標準	GB18580-	GB18580-	GB18580-	GB18580-
與等級	9–11L;E1	9-11L;E2	40L;E1	40L;E2
膠合板	0.2125	0.734	0.038	0.102
材料/標準	GB18580	GB18580		
與等級	穿孔法;El	穿孔法;E2		
粒片板與				
中密度纖維	0.248	0.689		
板				

帶入公式 4.15 後得到的穩態甲醛單位面積逸散率(mg/m<sup>2</sup>·hr)為:

材料/標準	GB18580-	GB18580-	GB18580-	GB18580-
與等級	9–11L;E1	9-11L;E2	40L;E1	40L;E2
膠合板	0.2125	0.734	0.038	0.102
材料/標準	GB18580	GB18580		
與等級	穿孔法;El	穿孔法;E2		
粒片板與				
中密度纖維	0.248	0.689		
板				

註:由於 GB18580 逸散試驗箱標準方法的通氣率與負載率都是 1,因此濃度與逸 散率值相同。

4-2-2.4 美國標準: 美國以 ASTM-E1333 為標準, 訂定粒片板、
中密度纖維板、及硬質合板(HWPW)的排放標準為 0.09、0.11、
0.05 ppm (0.11、0.135、0.06 mg/m<sup>3</sup>)。

帶入公式 4.15 後得到的穩態甲醛單位面積逸散率(mg/m<sup>2</sup>·hr)為:

材料/標準與等級	粒片板	中密度纖維板	硬質合板	

200 - 200 - 0.002	逸散率	0.129	0.260	0.032
-------------------	-----	-------	-------	-------

4-2-2 通氣率

通氣率:定義為每小時外氣量置換相當於該空間容積量的次數。Wu et al. (2003) (Wu, Li et al. 2003)於台灣的五棟辦公大樓進行甲醛室內濃度的監測,當中有 監測通氣率的數據,範圍在 0.35~3.32 h<sup>-1</sup>,平均值及標準差分別為 1.77 及 1.07。 李昭興(李昭興 2002)量測於已裝修一年的辦公空間,監測六棟辦公大樓及十六 個空間,針對開空調與非開空調的兩個時段情形下,發現上班時間開空調時的平 均通氣率為 1.43,非開空調時間為 0.2。全通氣率範圍為 0.06~1.85 h<sup>-1</sup>。另一 般情形下,各居室型態每小時的平均換氣次數如下表所示。最後選定 Wu et al. (2003)的研究數據做設定,可模擬的範圍包含大部分的居室型態。

居室形態	换氣次數(次/	備註
居室不開門或窗	0.5	當開口部加裝窗簾或遮
居室一面開門或窗	1	陽板時,
居室二面開門或窗	1.5	取表中數值之2/3。
居室三面開門或窗	2	若空氣由開口部之半面
入口門廳	2	流入,由
		另半面流出,則取表中數
		值之
		1/2 •
	1	1

表 4.1、標準狀態下住宅居室換氣次數(翁麗敏 2002)

註:標準狀態換氣次數適用於無強制換氣裝置之標準狀態下之住宅居室

機率分布設定:對數常態分布

平均值與標準差: 1.77±1.07



圖 4.1、換氣率之機率分布設定圖

4-2-3 空間體積

由於目前模式為一個單一空間的模式,因此適合考慮一個人生活於一個雅房內的 情況。另一方面,台灣目前缺乏整體國人居住室內坪數的統計,因此以保守的情 形來考慮,即生活於空間較小的雅房是比較洽當的。至台灣租屋網站上查詢雅房 的空間大小,大都落在4至10坪左右。樓高度則設定為2.4~3米。因此空間體 積落在31.7至99 立方公尺之間,並以此範圍的界線分別設在機率分布的第5% 及95%百分位,可模擬到較為極限的情形。



圖 4.2、空間體積之機率分布設定圖

家具表面積:家具表面積為本模式之可變參數,將模擬表面積為1、5、10、20、 30、40平方公尺逸散表面積家具的情形。

4-2-4 溫溼度校正

4-2-4.1標準方法的溫度與濕度

標準方法	溫度(T <sub>B</sub> )(℃)	濕度(HB)(%)
ASTM E1333	25	50
EN-717-1	23	45
GB18580	23	45

4-2-4.2 台灣室內空間的溫度與濕度

文獻回顧:林彥旭(林彥旭 2013)以占國人室內居處比例最高(73%)的 建築類別-住宅,在全臺11個縣市包含臺南、嘉義、臺中、新竹、臺北、 基隆、宜蘭、花蓮、臺東、恆春及高雄共30個室內空間中設置長期連續 性之溫溼度監測系統,記錄每小時溫度變化,收集時間自2012年九月至 2013年七月。結果顯示室內外的小時平均溫度分別為25.2±3.7℃(範 圍14.0-35.0℃)、小時平均濕度為70.9±9.4%(範圍31-97%)。 温度機率分布設定: 對數常態分布

平均值與標準差: 298.2±3.7



圖 4.3、室內溫度之機率分布設定圖(單位:K)

## 溼度機率分布設定:常態分布

平均值與標準差: 70.9±9.4



圖 4.4、室內溼度之機率分布設定圖

4-2-4.3 温度濕度校正係數

文獻回顧: 建議使用的係數有兩組,一為 Berge et al. (Berge, Mellegaard et al. 1980)為兩種挪威粒片版的計算,係數用來設定 1984 年的標準(ASTM, ANSI and Composite Panel Association (CPA)),試 驗溫度在 22 及 28 ℃、濕度 30 及 60%的情形,校正係數分別為溫度 9799 及濕度係數 0.0175。另一組係數為 Myers (Myers 1985)所建議,其收集 來自 11 個不同實驗室、40 種不同材料(粒片版、硬質合板)的數據,其 可以模擬的區間為 20 至 40 ℃,濕度 20 至 90%之間。校正係數分別為溫 度 8930 及濕度係數 0.0195。由於此係數可以模擬的範圍較廣,本計畫 採用 Myers 提供的係數。

溫度校正係數: 8930

溼度校正係數: 0.0195

4-2-5 衰退模式之半衰期

Versa (Versar 1988)於 1998 年對美國環保署的報告中,以 396 個房屋的橫斷面 數據進行了仔細的分析,估計甲醛的室內空間半衰期為 2.92 年。這個估計被認 為是一個房子的真實半衰期的上限,從建築的占用歷史發現一開始就有一些重要 的甲醛來源。而如果是針對個別產品來源的估計,可以預測的是與大部分住宅的 情形比較起來半衰期就相對短,如同 1988 年 Versar 報告中所概述的,研究估計 半衰期從 0.2 到 2.58 年不等。Matthews et al. (1985)等人使用各種組合的板材 (粒片板、中密度纖維板、硬質合板)於換氣率 0.4、溫度 23℃、濕度 50%的逸散 試驗箱法進行實驗,觀察到的半衰期為 1.52 年。若將條件換成以非常大的換氣 率讓濃度持續低於 0.1ppm,則根據不同板材其半衰期會降到 0.62 至 1.08 年之 間。綜合以上研究會發現大部分的研究對甲醛在空間或家具的半衰期約在 1.5 至 3年之間。因此本計畫會將半衰期機率分布的第5%及95%百分位,這樣做也可模擬較為極限的情形。

半衰期 1.5 年的速率常數 k: 0.231 years<sup>-1</sup>

半衰期3年的速率常數k: 0.462 years<sup>-1</sup>

速率常數分布設定:對數常態分布

第5及95百分位:0.231及0.462



圖 4.5、甲醛半衰期之機率分布設定圖

4-2-6 人體暴露參數

4-2-6.1 暴露時間假設:

一家具根據使用狀況少則壽命3至5年,多則可至數十年。以保守的估計方式,家具的壽命與一般房屋的使用壽命相同,亦即50年。目前本計畫假設家具的壽命與一人生活與單一室內的時間相同,亦即一人在同一室內空間內待50年。這是較於嚴格的估計。另外根據國立台灣大學公共衛生學院健康風險及政策評估中心2008年的台灣一般民眾暴露參數彙編中(國立台灣大學公共衛生學院2008),高高屏地區室內

外活動時間分配顯示一人每日待在住家室內的時間平日為13.4小時、 假日為14.1小時;每日待在工作地室內的時間平日為5.8小時、假日 為4.7小時;其他場所室內則各為0.5及0.4小時;在路上的時間為 1.2及1.0小時。因此可得知一人大部分的時間都在住家中的室內空間 中,在本計畫中也考慮以一人每日平均待在住家室內的時間13.6小時 計算致癌風險。

## 暴露時間設定:50年

4-2-6.2 呼吸率:

根據國立台灣大學公共衛生學院健康風險及政策評估中心 2008 年 的台灣一般民眾暴露參數彙編各性別年齡層每人每日平均呼吸通氣量, 考慮男女活動中與靜止狀態的呼吸量與實際活動中與靜止狀態呼吸量 的時間分配,計算一般成年人(男女)20 至 64 歲的平均呼吸量為 17.3±2 m<sup>3</sup>/day。每年的平均呼吸量為 6314.5±730.0 m<sup>3</sup>/year。

呼吸量分布設定:常態分布

平均值與標準差:6314.5±730.0



圖 4.6、呼吸率之機率分布設定圖

4-2-6.3 體重:

根據國立台灣大學公共衛生學院健康風險及政策評估中心 2008 年 的台灣一般民眾暴露參數彙編,計算一般成年人(男女)19 至 64 歲的體 重平均及標準差為 61.65±41.99 kg,第 5%及 95%百分位的體重分別為 45 及 85 公斤。

體重分布設定:常態分佈

第5及95百分位:45及85公斤



圖 4.7、體重之機率分布設定圖

4-2-.4 壽命:

人壽命的統計參考內政部 104 年簡易生命表(內政部 2015),國人 平均壽命為 80.2歲。標準差異的數據由於簡易生命表並未提供,則以假 設變異係數 10%為準,亦即標準差為 8.02。

壽命機率分布設定:常態分布

平均值與標準差:29273±2927.3天(假設一年365天)



圖 4.8、壽命之機率分布設定圖

4-2-7 室內外甲醛背景濃度

文獻回顧:室內部分,Lin and Yao (Lefebvre, Meuling et al. 2012)監測了 177 間住宅屋齡(0~>21 年)的甲醛濃度,監測到的濃度範圍為 1~129 ppb。Guo et al. (Guo, Kwok et al. 2009)則藉由跨國研究得以監測台灣 100 個住宅的 甲醛與 VOC 濃度值,在甲醛的部分發現濃度平均值及標準差為 87.1± 8.5  $\mu$ g/m<sup>3</sup>。 由於後者文獻的數據為近年的資料,且有平均值與標準差數據,因此較為適合。 室外部分,Wang et al. (2010) (Wang, Huang et al. 2010)監測了高雄市大氣 中羰基化合物的濃度,在楠梓與小港區於 5、8、10、12 月各三天分別測量到甲 醛的濃度平均值為 18.3 及 18.7  $\mu$ g/m<sup>3</sup>。在本計畫模式中則假設甲醛的室外平均 背景濃度為 18.5  $\mu$ g/m<sup>3</sup>。

室內甲醛背景濃度機率分布設定:對數常態分佈

平均值與標準差: 0.0871± 0.0085 mg/m<sup>3</sup>



圖 4.9、甲醛室內背景濃度之機率分布設定圖

4-2-8 甲醛致癌斜率

甲醛對人類的危害主要在致癌性、基因毒性與免疫系統上。致癌性的部分,依據 美國環保署癌症研究中心(IARC)的分析(IARC 2012),甲醛在人類有足夠證據證 明會造成鼻咽癌及白血病(人類證據充分)以及鼻竇癌(人類證據有限) (Kawanishi, Matsuda et al. 2014)。在基因毒性方面,甲醛被證明很容易與 DNA 中的鳥嘌呤和腺嘌呤反應,產生不同的 DNA 病變(如 DNA 鍵結物或 DNA-蛋白 質交聯)。因此在大部分的對於細菌與哺乳動物試管試驗中的基因毒性檢測皆為 陽性。因此甲醛的作用模式為與人細胞產生基因毒性最後致癌。而這樣的作用模 式有足夠的證據顯示與人相關。因此在評估上甲醛並無安全劑量,而是以沒有安 全限制的致癌斜率來進行劑量與反應關係分析。

美國環保署風險資訊評估系統 IRIS(Integrated Risk Information System) (IRIS 1989)及加拿大健康局 OEHHA(Office of Environmental Health Hazard Assessment)皆以 Kerns et al. (1983) (Kerns, Pavkov et al. 1983)两年慢 性的大鼠呼吸暴露實驗結果進行劑量與反應關係評估,進行線性的外插,取得甲 醛的致癌斜率,實驗的數據及資料如下:

動物物種:大鼠

發現癌症種類:鱗狀細胞癌

暴露方式:呼吸暴露

表 4.2、 Kerns et al. (1983)年進行甲醛大鼠呼吸暴露實驗之癌症發生率數據 \_\_\_\_\_\_\_\_ 劑量

老鼠暴露劑量(ppm)	人類等同劑量	癌症發生率
	(mg/kg/day)	
0	0	0/156
2	2	0/159

5.6	5. 6	2/153
14.3	14.3	94/140

獲得的毒理數據,經由美國環保署發展的 Benchmark 模式的模擬(Benchmark dose modeling)進行線性外插的致癌斜率計算如下圖所示。





圖 4.10、以 Benchmark dose 軟體中的多階致癌模式模擬甲醛劑量與反應關係。

甲醛致癌斜率:0.021 mg/kg/day

產品經由呼吸暴露甲醛的累積化學暴露量:等於本計畫計算的人經呼吸暴露 50 年平均甲醛累積暴露量。

尿素甲醛樹脂在產品中的比例: 吳松林(吳松林 2011)於其研究添加食品加工殘餘物對於粒片板甲醛釋出之影響時,使用的樹脂率為10%。Salem et al. (2013) 等人研究挪威雲杉製作的粒狀板及中密度纖維板性質,其中在粒片板及中密度纖 維板中三聚氰胺-尿素甲醛樹脂的比例為11%(粒片板表面)與8%。綜合文獻,假 設尿素甲醛樹脂在產品中佔10%。

可逸散甲醛的比例: Salem et al. (2013)等人研究挪威雲杉製作的粒片板及中 密度纖維板性質,其中對粒片板及中密度纖維板中三聚氰胺-尿素甲醛樹脂的自 由甲醛逸散量佔板材的比例< 0.2 %。因此計畫假設可逸散甲醛佔板材比例為 0.2%。

若一家具的重量為 50 公斤,其可能的自由甲醛含量為 50× 0.002= 0.1 kg= 100 g

4-3、結果與討論

4-3-1 案例研究(Case study)

假定情境: 一新購木製櫥櫃(W\*D\*H) = 80\*41\*223 cm 如下圖 4.11 所 示、表面積: 15.6 m<sup>2</sup> 於一房間中放置,此櫥櫃用的材料為中密度纖維板, 甲醛釋放量符合經濟部標檢局 CNS 標準(F3)(<1.5 mg/L)。



圖 4.11、假定木製櫥櫃樣態。

在本計畫中首先會以參數設定中 F3 等級的甲醛逸散速率、家具表面積、台灣室 內通風率、以及室內空間大小來做穩態室內甲醛濃度蒙地卡羅模擬(Monte Carlo Simulation)。模擬 10000 次得到的分布結果如下圖 4.12 所示,可得到室內甲醛 起始濃度的平均值為 0.19 mg/m<sup>3</sup>。



圖 4.12、以蒙地卡羅模擬 10000 次的穩態室內甲醛起始濃度機率分布。平均 值:0.19 mg/m<sup>3</sup>

接下來會以台灣溫度、濕度數據進行甲醛濃度的校正,以蒙地卡羅模擬 10000 次 得到的分布結果如下圖 4.13 所示,發現其濃度的平均值為 0.4 mg/m<sup>3</sup>,為未經溫 溼度校正濃度的 2 倍左右。這主要是因為台灣的平均溫濕度比原來逸散試驗箱法 控制的溫濕度高的緣故。



圖 4.13、以蒙地卡羅模擬 10000 次的室內甲醛溫溼度校正後濃度之機率分布。 平均值:0.4 mg/m<sup>3</sup>

接下來模式將會模擬不同半衰期時的室內甲醛濃度變化。如圖 4.14 所示,當甲 醛濃度達到穩態濃度 0.4 mg/m<sup>3</sup>時,會因為沉降(sink)及吸附的影響隨著時間慢 慢減少。如假設半衰期為 1.5 年時,大約要 10 年的時間濃度才能降至背景值 0, 如果假設半衰期 3 年,大約要 20 年才能降至背景值。本模式中則會模擬到半衰 期為 1.5 到 3 年的所有情境。



圖 4.14、半衰期 1.5 至 3 年對於室內甲醛濃度的影響。

將圖 4.14 的甲醛濃度對時間圖積分之後,可得到一 50 年的累積濃度值,之後搭配每年每人呼吸率、體重與年齡的數據,可計算若一人在同一室內空間中 50 年的終身每人每日的暴露劑量(LADD)值如圖 4.15 所示,平均值為 0.0044 mg/kg/day,第 95%分位的 LADD 值為 0.0129 mg/kg/day。



圖 4.15、以蒙地卡羅模擬 10000 次一人在同一室內空間中 50 年的甲醛終身每人 每日暴露劑量(LADD)機率分布。LADD 平均值為 0.0044 mg/kg/day、95% LADD 為 0.0129 mg/kg/day。

最後以 LADD 乘以甲醛之致癌斜率 0.021 可得到如圖 4.16 所示的致癌風險分布, 平均值為 9.3 × 10<sup>-5</sup> , 95%分位的值為 2.7× 10<sup>-4</sup>



圖 4.16、以蒙地卡羅模擬 10000 次一人在同一室內空間中 50 年的甲醛致癌機率 分布。致癌風險平均值為 9.3 × 10<sup>-5</sup>、95% 致癌風險為 2.7× 10<sup>-4</sup>。

若考慮一人在同一住家室內空間中每日為 13.6 小時,終身每人每日的暴露劑量 (LADD)值如圖 4.17 所示,平均值為 0.0029 mg/kg/day,第 95%分位的 LADD 值為 0.0084 mg/kg/day。甲醛之致癌斜率平均值為 6.2 ×  $10^{-5}$ ,第 95%分位致癌風險 為 1.8×  $10^{-4}$ 。



圖 4.17、以蒙地卡羅模擬 10000 次一人在住家室內空間(13.6 小時/日)甲醛終身 每人每日暴露劑量(LADD)機率分布。LADD 平均值為 0.0029 mg/kg/day、95% LADD 為 0.0084 mg/kg/day。



圖 4.18、以蒙地卡羅模擬 10000 次一人在住家室內空間(13.6 小時/日)甲醛終身 致癌機率分布。平均值為 6.2 × 10<sup>-5</sup>、95% 致癌風險為 1.8 × 10<sup>-4</sup>。

若考慮一人在住家室內空間(13.6小時/日),家具的使用時間改變時(5-50年), 平均及第95%分位的致癌風險如下表4.1,可發現家具使用時間減少至五年,平 均致癌風險減少50%,然而第95%分位之致癌風險只減少28%。

家具使用時間	平均致癌風險	第95%分位之致癌風險
5	3. 1× 10 <sup>-5</sup>	1. $3 \times 10^{-4}$
10	5. 7× 10 <sup>-5</sup>	1.6× 10 <sup>-4</sup>
20	$5.9 \times 10^{-5}$	1. $7 \times 10^{-4}$
30	6.0 × $10^{-5}$	1. $7 \times 10^{-4}$
50	6. 2 × 10 <sup>-5</sup>	1.8× $10^{-4}$

表 4.3 家具的使用時間 (5-50 年),造成平均及第 95%分位的甲醛致癌風險

利用敏感性分析,可了解輸入參數如何輸出風險的影響大小,是一種對於不確定的定量描述方法。從分析的結果如圖 4.19 所示,得知風險特性之主要敏感參數

為通風量、環境溫溼度與體積。通風量對於風險大小的影響最大,可影響整體評 估結果的-35.1%。環境溫度與濕度則是其次(21.9%、16.7%),但為正面影響,亦 即溫溼度越高風險越大。體積的影響亦為負面的(-12%)。其他的參數如體重(-4.9%)、半衰期(-5.9%)、呼吸量(2%)、壽命(-1.5%)、室外甲醛濃度(0%)對於整 體致癌風險的影響並不大。



圖 4.19、模式參數對於致癌風險的敏感度分析。

4-3-2 產品攝入係數(PiF)之計算

對於產品攝入係數(PiF)之計算,在分子的部分是以於假定情境的家具使用 50 年、 人持續暴露 50 年所可能暴露到甲醛的總量做計算。計畫以蒙地卡羅模擬 10000 次的 50 年累積每人暴露劑量機率分布如圖 4.20 所示,平均為 8021 mg,相當於 約 8 g。分母的甲醛含量估計則是以家具 50 公斤、自由甲醛佔了 0.2%為假設, 亦即家具中的可逸散甲醛量為 100 g。因此**此家具產品的攝入係數 PiF= 8 g/100g** = 0.08



圖 4.20、以蒙地卡羅模擬 10000 次的 50 年累積每人暴露劑量機率分布。

4-3-3 室內甲醛背景濃度風險

本計畫以文獻監測台灣住宅中的甲醛濃度 0.0871± 0.0085 mg/m<sup>3</sup>為依據,假定 呼吸暴露時間為 70 年,每日於住宅中生活 13.6 小時,搭配國人呼吸率、體重及 壽命以蒙地卡羅模擬 10000 次的終身每人每日暴露劑量(LADD)分布如圖 4.21 所 示,平均值為 0.012 mg/kg/day,95%分位的 LADD 為 0.018 mg/kg/day。在乘以 致癌斜率 0.021 後可得到致癌風險平均值為 2.5 × 10<sup>-4</sup>,95%分位致癌風險為 3.8 × 10<sup>-4</sup>。若以加拿大健康局(OEHHA)所建議的單位致癌風險(unit risk)(6× 10<sup>-6</sup>)(單位為( $\mu$ g/m<sup>3</sup>)<sup>-1</sup>),乘以台灣住宅甲醛背景校正濃度為 43  $\mu$ g/m<sup>3</sup>(考慮每日於住 宅中生活時間 13.6 小時),可得到平均致癌風險為 2.58 × 10<sup>-4</sup>。 比較兩種計算 致癌機率的方法所得到的風險值,差異甚小。



圖 4.21、70 年甲醛室內背景濃度造成的平均 LADD 為 0.012 mg/kg/day, 95%的 LADD 為 0.018 mg/kg/day。

4-3-4 環保署室內空氣品質標準致癌風險

根據中華民國 101 年 11 月 23 日行政院環境保護署環署空字第 1010106229 號令訂定室內空氣品質標準中甲醛的一小時標準值為 0.08 ppm、約等於 0.1  $mg/m^3$ 。若以此值為依據,假定呼吸暴露時間為 70 年,每日於住宅中生活 13.6 小時,搭配國人呼吸率、體重及壽命以蒙地卡羅模擬 10000 次的終身每人每日暴露 劑量(LADD)分布如圖 4.22 所示,平均 LADD 為 0.014 mg/kg/day,95%分位的 LADD 為 0.02 mg/kg/day。致癌風險平均值為 2.9× 10<sup>-4</sup>、95%分位的致癌風險為 4.2× 10<sup>-4</sup>。若以加拿大健康局(0EHHA)所建議的單位致癌風險(unit risk)(6× 10<sup>-6</sup>)(單 位為( $\mu g/m^3$ )<sup>-1</sup>),乘以台灣住宅甲醛平均濃度 100  $\mu g/m^3$ 之背景校正濃度為為 49  $\mu g/m^3$  (考慮每日於住宅中生活時間 13.6 小時),可得到平均致癌風險為 3× 10<sup>-4</sup>。比較兩種計算致癌機率的方法所得到的風險值,差異甚小。



圖 4.22、平均甲醛室內背景濃度造成的平均 LADD 為 0.014 mg/kg/day, 95%的 LADD 為 0.02 mg/kg/day。

4-3-5比較各國標準之下甲醛的致癌風險

在第一節的個案研究中,是以特定的表面積為基準進行評估,然而在實際的情形下,家具有不同的表面積,且表面積為一重要影響風險的參數,因此在本節將以不同表面積的情形下,並考慮考慮以一人每日平均待在住家室內 13.6 小時,與各國設定的標準所可能造成的風險比較。

4-3-5.1 台灣/日本標準

圖 4.23、4.24 為符合 F3、F2、F1 的粒片版(PB)或中密度纖維板(MDF) 板材家具對於不同表面積情形下的平均及第 95%分位終身每人每日暴 露劑量(LADD)。這裡粒片版及中密度纖維板對於每日劑量 LADD 的不同 是由於標準方法轉換(JISA 1460 至 ASTM E1333)所使用的轉換公式不 同所致。可以發現中密度纖維板比粒片版有稍微較高的暴露劑量,且在 F3 的標準下,暴露劑量隨著表面積越大增加的幅度也越大。相對於 F2 及 F1 則是比較平穩的增加。在致癌風險方面,圖 4.25、4.26 為符合 F3、F2、F1 的粒片版(PB)或中密度纖維板(MDF)家具對於不同表面積情 形下的平均及第 95%分位致癌風險。三個等級的板材的致癌風險都分布 在  $10^{-5}$  至  $10^{-4}$ 之間,但比較值得注意的是,F3 等級的板材在表面積等 於 40 m<sup>2</sup> 的情形可能造成一個室內環境背景值( $3.8 \times 10^{-4}$ )的風險(圖 4.26)。



圖 4.23、家具表面積與甲醛平均每人每日攝取劑量的關係(台灣/日本標準) PB:粒片板 MDF:中密度纖維板


圖 4.24、家具表面積與甲醛 95%每人每日攝取劑量的關係(台灣/日本標準) PB:粒片板 MDF:中密度纖維板



圖 4.25、家具表面積與甲醛致癌風險的關係(台灣/日本標準)



圖 4.26、家具表面積與甲醛 95%致癌風險的關係(台灣/日本標準)PB:粒片板 MDF: 中密度纖維板

4-3-5.2 歐洲標準

圖 4.27、4.28 為符合歐盟各種標準的板材對於不同表面積情形下的平 均及第 95%分位終身每人每日暴露劑量(LADD)。可以發現符合 EN 171-2 氣體分析法的標準方法下設定的 E2 等級可能導致的人終身暴露量幾 乎都比 EN 171-1 及 EN 120 標準方法的設定標準要來得高很多。原因 可能是由於在評估此標準方法時必須做兩次的標準方法轉換的緣故(EN 171-2 到 EN 120、再到 EN 171-1)來得到濃度值,誤差可能會非常大。 因此在本計畫中只當作參考不予以討論。以 EN 171-1 及 EN 120 穿孔 法的標準比較,材料可能導致的致癌風險以 EN 120 法的標準較小,但 差異不大。在致癌風險方面,圖 4.29、4.30 為為符合歐盟各種標準的 板材對於不同表面積情形下的平均及第 95%分位致癌風險。EN 171-1 及 EN 120 標準方法的 E1 等級材料平均致癌風險不會超過 5×10<sup>-5</sup> (圖 4.27)。



圖 4.27、家具表面積與甲醛平均每人每日攝取劑量的關係(歐洲標準) PB:粒片板 MDF:中密度纖維板 ;這裡的 PB 與 MDF 如分開列,並不是表示兩者的 標準不同,而是在進行標準方法轉換時所用的線性係數不同。



74

圖 4.28、家具表面積與甲醛 95%每人每日攝取劑量的關係(歐洲標準)。PB:粒片板 MDF:中密度纖維板;這裡的 PB 與 MDF 分開呈現,並不是表示兩者的標準不同,而是在進行標準方法轉換時所用的線性係數不同。



圖 4.29、家具表面積與甲醛平均致癌風險的關係(歐洲標準)



圖 4.30、家具表面積與甲醛 95%致癌風險的關係(歐洲標準)

4-3-5.3 美國標準

美國與其他國家標準設定不同,規定了每一種板材的逸散極限量標準。 美國標準亦與加拿大空氣資源局 California Air Resources Board (CARB)第二期標準相同。此第二期的標準是為符合加拿大新的室內甲醛 空氣品質濃度 0.05 ppm 所設定。圖 4.31、4.32 為符合美國各種標準的 板材對於不同表面積情形下的平均及 95%分位終身每人每日暴露劑量 (LADD)。可以發現中密度纖維板導致的人終身暴露量最高,粒片板其次, 最後是硬質合板。圖 4.33、4.34 為為符合美國標準的各板材對於不同 表面積情形下的平均及 95%分位致癌風險。可以發現即使是標準最寬鬆 的中密度纖維板,在最大的表面積下造成的第 95%分位致癌風險為 2.16× 10<sup>-4</sup> (圖 4.34)。



圖 4.31、家具表面積與甲醛平均每人每日攝取劑量的關係(美國標準)。PB:粒片板 MDF:中密度纖維板 HWPW:硬質合板



圖 4.32、家具表面積與甲醛 95%每人每日攝取劑量的關係(美國標準)。PB:粒片板 MDF:中密度纖維板 HWPW:硬質合板



圖 4.33、家具表面積與甲醛平均致癌風險的關係(美國標準)。PB:粒片板 MDF: 中密度纖維板 HWPW:硬質合板



圖 4.34、家具表面積與甲醛 95%致癌風險的關係(美國標準)。PB:粒片板 MDF:中密度纖維板 HWPW:硬質合板

4-3-5.4 中國標準

圖 4.25、4.26 為符合中國各種標準的板材對於不同表面積情形下的平 均及 95%分位終身每人每日暴露劑量(LADD)。可發現以玻璃乾燥器法 (9-11L)(針對膠合板)與穿孔法(perforator)(針對粒片板及中密度纖 維板)的 E2 標準暴露量較高。圖 4.27、4.28 為符合中國標準方法的各 標準值對於不同表面積情形下的平均及 95%分位致癌風險。可發現以玻 璃乾燥器法(9-11L)(針對膠合板)與穿孔法(perforator)(針對粒片板 及中密度纖維板)的 E2 標準風險值在家具表面積大於 30m<sup>2</sup>即可能超過 室內甲醛空氣造成的風險背景值(圖 4.28)。然而必須說明的是, E2 的 標準在中國規定必須經過表面的塗布處理才能使用於室內(GB18580-2001),因此實際的風險可能較小。



圖 4.35、家具表面積與甲醛平均每人每日攝取劑量的關係(中國標準)。9-11L: 玻璃乾燥器法;40L:玻璃乾燥器法;perfortor:穿孔法



圖 4.36、家具表面積與甲醛 95%每人每日攝取劑量的關係(中國標準)。9-11L:玻 璃乾燥器法;40L:玻璃乾燥器法;perfortor:穿孔法



圖 4.37、家具表面積與甲醛平均致癌風險的關係(中國標準)。9-11L:玻璃乾燥 器法;40L:玻璃乾燥器法;perfortor:穿孔法



圖 4.38、家具表面積與甲醛 95%致癌風險的關係(中國標準)。9-11L: 玻璃乾燥 器法;40L: 玻璃乾燥器法; perfortor:穿孔法

4-3-6 多國之間的標準造成的致癌風險比較

圖 4.39、4.40 比較了各國之間的標準造成的平均及第 95%分位致癌風險。可以 發現國內 F3 等級的材料,與中國玻璃乾燥器法(9-11L)(針對膠合板)與穿孔法 (perforator)(針對粒片板及中密度纖維板)的 E2 標準相似。歐洲 EN 171-1 及 EN 120 的 E1 標準值致癌風險,以及美國對於粒片板的標準與國內 F2 等級所造 成 的 風 險 相 近 。 中 國 玻 璃 乾 燥 器 法 (9-11L)(針 對 膠 合 板)與 穿 孔 法 (perforator)(針對粒片板及中密度纖維板)的 E1 標準,以及美國對於中密度纖 維板標準則介於 F3 與 F2 標準之間。美國硬質合板的標準則與國內 F1 等級相似。



圖 4.39、比較多國之間對於甲醛管制標準下的平均致癌風險。US:美國標準;GB 中國標準。



圖 4.40、比較多國之間對於甲醛管制標準下的 95%致癌風險。US:美國標準;GB: 中國標準。

4-4、生活用品中甲醛以外之揮發性有機物之健康風險評估

本計畫以家具作為評估生活用品之對象,因此蒐集國際間家具中甲醛以外含 揮發性有機物之相關規定,主要蒐集對象為歐盟、日本、美國與中國大陸。下 表為各國家或單位提出之相關文獻出處,國際間僅中國大陸制定 VOC 於家具中 之國家標準,日本之 VOC 標準是針對建築材料所至訂,美國與歐盟則是提供制 訂標準所需的評估方法。VOC 的項目不同,由於各國 VOC 的規範不同,因此制 訂標準的特定 VOC 則有所差異,中國大陸有 3 項(苯、甲苯、二甲苯)、日本有 4 項(甲苯、乙苯、二甲苯、苯乙烯)、歐盟分為致癌物與 LCI 列表物質目,美 國則以家具可能釋放之 VOC 項目作為目標 VOCs。家具釋放 VOC 的環境差異,日 本與中國大陸以室內環境作為評估的情境,美國則以辦公室的家具作為評估的 前題。家具中釋放 VOC 的標準值不同,中國大陸以濃度為標準,單位為 mg/m<sup>3</sup>; 日本以釋放率為標準,單位為 µg/m<sup>2</sup>h

國家/組	單位	條文/規定
織		
歐盟	EU	Commission Decision (EU) 2016/1332 of 28 July 2016
日本	JTCCM	建材からの VOC 放散速度基準
美國	BIFMA/CDPH	ANSI/BIFMA X7.1 - 2011(R2016)
		Emission testing method for California Specification
		01350
中國大陸	AQSIQ	GB 18584—xxxx木傢俱中揮發性有機物質及重金屬遷移限量

圖 4.41、各國 VOC 相關規定

各國制訂 VOC 標準之共同基本資訊分別有 VOC 之基準值與暴露情境下環境參 數。基準值:各國制定家具中 VOC 標準時,會以特定之基準值作為依據,如 EU-LCI(歐盟)、室內空氣濃度(日本、中國大陸)、 CREL(美國)。暴露情境:家 具擺放場所的環境條件會影響了由家具釋放 VOC 至室內空氣中的濃度,主要考量的參數有換氣率和附載率。換氣率:日本設定為 0.5(1/h)、中國大陸、美國、歐盟則設定為 1(1/h); 附載率為帶測家具的表面積(或體積)與檢驗用腔室的體積之比例:美國  $0.3-1(m^2/m^3)$ 、歐盟 0.25(-)、中國大陸 0.075~0.3(-)、日本  $2.2(m^2/m^3)$ 。

各國制訂 VOC 標準

歐盟:

以歐盟生態環保標章為標準而制訂家具中化學物質之限值,如下圖所示歐 盟分別制訂家具中甲醛、TVOC、TSVOC、致癌物質和LCI物質之限量,其中 分別考量短期暴露情境(3天)與長期暴露情境(28天)以及不同家具的使用 環境(辦公室、住家)下均有設定不同限量,而以28天之長期暴露情境下之 致癌物質設定最低(1 μg/m<sup>3</sup>)之限值。

Test parameter	Armchairs and Sofas		Office chairs		Other furniture items
Chamber volume			In the range of I	2-10m <sup>3</sup>	
Loading rate	Product sha	ll occupy approxim	ately 25% of ch	amber volume	*0.5-1.5m <sup>2</sup> /m <sup>3</sup>
Ventilation rate	4.0	m³/h	2.	0 m³/h	*0.5-1.5h <sup>-1</sup>
Substance	3d	28d	3d	28d	28d
Formaldehyde	-	60 µg/m³	-	60 µg/m³	60 µg/m³
TVOC*	≤ 3000 µg/m <sup>3</sup>	≤ 400 µg/m³	-	≤ 450 µg/m³	≤ 450 µg/m³
TSVOC	-	≤ 100 µg/m³	-	≤ 80 µg/m³	≤ 80 µg/m³
C-substances†	≤ 10 µg/m³ (total limit)	≤ 1 µg/m³ (per substance)	≤ 10 µg/m³ (total limit)	≤ 1 µg/m³ (per substance)	≤ 1 µg/m³ (per substance)
R-value for LCI substancestt	-	≤ 1	-	≤ 1	≤ 1

圖 4.42、歐盟之家具中化學物質限值標準

日本:

日本由一般財團法人建材試驗中心(Japan Testing Center for Construction Materials, JTCCM)針對建材制訂 VOC 之逸散標準(建材から の VOC 放散速度基準),其中針對個別之 VOC 制訂建材之逸散標準(甲苯、 二甲苯、乙苯、苯乙烯),選擇個別之 VOC 的標準是參考建材中可能釋放之 VOC 為依據,因而未以 TVOC 與苯制定逸散率標準。其標準如下圖所示

Target VOC	Symbol	Standard value of emission rate
Toluene	Т	$38\mu g/m^2h$
Xylene	Х	$120\mu g/m^2h$
Ethylbenzene	Е	$550 \mu g/m^2 h$
Styrene	S	$32\mu g/m^2h$

圖 4.43、日本之 VOC 與其限值標準

上圖所制定之逸散率標準是參考日本之建築法規中室內空氣濃度之現值並 考量分析方法之負載率與室內空氣換氣量等參數後,以不低估為原則所制 定之個別 VOC 逸散標準。

美國

美國有2個相關之標準分別為ANSI/BIFMA X7.1 - 2011(R2016)和 Emission testing method for California Specification 01350,BIFMA 是依照加州公共衛生部門(CDPH)公告之 VOC 評估方法制定期美國標準方 法,美國建議制定標準之 VOC 物質須考量到家具可能釋放之物質為主,而 CDPH 公告的評估範例中列舉 35 項化學物質,化學物質制定可接受濃度則 是參考 OHHSA 公告之慢性參考暴露濃度(chornic reference exposure level, CREL)的一半,因此有避免高估風險之疑慮,但由於美國是針對辦 公室之家具作為暴露環境,因此必須考量到換氣率與負載率之差異。

中國大陸

中國大陸針對木傢俱中揮發性有機物質及重金屬制定遷移限量(GB 18584— XXXX 木傢俱中揮發性有機物質及重金屬遷移限量),其中分別對甲醛、 苯、甲苯、二甲苯和 TVOC 制定限量值(詳如下圖)

项目	限量值 (mg/m³)
甲醛释放量	≪0.10
苯	≤0.11
甲苯	≤0.20
二甲苯	≤0. 20
TVOC	≤0.60

圖 4.44、中國之家具中 VOC 釋放限值

中國大陸制定木製家具之 VOC 限量值是配合室內空氣品質標準(GB/T 18883-2002 室內空气质量标准)所制定之 VOC 項目以及濃度值作為上限 值。

4-4-1 家具中個別 VOC 之暴露濃度

為了比較國際間 VOC 的限量之暴露濃度,依照上述的限量值與標準值配合 各國建議之分析方法中之換氣率與負載率則可估算不同國家標準下可接受 之 VOC 容許濃度,其結果如下表所示

VOCs	歐盟	日本	美國	中國大
				陸
苯	0.001		0.03	0.11
甲苯	2.9	0.19	0.15	0.2
二甲苯	0.5	0.6	0.35	0.2
乙苯	0.8	2.75	1	

苯乙烯	0.25	0.16	0.45	

圖 4.45、各國標準下可接受之 VOC 容許濃度

估算之公式參考日本估算的方法,而估算的 VOC 項目則是參考各國標準中 有重複之 VOC 項目,其中苯為 IARC 分類為第1類致癌物質,因此會針對苯 估算致癌風險(Cancer risk),其餘之 VOC 則會估算非致癌風險之危害指數 (Hazard Index, HI)。

4-4-2 符合各國家具中 VOC 限量下之健康風險資訊

估算 VOC 的健康風險時所使用的危害因子由於國內並未制定特定化學物質 的安全質,因此根據國際制訂的危害因子來作為估算風險的參數,致癌性 的致癌單位風險採用 WHO 的建議數值(6 x10<sup>-6</sup> per µg/m<sup>3</sup>),而非致癌性的 參考濃度則是採用 U.S. EPA IRIS 公告之參考濃度(Reference Concentration, RfC),苯、甲苯、二甲苯、乙苯、苯乙烯之 RfC 分別為 0.03、5、0.1、1、1 mg/m<sup>3</sup>。故可得符合各國家具中 VOC 限量下之健康風 險資訊如下表

VOCs	歐盟	日本	美國	中國大陸		
		致癌風險				
苯	$6 \ x10^{-6}$		1.8 x10 <sup>-</sup>	6.6		
			5	$x10^{-4}$		
	非致癌風險					
苯	0.03		1.00	3. 67		
甲苯	0.58	0.04	0.03	0.04		
二甲苯	5.00	6.00	3. 50	2.00		

乙苯	0.80	2.75	1.00	
苯乙烯	0.25	0.16	0.45	

圖 4.46、符合個國家具中 VOC 限量下之健康風險資訊

國際對於致癌性化學物質可接受之健康風險在10<sup>-4</sup>~10<sup>-6</sup>之間,健康風險評 估之結果顯示,中國大陸標準下之健康風險超過10<sup>-4</sup>,故不建議參考中國 大陸家具中苯的釋放量標準。非致癌風險的部分,依照國際間對於二甲苯 的管制濃度下HI>1,代表此評估情境下家具中之二甲苯會度人體造成健康 上之不良效應。另外日本標準下之乙苯與中國大陸標準下之苯都超過1, 因此制定國內家具中VOC標準時須進一步探討。

4-4-3 含揮發性有害物質生活用品之建議

目前國際與國內生活用品之揮發性有害物質之國家標準多以 TVOC 為管制標 第,缺乏針對個別 VOC 制訂限值之國家標準,雖然中國大陸已根據室內空 氣品質標準針對木傢俱中揮發性有機物質制定之限量最符合標準局所需之 資訊,但根據健康風險評估之結果除了甲苯已外均高於可接受之風險,因 此若針對家具中 VOC 之甲苯則可參考接受中國大陸之限量值 0.2 mg/m<sup>3</sup>,其 他 VOC 與其他國家標準則較不適用於標準局制定限量時使用,但其估算限 量值之方法亦可作為未來具備相關資料時的參考依據。 4-5、專家會議

本計畫於已於6月29日和11月28日分別完成2次專家會議,會議資訊如下: 會議名稱:「含揮發性有害物質之生活用品風險模擬研究計畫」— 專家會議 會議時間:106年6月29日(星期四)上午10時 會議地點:臺灣大學公共衛生學院 公衛大樓 711會議室 主持人:國立台灣大學職業醫學與工業衛生研究所 莊育權 專案計畫助理教授 參與專家:許世輝委員、何達仁委員(簽到簿詳見附錄二) 報告事項:詳見附錄三

會議紀實:





#### 專家建議:

許委員:

- 1. 標準局人員應一同參與專家會議以釐清計畫之目標與方向。
- 計畫名稱以"生活用品"為評估項目,計畫只以家具進行評估,是否會不符 合契約內容,計畫目標與結果須釐清。
- 由於不同的國際標準會有不同的假設與分析方法,希望本計畫能提供不同國際表標準如何選取的資訊。
- 應參考訂定標準時的限制條件,如日本制定4星標準時有適用通氣量和室內 空間大小等限制。

何委員:

- 1. 馬可夫鏈蒙地卡羅法在簡報中的起始矩陣與轉換矩陣為何?
- 2. 馬可夫鏈蒙地卡羅法如何在模擬模式中應用?
- 3. 最後估算 PiF 時的甲醛的含量假設條件中有問題,不符合實際情形。
- 依照標準規範的甲醛濃度,若已為健康風險認定為安全的結果,是否後續執 行計畫的意義。

5. 是否有將歐盟 EN717 系列的標準納入考量?

會議名稱:「含揮發性有害物質之生活用品風險模擬研究計畫」— 第2次專家會議

會議時間:106年11月28日(星期四)上午10時 會議地點:臺灣大學公共衛生學院 公衛大樓 710會議室 主持人:國立台灣大學職業醫學與工業衛生研究所 莊育權 專案計畫助理教授 參與專家:許世輝委員、葉明國委員、王松永委員 報告事項:詳見附錄三

會議紀實:





專家建議:

王松永委員

家俱上的甲醛以及 TVOC 最多是從塗料上所釋放,檢測時主要是測量其溢散率,依數值綠建材標章以 E1E2E3 給予分級,在做相關評估時可以參考。
 評估室內空氣時可以多考慮日本的數據,因日本的居家室內面積較接近台灣,美國的室內面積則通常要大過台灣,數據上日本的會更貼切較有說服力。
 在綠建材檢驗時甲醛與 TVOC 是一起測量,於兩者中取測量值較高的當評定的數值,可以提供參考。

許世輝委員

 本次會議所提到的標準數值,日本、歐盟、美國比較屬於自願性、環保標章 的部分,中國的比較屬於強制性標準,所以中國的數值都會比較高,強制性與 自願性的數據應區分清楚  2. 在執行時,應多加強標檢局權責之內容,如室內空氣之強制性及自願性規範 標準,其中強制性規範更是標檢局所側重之重點,應優先處理。

3.目前國內較常遇到的問題是某些檢測物質在數個國家皆有檢測,而標檢局選用的數值較高時容易引起廠商爭論,因此本計畫的方向可以放在處理此問題, 期許能在未來的計畫中,藉由健康風險評估的方式,評估各國所設定的數值, 提出適宜我國使用且具說服力之選擇。

#### 葉明國委員

計畫標題牽涉範圍太廣,應該針對長期計畫的安排設定中標題小標題,一年
 的計畫可能只做一到兩個物質的評估,加強計畫主題的針對性。

 計畫執行內容多針對室內空氣,可以多著重生活用品的部分,生活用品釋放 了多少揮發性物質或含有多少重金屬等等,並考慮國內有哪些試驗方法,是針 對室內空氣又或者用品本身。

參考各國資料時,國家太多會顯得雜亂,主要可以看中國、日本、美國、歐盟
 等地區資料,並考慮其試驗的方法、內容。

# 伍、經費使用分析

說明動支情形

項目	預算金額	實支金額	備註
一、直接薪資	1,159,268	1,159,268	
二、管理費用	169,818	169,818	
三、其他直接費用	538,914	538,914	
(一)差旅費	60,000	55,000	
(二) 文具紙張費	80, 000	77,000	
(三)報告印刷費	80,000	79,000	
(四)專家出席費	40,000	10,000	
(五) 資料蒐集費	80,000	77, 550	
(六)會議場地費	80,000	78, 500	
(七)設備租借費	70,000	67, 250	
(八)雜支	48, 914	94, 614	
總計	1,868,000	1,868,000	

# 陸、成效評估

本計畫的目的是希望能將風險評估的資訊導入國家標準中,以保障消費者 之安全,針對以生活用品中之家具作為評估對象,蒐集國內外揮發性有害物質之 相關標準,並估算其健康風險以提供制訂標準時的建議,依據健康風險評估的資 訊決定是否制訂相關標準。根據評估之健康風險評估結果下參考中國大陸家具之 甲苯逸散濃度需小於 0.2 mg/m<sup>3</sup>,但是否符合世界性貿易組織技術性貿易障礙協 定的原則還需進一步考量。

## 柒、建議事項

本計畫的目的是希望能將風險評估的資訊導入國家標準中,以保障消費者 之安全,但由於國家標準屬於自願性方式實施,而廠商並不一定會依照風險評估 的架構去評估與設計商品,將風險管理回歸到廠商的社會責任,也會是一個保障 消費者的選項。

7-1 不確定性描述

7-1-1 情境不確定性:

目前情境考慮的是比較極限的情況,亦即一個人待在雅房的空間情形暴 露家具所釋放甲醛,暫時沒有考慮像是家具放在辦公室或是公共場所等空間 較大的情況。另外對於家具使用年限的情境評估為50年,也是較為嚴格的 情境,因為家具有可能因產品的好壞導致損壞、或是新買家具而更新、亦或 搬家等原因會被丟掉使得實際的使用年限縮小至3年甚至更短。最後,在情 境設定上計劃假設人會待在同一個空間50年的時間,亦是比較嚴格的情境, 因為人的實際生活情形通常在一天內應有住家室內外、辦公室室內外、交通 工具內、其他公共場所(如學校)的情形。另外隨著年齡增長與工作,也會導 致居住地方的變更,而不再暴露到此家具釋放的甲醛。但這些其他的情境若 都考慮可能導致模擬結果的不確定性更大,因而可能低估了實際的風險值。 因此本計畫的情境選擇是以較為嚴格的情境設定來模擬。

0

7-1-2 參數不確定性:

7-1-2.1各國標準的轉換:由於只有用逸散試驗箱法所測量到的甲醛濃度, 才能用來套入本計畫模式中計算甲醛的濃度變化。因此只要其甲醛標準檢測 方法不是逸散試驗箱法都必須做方法轉換的設定。在以 CNS 方法轉換成美國 ASTM E1333 方法所引用的文獻, 粒片版的部分以六家不同廠商的粒片板(3家 工業粒片板與3家墊層粒片版)所做的相關曲線可信度較高, 而中密度纖維板 只有3家,因此中密度板的轉換上可能有所偏差。在轉換歐盟則 EN171-2氣 體分析標準方法的數據時,則必須先轉換成 EN120 穿孔萃取(Perafator)法 的濃度,再轉換成 EN171-1 的濃度。這樣經過二次標準方法轉換的數據不確 定性會非常高,因此估算風險的結果只能供以參考。中國標準方法之間轉換 的引用文獻,是以五種不同材料(中密度纖維板、粒片板、擋板、實木複合板 及強化地板)各一個來做標準方法相關性的曲線,在穿孔萃取及 9-11L 的標準 方法轉換還去除了強化地板的數據,因此只有用四個數據來得到相關曲線, 可能較為不足。

7-1-2.2 通氣率: 在敏感度分析的結果中,通氣率是較為敏感的參數,然而 目前台灣並沒有住家室內空間的通氣率數據,只有兩篇有辦公室室內空間的 通氣率數據,雖然目前模擬使用的數據在標準狀態下住宅居室換氣次數的範 圍內,但實際台灣住家換氣率的數據還是十分需要來降低此參數的不確性。7-1-2.3 空間體積: 由於暴露的情境鎖定在單一房間雅房,因此在房間大小 的設定上不確定性較小。未來如果考慮兩房間暴露模式,不確定性則可能會 變得比較大。

7-1-2.4 台灣室內空間溫溼度:台灣室內溫溼度數據是來自全台 11 個縣市 共 30 個室內空間中設置長期連續監測的溫溼度資料,資料的代表性足。然而 監測的時間範圍為九月至隔年七月,缺乏八月的溫溼度資料,有可能稍微低 估台灣室內空間的溫溼度。

7-1-2.5 衰退模式的半衰期:衰退模式的半衰期這裡設定為1.5至3年,於 敏感度分析結果顯示對於整體風險的變化改變不大。3 年設定所引用的文獻 是依據大量甲醛的房屋室內空間的監測資料,擬合度 R<sup>2</sup>僅0.35。1.5 年則是 材料以逸散箱監測實驗所得到的,可信度較高。若只考慮以半衰期1.5 年做 模擬,則案例研究中的家具平均致癌風險為4.6×10<sup>-5</sup>,與原考慮拜半衰期為 1.5至3年的情況降低約25%(6.2×10<sup>-5</sup>)。各國標準所導致的致癌風險亦可以

96

7-1-2.6人體暴露參數:計算暴露評估時,由於呼吸率和體重的設定是參照 國立台灣大學公共衛生學院健康風險及政策評估中心 2008 年的台灣一般民 眾暴露參數彙編。參數不確定性很低。在暴露評估裡的暴露時間(AT),在本 計畫中是以平均壽命代替,因為一般很難知道從暴露到得到癌症的時間,因 此實際上致癌物評估通常假設從出生至死亡的時間為暴露時間,亦即壽命。 7-1-2.7 PiF 中的化學物質量:此部分的設定是參考國外研究挪威雲杉製作 的粒片板及中密度纖維板性質,其中對粒片板及中密度纖維板中三聚氰胺-尿素甲醛樹脂的自由甲醛逸散量佔板材的比例 0.2 %做設定,但這部分台灣 並沒有相關的數據,因此不確定性較高。

7-1-3 模式不確定性:

本計畫所使用的模式是參考美國環保署所認可的室內空氣甲醛模式第二版 來建構 Formaldehyde Indoor Air Model - Pressed Wood Products, Version 2.0 (*FIAM-pwp* v2.0)。此模式的第一個步驟是使用 Matthews 發展的均匀混合系 統(Well-mixed model)來得到在單一空間中穩態下甲醛的濃度。此模式假設系統 內部為均匀混合系統、無甲醛的損失,無沉降與過濾效應,並且是單一排放源。 因此此模式無法模擬在達到穩態之前的甲醛濃度變化,是一個不確定性。甲醛能 否到達穩態也與通風的情況有關,因此此模式亦無法估算在不同時間點上通氣率 的變化對於甲醛濃度的影響,是另一個不確定性。而對於第二步的逸散衰減模式, 本計畫參考 FIAM-pwp 模式使用一次衰減模式(first order decay)。但目前國際 上對於到底要使用一次衰減模式還是用 Power law 模式來模擬長時間甲醛逸散 衰減仍然有很多爭論。研究會發現不同的衰減模式可能會分別適用來描述特定種 類的家具(如書櫃、沙發、衣櫃)的逸散衰減。

97

#### 7-2 不同板材種類的風險評估

板材之種類繁多,除了本計畫主要評估的粒片版與中密度纖維板外,CNS對 於板材的標準還設有 CNS 2871 方塊地板鑲嵌地板、CNS1349 普通合板、 CNS11029 裝修用集成材、CNS11031 結構用集成材、以及 CNS11818 單板層 積材,皆是以 F1-F3 的標準。然而對於地板、普通合板、粒片版與中密度纖 維板使用的容器為 9-11L 玻璃乾燥器、其他板材則是使用 40L 的壓克力容器 進行。本計畫得以進行粒片板及中密度纖維板標準之風險評估,原因在於能 夠經由文獻取得玻璃乾燥器法與逸散箱法對於此兩種板材的轉換曲線,進而 估計兩種板材在 CNS 標準下在逸散箱法測得的濃度。因此除這兩種板材外其 他的板材目前無可用的方法相關曲線做轉換。然而,由於中國的文獻有將地 板材料考慮進相關曲線內,因此對於 CNS 2871 地板的 F3 等級材料風險,應 相當於 GB18580 的9-11L標準E1(1.5 mg/L)的風險。可參考圖 4.28 及 4.29。

7-3考慮年齡因素進行風險評估

本計畫目前是評估成年人(16~64 歲)暴露甲醛的終身致癌風險,然而若要考 慮考慮其他族群的致癌風險,可以以依下列原則調整致癌風險斜率以評估之 危害,分析對於婦女、胎兒、孩童、長者或少數族群的確切危害並不是十分 確定,但在幼年時期暴露到致癌物可能導致終身致癌機率提高的理由為:

- 因為致癌是多階段的發展,而孩童時期如果發生第一階段的致癌過程,則很有可能會完成完整的過程產生腫瘤。
- 2. 組織正在快速成長和發育,因此對致癌物可能更敏感。在細胞快速 增殖階段,DNA 會快速完成週期循環並且有更高的機會錯誤修補細胞 損傷,或是轉變導致永久的細胞改變(例如突變或是 DNA 甲基化), 就可能最後導致癌症的發生。
- 早年發展時期,體內有較多的比例是未分化的幹細胞,並且代表較

大群的標的體細胞,可能會在細胞分化階段經歷永久的 DNA 改變。
4.可能對賀爾蒙致癌物更敏感,因為許多發育中的器官系統會受到賀爾蒙的影響(例如生殖系統與甲狀腺跟中樞神經系統的發育等等)。
5.其他因素可能也會提高致癌風險,例如免疫活性的差異、小腸的吸收能力、膽與腎的排泄、血液和脂肪分布、以及酵素系統活化或是去

毒性的表現能力等等。

如果在風險的計算時化學物的作用模式是有突變與致癌性,需要考慮使用兩個 可能的方法之中的一種來調整年齡的敏感性問題:

- 如果專屬於特定化學物的易感性資訊就依照所提供的不同年紀制定 特定的致癌係數。
- 2.如果沒有幼年暴露是否會較敏感的具體資料(如甲醛的情性)那就可以使用年齡校正因子 Age-Dependent Adjustment Factors (ADAFs)做調整,亦即 0~<2 歲的致癌斜率係數(CSF)要乘以 10,2~ <16 歲的孩童要乘以 3,其他的就不調整(關於老年人,目前沒有美 國環保署沒有公告調整係數),美國 2005 年致癌風險評估指引中使 用作用模式架構作早期生命階段風險評估,當中就有提到這個原 則。

然而目前國際上尚未將年齡因素考慮進甲醛的致癌單位風險或斜率因子中。

7-4 家具表面材料之風險評估

CNS11677 家具-表面材料有害物質之安全要求及試驗法中,表面材料有害物 質係指家具所用表面材料、表面塗料、表面印刷材料或表面著色物質,可遷 移或溶出對人體有害之物質。對於表面材料、表面塗料及表面印刷材料之甲 醛釋出量依據各材料規定之試驗法平均值必須為 0.5 mg/L 以下,最大值為 0.7 mg/L 以下,亦即 F2 等級。家具的表面處理後主要的逸散應主要會來自 於材料表面,因此此標準可視為一家具甲醛之逸散標準。若表面材料為板材 類,則可直接使用本計畫對於板材 F2 等級的評估結果,然若表面材料為塗 料,則本計畫之模式不合適。塗料的評估建議可採用美國環保署所建立的 IAQX v1.1 模式中模擬使用膠狀物或塗料後的表面 VOC 逸散模式:

$$R(t) = \left(\frac{K_L}{d_s}\right) W$$

R(t): 塗料中 VOC 的逸散速率(mg/h)

KL: 揮發常數(m/h)

Ds: 塗覆厚度(m)

W:VOCs 在表面的量(mg),可藉由以下公式得到:

$$\frac{\mathrm{dW}}{\mathrm{dt}} = -\left(\frac{K_L}{d_s}\right)W$$

7-5 貝式統計使用於本計畫之風險評估

本計畫根據第3章之健康風險評估模式與參數,使用 OpenBUGS 軟體以建構貝 式統計模式與馬可夫鏈蒙地卡羅模擬法,模式中參數之事前分佈是根據文獻資 料所建構(如圖 3.1 至圖 3.9),擬似函數則是根據式 2.1 至式 2.11 之評估模 式。因此以馬可夫鏈蒙地卡羅模擬法可得到評估參數之事後分佈與馬可夫鏈蒙 地卡羅模擬之結果(詳如下圖)。



圖 7.1 室內甲醛背景濃度馬可夫鏈模擬結果



圖 7.2 室內甲醛背景濃度之事後機率分佈,平均值與標準差: 0.0871±

0.0085 mg/m3



### 圖 7.3 壽命馬可夫鏈模擬結果





圖 7.4 壽命之事後機率分佈,平均值與標準差:29273±2927.3 天

圖 7.5 體重馬可夫鏈模擬結果



圖 7.6 體重之事後機率分佈,平均值與標準差: 61.65±41.99 kg



### 圖 7.7 室內溼度馬可夫鏈模擬結果



圖 7.8 室內溼度之事後機率分佈,平均值與標準差:70±9.4



圖 7.9 呼吸率馬可夫鏈模擬結果



圖 7.10 呼吸率之事後機率分佈,平均值與標準差:6314.5±730.0



圖 7.11 甲醛半衰期馬可夫鏈模擬結果



圖 7.12 甲醛半衰期之事後機率分佈,平均值與標準差: 0.298±0.303



圖 7.13 室內溫度馬可夫鏈模擬結果



圖 7.14 室內溫度之事後機率分佈,平均值與標準差: 298.2±3.7 K



圖 7.15 空間體積馬可夫鏈模擬結果



圖 7.16 空間體積之事後機率分佈,平均值與標準差:65±13



圖 7.17 換氣率馬可夫鏈模擬結果



圖 7.18 換氣率之事後機率分佈,平均值與標準差: 1.77±1.07 由於目前貝式統計模式中缺乏擬似值亦即實驗結果之濃度觀察值,因此參數 之事前分佈與事後分佈並無太大的差異,代表風險評估中的參數之不確定性 無法在缺乏觀察值的條件下有效降低,以致於最後模擬之健康風險亦無顯著 之差異。

7-6 建議:

 由於甲醛的致癌性非常高,即使以目前室內空氣品質的標準(0.08 ppm)仍然 能夠導致致癌機率大於可接受的風險(亦即百萬分之一(10<sup>-6</sup>))。世界各國仍致力 制定更嚴格之標準來降低甲醛之致癌風險,因此如加拿大第二期的室內空氣標準 已經降至 0.05 ppm,以此為依據美國亦調整其各種板材的甲醛逸散容許值至目 前的標準。

2. 從比較各國對於板材甲醛的逸散標準,可以發現我國 F3 等級的標準與各國相

105

比較為寬鬆,且雖然中國的標準如穿孔萃取法的 E2 標準與之雷同,但中國的 E2 標準有特別規定使用的限制(需經過表面處理)。

3. 以玻璃乾燥器所做出來的甲醛濃度值難以代表在空間中的甲醛濃度,若未來 要以"健康風險評估"作為決定 CNS 對於各種生活用品中揮發性有機化合物標 準設定時的參考,建議應以 CNS16000-9 室內空氣-第9部:建築產品與家飾逸 散揮發性有機化合物之測定-逸散試驗箱法或 CNS16000-10 室內空氣-第10部: 建築產品與家飾逸散揮發性有機化合物之測定-逸散試驗槽法來建立標準。

4. 由於目前貝式統計模式中缺乏擬似值亦即實驗結果之濃度觀察值,因此未來可以參考國立台灣科技大學研究團隊(秦偉庭 2009)以櫥櫃類家具評估於室內揮發性有機化合物當中,以全尺寸環控艙測試法(ASTM D6670-01)檢測木製櫥櫃類家具之甲醛濃度之逸散量測數值,可作為貝式統計分析中的觀察值進行模擬,修正馬可夫鏈蒙地卡羅法之事後分布之可信度,進而降低評估參數的不確定性。

5. 國際間制定生活用品中揮發性有害物質的標準時會參考相關法規之基準值後, 再依生活用品的使用特性與情境配合標準分析以評估特定生活用品中特定化學 物質之限量標準。以家具中 VOC 為例,由於家具與室內空氣品質有關,因此法規 的基準值初步評估可參考室內空氣品質標準作為依據(如日本、中國大陸),未來 可規劃以個別 VOC 的安全暴露濃度作為制訂標準的依據(美國、歐盟)。但由於目 前我國室內空氣品質標準並無個別 VOC 之濃度限值,在缺乏法規的基準值情況 下,制訂家具中 VOC 限值時可納入健康風險資訊的比較結果,可降低使用者的疑 慮。

7-6 制(修)定生活用品中揮發性有害物質含量之國家標準可符合世界貿易組織 技術性貿易障礙協定之標準作業程序

1. 決定生活用品之特定品項與欲制訂標準之特定揮發性有害物質:

生活用品所涵蓋之國家標準可能影響的範圍包含之產品本身、產品之原料與其目標產品之加工產物等,且相同生活用品類別中亦有不同型式與種類之產品與相對

106

應之揮發性有害物質,因此在生活用品之揮發性有害物質標準制訂前須明確界定 生活用品之品項與其相關之揮發性有害物質項目。

2. 根據特定生活用品品項之特定揮發性有害物質界定影響範疇:

由於生活用品中揮發性有害物質應以人類、動物及植物等對象之生命健康影響為 最優先的考量,因此制訂標準前應考慮消費者藉由使用特定生活用品品項而暴露 到特定揮發性有害物質之情境需優先界定。一般化學物質之暴露途徑可分為口腔 食入、皮膚接觸和呼吸暴露3種途徑,若考量特定揮發性有害物質之揮發特性則 呼吸暴露將會是主要之暴露途徑,其次若考量到特定生活用品的使用情境,必要 時則須將口腔食入、皮膚接觸等其他可能情境也納入暴露途徑之考量。除此之外 特,在特定生活用品的使用情境下亦能界定暴露之族群、頻率等暴露參數之假設。 由本計畫內容為例,家具之特定揮發性有害物質可能攝入人體之暴露途徑則可界 定影響範疇其特定環境下呼吸暴露為主要之影響範疇。

3. 蒐集並彙整國內外特定生活用品品項之特定揮發性有害物質之相關標準 由上一步驟可了解特定生活用品品項中特定揮發性有害物質之影響範疇,故根據 影響範疇蒐集相關標準。相關標準蒐集除了針對特定生活用品品項外,產品之原 料、產品之加工產物甚至相關範疇之產品都是標準蒐集的目標。標準蒐集的對象 則是依其影響範疇有關之相關政府部會和專責機構為主。彙整蒐集到之相關標準 並依其與特定生活用品品項之國家標準相關性進行分類與排序。

4. 國內外特定生活用品品項之特定揮發性有害物質相關標準之風險評估 根據蒐集到相關標準之相關性可以判定國內外目前針對特定揮發性有害物質之 管制情況,再依現有的相關標準資料進行相同基準下之風險評估。風險評估的基 準可為健康影響、貿易影響、產業影響等不同考量層面,但在不同評估之層面底 下需以相同的基準才能比較現有的相關標準之差異,如健康影響可以終生致癌性 風險或非致癌之危害指數作為基準、產業層面則可以成本差異與獲利金額作為基 準。風險評估的過程與結果須考量不同情境並說明其範疇、假設情境與條件以及
其不確定性等以利溝通使用。

5. 制(修)定生活用品中揮發性有害物質含量之國家標準研擬

由風險評估之結果,綜合不同層面下和不同情境下特定生活用品品項之特定揮發 性有害物質之國家標準各項風險與利益,依照最佳結果則可提出制(修)定生活用 品中揮發性有害物質含量之國家標準研擬方案。

#### 捌、参考文獻

- Berge, A., B. Mellegaard, P. Hanetho and E. B. Ormstad (1980).
   "Formaldehyde release from particleboard—Evaluation of a mathematical model." Holz Als Roh-und Werkstoff 38: 252-255.
- Suo, H., N. H. Kwok, H. R. Cheng, S. C. Lee, W. T. Hung and Y. S. Li (2009). "Formaldehyde and volatile organic compounds in Hong Kong homes: Concentrations and impact factors." <u>Indoor Air</u> 19: 206-217.
- Ξ \ IARC (2012). <u>"A review of human carcinogens: chemical agents and</u> related occupations," in International Agency for Research on <u>Cancer Monographs on the Evaluation of Carcinogenic Risks to</u> <u>Human</u>.
- 四、IRIS (1989). <u>Quantitative Estimate of Carcinogenic Risk from</u> <u>Inhalation Exposure</u>.
- Jolliet, O., A. S. Ernstoff, S. A. Csiszar and P. Fantke (2015).
   "Defining Product Intake Fraction to Quantify and Compare Exposure to Consumer Products." <u>Environmental Science and</u> <u>Technology</u> 49: 8924-8931.
- ☆、Kawanishi, M., T. Matsuda and T. Yagi (2014). "Genotoxicity of formaldehyde: molecular basis of DNA damage and mutation." Frontiers in Environmental Science 2.
- Kerns, W. D., K. L. Pavkov, D. J. Donofrio, E. J. Gralla and J.
   a. Swenberg (1983). "Carcinogenicity of Formaldehyde in Rats and Mice after Long-Term Inhalation Exposure Carcinogenicity of Formaldehyde in Rats and Mice after Long-Term Inhalation

Exposure." Cancer Research 43: 4382-4392.

- A Lefebvre, M. A., W. J. Meuling, R. Engel, M. C. Coroama, G. Renner, W. Pape and G. J. Nohynek (2012). "Consumer inhalation exposure to formaldehyde from the use of personal care products/cosmetics." <u>Regul Toxicol Pharmacol</u> 63(1): 171-176.
- た、Lerdau, M. and M. Keller (1997). "Controls on isoprene emission from trees in a subtropical dry forest." <u>Plant, Cell &</u> <u>Environment</u> **20**(5): 569-578.
- + Lim, S. K., H. S. Shin, K. S. Yoon, S. J. Kwack, Y. M. Um, J. H. Hyeon, H. M. Kwak, J. Y. Kim, T. Y. Kim, Y. J. Kim, T. H. Roh, D. S. Lim, M. K. Shin, S. M. Choi, H. S. Kim and B. M. Lee (2014).
  "Risk assessment of volatile organic compounds benzene, toluene, ethylbenzene, and xylene (BTEX) in consumer products." <u>J Toxicol Environ Health A</u> 77(22-24): 1502-1521.
- +- Matthews, T., A. Hawthorne, C. Daffron and T. a. C. Reed, M. (1983). Formaldehyde Release from Wood Products. <u>In Proceedings</u> of the 17th International Particleboard Symposium. Pullman, Washington State University.
- +=、 Myers, G. E. (1985). "The effects of temperature and humidity on formaldehyde emission from UF-bonded boards: a literature critique." <u>Forrest Products Journal</u> 35: 20-31.
- + = 、 Que, Z.-1., F.-b. Wang, L.-f. Ma and T. Furuno (2013). "Composites : Part B Effect of loading ratio, conditioning time and air exchange rate on the formaldehyde emission from woodbased board using large chamber and desiccator method."

Composites Part B 47: 278-282.

- 十四、 Risholm-sundman, M., A. Larsen, E. Vestin and A. Weibull (2007). "Formaldehyde emission — Comparison of different standard methods." <u>Atmospheric Environment</u> **41**: 3193-3202.
- +五、 Salem, M. Z. M., M. Böhm, J. Beránková and J. Srba (2011). "Effect of some manufacturing variables on formaldehyde release from particleboard: Relationship between different test methods." <u>Building and Environment</u> **46**: 1946-1953.
- +六、 Salem, M. Z. M., A. Zeidler, B. Martin and J. Srba (2013). "Norway Spruce (Picea abies [L.] Karst.) as a Bioresource: Evaluation of Solid Wood, Particleboard, and MDF Technological Properties and Formaldehyde Emission." <u>bioresources.com</u> 8: 1199-1221.
- + ↓ 、 Song, W., Y. Cao, D. Wang, G. Hou, Z. Shen and S. Zhang (2015). "An Investigation on formaldehyde emission characteristics of wood building materials in Chinese standard tests: Product emission levels, measurement uncertainties, and data correlations between various tests." <u>PLoS ONE</u> 10: 1-38.
- +八、 USEPA (2012). Formaldehyde Indoor Air Model Pressed Wood Products, Version 2.0 (FIAM-pwp v2.0): Model User Manual and Documentation, Washington DC.
- +九、 Versar (1988). Formaldehyde Exposure in Residential Settings: Sources, Levels, and Effectiveness of Control Options. Update (September 30, 1988) of 1986 report by Versar.
- ∴+、 Wang, H. K., C. H. Huang, K. S. Chen, Y. P. Peng and C. H.

Lai (2010). "Measurement and source characteristics of carbonyl compounds in the atmosphere in Kaohsiung city, Taiwan." <u>Journal</u> of Hazardous Materials **179**: 1115-1121.

=+-、Wu, P. C., Y. Y. Li, C. C. Lee, C. M. Chiang and H. J. J. Su (2003). "Risk assessment of formaldehyde in typical office

buildings in Taiwan." <u>Indoor Air</u> 13: 359–363.

二十二、內政部 (2015). 104 年簡易生命表.

- 二十三、行政院環境保護署. (2017, 2017/7/7). "室內空氣品質資訊網." from http://iaq.epa.gov.tw/indoorair/page/News\_9\_1.aspx.
- 二十四、吳松林(2011). 添加食品加工殘餘物對於粒片板甲醛釋出之影響. 碩 士論文, 國立嘉義大學.
- 二十五、李昭興(2002). 辦公空間相關變數對揮發性有機物質濃度影響之研究 -以台灣辦公空間為例. 碩士論文, 國立成功大學.
- 二十六、林彦旭(2013).建立以大氣溫度預測室內溫度變化之統計模式.碩士 論文,國立成功大學.
- 二十七、秦偉庭(2009). 室內揮發性有機物質逸散衰減模式對櫥櫃類家具適用 性及健康風險評估之研究. 碩士論文, 國立臺北科技大學.
- 二十八、翁麗敏 (2002). 梯間配置對開口模式及通風路徑之影響評估. 碩士論 文, 淡江大學.
- 二十九、國立台灣大學公共衛生學院 (2008). 台灣一般民眾暴露參數彙編, 台北.
- 三十、 陳智揚 (2009). 以甲殼素添加劑抑制建材甲醛逸散量及健康風險評估 之研究. 碩士論文, 國立臺北科技大學.

#### 玖、附錄

附錄一、已同意之 EU-LCI 值物質清單

#### Agreed EU-LCI values

No.	CAS no.	Compound	EU-LCI (µg/m³)	Status of EU-LCI value	Year of adoption
1		Aromatic hydrocarbons		•	
1-1	108-88-3	Toluene	<u>2900</u>	Derived EU-LCI	2013
1-2	100-41-4	Ethylbenzene	<u>850</u>	Derived EU-LCI	2013
1-3	1330-20-7 106-42-3 108-38-3 95-47-6	Xylene (o-, m-, p-) and mix of o-, m- and p-xylene isomers	<u>500</u>	Derived EU-LCI	2013
1-5	103-65-1	n-Propylbenzene	<u>950</u>	Derived EU-LCI	2013
1-6	108-67-8 95-63-6 526-73-8	Trimethylbenzene (1,2,3-,1,2,4-,1,3,5-)	<u>450</u>	Derived EU-LCI	2013
1-7	611-14-3	2-Ethyltoluene	550	Derived EU-LCI	2014
1-8	527-84-4 535-77-3 99-87-6 25155-15-1	Cymene (o-, m- ,p-,) (1-isopropyl-2(3,4)- methylbenzene) and mix of o-, m-, and p- cymene	1000	Ascribed EU-LCI	2013
1-9*	95-93-2	1,2,4,5-Tetramethylbenzene	250	Derived EU-LCI	2016
1-10	104-51-8	n-Butylbenzene	1100	Derived EU-LCI	2014
1-11	99-62-7 100-18-5	Diisopropylbenzene (1,3-, 1,4-)	<u>750</u>	Derived EU-LCI	2013
1-12	2189-60-8	Phenyl octane and isomers	<u>1100</u>	Derived EU-LCI	2013
1-16	100-42-5	Styrene	<u>250</u>	Derived EU-LCI	2013
1-23	91-20-3	Naphthalene	10	Derived EU-LCI	2015
1-25	95-13-6	Indene	450	Ascribed EU-LCI	2013
2		Saturated aliphatic hydrocarbons (n-,	iso- and cyc	clo-)	
2-1*	110-54-3	n-Hexane	4300	Derived EU-LCI	2016
2-2	110-82-7	Cyclohexane	6000	Ascribed EU-LCI	2013
2-3	108-87-2	Methyl cyclohexane	8100	Ascribed EU-LCI	2013
2-6		Other saturated aliphatic hydrocarbons C9-C16	6000	Ascribed EU-LCI	2013
3		Terpenes			
3-1	498-15-7	3-Carene	1500	Ascribed EU-LCI	2013
3-2	80-56-8	α-Pinene	<u>2500</u>	Derived EU-LCI	2013
3-3	127-91-3	ß-Pinene	1400	Ascribed EU-LCI	2013
3-4	138-86-3 5989-27-5 5989-54-8	Limonene	5000	Derived EU-LCI	2014
3-5		Other terpene hydrocarbons	1400	Ascribed EU-LCI	2013
4		Aliphatic alcohols			
4-1	75-65-0	2-Methyl-2-propanol (tert-butanol)	620	Ascribed EU-LCI	2013
4-2*	78-83-1	2-Methyl-1-propanol	11000	Derived EU-LCI	2016
4-3	71-36-3	1-Butanol	3000	Ascribed EU-LCI	2013

No.	CAS no.	Compound	EU-LCI (µg/m³)	Status of EU-LCI value	Year of adoption
4-4	71-41-0 30899-19-5 94624-12-1 6032-29-7 584-02-1 137-32-6 123-51-3 598-75-4 75-85-4 75-85-4 75-84-3	1-Pentanol (all isomers)	730	Ascribed EU-LCI	2013
4-5	111-27-3	1-Hexanol	2100	Ascribed EU-LCI	2013
4-6	108-93-0	Cyclohexanol	2000	Ascribed EU-LCI	2013
4-7	104-76-7	2-Ethyl-1-hexanol	300	Derived EU-LCI	2014
4-8*	111-87-5	1-Octanol	1700	Derived EU-LCI	2016
4-9	123-42-2	4-Hydroxy-4-methyl-pentane-2-on (diacetone alcohol)	960	Ascribed EU-LCI	2013
5		Aromatic alcohols			
5-2	128-37-0	BHT (2,6-di-tert-butyl-4-methylphenol)	100	Ascribed EU-LCI	2013
5-3	100-51-6	Benzyl alcohol	440	Ascribed EU-LCI	2013
6		Glycols, Glycol ethers, Glycol esters			
6-1*	107-21-1	Ethandiol (ethylenglykol)	3400	Derived EU-LCI	2016
6-4*	111-46-6	Diethylene glycol	5700	Derived EU-LCI	2016
6-5*	57-55-6	Propylene glycol (1,2-dihydroxypropane)	2100	Derived EU-LCI	2016
6-8	110-98-5 25265-71-8	Dipropylene glycol	670	Ascribed EU-LCI	2013
6-9	110-63-4	1,4-Butanediol	2000	Ascribed EU-LCI	2013
6-11	6846-50-0	2,2,4-Trimethylpentanediol diisobutyrate	450	Ascribed EU-LCI	2013
6-15	111-96-6	Diethylene glycol dimethyl ether (1-methoxy-2-(2-methoxy-ethoxy)-ethane)	28	Ascribed EU-LCI	2013
6-16	25265-77-4	2,2,4-Trimethyl-1,3-pentanediol monoisobutyrate	600	Ascribed EU-LCI	2013
6-17	109-59-1	Ethylene glycol isopropylether (2-methylethoxyethanol)	220	Ascribed EU-LCI	2013
6-19*	110-80-5	Ethylene glycol monoethyl ether (2-ethoxyethanol)	600	Derived EU-LCI	2016
6-20*	111-15-9	2-Ethoxyethyl acetate	900	Derived EU-LCI	2016
6-22	111-90-0	Diethylene glycol monoethyl ether (2-(2-ethoxyethoxy)ethanol)	350	Ascribed EU-LCI	2013
6-23	2807-30-9	Ethylene glycol monoisopropyl ether (2-propoxyethanol)	860	Ascribed EU-LCI	2013
6-24*	111-76-2	Ethylene glycol monobutylether (2-butoxyethanol)	1600	Derived EU-LCI	2016
6-25*	112-07-2	2-Butoxyethyl acetate	2200	Derived EU-LCI	2016
6-26	112-34-5	Diethylene glycol monobutylether	670	Ascribed EU-LCI	2013
6-27	124-17-4	Diethylene glycol monomethyl ether acetate (butyldiglykolacetate, 2-(2- butoxyethoxy) ethyl acetate)	850	Ascribed EU-LCI	2013
6-28*	122-99-6	2-Phenoxyethanol	60	Derived EU-LCI	2016
6-32	1589-47-5	1-Propylene glycol 2-methyl ether (2-methoxy-1-propanol)	19	Ascribed EU-LCI	2013

No.	CAS no.	Compound	EU-LCI (µg/m³)	Status of EU-LCI value	Year of adoption
6-33	70657-70-4	1-Propylene glycol 2-methyl ether acetate (2-methoxy-1-propyl acetate)	28	Ascribed EU-LCI	2013
6-35	34590-94-8	Dipropylene glycol monomethyl ether	3100	Ascribed EU-LCI	2013
6-40	63019-84-1 89399-28-0 111109-77-4	Dipropylene glycol dimethyl ether	1300	Ascribed EU-LCI	2013
7		Aldehydes			
7-1*	50-00-0	Formaldehyde	100	Derived EU-LCI	2016
7-2	75-07-0	Acetaldehyde	<u>1200</u>	Derived EU-LCI	2013
7-4	123-72-8	Butanal	<u>650</u>	Derived EU-LCI	2013
7-5	110-62-3	Pentanal	<u>800</u>	Derived EU-LCI	2013
7-6	66-25-1	Hexanal	<u>900</u>	Derived EU-LCI	2013
7-7	111-71-7	Heptanal	<u>900</u>	Derived EU-LCI	2013
7-8	123-05-7	2-Ethyl-hexanal	<u>900</u>	Derived EU-LCI	2013
7-9	124-13-0	Octanal	<u>900</u>	Derived EU-LCI	2013
7-10	124-19-6	Nonanal	<u>900</u>	Derived EU-LCI	2013
7-11	112-31-2	Decanal	<u>900</u>	Derived EU-LCI	2013
7-12	4170-30-3 123-73-9 15798-64-8	2-Butenal (crotonaldehyd)	5	Derived EU-LCI	2015
7-13	1576-87-0 764-39-6 31424-04-1	2-Pentenal	7	Derived EU-LCI	2015
7-14	6728-26-3 505-57-7 16635-54-4 1335-39-3 73543-95-0	Hexenal	7	Derived EU-LCI	2015
7-15	2463-63-0 18829-55-5 57266-86-1 29381-66-6	2-Heptenal	7	Derived EU-LCI	2015
7-16	2363-89-5 2548-87-0 25447-69-2 20664-46-4	2-Octenal	7	Derived EU-LCI	2015
7-17	2463-53-8 18829-56-6 60784-31-8	2-Nonenal	7	Derived EU-LCI	2015
7-18	3913-71-1 2497-25-8 3913-81-3	2-Decenal	7	Derived EU-LCI	2015
7-19	2463-77-6 53448-07-0 1337-83-3	2-Undecenal	7	Derived EU-LCI	2015
8		Ketones			
8-1*	78-93-3	2-Butanone (ethylmethylketone)	20000	Derived EU-LCI	2016
8-2	563-80-4	3-Methyl-2-butanone	7000	Ascribed EU-LCI	2013
8-3*	108-10-1	4-Methyl-2-pentanone (methylisobutylketone)	1000	Derived EU-LCI	2016

No.	CAS no.	Compound	EU-LCI (µg/m³)	Status of EU-LCI value	Year of adoption
8-4	120-92-3	Cyclopentanone	900	Ascribed EU-LCI	2013
8-5	108-94-1	Cyclohexanone	410	Ascribed EU-LCI	2013
8-7	583-60-8	2-Methylcyclohexanone	2300	Ascribed EU-LCI	2013
8-8	98-86-2	Acetophenone	490	Ascribed EU-LCI	2013
9		Acids			
9-1*	64-19-7	Acetic acid	1200	Derived EU-LCI	2016
9-2*	79-09-4	Propionic acid	1500	Derived EU-LCI	2016
9-10	149-57-5	2-Ethylhexanoic acid	150	Derived EU-LCI	2014
10		Ester			
10-1	108-21-4	Propyl acetate (n-, iso-)	4200	Ascribed EU-LCI	2013
10-2	108-65-6	2-Methoxy-1-methylethyl acetate	2700	Ascribed EU-LCI	2013
10-5*	80-62-6	Methyl methacrylate	750	Derived EU-LCI	2016
10-7	110-19-0	Isobutyl acetate	4800	Ascribed EU-LCI	2013
10-8	123-86-4	n-Butyl acetate	4800	Ascribed EU-LCI	2013
10-10	96-33-3	Methyl acrylate	180	Ascribed EU-LCI	2013
10-11	140-88-5	Ethyl acrylate	200	Ascribed EU-LCI	2013
10-12	141-32-2	n-Butyl acrylate	110	Ascribed EU-LCI	2013
10-13	103-11-7	2-Ethylhexyl acrylate	380	Ascribed EU-LCI	2013
10-14		Other acrylates (acrylic acid esters)	110	Ascribed EU-LCI	2013
10-15	627-93-0	Dimethyl adipate	50	Ascribed EU-LCI	2013
10-16	106-65-0	Dimethyl succinate	50	Ascribed EU-LCI	2013
10-17	1119-40-0	Dimethyl glutarate	50	Ascribed EU-LCI	2013
10-20	105-75-9	Dibutyl fumarate	50	Ascribed EU-LCI	2013
10-21	105-76-0	Maleic acid dibutylester	50	Ascribed EU-LCI	2013
10-22	13048-33-4	Hexamethylene diacrylate	10	Ascribed EU-LCI	2013
11		Chlorinated hydrocarbons			
11-3	106-46-7	1,4-Dichlorobenzene	<u>150</u>	Derived EU-LCI	2013
12		Others			
12-1	123-91-1	1,4-Dioxane	400	Derived EU-LCI	2015
12-2	105-60-2	Caprolactame	<u>300</u>	Derived EU-LCI	2013
12-3*	872-50-4	N-Methyl-2-pyrrolidone	1800	Derived EU-LCI	2016
12-4	556-67-2	Octamethylcyclotetrasiloxane (D4)	1200	Ascribed EU-LCI	2013
12-7	100-97-0	Hexamethylenetetramine	30	Ascribed EU-LCI	2013
12-8	96-29-7	2-Butanonoxime	15	Derived EU-LCI	2015
12-9*	126-73-8	Tributyl phosphate	300	Derived EU-LCI	2016
12-11	26172-55-4	5-Chloro-2-methyl-2H-isothiazol-3-one (CIT)	1	Ascribed EU-LCI	2013
12-12	2682-20-4	2-Methyl-4-isothiazolin-3-one (MIT)	100	Ascribed EU-LCI	2013
12-17*	2687-91-4	N-Ethyl-2-pyrrolidone	400	Derived EU-LCI	2016

\* new or altered in 2016

附錄二、第1次專家會議簽到表

會議名稱:「含揮發性有害物質之生活用品風險模擬研究計畫」— 專家會議 會議時間:106年6月29日(星期四)上午10時 會議地點:臺灣大學公共衛生學院 公衛天樓 711會議室

主 持 人;国立台湾大学飞棠医学与工业卫生研究所 在育權 专家计盘助理教授

	簽 名		簽 名
1	帮	11	
2	許世雄	12	
3	杨子	13	
4	F1916	14	
5	<b></b> 載 差 膚	15	
6		16	
7	-	17	
8		18	
9		19	
10		20	

附錄三、專家會議簡報資料

# 經濟部標準檢驗局106年度 「含揮發性有害物質之生活用品風險模擬 研究計畫」

計畫主持人:莊育權博士 國立台灣大學職業醫學與工業衛生研究所專案助理教授 報告人:蕭伊倫博士

120



 運用國際認可之模式包括貝式統計與馬可夫鏈蒙地卡羅模式等進行模擬,取得風險評估之重要參數,以建構適用我國生活用品之風險評估 之攝入係數

-121

## 評估一人因新購置木製家具產品造成的額外終身甲醛 暴露量

- 方法:利用USEPA發展的[甲醛室內空氣模擬模式-合板家具]來評估甲醛在空間時間中的濃度變化,在搭配國人體重、年齡、呼吸率數據計算出終身每人每日暴露量
- 特色:自行以EXCEL建構模式並利用蒙地卡羅模擬(Monte-Carlo Simulation) 5000次各 種暴露情境來計算終身暴露量

122

## 目前已發展的室內空氣品質模式

- Indoor Air Quality and Inhalation Exposure (IAQX v.I.I)-USEPA
- Indoor Air Quality Emission Simulation Tool (IA-QUEST v.1.1)- NRCC, Canada
- For 甲醛only:
- Formaldehyde Indoor Air Model Pressed Wood Products, Version 2.0 (FIAMpwp v2.0) -USEPA

## FIAM-PWP V2.0

 Component I: Predicts the initial "steady-state" formaldehyde concentration(s) in one or two zones of the house due to the combined actions of sources and sinks in a newly constructed home.

• Component II:A decay function that gradually reduces the estimated initial steady-state concentration(s) due to indoor sources and sinks over a specified period of time.

#### MATTHEWS SINGLE COMPARTMENT MODEL

假設:

- I. 均匀混合
- 2. 單一排放源
- 3. 無甲醛損失(sink, filtration)
- 4. 混合因子=I

[甲醛室內濃度]=[甲醛室外濃度]+逸散速率/(混合因子(I)×通氣率×空間體積) =[甲醛室外濃度]+(單位表面逸散速率 x 表面積)/Q CHOER' Q= 通氣率×空間體積  $[CH_2O]_{SS} = [CH_2O]_{out} + CH_2OER/(F * ACH * VOL)$ where:  $[CH_2O]_{SS}$  = steady-state formaldehyde concentration inside the compartment  $(mg/m^3)$  $[CH_2O]_{out}$  = formaldehyde concentration outside the compartment (mg/m<sup>3</sup>), assumed to be constant over time  $CH_2OER$  = emission rate of a formaldehyde source inside the compartment (mg/h)F= fraction of air coming into the compartment that mixes within the volume (i.e., the mixing factor) = air exchange rate with outdoors for the compartment  $(hr^{-1})$ ACH

*VOL* = volume of the compartment  $(m^3)$ .

#### 甲醛單位表面逸散速率

單位表面逸散速率=-質量傳遞係數(m) × 甲醛氣相濃度+ 常數(b)(甲醛濃度為0時之逸散率)

 $CH_2OER' = -m * [CH_2O]_V + b$ 

where:

b

- m = the mass transfer coefficient (m/hr)
- $[CH_2O]_V$  = the CH<sub>2</sub>O concentration in the vapor phase (mg/m<sup>3</sup>)
  - a constant; the emission rate at zero CH<sub>2</sub>O concentration in the air (mg/m<sup>2</sup>-hr).

\*consistent with a one-dimensional representation of Fick's Law

#### 假設甲醛氣相濃度=甲醛室內濃度

### 可評估不同材料來源所造成的室內甲醛初始平衡狀態 濃度

127

$$\begin{bmatrix} CH_2O \end{bmatrix}_{SS} = \frac{\frac{\sum_{k} (b_k * Area_k)}{Q} + [CH_2O]_{out}}{\frac{Q}{1 + \frac{\sum_{k} (m_k * Area_k)}{Q}}}$$

Ex. 粒狀板 中密度纖維板 軟性合板 硬性合板

### 溫溼度校正

 $C_{\rm TH} = C_{\rm 0} K_{\rm TH}$ 

where  $K_{TH}$  is the combined temperature and humidity adjustment factor:

$$K_{TH} = \frac{e^{\left[R\left(1/T_B - 1/T_U\right)\right]}}{1 + A\left(H_B - H_U\right)}$$

CTH:校正後濃度

Co:校正前濃度 (通常為以ASTM EI333標準方法測試條件(23 or 25 °C, 50% RH)所模擬的濃度) T<sub>B</sub>:原始溫度 T<sub>U</sub>:環境溫度

128

H<sub>B</sub>:原始相對溼度

H<sub>∪</sub>:環境相對溼度

R:溫度校正係數= 8930

A: 濕度校正係數 = 0.0195

可校正區間:溫度:20-40 °C RH:20-90%

## 室內甲醛濃度衰減模式

甲醛於某時間t的濃度=(甲醛室內初始濃度)e-kt

#### 不考慮甲醛環境背景濃度!

$$C_t = \mathcal{Q}_B + (C_i - \mathcal{Q}_B) e^{-kt}$$

where:

- $C_t$  = formaldehyde concentration indoors (ppb) at time *t* (in years), due to the combination of background concentration and emissions from PWPs (Note:  $C_t = C_i$  at t = 0)
- $C_B$  = background concentration (ppb), which is defined as the outdoor concentration plus the contribution from indoor sources other than pressed-wood products (assumed constant)
- $C_i$  = initial concentration indoors (ppb)
- k = first-order rate constant for the exponential decline (years<sup>-1</sup>).

### 半衰期的假設

- 1.5年 or 3年 k= 0.462 or 0.231
- The collective evidence indicates that an appropriate half-life value probably lies between 1.5 and 3.0 years. A careful analysis by Versar of a cross-sectional data set for 396 manufactured homes in the 1988 report, resulted in a half-life estimate of 2.92 years. Two studies were noted by Groah that involved chamber testing of a collection of pressedwood products as they aged. One estimated the emissions half-life to be 1.52 years and the other (Groah and Gramp) indicated a half-life of 2.10 years.



- 模式無法評估pre-steady state的濃度變化 (通常可在幾十小時內達到steady state) •
- 模式只能評估單一通風率的情況,無法評估隨通風率隨時間變化相對的甲醛濃度 ۲
- 模式只能評估單一體積、通風率、溫溼度、人體暴露參數等數據時的變化 •

QUICK LINKS	New Run File Ope	a Run File	Save Run Fil	e	
	FIAM House	e Scree	n		
	Run Title				
Rept 1	Run Notes				
Environmental Models	1		Apartment		¥
ISCST	Structure Type	Structure Type MAKEAC			
AERMOD	Air Euchanae Da	Air Euchanne Bate 02		changes pay house	INCHA
REACHSCAN	Air change Rate 10.2 air changes per house (ACH			(ACA)	
Exposure and Risk Screenings	Zones and Air Fl	Zones and Air Flows Check here if one-zone case			
ISCST Risk			Description	Volume (m <sup>2</sup> )	Flow from
Chemical Safety Mapper Module	and the second s	1			Outside(m*
Data File Upload	Zone 1	Zo	ne 1 (entire structur	261.3	52.26
Query Data From Database	Zone 2	0		0.0	0.0
Shape File Upload	and and an				1 mart
Monitoring Data File Upload	Background Cor	nc	7.3	>	ppb
Monitoring Data Online Submission	Temperature		20	.78	°C
Search Menthering Rata	Time from Initia	Conc	24	0	months
Formaldehyde Indoor Air Model	T			70.0	Theners
House Model	liemperature Co	emdent	99	79,0	1



#### CASE STUDY

• 情境假設: 一新購木製櫥櫃(W\*D\*H) = 80\*41\*223 cm 表面積: 15.6 m<sup>2</sup> 於一房間中放置, 此櫥櫃用的材料甲醛釋放量符合經濟部標檢局CNS標準(F3)(<1.5 mg/L)

132



需要參數列表

初始濃度預測	溫溼度校正	衰减速率	暴露參數
材料質量傳遞係數 (m)(m/h)	環境溫度 <b>(°C)</b>	一次速率常數k	呼吸通氣量(m <sup>3</sup> /day)
材料常數(b)(mg/m <sup>2</sup> hr)	環境濕度(%)		暴露時間 (year)
家具表面積 (m²)	溫度校正係數R		體重(kg)
空氣換氣率 (h <sup>-1</sup> )	濕度校正係數A		壽命(year)
空間體積 (m³)			

133

### 材料係數的取得與估計

#### $CH_2OER' = -m * [CH_2O]_V + b$

 美國以ASTM-1333方法改變通氣率、濕度條件可得某板材甲醛逸散率及濃度並做線性回歸 分析得到斜率(m)及截距(b),再以多家不同廠商的同類板材可得到平均的m,b

材料質量傳遞係數m:使用美國數據

- 粒片板Particle board: 0.7 (m/h)
- 中密度纖維板MDF: 1.06
- 硬質合板HWPW: 0.27
- 軟質合板SWPW: 0.61

Table D-2. Calculated Average Slopes and Intercepts for Eight Product Types						
Product Type	Average Slope	Average Intercept				
Particleboard Underlayment	0.83	0.34				
Mobile Home Decking	1.06	0.53				
Industrial Particleboard	0.70	0.35				
Medium Density Fiberboard <sup>a</sup>	1.06	1.02				
Hardwood Plywood Paneling (Print	0.51	0.27				
Hardwood Plywood Paneling (Paper)	0.21	0.19				
Hardwood Plywood Paneling (Veneer)	0.27	0.10				
Hardwood Plywood Paneling (Unknown)	0.44	0.12				

表:美國分析各種材料甲醛逸散率並做線性回歸分 析得到的斜率與截距平均值

### 材料常數(B)的估計-以F3, F2, F1的國內標準預測

 $b = [CH_2O]_{SS} * (1 + m * Area / Q) * (Q / Area)$ 

[CH2O]ss:以ASTM E1333 標準分析方法建立的甲醛釋放量標準規範,如加州空氣資源局CARB 2 對於MDF的標準為 0.11 ppm 或0.135 mg/m<sup>3</sup>

ASTM E 1. Conditions: 24°C, 50% humidity. 2. The period: 7 d. 1333

1. Test: 25°C, 50% humidity, 0.5  $h^{-1}$  air change rate, till a steady-state emission. 2. Sampling: By the distilled water.

TCAS

\*所得的b不是實際材料的值 而是以符合國內F3甲醛排放量標準<1.5 mg/L 為條件,估計材料的零點逸散速率

### 利用CNS排放標準估計材料常數

台灣CNS標準測量甲醛釋出量參考日本JISA 1460標準-乾燥玻璃腔法

JIS A 1460

1. Conditions: 20°C, 65% humidity. 2. The period:  $\leq$  7 days.

1. Test: 20°C, 24 h. 2. Sampling: By 300 mL distilled water.

#### 玻璃內容量: 9-11L 材料表面積: 150 mm\* 50 mm 試片、1800 cm<sup>2</sup> 以上(包含邊緣) 時間: 24h

經濟部標檢局CNS標準(F3)(平均值:1.5 mg/L)

CNS 1349 普通合板 CNS 2215 粒片板 CNS 9909 中密度纖維板

標示符號	平均值(mg/L)	最大值(mg/L)
F <sub>1</sub>	0.3 以下	0.4 以下
F <sub>2</sub>	0.5 以下	0.7 以下
F <sub>3</sub>	1.5 以下	2.1 以下

表4 甲醛釋出量

## CNS標準方法與ASTMI333方法轉換

Formaldehyde emission from wood products:

relationship between the values by the Chamber method and those by the Desiccator test



**Fig. 5.** Relationship between the concentration of formaldehyde (HCHO) emitted industrial particleboard and medium density fiberboard by the later of the method and by the desiccator test ( $0.04 \text{ ft}^2/\text{ft}^3$  loading ratio, 1-day conditioning).

Desiccator: I.5 mg/L Chamber: 0.2035 ppm= 0.25 mg/m3

 $mg/m^{3}$ formaldehyde = ppm formaldehyde \* 1.23

Z.-L. Que et al. / Composites: Part B 47 (2013) 278 - 282

# 以符合國內甲醛排放量標準為條件的各材料截距係數

材料/等級	F3	F2	FI
粒片板	3.300	0.6600	0.1320
中密度纖維板	3.390	0.6780	0.1356
硬性合板	3.193	0.6385	0.1277
軟性合板	3.278	0.6555	0.1311
複合板材(塗布)	3.255	0.6510	0.1302

138



設定:lognormal distribution, 1.77 h<sup>-1</sup>±1.07

• 依據:Wu P.C. et al. Risk assessment of formaldehyde in typical office buildings in Taiwan Indoor Air. 2003 13(4):359-63.

139

•	其他研究數據:
---	---------

標準狀態下住宅居室換氣次數

头'	凹旷	「九	毁义	扬

换氯次數(次/時) 居室形態 備註 居室不開門或窗 0.5 當開口部加裝窗簾或遮陽板時, 居室一面開門或窗 取表中數值之 2/3。 1 若空氣由開口部之半面流入,由 居室二面開門或窗 1.5 另半面流出,則取表中數值之 居室三面開門或窗 2  $1/2 \circ$ 入口門廳 2

其適用於無強制換氣裝置之標準狀態下之住宅居室

黃政達,「建築物單面通風之換氣效能研究」,碩士論文,中華大學營建管理研究 所,2008。



- 假設: 雅房空間(單一房間模式)
- 設定: 31.7~99 m<sup>3</sup> (Normal distribution; 5%&95%)

-140

- 坪數範圍:4-10坪
- 高度範圍: 2.4-3米

#### 台灣室內溫溼度平均

● 室內溫度: normal distribution; 25.2 °C±3.7

• 室內溼度: normal distribution; 70.9 % ± 9.4

參考資料:林彥旭,「建立以大氣溫度預測室內溫度變化之統計模式」,碩士論文,國立成功大 學環境醫學研究所,2013。n=30

#### 衰减速率的設定

• 半衰期設定: 1.5 ~ 3 years (k= 0.231~0.462) (lognormal distribution; 5%&95%)

Formaldehyde Indoor Air Model – Pressed Wood Products, Version 2.0 (FIAM-pwp v2.0): Model User Manual and Documentation

142

## 暴露參數(19-64歲成人)

- 暴露時間:50年(木製家具使用年限),實際暴露時間=家具使用年限(暫不考慮人在室外室內或進 出其他空間)
- 呼吸率: 17.3 ± 2 m<sup>3</sup>/day = 6315 ± 730 m<sup>3</sup>/year, normal distribution
- 體重: 45 (5%)- 85 (95%) Kg, normal distribution
- 壽命: 80.2 ± 8.02 years (29273 天), normal distribution

參考資料:台灣一般民眾暴露參數彙編,國立台灣大學公共衛生學院健康風險及政策評估中心,2008。 104年簡易生命表,內政部,2015。
### 結果分析-甲醛濃度-時間預測

- 材料假設:中密度纖維板,符合F3標準。
- 表面積:15.6 m<sup>2</sup>



# 不同材料及不同CNS標準下的終身平均每日接受劑量 (LADD)(平均/95%)

材料/等級	F3	F2	FI
粒片板	0.013/0.038	0.0030/0.0083	0.00090/0.002
中密度纖維板	0.013/0.035	0.0029/0.0071	0.00085/0.002
硬性合板	0.014/0.042	0.0032/0.0086	0.00097/0.002
軟性合板	0.014/0.040	0.0030/0.0085	0.00088/0.002



\*台灣室內環境背景的平均LADD = 0.015 mg/kg/day (濃度87.1 µg/m3,

中恭路

50

單位:mg/kg/day





結論與建議

- 成果:可藉由板材種類及表面積資訊計算某家具的終生甲醛每日暴露劑量
- 改善通風率能夠減少對甲醛的暴露
- 建議:
- I.以標準小腔體方法(ASTM D5116 10)建立台灣板材的逸散係數資料庫 (取得平均 m及b)
- 2. 針對個別板材設定逸散標準
- 3. 建立以產品導向的攝取係數資訊 (PiF)

### 簡介產品攝取係數(PIF)



參考資料: Jolliet et al. Defining Product Intake Fraction to Quantify and Compare Exposure to Consumer Products. Environ. Sci. Technol. 2015, 49, 8924-8931

### 以模式使用之該家具的條件(15.6平方公尺、符合F3標 準)為例

149

• 經由呼吸暴露的50年平均累積暴露量為:23.6g

- 假設家具重量:50 公斤
- 尿素甲醛樹脂占比: 10%
- 最大可能甲醛含量: 2.5 公斤 (I:I 甲醛:尿素 聚合)
- 此產品的PiF= 0.0094



- 建立兩個房間(Living room及 Sleeping room)的模擬系統
- 考慮待在房間內的時間分配
- 提供訊息如何減少甲醛的暴露(放置多少時間之後再賣)

150

• 算出致癌風險

#### THANK YOU FOR YOUR ATTENTION

-151

## 台灣室內外甲醛平均背景濃度(參考)

- 室外空間: 0.01853 mg/m<sup>3</sup>
- 参考資料:Wang et al. Measurement and source characteristics of carbonyl compounds in the atmosphere in Kaohsiung city, Taiwan. Journal of Hazardous Materials 179 (2010) 1115–1121
- 室內空間:0.0871 mg/m<sup>3</sup>
- 参考資料: Guo et al. Formaldehyde and volatile organic compounds in Hong Kong homes: concentrations and impact factors. Indoor Air 2009; 19: 206-217 (有台灣數據 n=100)



第2次專家會議 計畫主持人: 莊育權博士 執行單位: 國立台灣大學

# 國際間對於家具中揮發性有害物質之相關 規定

國家/ 組織	單位	條文/規定
歐盟	EU	Commission Decision (EU) 2016/1332 of 28 July 2016
日本	JTCCM	建材からのVOC放散速度基準
美國	BIFMA/ CDPH	ANSI/BIFMA X7.1 - 2011(R2016) Emission testing method for California Specification 01350
中國 大陸	AQSIQ	GB 18584—xxxx木傢俱中揮發性有機物質及重金屬遷移限量



#### Commission Decision (EU) 2016/1332 of 28 July 2016

## **Commission Decision (EU) 2016/1332 of 28 July 2016** establishing the ecological criteria for the award of the EU Ecolabel for furniture

Test parameter	Armchairs	and Sofas	Offic	ce chairs	Other furniture items
Chamber volume			In the range of I	2-10m³	
Loading rate	Product sha	ll occupy approxim	ately 25% of ch	amber volume	*0.5-1.5m <sup>2</sup> /m <sup>3</sup>
Ventilation rate	4.0	m³/h	2.	0 m³/h	*0.5-1.5h <sup>-1</sup>
Substance	3d	28d	3d	28d	28d
Formaldehyde	-	60 µg/m³	-	60 µg/m³	60 µg/m³
TVOC*	≤ 3000 µg/m³	≤ 400 µg/m³	-	≤ 450 µg/m³	≤ 450 µg/m³
TSVOC	-	≤ 100 µg/m³	-	≤ 80 µg/m³	≤ 80 µg/m³
C-substances†	≤ 10 µg/m³ (total limit)	≤ 1 µg/m³ (per substance)	≤ 10 µg/m³ (total limit)	≤ 1 µg/m³ (per substance)	≤ 1 µg/m³ (per substance)
R-value for LCI substances <del>  </del>	-	≤ 1	-	≤ 1	≤ 1



#### JTCCM-建材からのVOC放散速度基準

## 建材からの VOC 放散速度基準 Standard of emission rate of volatile organic compounds from building products

	Table 1Target VOC and the standard value							
	Target VOC	Symbol	Standard value of emission rate					
甲苯	Toluene	Т	$38\mu g/m^2h$					
二甲苯	Xylene	Х	$120\mu g/m^2h$					
乙苯	Ethylbenzene	Е	$550 \mu g/m^2 h$					
苯乙烯	Styrene	S	$32\mu g/m^2h$					

#### • 分析方法

 JIS A1901-建築材料の揮発性有機化合物(VOC),ホルムアルデビド及び他のカルボニル化合物放散測 定方法-小形チャンバー法 Determination of the emission of volatile organic compounds and aldehydes by building products-Small chamber method

## The ground of standard value(1/3)

- The target VOC was selected from chemical substances which can be measured based on JIS A1901, which is the target for concentration determined on public residences and the Housing Performance Indication Standards, and which is considered that may be used in building products.
- The standard value was calculated by the following view. It was referred to the technical evidence of the Building Standard Law against sick house. It was considered an actual VOC emission and condition of using building products. For this reason, this standard value is one criterion under assumed conditions (28°C), and is not a guideline value which is fulfilled with the condition under high temperature.

## The ground of standard value(2/3)

- Assumed conditions on this document were the same as the technical evidence of the Building Standard Law against sick house.
- > It was supposed that target products were used all surfaces in the room, and the surface area of the furniture was three times of the floor area. Therefore loading factor is calculated 3.4 (3.4=2.2+0.4\*3) m2 /m3.
- > It was supposed that air change rate was 0.5/h, and temperature was  $28^{\circ}C$ .

## The ground of standard value (3/3)

Name	Guideline value*	loading factor, L	air change rate	Standard value of
				emission rate
	$\mu g/m^3$	$m^2/m^3$	1/h	$\mu g/m^2h$
Toluene	260			38
Xylene	870		0.5	120
Ethylbenzene	3800	2.2+0.4*3=3.4	0.5	550
Styrene	220			32

Standard value  $\approx \frac{Guideline \ value \ \times air \ change \ rate}{Loading \ factor}$ 



#### -ANSI/BIFMA X7.1 - 2011(R2016)

#### -Emission testing method for California Specification 01350

#### ANSI/BIFMA M7.1-

Standard Test Method for Determining VOC Emissions From Office Furniture Systems, Components and Seating

 1.5 This standard Test Method does not specify or recommend limits of emission rates or concentration in building environments, however the data obtained by using this standard Test Method can be used to determine if the furniture or seating tested meet any applicable acceptance criteria for VOC emissions established elsewhere





#### ANSI/BIFMA M7.1-2011

-Standard Test Method for Determining VOC Emissions From Office Furniture Systems, Components and Seating

				Workstation	Seating	Individual (	Components
Compound Name	CASRN	MW	CREL	Maximum Allowable Conc. (μg/m³)	Maximum Allowable Conc. (μg/m³)	Open Plan Maximum Allowable Emission Factor (μg/m <sup>2</sup> h)	Private Office Maximum Allowable Emission Factor (µg/m <sup>2</sup> h)
Ethylbenzene	100-41-4	106.2	Y	1000	500	689	1392
Styrene	100-42-5	104.2	Y	450	225	310	627
p-Xylene	106-42-3	106.2	Y	350	175	241	487
1,4-Dichlorobenzene	106-46-7	147	Y	400	200	276	557
Epichlorohydrin	106-89-8	92.52	Y	1.5	0.75	1.0	2.1
Ethylene Glycol	107-21-1	62.1	Y	200	100	138	278
1-Methoxy-2-propanol (Propylene glycol monomethyl ether)	107-98-2	90.12	Y	3500	1750	2413	4874
Vinyl Acetate	108-05-4	86.1	Y	100	50	68.9	139
m-Xylene	108-38-3	106.2	Y	350	175	241	487
Toluene	108-88-3	92.1	Y	150	75	103	209
Chlorobenzene	108-90-7	112.56	Y	500	250	345	696
Phenol	108-95-2	94.1	Y	100	50	68.9	139
2-Methoxyethanol	109-86-4	76.1	Y	30	15	21	42
Ethylene glycol monomethyl ether acetate	110-49-6	118.13	Y	45	22.5	31	63
n-Hexane	110-54-3	86.2	Y	3500	1750	2413	4874
2-Ethoxyethanol	110-80-5	90.1	Y	35	17.5	24	49
2-Ethoxyethyl acetate	111-15-9	132.2	Y	150	75	103	209
1,4-Dioxane	123-91-1	88.1	Y	1500	750	1034	2089

CDPH/California Specification 01350

-Standard Method For The Testing And Evaluation Of Volatile Organic Chemical Emission From Indoor Sources Using Environmental Chambers

#### **Table 4-1**Target CREL VOCs and their maximum allowable concentrations

No.	Compound Name	CAS No.	Allowable Conc. <sup>a</sup> (µg/m <sup>3</sup> )	No.	Compound Name	CAS No.	Allowable Conc. <sup>a</sup> (µg/m <sup>3</sup> )
1	Acetaldehyde	75-07-0	70	18	Formaldehyde	50-00-0	16.5 °
2	Benzene	71-43-2	30	19	Hexane (n-)	110-54-3	3,500
3	Carbon disulfide	75-15-0	400	20	Isophorone	78-59-1	1,000
4	Carbon tetrachloride	56-23-5	20	21	Isopropanol	67-63-0	3,500
5	Chlorobenzene	108-90-7	500	22	Methyl chloroform	71-55-6	500
6	Chloroform	67-66-3	150	23	Methylene chloride	75-09-2	200
7	Dichlorobenzene (1,4-)	106-46-7	400	24	Methyl <i>t</i> -butyl ether	1634-04-4	4,000
8	Dichloroethylene (1,1)	75-35-4	35	25	Naphthalene	91-20-3	4.5
9	Dimethylformamide (N,N-)	68-12-2	40	26	Phenol	108-95-2	100
10	Dioxane (1,4-)	123-91-1	1,500	27	Propylene glycol monomethyl ether	107-98-2	3,500
11	Epichlorohydrin	106-89-8	1.5	28	Styrene	100-42-5	450
12	Ethylbenzene	100-41-4	1,000	29	Tetrachloroethylene	127-18-4	17.5
13	Ethylene glycol	107-21-1	200	30	Toluene	108-88-3	150
14	Ethylene glycol monoethyl ether	110-80-5	35	31	Trichloroethylene	79-01-6	300
15	Ethylene glycol monoethyl ether acetate	111-15-9	150	32	Vinvl acetate	108-05-4	100
16	Ethylene glycol monomethyl ether	109-86-4	30	33-35	5 Xylenes, technical mixture	108-38-3,	350
17	Ethylene glycol monomethyl ether acetate	110-49-6	45		(m-, o-, p-xylene combined)	95-47-6.	
						106-42-3	

California E

**PublicHealth** 



#### GB 18584—xxxx

木傢俱中揮發性有機物質及重金屬遷移限量

### GB 18584—×××× 木傢俱中揮發性有機物質及重 金屬遷移限量

### GB/T 18883-2002 室内空气质量标准

\*\*\*\* \* 1 .4. 114 \*\*\*\*0 \*\*\* 木家具中甲醛和苯、甲苯、二甲苯、TVOC 限量 化学性 11 甲醛 HCHO mg/m<sup>3</sup> 0.10 1 小时均值 应符合表1的规定。 12 苯CdHd mg/m<sup>3</sup> 1 小时均值 0.11甲苯 C,H。 13  $mg/m^3$ 1 小时均值 0.20 表1 木家具中甲醛和苯、甲苯、二甲苯、TVOC 限量 14 ·二甲苯 C<sub>8</sub>H<sub>10</sub> mg/m<sup>3</sup> 0.20 1 小时均值 限量值 (mg/m<sup>3</sup>) 项目 15 苯并 [a] 芘 B (a)P ng/m<sup>3</sup> 1.0 日平均值 可吸入颗粒物 PMu 甲醛释放量 ≤0.10 16 mø/m<sup>3</sup> 0.15 日平均值 17 总挥发性有机物 TVOC  $mg/m^3$ 苯 8小时均值 ≤0.11 0.60甲苯 ≤0.20 • A.4.1 篩選法採樣:採樣前 二甲苯 ≤0.20 關閉門窗12h,採樣時關 TVOC ≤0.60 閉門窗,至少採樣45 min。

### GB 18584—×××× 木傢俱中揮發性有機物質及重 金屬遷移限量

5.3.1.3 气候舱选择
 气候舱的体积承载率应满足(0.075~0.3)的范围,并按体积承载率最接近0.15的原则选择合适的气候舱。

n = Q / V = a / 0.15 (1)

• 5.3.1.5 甲醛和 VOC 的采集

试验期间,气候舱内试验条件应满足:

----温度(23±2)℃;

----相对湿度(45±5)%;

----空气交换率,按式(1)计算;

----空气流速(0.1~0.3)m/s;

----进给空气中甲醛和苯、甲苯、二甲苯、TVOC浓度:甲醛<0.006mg/m3,单个VOC<0.005mg/m3,TVOC <0.05mg/m3;

样品放入气候舱内(20±0.5)h后,按GB/T 31106-2014中的规定进行空气采样,1h内完成。

# 各國制訂VOC標準之差異

- 國際間僅中國大陸制定VOC於家具中之國家標準,日本之VOC標準是針對 建築材料所至訂,美國與歐盟則是提供制訂標準所需的評估方法。
- VOC的項目不同,由於各國VOC的規範不同,因此制訂標準的特定VOC則 有所差異,中國大陸有3項(苯、甲苯、二甲苯)、日本有4項(甲苯、乙苯、 二甲苯、苯乙烯)、歐盟分為致癌物與LCI列表物質目,美國則以家具可能 釋放之VOC項目作為目標VOCs。
- 家具釋放VOC的環境差異,日本與中國大陸以室內環境作為評估的情境, 美國則以辦公室的家具作為評估的前題。
- 家具中釋放VOC的標準值不同,中國大陸以濃度為標準,單位為mg/m<sup>3</sup>; 日本以釋放率為標準,單位為µg/m<sup>2</sup>h

# 各國制訂VOC標準之共同基本資訊

- 基準值:各國制定家具中VOC標準時,會以特定之基準值作為依據,如EU-LCI(歐盟)、室內空氣濃度(日本、中國大陸)、CREL(美國)。
- 暴露情境:家具擺放場所的環境條件會影響了由家具釋放VOC至室 內空氣中的濃度,主要考量的參數有換氣率和附載率。
  - 換氣率:日本-0.5 (1/h)、中國大陸、美國、歐盟-1(1/h)
  - 附載率:美國 0.3-1 (m2/m3)、歐盟 0.25(-)、中國大陸 0.075~0.3(-)、日本 2.2 (m2/m3)

# 符合標準下個別VOC之暴露濃度

	歐盟	日本	美國	中國大陸
苯	0.001		0.03	0.11
甲苯	2.9	0.19	0.15	0.2
二甲苯	0.5	0.6	0.35	0.2
乙苯	0.8	2.75	1	
苯乙烯	0.25	0.16	0.45	
				·迪府留位为ma/m3

濃度單位為mg/m<sup>2</sup>

# 各國符合標準下個別VOC之可接受健康風 險值

VOCs	危害因子	歐盟	日本	美國	中國大陸		
致癌性	Uint risk (WHO)	血癌風險					
苯	$6 \text{ x} 10^{-6} \text{ per } \mu\text{g}/\text{m}^3$	6 x10 <sup>-6</sup>		1.8 x10 <sup>-5</sup>	6.6 x10 <sup>-4</sup>		
非致癌性	RfC (US EPA)		非致癌風險	<b>à</b> -危害指數			
苯	0.03	0.03		1.00	3.67		
甲苯	5	0.58	0.04	0.03	0.04		
二甲苯	0.1	5.00	6.00	3.50	2.00		
乙苯	1	0.80	2.75	1.00			
苯乙烯	1	0.25	0.16	0.45			



- 國際對於致癌性化學物質可接受之健康風險在10-4~10-6之間,健康風險評估之結果顯示,中國大陸標準下之健康風險超過10-4,故不建議參考中國大陸家具中苯的釋放量標準。
- 非致癌風險的部分,依照國際間對於二甲苯的管制濃度下HI>1,代表此評估情境下家具中之二甲苯會度人體造成健康上之不良效應。
  另外日本標準下之乙苯與中國大陸標準下之苯都超過1,因此制定國內家具中VOC標準時須進一步探討。

## 制訂VOC標準之建議

- 國際間制定生活用品中揮發性有害物質的標準時會參考相關法規之基準值後,再依生活用品的使用特性與情境配合標準分析以評估特定生活用品中特定化學物質之限量標準。
- 以家具中VOC為例,由於家具與室內空氣品質有關,因此法規的基準值初步評估可參考室內空氣品質標準作為依據(如日本、中國大陸),未來可規劃以個別VOC的安全暴露濃度作為制訂標準的依據(美國、歐盟)。
- 但由於目前我國室內空氣品質標準並無個別VOC之濃度限值,在缺乏法規 的基準值情況下,制訂家具中VOC限值時可納入健康風險資訊的比較結果, 可降低使用者的疑慮。

# Thank you for your attention

附錄四、期中報告會前會會議資料

#### 106年度「含揮發性有害物質之生活用品風險模擬研究計畫」

#### 期中報告會前會

#### 會議紀錄

- 一、時間:106年6月30日(星期五)下午2時
- 二、地點:本局第6會議室(臺北市濟南路1段4號標準資料大樓3樓)

三、主持人:倪組長士瑋

記錄:陳永翰

- 四、出席人員:詳如出席人員名冊
- 五、業務單位(第一組第四科)報告:略。
- 六、受託單位(國立臺灣大學)報告:略。
- 七、決議事項:請受委託單位修正及增加報告內容如下:
  - (一)揮發性有害物質包含如:苯系物、有機氯化物、有機酮、胺、醇、 醚等,惟受託單位僅模擬甲醛一項,內容不夠充分,建請增加其 他物質之模擬。
  - (二)因國內環境溫度與濕度變化明顯,故請增加說明敏感度分析部分 之內容。
  - (三)有關報告內容是以家俱產品作為模擬對象,建議未來亦將兒童用品作為模擬之對象。
  - (四)請增加說明本計畫之研究基礎及各模擬參數之影響,另請提出貝
    - 式統計與馬可夫鏈蒙地卡羅與其他模型之優缺點說明。
  - (五)報告內容有大量引用文獻計算公式部分,請標明出處並將每一代數代

表之意義用中文清楚說明。

- (六)報告內容說明請用簡單易懂之敘述方式。
- (七)依 WTO 的技術性貿易障礙協定,要求國家標準必須與國際標準進行調

和,若無法調和則需要證明此一國際標準無法適用於該國家,而本計 畫之目的,是以模擬出適用於臺灣環境的各種揮發性有害物質對於 人體的風險評估數據並能接受國際檢驗,受託單位應朝此目的執 行本計畫。

- (八)有關甲醛測試方法有許多方式如小型模擬箱法或乾燥瓶法等,這些測試方法代表的意義為何,各測試方法所得數據是否可互相進行轉換,請報告內增加說明。
- (九)請參考行政院環保署訂定之室內空氣品質法,作為本計畫模擬之 依據。
- (十)報告內容中提到致癌風險部分,請加強論述說明。
- (十一)未來執行方向應朝家俱或其他日常用品之揮發性有害物質限 量值的提供為主。
- (十二)產品攝取係數僅只有一件,數量不足,請增加其他 VOC 之模擬 攝取係數至少達八件。
- (十三)有關家俱之模擬箱法甲醛釋出量的實驗數據,建議受託單位可 洽內政部建築研究所協助提供。
- (十四)有關行政院環保署訂定之室內空氣品質法規定甲醛一小時釋

放量為 0.08 ppm,請增加以此參數模擬之健康風險評估數據。 八、臨時動議:無。

#### 九、散會

附錄五、國際間家具中非甲醛之 VOC 標準
# DECISIONS

# COMMISSION DECISION (EU) 2016/1332

# of 28 July 2016

# establishing the ecological criteria for the award of the EU Ecolabel for furniture

(notified under document C(2016) 4778)

## (Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel (<sup>1</sup>), and in particular Articles 6(7) and 8(2) thereof,

After consulting the European Union Eco-labelling Board,

Whereas:

- (1) Under Regulation (EC) No 66/2010, the EU Ecolabel may be awarded to products which have a reduced environmental impact during their entire life cycle.
- (2) Regulation (EC) No 66/2010 provides that specific EU Ecolabel criteria are to be established according to product groups.
- (3) Commission Decision 2009/894/EC (<sup>2</sup>) has established the ecological criteria and the related assessment and verification requirements for wooden furniture, which are valid until 31 December 2016.
- (4) In order to better reflect the range of furniture products on the market, the state of the art for these products and to take into account the innovation of the last few years, it is appropriate to extend the scope of the product group to include non-wooden furniture and to establish a revised set of ecological criteria.
- (5) The revised ecological criteria aim at using materials produced in a more sustainable way (considering a life cycle analysis approach), limiting the use of hazardous compounds, the levels of hazardous residues, the contribution of furniture to indoor air pollution and promoting a durable and high-quality product that is easy to repair and disassemble. The revised criteria, along with the related assessment and verification requirements should be valid for six years from the date of adoption of this Decision, taking into account the innovation cycle for this product group.
- (6) Decision 2009/894/EC should therefore be replaced.
- (7) It is appropriate to allow a transitional period for producers whose products have been awarded the EU Ecolabel for wooden furniture on the basis of the ecological criteria set out in Decision 2009/894/EC, so that they have sufficient time to adapt their products to comply with the revised ecological criteria and requirements. Producers should also be allowed to submit applications based on the ecological criteria set out in Decision 2009/894/EC for a sufficient period of time.

<sup>(&</sup>lt;sup>1</sup>) OJ L 27, 30.1.2010, p. 1.

<sup>(2)</sup> Commission Decision 2009/894/EC of 30 November 2009 on establishing the ecological criteria for the award of the Community ecolabel for wooden furniture (OJ L 320, 5.12.2009, p. 23).

(8) The measures provided for in this Decision are in accordance with the opinion of the Committee established by Article 16 of Regulation (EC) No 66/2010,

HAS ADOPTED THIS DECISION:

## Article 1

1. The product group 'furniture' shall comprise free-standing or built-in units whose primary function is to be used for the storage, placement or hanging of items and/or to provide surfaces where users can rest, sit, eat, study or work, whether for indoor or outdoor use. The scope extends to domestic furniture and contract furniture items for use in domestic or non-domestic environments. Bed frames, legs, bases and headboards are included in the scope.

- 2. The product group shall not comprise the following products:
- (a) Bed mattresses, which are covered by the criteria set out in Commission Decision 2014/391/EU (1),
- (b) Products whose primary function is not to be used as per paragraph 1, including streetlights, railings and fences, ladders, clocks, playground equipment, stand-alone or wall-hung mirrors, electrical conduits, road bollards and building products such as steps, doors, windows, floor coverings and cladding.
- (c) Second-hand, refinished, refurbished or remanufactured furniture products.
- (d) Furniture fitted in vehicles used for public or private transit.
- (e) Furniture products which consist of more than 5 % (weight by weight) of materials not included in the following list: solid wood, wood-based panels, cork, bamboo, rattan, plastics, metals, leather, coated fabrics, textiles, glass and padding/filling materials.

#### Article 2

For the purpose of this Decision, the following definitions shall apply:

- (a) 'Aniline leather' means leather whose natural grain is clearly and completely visible and where any surface coating with a non-pigmented finish is less than or equal to 0,01 mm, as defined in EN 15987;
- (b) 'Semi-aniline leather' means leather that has been coated with a finish containing a small amount of pigment, so that the natural grain is clearly visible, as defined in EN 15987;
- (c) 'Pigmented and pigmented split leather' means leather or split leather whose natural grain or surface is completely concealed with a finish containing pigments, as defined in EN 15987;
- (d) 'Patent and patent split leather' means leather or split leather with generally a mirror-like effect, obtained by application of a layer of pigmented or non-pigmented varnishes, or synthetic resins, whose thickness does not exceed one third of the total thickness of the product, as defined in EN 15987;
- (e) 'Coated and coated split leather' means leather or split leather where the surface coating, applied to the outer side, does not exceed one third of the total thickness of the product but is in excess of 0,15 mm, as defined in EN 15987;
- (f) 'Volatile organic compound' (VOC) means any organic compound having an initial boiling point of less than or equal to 250 °C measured at a standard pressure of 101,3 kPa as defined in Directive 2004/42/EC of the European Parliament and of the Council (<sup>2</sup>) and which, in a capillary column, are eluting up to and including tetradecane  $(C_{14}H_{30})$ ;

<sup>(&</sup>lt;sup>1</sup>) Commission Decision 2014/391/EU of 23 June 2014 establishing the ecological criteria for the award of the EU Ecolabel for bed mattresses (OJ L 184, 25.6.2014, p. 18).

<sup>(2)</sup> Directive 2004/42/CE of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC (OJ L 143, 30.4.2004, p. 87).

- (g) 'Semi volatile organic compound' (SVOC) means any organic compound having a boiling point of greater than 250 °C and less than 370 °C measured at a standard pressure of 101,3 kPa and which, in a capillary column are eluting with a retention range after n-tetradecane ( $C_{14}H_{30}$ ) and including n-Docosane ( $C_{22}H_{46}$ );
- (h) 'Recycled content' means the proportion, by mass, of recycled material in a product or packaging; only preconsumer and post-consumer materials are considered as recycled content, as defined in ISO 14021;
- (i) 'Pre-consumer material' means material diverted from the waste stream during a manufacturing process but excluding the reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it as defined in ISO 14021 and also excludes waste wood, chips and fibres from logging and sawmilling operations;
- (j) 'Post-consumer material' means material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose, including returns of material from the distribution chain, as defined in ISO 14021;
- (k) 'Recovered/reclaimed material' means material that would have otherwise been disposed of as waste or used for energy recovery, but has instead been collected and recovered/reclaimed as a material input, in lieu of new primary material, for a recycling or a manufacturing process, as defined in ISO 14021;
- (l) 'Recycled material' means material that has been reprocessed from recovered/reclaimed material by means of a manufacturing process and made into a final product or into a component for incorporation into a product as defined in ISO 14021, but excludes waste wood, chips and fibres from logging and sawmilling operations;
- (m) 'Wood-based panels' means panels fabricated from wood fibres by one of several different processes that may involve the use of elevated temperatures, pressures and binding resins or adhesives;
- (n) 'Oriented Strand Board' means multi-layered board mainly made from strands of wood together with a binder, as defined in EN 300. The strands in the external layer are aligned and parallel to the board length or width. The strands in the internal layer or layers can be randomly orientated or aligned, generally at right angles to the strands in the external layers;
- (o) 'Particleboard' means a panel material manufactured under pressure and heat from particles of wood (wood flakes, chips, shavings, saw-dust and similar) and/or other lignocellulosic material in particle form (flax shives, hemp shives, bagasse fragments and similar), with the addition of an adhesive, as defined in EN 309;
- (p) 'Plywood' means wood-based panels consisting of an assembly of layers glued together with the direction of the grain in adjacent layers usually at right angles, as defined in EN 313. Many different sub-categories of plywood can be referred to based on how the plywood is structured (such as, veneer plywood, core plywood, balanced plywood) or its predominant end use (for instance, marine plywood);
- (q) 'Fibreboards' means a broad set of panel types which are defined in EN 316 and EN 622 and which can be split into the sub-categories of hardboards, medium boards, soft-boards and dry-process boards based on their physical properties and production process;
- (r) 'Readily biodegradable substance' means a substance that shows 70 % degradation of dissolved organic carbon within 28 days or 60 % of theoretical maximum oxygen depletion or carbon dioxide generation within 28 days using one of the following test methods: OECD 301 A, ISO 7827, OECD 301 B, ISO 9439, OECD 301 C, OECD 301 D, ISO 10708, OECD 301 E, OECD 301 F, ISO 9408;
- (s) 'Inherently biodegradable substance' means a substance that shows 70 % degradation of dissolved organic carbon within 28 days or 60 % of theoretical maximum oxygen depletion or carbon dioxide generation within 28 days using one of the following test methods: ISO 14593, OECD 302 A, ISO 9887, OECD 302 B, ISO 9888, OECD 302 C;
- (t) 'Finishing operations' means methods where an over-layer or coating is applied to the surface of a material. Methods may include the application of paints, prints, varnishes, veneers, laminates, impregnated papers and finishing foils;

- (u) 'Biocidal product' as defined in Regulation (EU) No 528/2012 of the European Parliament and of the Council (<sup>1</sup>) means:
  - any substance or mixture, in the form in which it is supplied to the user, consisting of, containing or generating one or more active substances, with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical action,
  - any substance or mixture generated from substances or mixtures which do not themselves fall under the preceding paragraph, to be used with the intention of destroying, deterring, rendering harmless, preventing the action of, or otherwise exerting a controlling effect on, any harmful organism by any means other than mere physical or mechanical means, and
  - a treated article that has a primary biocidal function;
- (v) 'Wood preservatives' means biocidal products which are applied by surface treatment (e.g. spraying, brushing) or deep penetrating processes (e.g. vacuum-pressure, double vacuum) to wood (i.e., logs received at the sawmill for commercial use and for all subsequent uses of the wood and wood-based products) or wood-based products themselves, or which are applied to non-wood substrates (e.g. masonry and building foundations) solely for the purpose of protecting adjacent wood or wood-based products from attack by wood-destroying organisms (e.g. dry rot and termites) according to the definition agreed upon by the European Committee for Standardisation (source CEN/TC 38 'Durability of wood and wood-based products');
- (w) 'E1' means a classification for formaldehyde-containing wood-based panels adopted across EU Member States based on formaldehyde emissions. According to the definition provided in Annex B to EN 13986, a wood-based panel shall be classified as E1 if emissions are equivalent to steady state concentrations of less than or equal to 0,1 ppm (0,124 mg/m<sup>3</sup>) of formaldehyde after 28 days of a chamber test carried out according to EN 717-1 or that the formaldehyde content is determined to be less than or equal to 8 mg/100 g oven dry board when measured according to EN 120 or that formaldehyde emission rates are less than or equal to 3,5 mg/m<sup>2</sup>.h according to EN 717-2 or less than or equal to 5,0 mg/m<sup>2</sup>.h according to the same method but within 3 days after production;
- (x) 'Coated fabrics' means fabrics with an adherent, discrete continuous layer of rubber and/or plastic based material on one or both surfaces, as defined in EN 13360, including upholstery materials commonly referred to as 'faux leather';
- (y) 'Textiles' mean natural fibres, synthetic fibres and man-made cellulose fibres;
- (z) 'Natural fibres' means cotton and other natural cellulosic seed fibres, flax and other bast fibres, wool and other keratin fibres;
- (aa) 'Synthetic fibres' means acrylic, elastane, polyamide, polyester and polypropylene fibres;
- (bb) 'Man-made cellulose fibres' means lyocell, modal and viscose fibres;
- (cc) 'Upholstery' means the materials used in the craft of covering, padding and stuffing of seating, bedding or other furniture products and may include covering materials such as leather, coated fabrics and textiles as well as padding materials such as flexible cellular polymeric materials based on rubber latex and polyurethane;
- (dd) 'Substance', means a chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition, as defined in Article 3(1) of Regulation (EC) No 1907/2006 of the European Parliament and of the Council (<sup>2</sup>);
- (ee) 'Mixture' means a mixture or solution composed of two or more substances as defined in Article 3(2) of Regulation (EC) No 1907/2006;

<sup>(&</sup>lt;sup>1</sup>) Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 concerning the making available on the market and use of biocidal products (OJ L 167, 27.6.2012, p. 1).

<sup>(2)</sup> Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC (OJ L 396, 30.12.2006, p. 1).

- (ff) 'Component part' means rigid and discrete units whose shape and form does not need to be altered prior to assembly of the final product in its fully functional form, although its position may change during use of the final product and includes hinges, screws, frames, drawers, wheels and shelves;
- (gg) 'Component materials' means materials whose shape and form may change prior to furniture assembly or during use of the furniture product, and includes textiles, leather, coated fabrics and polyurethane foams used in upholstery. Supplied timber may be considered as a component material but be later sawn and treated to be converted into a component part.

## Article 3

In order to be awarded the EU Ecolabel under Regulation (EC) No 66/2010, a product shall fall within the product group 'furniture' as defined in Article 1 of this Decision and shall comply with the ecological criteria as well as the related assessment and verification requirements set out in the Annex to this Decision.

#### Article 4

The ecological criteria for the product group 'furniture' and the related assessment and verification requirements shall be valid for six years from the date of adoption of this Decision.

#### Article 5

For administrative purposes, the code number assigned to the product group 'furniture' shall be '049'.

Article 6

Decision 2009/894/EC is repealed.

Article 7

1. By derogation from Article 6, applications for the EU Ecolabel for products falling within the product group 'wooden furniture' submitted before the date of adoption of this Decision shall be evaluated in accordance with the conditions laid down in Decision 2009/894/EC.

2. Applications for the EU Ecolabel for products falling within the product group 'wooden furniture' submitted within two months from the date of adoption of this Decision may be based either on the criteria set out in Decision 2009/894/EC or on the criteria set out in this Decision.

Applications shall be evaluated in accordance with the criteria on which they are based.

3. EU Ecolabel licences awarded in accordance with the criteria set out in Decision 2009/894/EC may be used for 12 months from the date of adoption of this Decision.

# Article 8

This Decision is addressed to the Member States.

Done at Brussels, 28 July 2016.

For the Commission Karmenu VELLA Member of the Commission

## ANNEX

#### FRAMEWORK

# EU ECOLABEL CRITERIA

Criteria for awarding the EU Ecolabel to furniture products:

- 1. Product description
- 2. General requirements for hazardous substances and mixtures
- 3. Wood, cork, bamboo and rattan
- 4. Plastics
- 5. Metals
- 6. Upholstery covering materials
- 7. Upholstery padding materials
- 8. Glass: use of heavy metals
- 9. Final product requirements
- 10. Consumer information
- 11. Information appearing on the EU Ecolabel

## ASSESSMENT AND VERIFICATION REQUIREMENTS

The specific assessment and verification requirements are indicated within each criterion.

Where the applicant is required to provide declarations, documentation, analyses, test reports, or other evidence to show compliance with the criteria, these may originate from the applicant and/or his supplier(s) and/or their suppliers, etc., as appropriate.

Competent bodies shall preferentially recognise attestations which are issued by bodies accredited according to the relevant harmonised standard for testing and calibration laboratories and verifications by bodies that are accredited according to the relevant harmonised standard for bodies certifying products, processes and services.

Where appropriate, test methods other than those indicated for each criterion may be used if the competent body assessing the application accepts their equivalence.

Where appropriate, competent bodies may require supporting documentation and may carry out independent verifications.

As a pre-requisite, the product must meet all respective legal requirements of the country (countries) in which the product is intended to be placed on the market. The applicant shall declare the product's compliance with this requirement.

The EU Ecolabel criteria reflect the best environmental performing products on the furniture market. The criteria are focused on a 'per material' basis for ease of assessment given that many furniture products will only contain one or two of the above listed materials.

Whilst the use of chemicals and release of pollutants is part of the production process, the use of hazardous substances are excluded whenever possible or limited to the minimum necessary to provide an adequate function and at the same time strict quality and safety standards for furniture products. For this purpose, derogation conditions for specific substances/groups of substances are granted in exceptional circumstances, in order not to shift the environmental burden to other life cycle phases or impacts and only when there are no viable alternatives existing on the market.

#### **Criterion 1** — **Product Description**

Technical drawings that illustrate the assembly of component parts/materials and sub-component parts/materials that form the final furniture product and its dimensions shall be provided to the competent body along with a bill of materials for the product that shall state the total weight of the product itself and how this is split between the following different materials: solid wood, wood-based panels, cork, bamboo, rattan, plastics, metals, leather, coated fabrics, textiles, glass and padding/filling materials.

Any remaining materials that do not fall within the categories above shall be listed as 'other' materials.

The total quantity of 'other' materials shall not exceed 5 % of the total product weight.

Assessment and verification: The applicant shall provide documentation to the competent body containing:

- (i) Technical drawings that illustrate the different component parts/materials and sub-component parts/materials used in the assembly of the furniture product;
- (ii) An overall bill of materials stating the total weight of the product unit and how the weight is split amongst solid wood, wood-based panels, cork, bamboo, rattan, plastics, metals, leather, textiles, coated fabrics, glass, padding/filling and 'other' materials. Weights of different materials shall be expressed as grams or kilograms and as a percentage of the total product unit weight.

# Criterion 2 — General requirements for hazardous substances and mixtures

The presence in the product and any component parts/materials thereof, of substances that are identified according to Article 59(1) of Regulation (EC) No 1907/2006 as substances of very high concern (SVHCs) or substances and mixtures that meet the criteria for Classification, Labelling and Packaging (CLP) according to Regulation (EC) No 1272/2008 of the European Parliament and of the Council (<sup>1</sup>) for the hazards listed in Table 1, shall be restricted in accordance with criteria 2.1, 2.2(a) and 2.2(b).

For the purpose of this criterion Candidate List SVHCs and CLP hazard classifications are grouped in Table 1 according to their hazardous properties.

Table 1

# Grouping of restricted hazards

#### Group 1 hazards — SVHCs and CLP

Hazards that identify a substance or mixture as being within Group 1:

Substances that appear on the Candidate List for SVHCs

Carcinogenic, Mutagenic and/or Toxic for Reproduction (CMR) Category 1A or 1B: H340, H350, H350i, H360, H360F, H360D, H360Fd, H360Df

<sup>(&</sup>lt;sup>1</sup>) Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (OJ L 353, 31.12.2008, p. 1).

# Group 2 hazards — CLP

Hazards that identify a substance or mixture as being within Group 2: Category 2 CMR: H341, H351, H361f, H361d, H361fd, H362 Category 1 aquatic toxicity: H400, H410 Category 1 and 2 acute toxicity: H300, H310, H330 Category 1 aspiration toxicity: H304 Category 1 Specific Target Organ Toxicity (STOT): H370, H372 Category 1 Skin Sensitiser H317

## Group 3 hazards — CLP

Hazards that identify a substance or mixture as being within Group 3: Category 2, 3 and 4 aquatic toxicity: H411, H412, H413 Category 3 acute toxicity: H301, H311, H331, EUH070 Category 2 STOT: H371, H373

#### 2.1. Restriction of SVHCs

The product and any component parts/materials thereof, shall not contain SVHCs, at concentrations greater than 0,10 % (weight by weight).

No derogation from this requirement shall be given to Candidate List SVHCs present in the product or any component parts/materials thereof at concentrations greater than 0,10 % (weight by weight).

Textiles that have been awarded the EU Ecolabel based on the ecological criteria established in Commission Decision 2014/350/EU (<sup>1</sup>) are considered to comply with criterion 2.1.

Assessment and verification: The applicant shall compile declarations of the absence of SVHCs at or above the specified concentration limit for the product and any component parts/materials used in the assembly of the product. Declarations shall be with reference to the latest version of the Candidate List published by ECHA (<sup>2</sup>).

For textiles that have been awarded the EU Ecolabel in accordance with Decision 2014/350/EU, a copy of the EU Ecolabel certificate must be provided as a proof of compliance.

2.2. Restriction of CLP classified substances and mixtures used in the furniture product

The requirements are split into two parts, based on the production stage of the furniture product. Part a) refers to substances and mixtures used during any finishing or assembly operations carried out directly by the furniture manufacturer. Part b) refers to substances and mixtures used during the production of supplied component parts/ materials.

Textiles that have been awarded the EU Ecolabel based on the ecological criteria established in Decision 2014/350/EU are considered to comply with criteria 2.2(a) and 2.2(b).

2.2(a) Substances and mixtures used by the furniture manufacturer

None of the adhesives, varnishes, paints, primers, wood stains, biocidal products (such as wood preservatives), flame retardants, fillers, waxes, oils, joint fillers, sealants, dyestuff, resins or lubricating oils directly used by the furniture manufacturer shall be classified with any of the CLP hazards listed in Table 1, unless their use is specifically derogated in Table 2.

2.2(b) Substances and mixtures used by suppliers of defined component parts/materials

This criterion shall not apply to individual component parts/materials from suppliers that: (i) weigh less than 25 g and that (ii) do not come into direct contact with users during normal use.

<sup>(&</sup>lt;sup>1</sup>) Commission Decision 2014/350/EU of 5 June 2014 establishing the ecological criteria for the award of the EU Ecolabel for textile products (OJ L 174, 13.6.2014, p. 45).

<sup>(2)</sup> ECHA, Candidate List of substances of very high concern for Authorisation, http://www.echa.europa.eu/candidate-list-table.

None of the substances or mixtures used by suppliers that fall within the scope defined below shall be classified with any of the CLP hazards listed in Table 1, unless their use is specifically derogated in Table 2:

- Solid wood and wood-based panels: adhesives, varnishes, paints, wood stains, biocidal products (such as
  wood preservatives), primers, flame retardants fillers, waxes, oils, joint fillers, sealants and resins used.
- Plastics: pigments, plasticisers, biocidal products and flame retardants used as additives.
- Metals: paints, primers or varnishes applied to the metal surface.
- Textiles, leather and coated fabric upholstery: dyestuff, varnishes, optical brighteners, stabilisers, auxiliary compounds, flame retardants, plasticisers, biocidal products or water/dirt/stain repellents used.
- Upholstery padding materials: biocidal products, flame retardants or plasticisers applied to the material.

#### Table 2

# Derogations to the hazard restrictions in Table 1 and applicable conditions

Substance/mixture type	Applicability	Derogated classification(s)	Derogation conditions
(a) Biocidal products (such as wood preservatives)	Treatment of furni- ture component parts and/or uphols- tery materials to be used in the final product	All group 2 and 3 hazards listed in Table 1 except for CMR hazards	Only if the active substance contained in the biocidal product is approved, or un- der examination pending a decision on approval, under Regulation (EU) No 528/2012 or included in Annex I of that Regulation, and in the following cir- cumstances, as appropriate:
			i. For in-can preservatives present in coating formulations applied to in- door or outdoor furniture component parts/materials.
			ii. For dry-film preservatives present in coatings applied to outdoor furniture only.
			iii. For preservation treatment of wood to be used in outdoor furniture but only if the original wood does not meet the requirements for Durability class 1 or 2 as per EN 350.
			iv. For textile fabrics or coated fabrics used in outdoor furniture products.
			Verification:
			The applicant shall declare which, if any, active substances contained in the bioci- dal product have been used in the manu- facture of different furniture component parts/materials, supported by declarations from suppliers, relevant SDSs, CAS num- bers and results from EN 350 testing, as appropriate.

Substance/mixture type	Applicability	Derogated classification(s)	Derogation conditions
(b) Flame retardants	Textiles, leather, coated fabrics in fur- niture upholstery covering materials and also padding materials	H317, H373, H411, H412, H413	The product must be intended to be used in applications in which it is required to meet fire protection requirements for ISO, EN, Member State or public sector pro- curement standards and regulations.
(c) Flame retardants/ Antimony Triox- ide (ATO)		H351	<ul> <li>ATO is only permitted when all of the following conditions are met:</li> <li>i. The product must be intended to be used in applications in which it is required to meet fire protection requirements in ISO, EN, Member State or public sector procurement standards and regulations.</li> <li>ii. It is used as a synergist with textiles or coated fabrics.</li> <li>iii. Emissions to air in the workplace where the flame retardant is applied to the textile product shall meet an eight hour occupational exposure limit value of 0,50 mg/m<sup>3</sup>.</li> </ul>
(d) Nickel	Metal component parts	Н317, Н351, Н372	Only permitted when used in stainless steel or nickel-plated component parts and when the nickel release rate is less than 0,5 $\mu$ g/cm <sup>2</sup> /week according to EN 1811.
(e) Chromium com- pounds		H317, H411	Derogation only applies to chromium III compounds used in electroplating opera- tions (e.g., chromium III chloride).
(f) Zinc compounds		H300, H310, H330, H400, H410	Derogation only applies to zinc com- pounds used in electroplating or hot-dip galvanisation operations (such as, zinc oxide, zinc chloride and zinc cyanide).
(g) Dyestuff for dye- ing and non-pig- ment printing	Textiles, leather and coated fabrics in fur- niture upholstery covering materials	H301, H311, H317, H331	When dust free dye formulations or auto- matic dosing and dispensing of dyes are used by dye houses and printers to mini- mise worker exposure.

Substance/mixture type	Applicability	Derogated classification(s)	Derogation conditions
		H411, H412, H413	<ul> <li>Dyeing processes using reactive, direct, vat or sulphur dyes with these classifications shall meet a minimum of one of the following conditions: <ol> <li>Use of high affinity dyes;</li> <li>Achievement of a reject rate of less than 3,0 %;</li> </ol> </li> <li>Use of colour matching instrumentation;</li> <li>Implementation of standard operating procedures for the dyeing process;</li> <li>Use of colour removal to treat wastewater (*).</li> </ul>
(h) Optical bright- eners	Textiles, leather and coated fabrics in fur- niture upholstery covering materials	H411, H412, H413	Optical brighteners may only be applied in the following cases: i. In white coloured printing; ii. As additives during the production of acrylic, polyamide or polyester with a recycled content.
(i) Water, dirt and stain repellents	Use in any surface treatments of furni- ture component parts/materials	H413	<ul> <li>The repellent and its degradation products shall either:</li> <li>i. be readily and/or inherently biodegradable or</li> <li>ii. have a low potential to bioaccumulate (an octanol-water partition coefficient Log Kow ≤ 3,2 or a Bioconcentration Factor (BCF) &lt; 100) in the aquatic environment, including aquatic sediment.</li> </ul>
(j) Stabilisers and varnishes	Use in coated fabric production	H411, H412, H413	Automatic dosing and/or personal protective equipment must be used to minimise worker exposure. At least 95 % of these additives must show at least 80 % degradation of dissolved organic carbon within 28 days using OECD 303A/B and/or ISO 11733 test methods.
(k) Auxiliaries (com- prising carriers, levelling agents, dispersing agents, surfactants, thick- eners and binders)	Use in treatment of furniture upholstery covering materials (textiles, leather or coated fabrics)	H301, H311, H317, H331, H371, H373, H411, H412, H413, EUH070	Recipes shall be formulated using auto- matic dosing systems and processes shall follow standard operating procedures. Substances classified with H311 or H331 shall not be present on the material at concentrations greater than 1,0 % w/w.

Substance/mixture type	Applicability	Derogated classification(s)	Derogation conditions	
(l) Paints, varnishes, resins and adhe- sives	Any furniture com- ponent part/material	H304, H317, H412, H413, H371, H373	A Safety Data Sheet (SDS) of the chemical mixture which clearly outlines the correct Personal Protective Equipment and ade- quate procedures for storage, handling, use and disposal of these mixtures during use and a declaration of proof of compli- ance with these measures shall be pro- vided.	
		H350	Only applicable to formaldehyde-based resins where the free formaldehyde con- tent in the resin formulation (resins, adhe- sives and hardeners) does not exceed 0,2 % (w/w) as determined by ISO 11402 or equivalent methodology.	
(m) Lubricating oils	In component parts designed to move re- peatedly during nor- mal use	All Group 2 hazards except CMR and all Group 3 hazards listed in Table 1	Lubricants shall only be permitted for use if it can be demonstrated by relevant OECD or ISO tests to be readily or inher- ently biodegradable in the aquatic envir- onment, including aquatic sediment.	
(*) Colour removal in wastewater treatment shall be considered as taking place when effluents from the dyehouse meets the fol-				

(\*) Colour removal in wastewater treatment shall be considered as taking place when efficients from the dyenouse meets the lowing spectral coefficients: (i) 7m<sup>-1</sup> at 436 nm, 5m<sup>-1</sup> at 525 nm and 3m<sup>-1</sup> at 620 nm.

Assessment and verification: The applicant shall provide a declaration of compliance with criterion 2.2(a) and 2.2(b) supported, where appropriate, by declarations from suppliers. Declarations shall be supported by lists of relevant mixtures or substances used together with information about their hazard classification or non-classification.

The following information shall be provided to support declarations of the hazard classification or non-classification for each substance or mixture:

- (i) The CAS, EC or list number (where available for mixtures);
- (ii) The physical form and state in which the substance or mixture is used;
- (iii) Harmonised CLP hazard classifications for substances;
- (iv) Self-classification entries in ECHA's REACH registered substance database (1) (if no harmonised classification is available).
- (v) Mixture classifications according to the criteria laid down in the CLP Regulation.

When considering self-classification entries in the REACH registered substance database, priority shall be given to entries from joint submissions.

Where a classification is recorded as 'data-lacking' or 'inconclusive' according to the REACH registered substance database, or where a substance has not yet been registered under the REACH system, toxicological data meeting the requirements in Annex VII to Regulation (EC) No 1907/2006 shall be provided that is sufficient to support conclusive self-classifications in accordance with Annex I to Regulation (EC) No 1272/2008 and ECHA's supporting guidance. In the case of 'data lacking' or 'inconclusive' database entries, self-classifications shall be verified, with the following information sources being accepted:

(i) Toxicological studies and hazard assessments by ECHA peer regulatory agencies (<sup>2</sup>), Member State regulatory bodies or Intergovernmental bodies;

<sup>(1)</sup> ECHA, REACH registered substances database: http://www.echa.europa.eu/information-on-chemicals/registered-substances.

<sup>(2)</sup> ECHA, Cooperation with peer regulatory agencies, http://echa.europa.eu/about-us/partners-and-networks/international-cooperation/ cooperation-with-peer-regulatory-agencies.

- (ii) A Safety Data Sheet (SDS) fully completed in accordance with Annex II to Regulation (EC) No 1907/2006;
- (iii) A documented expert judgment provided by a professional toxicologist. This shall be based on a review of scientific literature and existing testing data, where necessary supported by results from new testing carried out by independent laboratories using methods approved by ECHA;
- (iv) An attestation, where appropriate based on expert judgment, issued by an accredited conformity assessment body that carries out hazard assessments according to the Globally Harmonised System (GHS) of the classification and labelling of chemicals or CLP hazard classification systems.

Information on the hazardous properties of substances or mixtures may, in accordance with Annex XI to Regulation (EC) No 1907/2006, be generated by means other than tests, for instance through the use of alternative methods such as in vitro methods, by quantitative structure activity models or by the use of grouping or read-across.

For the derogated substances and mixtures listed in Table 2, the applicant shall provide proof that all derogation conditions are met.

Textile-based materials that have been awarded the EU Ecolabel in accordance with Decision 2014/350/EU shall be considered compliant with criteria 2.2(a) and 2.2(b), however a copy of the EU Ecolabel certificate must be provided.

## Criterion 3 — Wood, cork, bamboo and rattan

The term 'wood' applies not only to solid wood but also to wood chips and wood fibres. Where criteria refer solely to wood-based panels, this is mentioned in the title of those criteria.

Plastic foils manufactured using Vinyl Chloride Monomer (VCM) shall not be used in any part of the furniture product.

3.1. Sustainable wood, cork, bamboo and rattan

This criterion shall only apply when the content of wood or wood-based panels exceeds 5 % w/w of the final product weight (excluding packaging).

All wood, cork, bamboo and rattan shall be covered by chain of custody certificates issued by an independent third party certification scheme such as the Forest Stewardship Council (FSC), the Programme for the Endorsement of Forest Certification (PEFC) or equivalent.

All virgin wood, cork, bamboo and rattan shall not originate from GMO species and shall be covered by valid sustainable forest management certificates issued by an independent third party certification scheme such as FSC, PEFC or equivalent.

Where a certification scheme allows the mixing of uncertified material with certified and/or recycled materials in a product or production line, a minimum of 70 % of the wood, cork, bamboo or rattan material, as appropriate, shall be sustainable certified virgin material and/or recycled material.

Uncertified material shall be covered by a verification system which ensures that it is legally sourced, and meets any other requirement of the certification scheme with respect to uncertified material.

The certification bodies issuing forest and/or chain of custody certificates shall be accredited or recognised by that certification scheme.

Assessment and verification: The applicant or material supplier, as appropriate, shall provide a declaration of compliance supported by valid, independently certified chain of custody certificate(s) for all wood, cork, bamboo or rattan material used in the product or production line and demonstrate that at least 70 % of the material originates from forests or areas managed according to Sustainable Forestry Management principles and/or from recycled sources that meet the requirements set out by the relevant independent chain of custody scheme. FSC, PEFC or equivalent schemes shall be accepted as independent third party certification. In case the scheme does not specifically require that all virgin material is sourced from non-GMO species, additional evidence shall be provided to demonstrate this.

If the product or production line includes uncertified virgin material, proof shall be provided that the content of uncertified virgin material does not exceed 30 % and is covered by a verification system which ensures that it is legally sourced and meets any other requirement of the certification scheme with respect to uncertified material.

3.2. Restricted substances

In addition to the General conditions on hazardous substances set out in criterion 2, the following conditions shall specifically apply to any furniture component parts made of wood, cork, bamboo or rattan or specifically only to wood-based panels where the latter term is mentioned in the criterion title:

3.2(a) Contaminants in recycled wood used in wood-based panels

Any recycled wood fibres or wood chips used in the manufacture of wood based panels shall be tested in accordance with the European Panel Federation (EPF) standard for delivery conditions of recycled wood (<sup>1</sup>) and comply with the limits for contaminants as listed in Table 3.

#### Table 3

#### Limits for contaminants in recycled wood

Contaminant	Limit values (mg/kg recycled wood)	Contaminant	Limit values (mg/kg recycled wood)
Arsenic (As)	25	Mercury (Hg)	25
Cadmium (Cd)	50	Fluorine (F)	100
Chromium (Cr)	25	Chlorine (Cl)	1 000
Copper (Cu)	40	Pentachlorophenol (PCP)	5
Lead (Pb)	90	Creosote (Benzo(a)pyrene)	0,5

Assessment and verification: The applicant shall provide either:

- (i) A declaration from the wood-based panel manufacturer that no recycled wood fibres were used in the panel, or
- (ii) A declaration from the wood-based panel manufacturer that all recycled wood fibres used have been representatively tested in accordance with the 2002 'EPF Standard conditions for the delivery of recycled wood', supported by appropriate test reports that demonstrate compliance of the recycled wood samples with the limits specified in Table 3.
- (iii) A declaration from the wood-based panel manufacturer that all recycled wood fibres used have been representatively tested by other equivalent standards that have equal or stricter limits than the 2002 'EPF Standard conditions for the delivery of recycled wood', supported by appropriate test reports that demonstrate compliance of the recycled wood samples with the limits specified in Table 3.
- 3.2(b) Heavy metals in paints, primers and varnishes

Paints, primers or varnishes used on wood or wood-based materials shall not contain substances based on cadmium, lead, chromium VI, mercury, arsenic or selenium, at concentrations exceeding 0,010 % w/w for each individual metal in the in-can paint, primer or varnish formulation.

Assessment and verification: The applicant or material supplier, as appropriate, shall provide a declaration of compliance with this criterion and provide the respective SDS from the suppliers of the paints, primers and/or varnishes used.

 <sup>(1) &#</sup>x27;EPF Standard for delivery conditions of recycled wood', October 2002. Can be viewed online at: http://www.europanels.org/upload/EPF-Standard-for-recycled-wood-use.pdf

3.2(c) VOC content in paints, primers and varnishes

This criterion does not apply to untreated wooden surfaces or to natural wooden surfaces treated with soap, wax or oil.

This criterion shall only apply when the content of coated wood or wood-based panels (excluding untreated wooden surfaces or natural wooden surfaces treated with soap, wax or oil) exceeds 5 % w/w in the final furniture product (excluding packaging).

It shall not be necessary to meet the requirements of this criterion if compliance with criterion 9.5 can be demonstrated.

The VOC content of any paints, primers or varnishes used to coat any wood or wood-based panels used in the furniture product shall not exceed 5 % (in-can concentration).

However, higher VOC content coatings may be used, if it can be demonstrated that either:

- The total quantity of VOCs in the paint, primer or varnish used during the coating operation amounts to less than  $30 \text{ g/m}^2$  of coated surface area, or
- The total quantity of VOCs in the paint, primer or varnish used during the coating operation is between 30 and 60  $g/m^2$  of coated surface area and that the surface finish quality meets all of the requirements set out in Table 4.

Table 4

#### Surface finish quality requirements if VOC application rate is 30-60 g/m<sup>2</sup>

Condition	Required result	
Contact with water	No change after 24 hour contact	
Contact with grease	No change after 24 hour contact	
Contact with alcohol	No change after 1 hour contact	
Contact with coffee	No change after 1 hour contact	
Contact with 70 °C heat source	No change after testing	
Contact with 70 °C heat source	No change after testing	
Contact with diamond scratching tip	Method A: no scratches $\geq 0,30$ mm when a load of 5 N has been applied or, Method B: no scratches visible in $\geq 6$ slots in the viewing template where a load of 5 N has been applied	
	Condition         Contact with water         Contact with grease         Contact with alcohol         Contact with coffee         Contact with 70 °C heat source         Contact with 70 °C heat source         Contact with diamond scratching tip	

Assessment and verification: The applicant shall provide a declaration of compliance, specifying whether compliance is achieved because the furniture product is exempt from the criterion or if it is achieved by the controlled use of VOCs in the coating operation.

In the latter case, the declaration by the applicant shall be supported by information from the paint, primer or varnish supplier stating the VOC content and density of the paint, primer or varnish (both in g/L) and a calculation of the effective percentage VOC content.

If the VOC content of the paint, primer or varnish is greater than 5 % (in-can concentration), then the applicant shall either:

- (i) Provide calculations demonstrating that the effective quantity of VOCs applied to the coated surface area of the final assembled furniture product is less than 30  $g/m^2$ , in accordance with the guidance provided in Appendix I.
- (ii) Provide calculations demonstrating that the effective quantity of VOCs applied to the coated surface area of the final assembled furniture product is less than 60  $g/m^2$ , in accordance with the guidance provided in Appendix I and provide test reports demonstrating compliance of the surface finishes with the requirements of Table 4.
- 3.3. Formaldehyde emissions from wood-based panels

This criterion shall only apply when the content of wood-based panels in the final furniture product (excluding packaging) exceeds 5 % w/w.

Formaldehyde emissions from all supplied wood-based panels, in the form that they are used in the furniture product (in other words, unfaced, coated, overlaid, veneered), and which were manufactured using formaldehyde-based resins shall either:

- Be lower than 50 % of the threshold value allowing them to be classified as E1.
- Be lower than 65 % of the E1 threshold value, in the case of Medium Density Fibreboard (MDF) panels.
- Be lower than the limits set out in the CARB Phase II or the Japanese F-3 star or F-4 star standards.

Assessment and verification: The applicant shall provide a declaration of compliance with this criterion, stating that no other further modification or treatment has been applied by the applicant to the panels that would compromise their compliance with the formaldehyde emission limits of the panels as supplied. The assessment and verification of low formaldehyde emission panels shall vary depending on the certification scheme it falls under. The verification documentation required for each scheme is described in Table 5.

#### Table 5

#### Assessment and verification of low formaldehyde emission panels

Certification scheme	Verification documentation
E1 (as defined in Annex B of EN 13986)	A declaration from the wood-based panel manufacturer, stating that the panel is compliant with 50 % of E1 emission limits or, in the case of MDF panels, with 65 % of E1 emission limits, supported by test reports carried out according to either EN 717-2, EN 120, EN 717-1 or equivalent methods.
CARB — California Air Resources Board: Phase II limits	A declaration from the wood-based panel manufacturer, supported by test results according to ASTM E1333 or ASTM D6007, demonstrating panel compliance with the formaldehyde Phase II emission limits defined in the California Composite Wood Products Regulation 93120 ( <sup>1</sup> ).
	The wood-based panel may be labelled in accordance with Section 93120.3(e), containing details in respect of the manufacturer's name, the product lot number or batch produced, and the CARB assigned number for the third party certifier (this part is not mandatory if the products are sold outside of California or if they were made using no-added formaldehyde or certain ultra-low emitting formaldehyde-based resins).

Certification scheme	Verification documentation		
F-3 or 4 star limits	A declaration from the wood-based panel manufacturer of compliance with the formaldehyde emission limits as per JIS A 5905 (for fibreboard) or JIS A 5908 (for particleboard and plywood), supported by test data according to the JIS A 1460 desicator method.		

 Regulation 93120 'Airborne toxic control measure to reduce formaldehyde emissions from composite wood products'-California Code of Regulations.

#### Criterion 4 — Plastics

Plastics manufactured using Vinyl Chloride Monomer (VCM) shall not be used in any part of the furniture product.

4.1. Marking of plastic component parts

Plastic parts with a mass greater than 100 g shall be marked in accordance with EN ISO 11469 and EN ISO 1043 (parts 1-4). The lettering used in markings shall be at least 2,5 mm high.

Where any fillers, flame retardants or plasticisers are intentionally incorporated into the plastic in proportions greater than 1 % w/w, their presence shall also be included in the marking as per EN ISO 1043 parts 2-4.

In exceptional cases, non-marking of plastic parts with a weight greater than 100 g is permitted if:

- Marking would impact on the performance or functionality of the plastic part;
- Where marking is not technically possible due to the production method;
- Where parts cannot be marked because there is not enough appropriate surface area available for the marking to be of a legible size to be identified by a recycling operator.

In the above cases, where non-marking is allowed, further details about the polymer type and any additives as per the requirements of EN ISO 11469 and EN ISO 1043 (parts 1-4) shall be included with consumer information referred to in criterion 10.

Assessment and verification: The applicant shall provide a declaration of compliance with this criterion, listing all the plastic component parts with a weight greater than 100 g in the furniture product and stating whether or not they have been marked according to EN ISO 11469 and EN ISO 1043 (parts 1-4).

The marking of any plastic component parts shall be clearly visible upon visual examination of the plastic component part. Marking does not necessarily need to be clearly visible in the final assembled furniture product.

If any plastic parts with a weight greater than 100 g have not been marked, the applicant shall provide justification for non-marking and indicate where relevant information has been included in consumer information.

In cases of doubt regarding the nature of the plastic for component parts with a weight greater than 100 g and in case suppliers do not provide the required information, laboratory test data using infra-red or Raman spectroscopy or any other suitable analytical techniques to identify the nature of the plastic polymer and the quantity of fillers or other additives shall be provided as evidence supporting the EN ISO 11469 and EN ISO 1043 marking.

4.2. Restricted substances

In addition to the general requirements for hazardous substances established in Criterion 2, the conditions listed below shall apply for plastic component parts.

4.2(a) Heavy metals in plastic additives

Plastic component parts and any surface layers shall not be manufactured using additives that contain cadmium (Cd), chromium VI (CrVI), lead (Pb), mercury (Hg) or tin (Sn) compounds.

Assessment and verification: The applicant shall provide a declaration of compliance with this criterion.

Where only virgin plastic is used, a declaration from the supplier of the virgin plastic material that no additives containing cadmium, chromium VI, lead, mercury or tin have been used shall be accepted.

Where virgin plastic has been combined with pre-consumer plastic recyclates from known sources and/or with post-consumer polyethylene terephthalate (PET), polystyrene (PS), polyethylene (PE) or polypropylene (PP) from municipal collection schemes, a declaration from the supplier of the recycled plastic material that no compounds containing cadmium, chromium VI, lead, mercury or tin have been intentionally added shall be accepted.

If no suitable declarations are provided by the supplier, or where virgin plastic is combined with pre-consumer recyclates from mixed or unknown sources, representative testing of the plastic component parts shall demonstrate compliance with the conditions set out in Table 6.

# Table 6

### Assessment and verification of heavy metal impurities in plastics

Metal	Mathad	Limit (mg/kg)	
	мешоа	Virgin	Recycled
Cd	XRF (X-Ray Fluorescence) or acid digestion followed by in- ductively coupled plasma or atomic absorption spectropho-	100	1 000
РЬ	tometry or other equivalent methods for measuring total metal content	100	1 000
Sn		100	1 000
Hg		100	1 000
CrVI	EN 71-3	0,020	0,20

4.3. Recycled plastic content

This criterion shall only apply if the total content of plastic material in the furniture product exceeds 20 % of the total product weight (excluding packaging).

The average recycled content of plastic parts (not including packaging) shall be at least 30 % w/w.

Assessment and verification: The applicant shall provide a declaration from the plastic supplier(s) stating the average recycled content in the final furniture product. Where plastic component parts come from different sources or suppliers, the average recycled content shall be calculated for each plastic source and the overall average recycled plastic content in the final furniture product shall be stated.

The declaration of recycled content from the plastic manufacturer(s) shall be supported by traceability documentation for plastic recyclates. An option would be to provide batch delivery information as per the framework set out in Table 1 of EN 15343.

#### Criterion 5 — Metals

In addition to the general requirements for hazardous substances stated in Criterion 2, the conditions listed below shall apply for metal component parts in the furniture product.

5.1. Electroplating restrictions

Chromium VI or cadmium shall not be used for electroplating operations of any metal component parts used in the final furniture product.

Nickel shall only be permitted in electroplating operations if the nickel release rate from the electroplated component part is less than  $0.5 \ \mu g/cm^2/week$  according to EN 1811.

Assessment and verification: The applicant shall provide a declaration from the supplier of the metal component part(s) that no plating treatments involving chromium VI or cadmium substances have been used in any metal component parts.

Where nickel has been used in electroplating operations, the applicant shall provide a declaration from the supplier of the metal component part(s), supported by a test report according to EN 1811, where results reveal nickel release rates to be less than  $0.5 \text{ µg/cm}^2/\text{week}$ .

5.2. Heavy metals in paints, primers and varnishes

Paints, primers or varnishes used on metal component parts shall not contain additives based on cadmium, lead, chromium VI, mercury, arsenic or selenium, at concentrations exceeding 0,010 % w/w for each individual metal in the in-can paint, primer or varnish formulation.

Assessment and verification: The applicant shall provide a declaration of compliance with this criterion and provide the respective SDS from the suppliers of the paints, primers or varnishes used.

5.3. VOC content in paints, primers and varnishes

This sub-criterion shall only apply when the content of coated metal component parts exceeds 5 % w/w in the final furniture product (excluding packaging).

It shall not be necessary to meet the requirements of this sub-criterion if compliance with criterion 9.5 can be demonstrated.

The VOC content of any paints, primers or varnishes used to coat any metal component parts used in the furniture product shall not exceed 5 % (in-can concentration).

However, higher VOC content coatings may be used, if it can be demonstrated that either:

- The total quantity of VOCs in the paint, primer or varnish used during the coating operation amounts to less than  $30 \text{ g/m}^2$  of coated surface area, or
- The total quantity of VOCs in the volume of paint, primer or varnish that is used during the coating operation is between 30 and 60 g/m<sup>2</sup> of coated surface area and that the surface finish quality meets the requirements set out in Table 7.

#### Table 7

## Surface finish quality requirements if VOC application rate is 30-60 g/m<sup>2</sup>

Test standard	Condition	Required result	
EN 12720. Furniture — Assessment of surface resistance to cold liquids	Contact with water	No change after 24 hour contact	
-	Contact with grease	No change after 24 hour contact	
	Contact with alcohol	No change after 1 hour contact	
	Contact with coffee	No change after 1 hour contact	

Test standard	Condition	Required result
EN 12721. Furniture — Assessment of a surface resistance to wet heat	Contact with 70 °C heat source	No change after testing
EN 12722. Furniture — Assessment of surface resistance to dry heat	Contact with 70 °C heat source	No change after testing
EN 15186. Furniture — Assessment of the surface resistance to scratch- ing	Contact with diamond scratching tip	Method A: no scratches $\ge 0,30$ mm when a load of 5 N has been applied or, Method B: no scratches visible in $\ge 6$ slots in the viewing template where a load of 5 N has been applied

Assessment and verification: The applicant shall provide a declaration of compliance, specifying whether compliance is achieved because the furniture product is exempt from the criterion or if it is achieved by the controlled use of VOCs in the coating operation.

In the latter case, the declaration by the applicant shall be supported by information from the paint, primer or varnish supplier stating the VOC content and density of the paint, primer or varnish (both in g/L) and the effective percentage of VOC content.

If the VOC content of the paint, primer or varnish is greater than 5 % (in-can concentration), then the applicant shall either:

- Provide calculations demonstrating that the effective quantity of VOCs applied to the coated surface area of the final assembled furniture product is less than 30  $g/m^2$ , in accordance with the guidance provided in Appendix I.
- Provide calculations demonstrating that the effective quantity of VOCs applied to the coated surface area of the final assembled furniture product is less than 60 g/m<sup>2</sup>, in accordance with the guidance provided in Appendix I and provide test reports that show compliance of the surface finishes with the requirements of Table 7.

# Criterion 6 — Upholstery Covering Materials

Upholstery covering materials manufactured using Vinyl Chloride Monomer (VCM) shall not be used in any part of the furniture product.

6.1. Physical quality requirements

Any leather used as upholstery covering material shall comply with the physical quality requirements presented in Appendix II.

Any textiles used as upholstery covering material shall comply with the physical quality requirements presented in Table 8.

Any coated fabrics used as upholstery covering material shall comply with the physical quality requirements stated in Table 9.

Table 8

# Physical requirements for textile fabric covering materials in furniture upholstery

Test factor	Method	Removable and washable coverings	Non-removable and wash- able coverings
Dimensional changes during washing and drying	Domestic washing: ISO 6330 + EN ISO 5077 (three washes at temperatures as in- dicated in the product with tumble drying after each washing cycle) Commercial washing: ISO 15797 + EN ISO 5077 (at minimum of 75 °C)	woven furniture upholstery fabrics: ± 2,0 % woven furniture ticking fabric: ± 3,0 % non-woven furniture ticking: ± 5,0 % non-woven furniture upholstery fabrics: ± 6,0 %	N/A
Colour fastness to washing	Domestic washing: ISO 105- C06 Commercial washing: ISO 15797 + ISO 105-C06 (at minimum of 75 °C)	≥ level 3-4 for colour change ≥ level 3-4 for staining	N/A
Colour fastness to wet rubbing (*)	ISO 105 X12	≥ level 2-3	≥ level 2-3
Colour fastness to dry rubbing (*)	ISO 105 X12	≥ level 4	≥ level 4
Colour fastness to light	ISO 105 B02	≥ level 5 (**)	≥ level 5 (**)
Fabric resistance to pilling and abrasion	Knitted and non-woven prod- ucts: ISO 12945-1 Woven fabrics: ISO 12945-2	ISO 12945-1 result > 3 ISO 12945-2 result > 3	ISO 12945-1 result > 3 ISO 12945-2 result > 3

(\*) Does not apply to white products or products that are neither dyed nor printed.
 (\*\*) A level of 4 is nevertheless allowed when furniture covering fabrics are both light coloured (standard depth < 1/12) and made of more than 20 % wool or other keratin fibres, or more than 20 % linen or other bast fibres.</li>

## Table 9

# Physical requirements for coated fabric covering materials in furniture upholstery

Property	Method	Requirement
Tensile strength	ISO 1421	CH ≥ 35 daN and TR ≥ 20 daN
Tear resistance of coated fabrics by the trouser tear method	ISO 13937/2	CH ≥ 2,5 daN and TR ≥ 2 daN

Property	Method	Requirement
Colour fastness to artificial weathering — Xenon arc fading lamp test	EN ISO 105-B02	Indoor use ≥ 6; Outdoor use ≥ 7
Textiles — abrasion resistance by the Martindale method	ISO 5470/2	≥ 75 000
Determination of coating adhesion	EN 2411	CH ≥ 1,5 daN and TR $\ge$ 1,5 daN
Where: daN = deca Newtons, CH = Warp and TR = Weft	1	

Assessment and verification: The applicant shall provide a declaration from the leather supplier, textile fabric supplier or coated fabric supplier, as appropriate, supported by relevant test reports, stating that the upholstery covering material meets the physical requirements for leather, textile fabrics or coated fabrics as specified in Appendix II, Table 8 or Table 9 respectively.

Textile-based materials that have been awarded the EU Ecolabel in accordance with Decision 2014/350/EU shall be considered compliant with this criterion, however a copy of the EU Ecolabel certificate must be provided.

# 6.2. Chemical testing requirements

This criterion applies to the upholstery covering materials in the final treated form that they are to be used in the furniture product. In addition to the general conditions on hazardous substances set out in criterion 2, the following restrictions listed in Table 10 shall specifically apply to upholstery covering materials:

## Table 10

# Chemical testing requirements for leather, textiles and coated fabric covering material

Chemical	Applicability	Limits	(mg/kg)	Test method
Restricted arylamines from cleavage of azodyes (*)	Leather	≤ 30 for each amine (*)		EN ISO 17234-1
	Textiles and coated fabrics			EN ISO 14362-1 and EN ISO 14362-3
Chromium VI	Leather	< 3 (**)		EN ISO 17075
Free formaldehyde	Leather	$\leq$ 20 (for children's furniture) (***) or $\leq$ 75 for other furniture		EN ISO 17226-1
	Textiles and coated fabrics			EN ISO 14184-1
Extractable heavy metals	Leather	Arsenic ≤ 1,0	Antimony $\leq$ 30,0	EN ISO 17072-1
		Chromium ≤ 200,0	Cadmium ≤ 0,1	
		Cobalt ≤ 4,0	Copper ≤ 50,0	
		Lead ≤ 1,0	Mercury ≤ 0,02	
		Nickel ≤ 1,0		

Chemical	Applicability	Limits	(mg/kg)	Test method
	Textiles and coated fabrics	Arsenic ≤ 1,0	Antimony ≤ 30,0 (****)	EN ISO 105 E04
		Chromium ≤ 2,0	Cadmium ≤ 0,1	
		Cobalt ≤ 4,0	Copper ≤ 50,0	
		Lead ≤ 1,0	Mercury ≤ 0,02	
		Nickel ≤ 1,0		
Chlorophenols	Leather	Pentachlorophenol ≤ Tetrachlorophenol ≤	0,1 mg/kg 0,1 mg/kg	EN ISO 17070
Alkylphenols	Leather, textiles and coated fabrics	Nonylphenol, mixed 25154-52-3; 4-Nonylphenol (CAS 4-Nonylphenol, br 84852-15-3) Octylphenol (CAS No 4-Octylphenol (CAS No 4-Octylphenol (CAS No 4-Octylphenol (CAS No 4-tert-Octylphenol (CAS No 4-Octylphenol (CAS No	l isomers (CAS No No 104-40-5) anched (CAS No 0 27193-28-8) No 1806-26-4) CAS No 140-66-9) es (APEOs) and their yl phenol (CAS No nyl phenol (CAS No onyl phenol (CAS No onyl phenol (CAS No le: les or coated fabrics her	For leather: EN ISO 18218-2 (in- direct method) For textiles and coated fabrics: EN ISO 18254 for al- kylphenolethoxylates. For alkylphenols final product testing is to be carried out by sol- vent extraction fol- lowed by LC-MS or GC-MS
Polycyclic Aromatic Hydrocarbons	Textiles, coated fab- rics or leather	PAHs restricted un No 1907/2006: Chrysene (CAS No 2 Benzo[a]anthracene ( Benzo[k]fluoranthene Benzo[a]pyrene (CAS Dibenzo[a,h]anthrane 53-70-3) Benzo[j]fluoranthene Benzo[b]fluoranthene Benzo[e]pyrene (CAS	der Regulation (EC) 18-01-9) CAS No 56-55-3) e (CAS No 207-08-9) No 50-32-8) cene (CAS No (CAS No 205-82-3) e (CAS No 205-82-2) No 192-97-2)	AfPS GS 2014:01 PAK

Chemical	Applicability	Limits (mg/kg)	Test method
		Individual limits for 8 PAHs listed above:	
		≤ 1 mg/kg	
		Additional PAHs subject to restriction:	
		Naphthalene (CAS No 91-20-3)	
		Acenaphthylene (CAS No 208-96-8)	
		Acenaphthene (CAS No 83-32-9)	
		Fluorene (CAS No 86-73-7)	
		Phenanthrene (CAS No 85-1-8)	
		Anthracene (CAS No 120-12-7)	
		Fluoranthene (CAS No 206-44-0)	
		Pyrene (CAS No 129-00-0)	
		Indeno[1,2,3-c,d]pyrene (CAS No 193- 39-5)	
		Benzo[g,h,i]perylene (CAS No 191-24-2)	
		Sum Total limit for 18 PAHs listed above:	
		$\leq$ 10 mg/kg	
N,N-Dimethylaceta- mide (CAS No 127- 19-5)	Elastane or acrylic- based textiles	Result ≤ 0,005 % w/w (≤ 50 mg/kg)	Solvent extraction followed by GCMS or LCMS
Chloralkanes	Leather	C10-C13 (SCCP) chloralkanes not detectable C14-C17 (MCCP) chloralkanes ≤ 1 000 mg/kg;	EN ISO 18219

(\*) A total of 22 arylamines listed in Entry 43 of Annex XVII to Regulation (EC) No 1907/2006 plus two other compounds (see Table 1 in Appendix III for a full listed of the arylamines to be tested). Limit of detection for EN ISO 17234-1 is 30 mg/kg.

(\*\*) The detection limit for the EN ISO 17075 is generally assumed to be 3 mg/kg.

(\*\*\*) Furniture designed specifically for babies and children less than 3 years old.

(\*\*\*\*) If the tested textiles have been treated with ATO as a synergist, in accordance with the derogation conditions for ATO use in entry (c) of Table 2, then it shall be exempted from compliance with the leaching limit for antimony.

Assessment and verification: The applicant shall provide a declaration that the leather, textile fabric or coated fabric upholstery covering material complies with the limits specified in Table 10, supported by test reports.

Textile-based materials that have been awarded the EU Ecolabel in accordance with Decision 2014/350/EU shall be considered compliant with this criterion, however a copy of the EU Ecolabel certificate must be provided.

## 6.3. Restrictions during production processes

If the upholstery covering materials account for more than 1,0 % w/w of the total furniture product weight (excluding packaging), the supplier of the material shall comply with the restrictions specified in Table 11 on the use of hazardous substances during production.

# Table 11

# Restricted substances used in leather, textile and coated fabric production stages

# 1 — Hazardous substances used in different production stages

# (a) Detergents, surfactants, softeners and complexing agents

Applicability: To dyeing and finishing process stages in textile, leather or coated fabric production	All non-ionic and cationic detergents and surfactants must be ultimately biodegradable under anaerobic conditions. <i>Assessment and verification:</i> The applicant shall provide a declaration from the leather, tex- tile or coated fabric producer, supported by a declaration from their chemical supplier(s) and by relevant SDSs and results of EN ISO 11734 or ECETOC No 28 OECD 311 tests. The latest revision of the Detergents Ingredients Database shall be used as a reference point for biodegradability and may, at the discretion of the competent body, be accepted as an alternative to providing test reports. http://ec.europa.eu/environment/ecolabel/documents/did_list/didlist_part_a_en.pdf
	Long chain perfluoroalkyl sulfonates ( $\geq$ C6) and perfluorocarboxylic acids ( $\geq$ C8) shall not be used in the production processes. Assessment and verification: The applicant shall provide a declaration from the leather, tex- tile or coated fabric producer, supported by a declaration from their chemical supplier(s) and by relevant SDSs of the non-use of these substances for each production stage.

# (b) Auxiliaries (used in mixtures, formulations and adhesives)

Applicability: Dveing and finishing	The following substances shall not be used in any mixtures or formulations for dyeing and finishing of leather, textiles or coated fabrics:
operations for leather,	bis(hydrogenated tallow alkyl) dimethyl ammonium chloride (DTDMAC)
textile or coated fabric	distearyl dimethyl ammonium chloride (DSDMAC)
production	di(hardened tallow) dimethyl ammonium chloride (DHTDMAC)
	ethylene diamine tetra acetate (EDTA),
	diethylene triamine penta acetate (DTPA)
	4-(1,1,3,3-tetramethylbutyl)phenol
	Nitrilotriacetic acid (NTA)
	Assessment and verification: The applicant shall provide a declaration from the leather, tex- tile or coated fabric supplier, supported by relevant SDSs, that these compounds have not been used in any dyeing and finishing operations for leather, textiles or coated fabrics.

# (c) Solvents

Applicability: Processing of leather, textile or coated fabric materials	The following substances shall not be used in any mixtures or formulations for the pro- cessing of leather, textile or coated fabric materials: 2-Methoxyethanol N,N-dimethylformamide 1-Methyl-2-pyrrolidone Bis(2-methoxyethyl) ether 4,4'- Diaminodiphenylmethane 1,2,3-trichloropropane 1,2-Dichloroethane (ethylene dichloride) 2-Ethoxyethanol
---	---

Benzene-1,4-diamine dihydrochloride
Bis(2-methoxyethyl) ether
Formamide
N-methyl-2-pyrrolidone
Trichloroethylene
Assessment and verification: The applicant shall provide a declaration from the leather, tex- tile or coated fabric producer, supported by relevant SDSs, that these solvents have not been used in any of the leather, textile or coated fabric production processes.

2 — Dyes used in dyeing and printing processes

Т

(i)	Carriers used in dyeing process Applicability: Dyeing and printing processes	Where disperse dyes are used, halogenated dyeing accelerants (carriers) shall not be used (Examples of carriers include: 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, chlorophe- noxyethanol). Assessment and verification: The applicant shall provide a declaration, supported by declara- tions of leather, textile or coated fabric producers, their chemical supplier(s) and any rel- evant SDSs, that states the non-use of any halogenated carriers during the dyeing process of any leather, textiles or coated fabrics used in the furniture product.
(ii)	Chrome mordant dyes Applicability: Dyeing and printing processes	Chrome mordant dyes shall not be used. Assessment and verification: The applicant shall provide a declaration, supported by declara- tions of leather, textile or coated fabric producers, their chemical supplier(s) and any rel- evant SDSs, that states the non-use of any chrome mordant dyes during the dyeing pro- cess of any leather, textiles or coated fabrics used in the furniture product.
(iii)	Pigments Applicability: Dyeing and printing processes	Pigments based on cadmium, lead, chromium VI, mercury, arsenic and antimony shall not be used. <i>Assessment and verification:</i> The applicant shall provide a declaration, supported by declara- tions of leather, textile or coated fabric producers, their chemical supplier(s) and any rel- evant SDSs, that states the non-use of any pigments based on the mentioned heavy me- tals during dyeing or printing processes with any leather, textiles or coated fabrics used in the furniture product.

# 3 — Finishing processes

Fluorinated compounds Applicability: Upholstery covering materials with integrated water or stain repellent function	Fluorinated compounds shall not be impregnated into furniture upholstery covering ma- terial finishes in order to impart water, stain and oil repellent functions. This restriction includes perfluorinated and polyfluorinated substances. Non-fluorinated treatments using substances that are readily or inherently biodegradable or have a low potential to bioac- cumulate in the aquatic environment shall be permitted.
	Assessment and verification: The applicant shall provide a declaration of compliance, sup- ported by declarations from leather, textile or coated fabric producers, declarations from chemical supplier(s) and any relevant SDSs, that state non-use of fluorinated, perfluori- nated or polyfluorinated substances in leather, textile or coated fabric finishing opera- tions.
	In the absence of an acceptable declaration, the competent body may further request test- ing of the covering material according to the methods defined by CEN/TS 15968.
	For non-fluorinated treatments, readily or inherently biodegradability properties may be demonstrated by tests conducted according to the following methods: OECD 301 A, ISO 7827, OECD 301 B, ISO 9439, OECD 301 C, OECD 301 D, ISO 10708, OECD 301 E, OECD 301 F, ISO 9408.

A low potential to bioaccumulate shall be demonstrated by tests that show an octanol- water partition coefficients (Log Kow) of < 3,2 or Bioconcentration Factors (BCF) < 100.
With non-fluorinated treatments, the latest revision of the Detergents Ingredients Data- base shall be used as a reference point for biodegradability and may, at the discretion of the competent body, be accepted as an alternative to providing test reports.
http://ec.europa.eu/environment/ecolabel/documents/did_list/didlist_part_a_en.pdf

# 4 — Tannery effluent quality and specific water consumption

Applicability: Leather production process	(i) The COD value in wastewater from leather tanning sites, when discharged to surface waters after treatment (whether on-site or off-site), shall not exceed 200 mg/l. Assessment and verification: the applicant or material supplier, as appropriate, shall provide a declaration of compliance supported by detailed documentation and test reports in accordance with ISO 6060 showing compliance with this criterion on the basis of monthly averages for the six months preceding the application. The data shall demonstrate compliance of the production site or, if the effluent is treated off-site of the wastewater treatment operator.		
	(ii) Total chromium concentration in tannery wastewater after trea exceed 1,0 mg/l as specified in the Commission Impleme 2013/84/EU ( <sup>1</sup> ).	tment shall not enting Decision	
	<ul> <li>Assessment and verification: the applicant or material supplier, as appropriate, shall provide a declaration of compliance supported by a test report using one of the following test methods: ISO 9174 or EN 1233 or EN ISO 11885 for chromium and showing compliance with this criterion on the basis of monthly averages for the six months preceding the application. The applicant shall provide a declaration of compliance with BAT 10, and either BAT 11 or 12, as appropriate, of Implementing Decision 2013/84/EU for the reduction of chromium content of wastewater discharges.</li> <li>(iii) Water consumption expressed as annual average volume of water consumed per</li> </ul>		
	tonne of raw mues and skins shall not exceed the limits given below		
	Hides	28 m³/t	
	Skins	45 m³/t	
	Vegetable tanned leather	35 m³/t	
	Pig skin	80 m³/t	
	Sheepskins	180 l/skin	
	Assessment and verification: the applicant shall provide a declaration of compliance from the leather supplier or leather manufacturing company, as appropriate. The declaration shall specify the annual amount of leather production and related water consumption based on the monthly average values of the last 12 months preceding the application, measured by the quantity of waste water discharged.		
	If the leather production process is conducted in different geographical l plicant or supplier of semi-finished leather shall provide documentation quantity of water discharged (m <sup>3</sup> ) for the quantity of semi-finished leat tonnes (t) or number of skins for sheepskin, as appropriate, based on the age values during the 12 months preceding the application.	ocations, the ap- that specifies the her processed in he monthly aver-	

<sup>(1)</sup> Commission Implementing Decision 2013/84/EU of 11 February 2013 establishing the best available techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions for the tanning of hides and skins (OJ L 45, 16.2.2013, p. 13).

Assessment and verification: The applicant shall compile all relevant declarations, SDSs and supporting test reports from leather, textile or coated fabric producers, or their suppliers, that are relevant to demonstrate compliance with the requirements for non-use of the hazardous substances listed in Table 11.

Upholstery covering materials made of textiles that have been awarded the EU Ecolabel in accordance with Decision 2014/350/EU shall be considered compliant with this criterion for non-use of the listed hazardous substances during production processes, however a copy of the EU Ecolabel certificate must be provided.

6.4. Cotton and other natural cellulosic seed fibres

Cotton that contains equal or greater than 70 % weight by weight of recycled content is exempted from the requirements of criterion 6.4.

Cotton and other natural cellulosic seed fibres (hereinafter referred to as cotton) that are not recycled fibres, shall contain a minimum content of either organic cotton (see criterion 6.4(a)) or integrated pest management (IPM) cotton (see criterion 6.4(b)).

Textiles that have been awarded the EU Ecolabel based on the ecological criteria established in Decision 2014/350/EU are considered to comply with criterion 6.4.

Assessment and verification: The applicant or material supplier, as appropriate, shall provide a declaration of compliance.

Where EU Ecolabel textiles are used, the applicant shall provide a copy of the EU Ecolabel certificate showing that it was awarded in accordance with Decision 2014/350/EU.

Where applicable, recycled content shall be traceable back to the reprocessing of the feedstock. This shall be verified by independent third party certification of the chain of custody or by documentation provided by feedstock suppliers and reprocessors.

#### 6.4(a) Organic production standard

A minimum of 10 % weight by weight of the non-recycled cotton fibre used in upholstery materials shall be grown according to the requirements laid down in Council Regulation (EC) No 834/2007 (<sup>1</sup>), the US National Organic Programme (NOP) or equivalent legal obligations set by trading partners of the EU. The organic cotton content may include organically grown cotton and transitional organic cotton.

Where the organic cotton is to be blended with conventional or IPM cotton, cotton shall be from non-genetically modified varieties.

Organic content claims may only be made when the organic content is a minimum of 95 %.

Assessment and verification: The applicant or material supplier, as appropriate, shall provide a declaration of compliance for the organic content supported by evidence certified by an independent control body to have been produced in conformity with the production and inspection requirements laid down in Regulation (EC) No 834/2007, the US National Organic Programme (NOP) or those set by other trading partners. Verification shall be provided for each country of origin.

The applicant or material supplier, as appropriate, shall demonstrate compliance with the minimum organic cotton content requirement based on the annual volume of cotton purchased to manufacture the final product(s) and according to each product line. Transaction records and/or invoices shall be provided that document the quantity of certified cotton purchased.

For conventional or IPM cotton that is used in blends with organic cotton, a screening test for common genetic modifications shall be accepted as a proof of compliance of the cotton variety.

<sup>(&</sup>lt;sup>1</sup>) Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91 (OJ L 189, 20.7.2007, p. 1).

# 6.4(b) Cotton production according to Integrated Pest Management (IPM) principles and restriction on pesticides

A minimum of 20 % weight by weight of the non-recycled cotton fibre used in upholstery materials shall be grown according to IPM principles as defined by the UN Food and Agricultural Organisation (FAO) IPM programme, or Integrated Crop Management (ICM) systems incorporating IPM principles.

IPM cotton destined for use in the final product shall be grown without the use of any of the following substances: aldicarb, aldrin, campheclor (toxaphene), captafol, chlordane, 2,4,5-T, chlordimeform, cypermethrin, DDT, dieldrin, dinoseb and its salts, endosulfan, endrin, heptachlor, hexachlorobenzene, hexachlorocyclohexane (total isomers), methamidophos, methylparathion, monocrotophos, neonicotinoids (clothianidine, imidacloprid, thiametoxam), parathion, pentachlorophenol.

Assessment and verification: The applicant or material supplier, as appropriate, shall provide a declaration of compliance with criterion 6.4(b), supported by evidence that at least 20 % weight by weight of the non-recycled cotton contained in the product has been grown by farmers that have participated in formal training programmes of the UN FAO or Government IPM and ICM programmes and/or that have been audited as part of third party certified IPM schemes. Verification shall either be provided on an annual basis for each country of origin or on the basis of certifications for all IPM cotton purchased to manufacture the product.

The applicant of material supplier, as appropriate, shall also declare that the IPM cotton was not grown using any of the substances listed in criterion 6.4(b). IPM certification schemes that exclude the use of listed substances shall be accepted as a proof of compliance.

# **Criterion 7** — **Upholstery padding materials**

- 7.1. Latex foam
- 7.1(a) Restricted substances

The concentrations in the latex foam of the substances listed below shall not exceed the limit values shown in Table 12.

#### Table 12

# Restricted substances in latex foams used in furniture upholstery padding materials

Group of substances	Substance	Limit value (ppm)	Assessment and verifi- cation conditions
Chlorophenols	mono- and di-chlorinated phe- nols (salts and esters)	1	А
	Other chlorophenols	0,1	А
Heavy metal	As (Arsenic)	0,5	В
	Cd (Cadmium)	0,1	В
	Co (Cobalt)	0,5	В
	Cr (Chromium), total	1	В
	Cu (Copper)	2	В
	Hg (Mercury)	0,02	В
	Ni (Nickel)	1	В
	Pb (Lead)	0,5	В
	Sb (Antimony)	0,5	В

L 210/130

EN

Group of substances	Substance	Limit value (ppm)	Assessment and verifi- cation conditions
Pesticides (only to be tested for foams composed of natural latex by at least 20 % by weight),	Aldrin	0,04	С
	o,p-DDE	0,04	С
	p,p-DDE	0,04	С
	o,p-DDD	0,04	С
	p,p-DDD	0,04	С
	o,p-DDT	0,04	С
	p,p-DDT	0,04	С
	Diazinone	0,04	С
	Dichlorfenthion	0,04	С
	Dichlorvos	0,04	С
	Dieldrin	0,04	С
	Endrin	0,04	С
	Heptachlor	0,04	С
	Heptachlorepoxide	0,04	С
	Hexachlorobenzene	0,04	С
	Hexachlorocyclohexane	0,04	С
	α-Hexachlorocyclohexane	0,04	С
	β-Hexachlorcyclohexane	0,04	С
	γ-Hexachlorocyclohexane (Lin- dane)	0,04	С
	δ-Hexachlorocyclohexane	0,04	С
	Malathion	0,04	С
	Methoxichlor	0,04	С
	Mirex	0,04	С
	Parathion-ethyl	0,04	С
	Parathion-methyl	0,04	С
Other specific substances that are restricted	Butadiene	1	D

Assessment and verification: The applicant shall provide a declaration of compliance with criterion 7.1(a) and, if applicable, test reports according to the following methods:

A. For clorophenols the applicant shall provide a report presenting the results of the following test procedure. 5 g of sample shall be milled and clorophenols shall be extracted in the form of phenol (PCP), sodium salt (SPP) or esters. The extracts shall be analysed by means of gas chromatography (GC). Detection shall be made with mass spectrometer or electron capture detector (ECD).

- B. For heavy metals the applicant shall provide a report presenting the results of the following test procedure. Milled sample material is eluted in accordance with DIN 38414-S4 or equivalent in a ratio of 1:10. The resultant filtrate shall be passed through a 0,45 µm membrane filter (if necessary by pressure filtration). The solution obtained shall be examined for the content of heavy metals by inductively coupled plasma optical emission spectrometry (ICP-OES), also known as inductively coupled plasma atomic emission spectrometry (ICP-AES), or by atomic absorption spectrometry using a hydride or cold vapour process.
- C. For pesticides the applicant shall provide a report presenting the results of the following test procedure. 2 g of sample is extracted in an ultrasonic bath with a hexane/dichloromethane mixture (85/15). The extract is cleaned up by acetonitrile agitation or by adsorption chromatography over florisil. Measurement and quantification are determined by gas chromatography with detection on an electron capture detector or by coupled gas chromatography/mass spectrometry. The testing on pesticides is requested for latex foams with a content of at least 20 % natural latex.
- D. For butadiene the applicant shall provide a report presenting the results of the following test procedure. Following milling and weighing of the latex foam, headspace sampling shall be performed. Butadiene content shall be determined by gas chromatography with detection by flame ionisation.

## 7.1(b) 24h VOC emissions

After 24 hours, the test chamber concentrations of the VOCs listed below shall not exceed the limit values shown in Table 13.

#### Table 13

#### VOC emission limits for latex foams

Substance	Limit value (mg/m <sup>3</sup> )
1,1,1 — trichloroethane	0,2
4-Phenylcyclohexene	0,02
Carbon Disulphide	0,02
Formaldehyde	0,005
Nitrosamines (*)	0,0005
Styrene	0,01
Tetrachloroethylene	0,15
Toluene	0,1
Trichlorethylene	0,05
Vinyl chloride	0,0001
Vinyl cyclohexene	0,002
Aromatic hydrocarbons (total)	0,3
VOCs (total)	0,5

(\*) N-nitrosodimethylamine (NDMA), N-nitrosodiethylamine (NDEA), N-nitrosomethylethylamine (NMEA), N-nitrosodi-i-propylamine (NDIPA), N-nitrosodi-n- propylamine (NDPA), N-nitrosodi-n-butylamine (NDBA), N-nitrosopyrrolidinone (NPYR), N-nitrosopiperidine (NPIP), N-nitrosomorpholine (NMOR).

Assessment and verification: The applicant shall provide a declaration of compliance with criterion 7.1(b) which, if applicable, shall be supported by a test report presenting the results of chamber test analysis in accordance with ISO 16000-9.

The wrapped sample shall be stored at room temperature at least for 24 hours. After this period the sample shall be unwrapped and immediately transferred into the test chamber. The sample shall be placed on a sample holder, which allows air access from all sides. The climatic factors shall be adjusted according to ISO 16000-9. For comparison of test results, the area specific ventilation rate (q = n/l) shall be 1. The ventilation rate shall be between 0,5 and 1. The air sampling shall be done  $24 \pm 1$  h after loading of the chamber during 1 hour on DNPH cartridges for the analysis of formaldehyde and other aldehydes and on Tenax TA for the analysis of other volatile organic compounds. Sampling duration for other compounds may be longer but shall be completed before 30 hours.

The analysis of formaldehyde and other aldehydes shall comply with the standard ISO 16000-3. Unless specified differently, the analysis of other volatile organic compounds shall comply with the standard ISO 16000-6.

Testing following the standard CEN/TS 16516 shall be considered as equivalent to those of the ISO 16000 series of standards.

The analysis of nitrosamines shall be done by means of gas chromatography in combination with a thermal energy analysis detector (GC-TEA), in accordance with the BGI 505-23 method (formerly: ZH 1/120.23) or equivalent.

#### 7.2. Polyurethane (PUR) foam

7.2(a) Restricted substances and mixtures

The concentrations in the PUR foam of the substances and mixtures listed below shall not exceed the limit values shown in Table 14.

#### Table 14

Substance group	Substance (acronym, CAS number, element symbol)	Limit value	Method
Biocidal products		Not added inten- tionally	А
Flame retardants		Not added (unless in compliance with conditions in Ta- ble 2 entries (b) and (c)	А
Heavy Metals	As (Arsenic)	0,2 ppm	В
	Cd (Cadmium)	0,1 ppm	В
	Co (Cobalt)	0,5 ppm	В
	Cr (Chromium), total	1,0 ppm	В
	Cr VI (Chromium VI)	0,01 ppm	В
	Cu (Copper)	2,0 ppm	В
	Hg (Mercury)	0,02 ppm	В
	Ni (Nickel)	1,0 ppm	В
	Pb (Lead)	0,2 ppm	В
	Sb (Antimony)	0,5 ppm	В
	Se (Selenium)	0,5 ppm	В

#### List of restricted substances and mixtures in PUR

4.8.2016

EN

Substance group	Substance (acronym, CAS number, element symbol)	Limit value	Method
Plasticizers	Dibutylphthalate (DBP, 84-74-2) (*)	0,01 % w/w (sum	С
	Di-n-octylphthalate (DNOP, 117-84-0) (*)	in furniture for	
	Di (2-ethylhexyl)-phthalate (DEHP, 117-81-7) (*)	3 years old)	
	Butylbenzylphthalate (BBP, 85-68-7) (*)		
	Di-iso-decylphthalate (DIDP, 26761-40-0)		
	Di-iso-nonylphthalate (DINP, 28553-12-0)		
	ECHA Candidate List (**) phthalates	Not added inten- tionally	А
TDA and MDA	2,4 Toluenediamine (2,4-TDA, 95-80-7)	5,0 ppm	D
	4,4'-Diaminodiphenylmethane (4,4'-MDA, 101-77-9)	5,0 ppm	D
Tinorganic substances	Tributyltin (TBT)	50 ppb	Е
	Dibutyltin (DBT)	100 ppb	E
	Monobutyltin (MBT)	100 ppb	E
	Tetrabutyltin (TeBT)	—	_
	Monooctyltin (MOT)	—	_
	Dioctyltin (DOT)	_	_
	Tricyclohexyltin (TcyT)	_	_
	Triphenyltin (TPhT)	_	_
	Sum	500 ppb	Е
Other specific substances that are restricted	Chlorinated or brominated dioxins or furans	Not added inten- tionally	А
	Chlorinated hydrocarbons: (1,1,2,2-Tetrachlor- oethane, Pentachloroethane, 1,1,2-Trichlor- oethane, 1,1-Dichloroethylene)	Not added inten- tionally	А
	Chlorinated phenols (PCP, TeCP, 87-86-5)	Not added inten- tionally	А
	Hexachlorocyclohexane (58-89-9)	Not added inten- tionally	А
	Monomethyldibromo–Diphenylmethane (99688- 47-8)	Not added inten- tionally	А
	Monomethyldichloro-Diphenylmethane (81161- 70-8)	Not added inten- tionally	A
	Nitrites	Not added inten- tionally	A
	Polybrominated Biphenyls (PBB, 59536-65-1)	Not added inten- tionally	А
	Pentabromodiphenyl Ether (PeBDE, 32534-81-9)	Not added inten- tionally	А

Substance group	Substance (acronym, CAS number, element symbol)	Limit value	Method
	Octabromodiphenyl Ether (OBDE, 32536-52-0)	Not added inten- tionally	А
	Polychlorinated Biphenyls (PCB, 1336-36-3)	Not added inten- tionally	А
	Polychlorinated Terphenyls (PCT, 61788-33-8)	Not added inten- tionally	А
	Tris(2,3-dibromopropyl) phosphate (TRIS, 126- 72-7)	Not added inten- tionally	А
	Trimethylphosphate (512-56-1)	Not added inten- tionally	А
	Tris-(aziridinyl)-phosphinoxide (TEPA, 545-55-1)	Not added inten- tionally	А
	Tris(2-chloroethyl)-phosphate (TCEP, 115-96-8)	Not added inten- tionally	А
	Dimethyl methylphosphonate (DMMP, 756-79-6)	Not added inten- tionally	А

(\*) 0,01 % w/w (sum of 4 phthalates in all other furniture products)

(\*\*) With reference to the latest version of the ECHA Candidate List at the time of application.

Assessment and verification: The applicant shall provide a declaration of compliance with criterion 7.2(a). Where testing is required, the applicant shall provide the test results and demonstrating compliance with the limits in Table 14. For methods B, C, D and E where analysis is required, 6 composite samples shall be taken from a maximum depth of up to 2 cm from the surface faces of the material sent to the relevant laboratory.

- A. For biocidal products, phthalates and other specific substances that are restricted the applicant shall provide a declaration supported by declarations from suppliers of the foam confirming that they have not been added intentionally to the foam formulation.
- B. For heavy metals the applicant shall provide a report presenting the results of the following test procedure. Milled sample material is eluted in accordance with DIN 38414-S4 or equivalent in a ratio of 1:10. The resultant filtrate shall be passed through a 0,45 μm membrane filter (if necessary by pressure filtration). The solution obtained shall be examined for the content of heavy metals by atomic emission spectrometry with inductively coupled plasma (ICP-AES or ICP-OES) or by atomic absorption spectrometry using a hydride or cold vapour process.
- C. For the total amount of plasticizers the applicant shall provide a report presenting the results of the following test procedure. Extraction shall be performed using a validated method such as the subsonic extraction of 0,3 g of sample in a vial with 9 ml of t-Butylmethylether during 1 hour followed by the determination of phthalates by GC using a single ion monitoring mass selective detector (SIM Modus).
- D. For TDA and MDA the applicant shall provide a report presenting the results of the following test procedure. Extraction of a 0,5 g composite sample in a 5 ml syringe shall be performed with 2,5 ml of 1 % aqueous acetic acid solution. The syringe is squeezed and the liquid returned to the syringe. After repeating this operation 20 times, the final extract is kept for analysis. A new 2,5 ml of 1 % aqueous acetic acid is then added to the syringe and another 20 cycles repeated. After this, the extract is combined with the first extract and diluted to 10 ml in a volumetric flask with acetic acid. The extracts shall be analysed by high-performance liquid chromatography (HPLC-UV) or HPLC-MS. If HPLC-UV is performed and interference is suspected, reanalysis with high performance liquid chromatography–mass spectrometry (HPLC-MS) shall be performed.

E. For tinorganic substances the applicant shall provide a report presenting the results of the following test procedure. A composite sample of 1-2 g weight shall be mixed with at least 30 ml of extracting agent during 1 hour in an ultrasonic bath at room temperature. The extracting agent shall be a mixture composed as it follows: 1 750 ml methanol + 300 ml acetic acid + 250 ml buffer (pH 4,5). The buffer shall be a solution of 164 g of sodium acetate in 1 200 ml of water and 165 ml acetic acid, to be diluted with water to a volume of 2 000 ml. After extraction the alkyl tin species shall be derivatised by adding 100  $\mu$ l of sodium tetraethylborate in tetrahydrofuran (THF) (200 mg/ml THF). The derivative shall be extracted with n-hexane and the sample shall be submitted to a second extraction procedure. Both hexane extracts shall be combined and further used to determine the organotin compounds by gas chromatography with mass selective detection in SIM modus.

#### 7.2(b) 72h VOC emissions

After 72 hours, the test chamber concentrations of the substances listed below shall not exceed the limit values shown in Table 15.

#### Table 15

#### 72-hour VOC emission limits for PUR foams

Substance (CAS number)	Limit value (mg/m <sup>3</sup> )
Formaldehyde (50-00-0)	0,005
Toluene (108-88-3)	0,1
Styrene (100-42-5)	0,005
Each detectable compound classified as categories C1A or C1B according to Regulation (EC) No 1272/2008	0,005
Sum of all detectable compound classified as categories C1A or C1B according to Regulation (EC) No $1272/2008$	0,04
Aromatic hydrocarbons	0,5
VOCs (total)	0,5

Assessment and verification: The applicant shall provide a declaration of compliance with criterion 7.2(b). If applicable, the declaration shall be supported by test results that show compliance with the limits stated in Table 15. The test sample/chamber combination shall be either:

1 sample of  $25 \times 20 \times 15$  cm dimensions is placed in a 0.5 m<sup>3</sup> test chamber or

2 samples of  $25 \times 20 \times 15$  cm dimensions are placed in a 1,0 m<sup>3</sup> test chamber.

The foam sample shall be placed on the bottom of an emission test chamber and conditioned for 3 days at 23 °C and 50 % relative humidity, applying an air exchange rate n of 0,5 per hour and a chamber loading L of 0,4 m<sup>2</sup>/ m<sup>3</sup> (= total exposed surface of sample in relation to chamber dimensions without sealing edges and back) in accordance with ISO 16000-9 and ISO 16000-11.

Sampling shall be done  $72 \pm 2$  h after loading of the chamber during 1 hour via Tenax TA and DNPH cartridges for VOC and formaldehyde analysis respectively. The emissions of VOC are being trapped on Tenax TA sorbent tubes and subsequently analysed by means of thermo-desorption-GC-MS in accordance to ISO 16000-6.
Results are semi-quantitatively expressed as toluene equivalents. All specified individual analytes are reported from a concentration limit  $\ge 1 \ \mu g/m^3$ . Total VOC value is the sum of all analytes with a concentration  $\ge 1 \ \mu g/m^3$  and eluting within the retention time window from n-hexane (C6) to n-hexadecane (C16), both included. The sum of all detectable compounds classified as categories C1A or C1B according to Regulation (EC) No 1272/2008 is the sum of all these substances with a concentration  $\ge 1 \ \mu g/m^3$ . In case the test results exceed the standard limits, substance specific quantification needs to be performed. Formaldehyde can be determined by collection of the sampled air onto DNPH cartridge and subsequent analysis by HPLC/UV in accordance to ISO 16000-3.

Testing following the standard CEN/TS 16516 shall be considered as equivalent to those of the ISO 16000 series of standards.

#### 7.2(c) Blowing agents

Halogenated organic compounds shall not be used as blowing agents or as auxiliary blowing agents.

Assessment and verification: The applicant shall provide a declaration of non-use from the manufacturer of the foam.

7.3. Other padding materials

Other materials may be permitted to be used as padding in furniture upholstery if the following conditions are met:

- General requirements for hazardous substances set out in criterion 2 are respected.
- Halogenated organic compounds are not used as blowing agents or as auxiliary blowing agents.
- Feathers or down are not be used as padding/filling material either alone or in blends.
- If the padding/filling material uses coconut fibre rubberised using latex, compliance with criterion 7.1(a) and 7.1(b) is demonstrated.

Assessment and verification: The applicant shall provide a declaration of compliance stating:

- (i) The nature of the padding/filling material used and any other blended materials;
- (ii) That the material does not contain any SVHCs or other hazardous substances that are not specifically derogated in Table 2.
- (iii) That halogenated organic compounds have not been used as blowing agents or as auxiliary blowing agents.
- (iv) That down or animal feathers have not been used in the filling/padding material, either alone or in blends.
- (v) If coconut fibres have been rubberised with latex, then compliance with criterion 7.1 for restricted substances and VOC emissions shall be demonstrated.

#### Criterion 8 — Glass: use of heavy metals

This criterion applies to any glass-material included in the final furniture product regardless of the weight fraction it presents.

Any glass used in the furniture product shall comply with the following conditions:

- Not contain leaded glass.
- Not contain lead, mercury or cadmium impurities at levels exceeding 100 mg/kg per metal.

<sup>—</sup> For mirror glass, any paints, primers or varnishes used on the mirror backing shall have a lead content less than 2 000 mg/kg of the in-can substance. Coatings shall be applied using the 'tin process' instead of the 'copper process'.

Assessment and verification:

- (i) The applicant shall provide a declaration from the glass supplier stating that no leaded glass is present in the final furniture product. In the absence of a suitable declaration, the competent body may request analysis of glass in the final furniture product via a non-destructive method using a portable X-Ray Flourescence instrument.
- (ii) The applicant shall provide a declaration from the glass supplier stating that the glass present in the furniture product does not contain lead, mercury or cadmium impurities at levels exceeding 100 mg/kg (0,01 % w/w). In the absence of a suitable declaration, the competent body may request testing of these metals in the glass by X-Ray Fluorescence according to the principles of the ASTM F2853-10 standard or equivalent.
- (iii) The applicant shall provide a declaration from the mirror supplier that all paint, primer and varnish formulations used on any mirror backing contains less than 2 000 mg/kg lead (0,2 % w/w). The declaration shall be supported by a relevant SDS or similar documentation. A further declaration from the mirror glass supplier shall be provided stating that the backing has been applied using the 'tin process' and not the 'copper process'.

### Criterion 9 — Final product requirements

9.1. Fitness for use

EU Ecolabel furniture shall be considered as fit for use if it complies with the requirements set out in the latest versions of any relevant EN standards listed in Appendix IV that relate to the durability, dimensional requirements, safety and strength of the product.

Assessment and verification: The applicant shall provide a declaration stating which (if any) standards in Appendix IV apply to the product and then provide a declaration of compliance with any relevant EN standards, supported by test reports from either the furniture manufacturer or component part/material suppliers, as appropriate.

9.2. Extended product guarantee

The applicant shall provide at no additional cost a minimum of a five year guarantee effective from the date of delivery of the product. This guarantee shall be provided without prejudice to the legal obligations of the manufacturer and seller under national law.

Assessment and verification: The applicant shall provide a declaration of compliance and indicate the terms and conditions of the extended product guarantee that are provided in consumer information documentation and that meet the minimum requirements set out in this criterion.

9.3. Provision of spare parts

The furniture manufacturer shall make spare parts available to customers for a period of at least 5 years from the date of delivery of the product. The cost (if any) of spare parts shall be proportional to the total cost of the furniture product. Contact details that shall be used in order to arrange the delivery of spare parts shall be provided.

Assessment and verification: The applicant shall provide a declaration that spare parts shall be available for a period of at least 5 years from the date of delivery of the product. The parts shall be available for free during the guarantee period if the goods are found to be faulty during normal use or at a proportionate cost if the goods were damaged by misuse. Contact information shall be included in consumer information.

9.4. Design for disassembly

For furniture consisting of multiple component parts/materials, the product shall be designed for disassembly with a view to facilitating repair, reuse and recycling. Simple and illustrated instructions regarding the disassembly and replacement of damaged component parts/materials shall be provided. Disassembly and replacement operations shall be capable of being carried out using common and basic manual tools and unskilled labour.

Assessment and verification: The applicant shall provide technical drawings that illustrate how the furniture item can be assembled/disassembled using basic tools and unskilled labour. In the case of upholstery, such disassembly may include the use of zip fastenings and velcro to attach/detach sofa cushions from the frame and interior padding from covering materials. If necessary, provision must be made for screw fittings that go directly into wood-based panels so that the screw can be re-inserted during reassembly at a different point than where it was removed from during disassembly.

9.5. VOC emissions

If the furniture product contains any of the component parts/materials listed below, VOC emission testing shall be required:

- Upholstery coverings made of leather;
- Upholstery coverings made of coated fabrics;
- Any component parts that account for more than 5 % of the total furniture product weight (excluding packaging) and that have been treated with high VOC content (higher than 5 %) coating formulations that have been applied at rates greater than 30  $g/m^2$  of coated surface area or whose application rates have not been calculated.

Packaging and delivery of samples sent for testing, their handling and conditioning, test chamber requirements and gas analysis methods shall follow the procedures described in the ISO 16000 set of standards.

Testing may be carried out on the entire furniture product (see conditions and limits in Table 16) or in smaller test chambers specifically for the component parts/materials listed above (see conditions and limits in Table 17).

VOC emissions shall not exceed the limit values given in Table 16 and Table 17.

### Table 16

# Maximum VOC emission limit values for specific furniture products

Test parameter	Armchairs	and Sofas Office of		chairs	Other furniture items
Chamber volume		In	the range of 2-10	m³	
Loading rate	Product sha	roduct shall occupy approximately 25 % of chamber volume			(*) 0,5-1,5 m <sup>2</sup> / m <sup>3</sup>
Ventilation rate	4,0	m³/h	2,0 m³/h		(*) 0,5-1,5 h <sup>-1</sup>
Substance	3d	28d	3d	28d	28d
Formaldehyde	_	60 µg/m³	_	60 µg/m³	60 µg/m³
TVOC (*)	≤ 3 000 µg/m³	≤ 400 µg/m³	_	≤ 450 µg/m³	≤ 450 µg/m³
TSVOC	_	≤ 100 µg/m³		≤ 80 µg/m³	≤ 80 µg/m³

Test parameter	Armchairs	and Sofas	Office chairs		Other furniture items
C-substances (1)	≤ 10 µg/m³ (to- tal limit)	≤ 1 µg/m³ (per substance)	≤ 10 µg/m³ (to- tal limit)	≤ 1 µg/m³ (per substance)	≤ 1 µg/m³ (per substance)
R-value for LCI substances ( <sup>2</sup> )	_	≤ 1	_	≤ 1	≤ 1

(\*) Although there is scope to vary the loading rate and ventilation rate for other furniture items, the ratio between the loading rate  $(m^2/m^3)$  and the ventilation rate  $(h^{-1})$  shall be maintained at 1,0.

 Formaldehyde is excluded from consideration within cumulative carcinogenic VOC emission calculations and instead has its own individual limit.

(2) R value = total of all quotients ( $C_i/LCI_i$ ) < 1 (where  $C_i$  = substance concentration in the chamber air,  $LCI_i$  = LCI value of the substance as defined by the latest data defined under the European Collaborative Action 'Urban air, indoor environment and human exposure'.

### Table 17

### Maximum VOC emission limit values for targeted furniture materials/parts

Test parameter	Coated component parts		Leather or coated fabric upholstery covering materials	
Minimum allowed chamber volume	200 L for wood-based component parts 20 L for other component parts		20 L	
Ventilation rate	0,5	h- 1	1,5 m	<sup>3</sup> /m <sup>2</sup> ·h
Substance	3d	28d	3d	28d
Formaldehyde	_	60 µg/m³	—	60 µg/m³
TVOC	$\leq$ 3 000 µg/m <sup>3</sup>	$\leq 400 \ \mu g/m^3$		≤ 450 µg/m³
TSVOC	_	$\leq 100 \ \mu g/m^3$		≤ 80 µg/m³
C-substances (1)	≤ 10 μg/m³ (total limit)	≤ 1 µg/m³ (per sub- stance)	≤ 10 µg/m³ (total limit)	≤ 1 µg/m³ (per sub- stance)
R-value for LCI sub- stances ( <sup>2</sup> )	_	≤ 1	_	≤ 1

<sup>(1)</sup> Formaldehyde is excluded from consideration within cumulative carcinogenic VOC emission calculations and instead has its own individual limit.

(2) R value = total of all quotientes ( $C_i/LCI_i$ ) < 1 (where  $C_i$  = substance concentration in the chamber air,  $LCI_i$  = LCI value of the substance as defined by the latest data defined under the European Collaborative Action 'Urban air, indoor environment and human exposure'.

Assessment and verification: Where the furniture product is deemed to require final product VOC emission testing, the applicant shall provide a declaration of compliance, supported by a test report from chamber tests carried according to the ISO 16000 series of standards. Tests carried out according to CEN/TS 16516 shall be considered as equivalent to ISO 16000. If the chamber concentration limits specified at 28 days can be met 3 days after placing the sample in the chamber, or any other time period between 3 and 27 days after placing the sample in the chamber, then the compliance with the requirements can be declared and the test may be stopped prematurely.

Test data from up to 12 months prior to the EU Ecolabel application shall be valid for products or component parts/materials so long as no changes to the manufacturing process or chemical formulations used have been made that would be considered to increase VOC emissions from the final product or relevant component parts/materials.

Test data demonstrating compliance with the limits in Table 17 for relevant component parts/materials that is provided directly by suppliers shall also be accepted if they are accompanied by a declaration from that supplier.

# Criterion 10 — Consumer Information

A single consumer information document shall be provided with the product which includes information in the language of the country where the product is placed on the market, relating to the following aspects:

- A product description as per the requirements of criterion 1.
- A detailed description of the best ways to dispose of the product (i.e. reuse, take-back initiative by the applicant, recycling, energy recovery) shall be given to the consumer, ranking them according to their impact on the environment.
- Information about the polymer types of any plastic component parts with a weight greater than 100 g that were not marked in accordance with the requirements of criterion 4.1.
- A declaration that the designation, description, label or marking of leather are used in accordance with the requirements established in EN 15987 and EN 16223.
- A clear statement under what conditions the furniture product should be used. For example indoors, outdoors, temperature ranges, load bearing capacities and how to correctly clean the product.
- Information regarding the type of glass used, any safety information, its suitability for contact with hard materials such as glass, metal or stone and information regarding the correct disposal of the glass, for example its compatibility or non-compatibility with post-consumer container glass.
- A declaration of compliance with relevant fire safety regulations in the country of sale for upholstered furniture, details regarding which flame retardants have been used (if any) and in what materials (if any).
- A declaration of the non-use of biocidal products in order to provide a final disinfective effect in any furniture that is clearly marketed for indoor use and with outdoor furniture, a declaration of which active substances of biocidal products have been used (if any) and in what materials (if any).
- A statement of compliance with any relevant EN standards as referred to in criterion 9.1 and Appendix IV.
- Relevant information regarding the terms and conditions of the product guarantee as per the requirements of criterion 9.2.
- Relevant contact information regarding provision of spare parts as per the requirements of criterion 9.3.
- Well illustrated assembly and disassembly instructions as per the requirements of criterion 9.4.

Assessment and verification: The applicant shall provide a copy of the consumer information document that is to be provided with the product that shows compliance with each of the points listed in the criterion, as appropriate.

### Criterion 11 — Information appearing on the EU Ecolabel

If the optional label with text box is used, it shall contain, where relevant, three of the following statements:

- Wood, cork, bamboo and rattan from sustainably managed forests
- Recycled content (wood or plastic, if applicable)
- Restricted hazardous substances

- Not treated with biocidal products (if applicable)
- Not treated with flame retardants (if applicable)
- Low formaldehyde emission product
- Low VOC emission product
- Product designed for disassembly and ease of repair
- Where cotton-based textile materials have been used in furniture upholstery using organic or IPM cotton, text may
  be displayed in box 2 of the EU Ecolabel as follows:

# Table 18

# Information that may appear alongside the EU Ecolabel relating to cotton in textiles

Production specification	Text that may be displayed	
Organic content of more than 95 %	Textiles made with organic cotton	
IPM content of more than 70 %	Cotton grown with reduced use of pesticides	

The guidelines for the use of the optional label with the text box can be found in the 'Guidelines for the use of the EU Ecolabel logo' on the website:

http://ec.europa.eu/environment/ecolabel/documents/logo\_guidelines.pdf

Assessment and verification: The applicant shall provide a declaration of compliance with this criterion.

### L 210/142 EN

### Appendix I

# GUIDANCE FOR CALCULATING VOC USED IN SURFACE COATINGS

The calculation method requires the following information:

- Total coated surface area of final assembled product
- The VOC content of the coating compound (in g/L).
- The volume of coating compound present before the coating operation.
- The number of identical units processed during the coating operation.
- The volume of coating compound remaining after the coating operation.
- An example calculation is as follows:

Total coated surface area of final assembled product	$= 1,5 \text{ m}^2.$
The VOC content of the coating compound (in g/L)	= 120 g/L.
The volume (1) of coating compound present before coating operation	= 18,5 L.
The number of identical units processed during the coating operation	= 4.
The volume (1) of coating compound remaining after coating operation	= 12,5 L

Total area coated	$= 4 \times 1.5 \text{ m}^2$	$= 6 \text{ m}^2$ .
Total volume of coating compound used	= 18,5 — 12,5	= 6 L.
Total VOC applied to surface	= 3,9 L × 120 g/L	= 468 g
Total VOC applied per m <sup>2</sup>	$= 468 \text{ g}/6 \text{ m}^2$	$= 78 \text{ g/m}^2$ .

Where more than one coating compound is applied, such as primers or finishing coats, the volumetric consumption and VOC contents shall also be calculated and added together.

Options to lower the total quantity of VOCs content used in coating operations include using more efficient techniques. Indicative efficiencies of different coating techniques are shown below.

# Table

# Indicative efficiency factors for coating techniques:

Coating technique	Effectiveness (%)	Efficiency factor
Spraying device without recycling	50	0,5
Electrostatic spraying	65	0,65
Spraying device with recycling	70	0,7
Spraying bell/disk	80	0,8

<sup>&</sup>lt;sup>(1)</sup> Note that weight measurements can be used instead of volume so long as the density of the coating compound is known and accounted for in the calculation.

Coating technique	Effectiveness (%)	Efficiency factor
Roller varnishing	95	0,95
Blanket varnishing	95	0,95
Vacuum varnishing	95	0,95
Dipping	95	0,95
Rinsing	95	0,95

L 210/144

EN

Appendix II

# EN 13336 REQUIREMENTS FOR FURNITURE LEATHER

Table

# Physical requirements of leather used in EU Ecolabel furniture (as per EN 13336)

Fundamental characteristics	Test method EN ISO 4045		Recommended values		
rundamentar enaraceristics			Nubuck, Suede and Aniline (*)	Semi-aniline (*)	Coated, pigmented and other (*)
pH and ∆pH			$\ge$ 3,5 (if the pH is < 4,0, $\Delta$ pH shall be $\le$ 0,7		
Tear load, average value	EN ISO 3377-1			> 20 N	
Colour fastness to to-and-fro rubbing	EN ISO 11640. Total mass of finger	Aspects to be evaluated	Change of leather colour and felt staining	Change of leather colour and felt staining No destruction of fi	
	1 000 g.	using dry felt	50 cycles, ≥ 3 grey scale	500 cycles,	≥ 4 grey scale
	solution as defined in EN ISO 11641.	using wet felt	20 cycles, ≥ 3 grey scale	80 cycles, ≥ 3/4 grey scale	250 cycles, ≥ 3/4 grey scale
		using felt wetted with artificial perspiration	20 cycles, ≥ 3 grey scale	50 cycles, ≥ 3/4 grey scale	80 cycles, ≥ 3/4 grey scale
Colour fastness to artificial light	EN ISO 105-B02 (method 3)		≥ 3 blue scale	≥ 4 blue scale	≥ 5 blue scale
Dry finish adhesion	EN ISO 11644	EN ISO 11644		≥ 2 N/10 mm	
Dry flex resistance	EN ISO 5402-1		For aniline leather with non- pigmented finish only, 20 000 cycles (no finish damage cracks)	50 000 cycles (no finish dam- age cracks)	50 000 cycles (no finish damage cracks)
Colour fastness to water spotting	EN ISO 15700	EN ISO 15700		≥ 3 grey scale (no permanent swelling)	
Cold crack resistance of finish	EN ISO 17233		— – 15 °C (no finish crack)		o finish crack)
Fire resistance	EN 1021 or relevant national standards		Pass		
(*) Definitions of these leather types are accord	ing to EN 15987.				

#### Appendix III

## PROHIBITED ARYLAMINE COMPOUNDS IN FINAL LEATHER, TEXTILE AND COATED FABRIC MATERIALS

Included here are the substances listed in Entry 43 of Annex XVII to Regulation (EC) No 1907/2006 that shall be tested for in any dyed leather (using the EN 17234 standard) or textiles (using the EN 14362-1 and -3 standards).

### Table 1

# Carcinogenic arylamines to be tested in textiles or leather.

Aryl amine	CAS Number	Aryl amine	CAS Number
4-aminodiphenyl	92-67-1	4,4'-oxydianiline	101-80-4
Benzidine	92-87-5	4,4'-thiodianiline	139-65-1
4-chloro-o-toluidine	95-69-2	o-toluidine	95-53-4
2-naphtylamine	91-59-8	2,4-diaminotoluene	95-80-7
o-amino-azotoluene	97-56-3	2,4,5-trimethylaniline	137-17-7
2-amino-4-nitrotoluene	99-55-8	4-aminoazobenzene	60-09-3
4-chloroaniline	106-47-8	o-anisidine	90-04-0
2,4-diaminoanisol	615-05-4	2,4-Xylidine	95-68-1
4,4'-diaminodiphenylmethane	101-77-9	2,6-Xylidine	87-62-7
3,3'-dichlorobenzidine	91-94-1	p-cresidine	120-71-8
3,3'-dimethoxybenzidine	119-90-4	3,3'-dimethylbenzidine	119-93-7
3,3'-dimethyl-4,4'-diaminodiphenyl- methane	838-88-0	4,4'-methylene-bis-(2-chloro-aniline)	101-14-4

A number of other dye compounds, which are not directly restricted by Entry 43 of Annex XVII to Regulation (EC) No 1907/2006, are known to cleave during processing to form some of the prohibited substances listed in Table 1. In order to greatly reduce uncertainty about compliance with the established limit of 30 mg/kg for the substances listed in Table 1, manufacturers are recommended, but not obliged, to avoid the use of the dyes listed in Table 2.

# Table 2

### Indicative list of dyes that may cleave to form carcinogenic arylamines

Disperse dyes			Basic dyes	
Disperse Orange 60	Disperse Yellow 7	Basic Brown 4	Basic Red 114	
Disperse Orange 149	Disperse Yellow 23	Basic Red 42	Basic Yellow 82	
Disperse Red 151	Disperse Yellow 56	Basic Red 76	Basic Yellow 103	
Disperse Red 221	Disperse Yellow 218	Basic Red 111		

Ι	Disperse dyes		Basic dyes			
Acid dyes						
CI Acid Black 29	CI Acid Red 4	CI Acid Red 85	CI Acid Red 148			
CI Acid Black 94	CI Acid Red 5	CI Acid Red 104	CI Acid Red 150			
CI Acid Black 131	CI Acid Red 8	CI Acid Red 114	CI Acid Red 158			
CI Acid Black 132	CI Acid Red 24	CI Acid Red 115	CI Acid Red 167			
CI Acid Black 209	CI Acid Red 26	CI Acid Red 116	CI Acid Red 170			
CI Acid Black 232	CI Acid Red 26:1	CI Acid Red 119:1	CI Acid Red 264			
CI Acid Brown 415	CI Acid Red 26:2	CI Acid Red 128	CI Acid Red 265			
CI Acid Orange 17	CI Acid Red 35	CI Acid Red 115	CI Acid Red 420			
CI Acid Orange 24	CI Acid Red 48	CI Acid Red 128	CI Acid Violet 12			
CI Acid Orange 45	CI Acid Red 73	CI Acid Red 135				
		Direct dyes				
Direct Black 4	Direct Blue 192	Direct Brown 223	Direct Red 28			
Direct Black 29	Direct Blue 201	Direct Green 1	Direct Red 37			
Direct Black 38	Direct Blue 215	Direct Green 6	Direct Red 39			
Direct Black 154	Direct Blue 295	Direct Green 8	Direct Red 44			
Direct Blue 1	Direct Blue 306	Direct Green 8.1	Direct Red 46			
Direct Blue 2	Direct Brown 1	Direct Green 85	Direct Red 62			
Direct Blue 3	Direct Brown 1:2	Direct Orange 1	Direct Red 67			
Direct Blue 6	Direct Brown 2	Direct Orange 6	Direct Red 72			
Direct Blue 8	Basic Brown 4	Direct Orange 7	Direct Red 126			
Direct Blue 9	Direct Brown 6	Direct Orange 8	Direct Red 168			
Direct Blue 10	Direct Brown 25	Direct Orange 10	Direct Red 216			
Direct Blue 14	Direct Brown 27	Direct Orange 108	Direct Red 264			
Direct Blue 15	Direct Brown 31	Direct Red 1	Direct Violet 1			
Direct Blue 21	Direct Brown 33	Direct Red 2	Direct Violet 4			
Direct Blue 22	Direct Brown 51	Direct Red 7	Direct Violet 12			
Direct Blue 25	Direct Brown 59	Direct Red 10	Direct Violet 13			
Direct Blue 35	Direct Brown 74	Direct Red 13	Direct Violet 14			
Direct Blue 76	Direct Brown 79	Direct Red 17	Direct Violet 21			
Direct Blue 116	Direct Brown 95	Direct Red 21	Direct Violet 22			
Direct Blue 151	Direct Brown 101	Direct Red 24	Direct Yellow 1			
Direct Blue 160	Direct Brown 154	Direct Red 26	Direct Yellow 24			
Direct Blue 173	Direct Brown 222	Direct Red 22	Direct Yellow 48			

Appendix IV

# FURNITURE PRODUCT DURABILITY, STRENGTH AND ERGONOMIC STANDARDS

# Table

# Indicative list of EN furniture standards (elaborated by the Technical Committee CEN/TC 207 'Furniture') relevant to criterion 9.1.

Standard	Title
Upholstered furn	niture
EN 1021-1	Furniture — Assessment of the ignitability of upholstered furniture — Part 1: Ignition source smouldering cigarette
EN 1021-2	Furniture — Assessment of the ignitability of upholstered furniture — Part 2: Ignition source match flame equivalent
Office furniture	
EN 527-1	Office furniture — Work tables and desks — Part 1: Dimensions
EN 527-2	Office furniture — Work tables and desks — Part 2: Mechanical safety requirements
EN 1023-2	Office furniture — Screens — Part 2: Mechanical safety requirements
EN 1335-1	Office furniture — Office work chair — Part 1: Dimensions — Determination of dimensions
EN 1335-2	Office furniture — Office work chair — Part 2: Safety requirements
EN 14073-2	Office furniture — Storage furniture — Part 2: Safety requirements
EN 14074	Office furniture — Tables and desks and storage furniture — Test methods for the determination of strength and durability of moving parts. (after testing, the components shall not be damaged and shall still function as intended).

# **Outdoor furniture**

EN 581-1	Outdoor furniture — Seating and tables for camping, domestic and contract use — Part 1: General safety requirements
EN 581-2	Outdoor furniture — Seating and tables for camping, domestic and contract use — Part 2: Mechan- ical safety requirements and test methods for seating
EN 581-3	Outdoor furniture — Seating and tables for camping, domestic and contract use — Part 3: Mechan- ical safety requirements and test methods for tables

# Seating furniture

EN 1022	Domestic furniture — Seating — Determination of stability
---------	---

L 210/148

EN

Standard	Title
EN 12520	Furniture — Strength, durability and safety — Requirements for domestic seating
EN 12727	Furniture — Ranked seating — Test methods and requirements for strength and durability
EN 13759	Furniture — Operating mechanisms for seating and sofa-beds — Test methods
EN 14703	Furniture — Links for non-domestic seating linked together in a row — Strength requirements and test methods
EN 16139	Furniture — Strength, durability and safety — Requirements for non-domestic seating
Tables	
EN 12521	Furniture — Strength, durability and safety — Requirements for domestic tables
EN 15372	Furniture — Strength, durability and safety — Requirements for non-domestic tables
Kitchen furniture	
EN 1116	Kitchen furniture — Coordinating sizes for kitchen furniture and kitchen appliances
EN 14749	Domestic and kitchen storage units and worktops — Safety requirements and test methods
Beds	
EN 597-1	Furniture — Assessment of the ignitability of mattresses and upholstered bed bases — Part 1: Igni- tion source: Smouldering cigarette
EN 597-2	Furniture — Assessment of the ignitability of mattresses and upholstered bed bases — Part 2: Igni- tion source: Match flame equivalent
EN 716-1	Furniture — Children's cots and folding cots for domestic use — Part 1: Safety requirements
EN 747-1	Furniture — Bunk beds and high beds — Part 1: Safety, strength and durability requirements
EN 1725	Domestic furniture — Beds and mattresses — Safety requirements and test methods
EN 1957	Furniture — Beds and mattresses — Test methods for determination of functional characteristics and assessment criteria
EN 12227	Playpens for domestic use — Safety requirements and test methods

Storage furniture

EN 16121	Non-domestic storage furniture — Requirements for safety, strength, durability and stability
EN 16121	Non-domestic storage furniture — Requirements for safety, strength, durability and stability

Standard

Title

Other types of	Other types of furniture				
EN 1729-1	Furniture — Chairs and tables for educational institutions — Part 1: Functional dimensions				
EN 1729-2	Furniture — Chairs and tables for educational institutions — Part 2: Safety requirements and test methods				
EN 13150	Workbenches for laboratories — Dimensions, safety requirements and test methods				
EN 14434	Writing boards for educational institutions — Ergonomic, technical and safety requirements and their test methods				

# 建材からの VOC 放散速度基準

平成 20 年 4 月 1 日制定

建材からのVOC放散速度基準化研究会 (事務局:財団法人建材試験センター)

序文3	_
1. 適用範囲 3	_
1−1. 対象の資材 3	-
1−2. 引用規格及び用語 3	-
2. 建材からの VOC 放散速度基準値 3	_
3. 試験方法 4	-
3-1. 一般 4	_
3-2. 試験体の選定方法並びに試験片の作製方法 4	_
3-3. 試験条件	-
3-4. 試験結果	-
3-5. 報告書 4	-
付属書(参考)5	_
1. 引用規格 - 5	-
2. 表示内容の基本事項 5	_
3. 適合証明・表示区分5	-
4. 適合証明・表示の要件 5	_
解説7	_

委員名簿

(平成 19 年 7 月 6 日現在)

	氏名	会社	所属	役職
1	村上 周三	慶應義塾大学	理工学部システムデザイン工学科	教授
2	吉野 博	東北大学大学院	工学研究科 都市·建築学専攻建 築環境工学	教授
3	田辺 新一	早稲田大学	理工学術院 建築学科	教授
4	伊藤 一秀	九州大学大学院	総合理工学研究院 エネルギー環 境共生工学部門	准教授
5	土屋 邦男	社団法人公共建築協会		参事
6	内田 和昌	社団法人文教施設協会	企画部	部長
7	ЩП —	清水建設株式会社 (社団法人建築業協会)	技術研究所	主席研究員
8	藤村 孝夫	社団法人住宅生産団体連合会	住宅性能部	部長
9	姫野 富幸	日本繊維板工業会		顧問
10	木村 浩芳	有限責任中間法人日本壁装協会		専務理事
11	藤田 清臣	松下電工株式会社 (社団法人日本建材・住宅設備産業 協会)	住建事業企画室	
12	田村彰	財団法人日本合板検査会	調査研究部	部長
13	秋元 直司	日本複合床板工業会		
14	澤田 幸三	日本接着剤工業会		
15	井上 雅雄	日本接着剤工業会		
16	吉田 洋一	財団法人日本塗料検査協会	性能評価部	部長
17	橋本 久幸	社団法人全国家具工業連合会		専務理事 · 事 務局長
18	田中 正躬	財団法人建材試験センター		理事長
関	森下 加代子	有限責任中間法人日本壁装協会		技術担当課長
関	黒木 勝一	財団法人建材試験センター	中央試験所	副所長
関	仲谷 一郎	財団法人建材試験センター	性能評価本部	副本部長
関	島崎 清幸	財団法人建材試験センター	適合証明課	課長代理
関	舟木 理香	財団法人建材試験センター	性能評定課	
			1	-

事	佐藤 哲夫	財団法人建材試験センター	調査研究開発課	課長
事	天野 康	財団法人建材試験センター	調査研究開発課	上級専門職
事	佐伯 智寛	財団法人建材試験センター	適合証明課	技術主任

関:関係者、 事:事務局

序文

この基準は、「小形チャンバー法」のJIS制定を受けて、建築資材(以下、資材という。) から放散する揮発性有機化合物(VOC)の放散速度に関して、製造・購入等の関係者(建 材の生産者、建設業者、建設工事の発注者、設計者、居住者、仕様書等作成者等)が共通 の認識により資材の評価・判断が可能となる基本事項を定めたものである。

本基準は、「建材からのVOC放散速度基準化研究会」の基準として制定する。

- 1. 適用範囲
- 1-1. 対象の資材

この基準にて対象とする資材(以下、対象資材という。)は、居室に使用される次のもの とする。

- ① JIS A1902-1 で対象としている建築用ボード類、壁紙、床材
- JIS A1902-2 で対象としている接着剤
- ③ JIS A1902-3 で対象としている塗料、建築用仕上塗材
- ④ JIS A1902-4 で対象としている断熱材
- ⑤ その他、対象 VOC を使用している資材のうち当該基準で評価することが合理的なもの
- 1-2. 引用規格及び用語

この基準では、次の規格を原則として引用する。

- JIS A1901:2003 建築材料の揮発性有機化合物(VOC), ホルムアルデヒド及び他のカル ボニル化合物等の放散速度の測定方法-小形チャンバー法
- JIS A1902-1:2006 建築材料の揮発性有機化合物(VOC),ホルムアルデヒド及び他のカル ボニル化合物放散量測定におけるサンプル採取,試験片作製及び試 験条件-第1部:ボード類,壁紙及び床材
- JIS A1902-2:2006 建築材料の揮発性有機化合物(VOC),ホルムアルデヒド及び他のカル ボニル化合物放散量測定におけるサンプル採取,試験片作製及び試 験条件-第2部:接着剤
- JIS A1902-3:2006 建築材料の揮発性有機化合物(VOC),ホルムアルデヒド及び他のカル ボニル化合物放散量測定におけるサンプル採取,試験片作製及び試 験条件-第3部:塗料及び建築用仕上塗材
- JIS A1902-4:2006 建築材料の揮発性有機化合物(VOC),ホルムアルデヒド及び他のカル ボニル化合物放散量測定におけるサンプル採取,試験片作製及び試 験条件-第4部:断熱材

2. 建材からの VOC 放散速度基準値

建材からの VOC 放散速度は、表1の対象 VOCについて定めるものとし、3.の試験方法による7日目の測定結果が、表1の基準値以下であることとする。なお、減衰傾向が認められる場合には7日目以前の測定値により判断してもよい。

対象VOC	略記号	放散速度基準値(μg/m²h)
トルエン	Т	38
キシレン	Х	120
エチルベンゼン	E	550
スチレン	S	3 2

表1 対象VOCと基準値

注: 放散速度基準値の算定は、実際の建物使用時の負荷率を 3.4m<sup>2</sup>/m<sup>3</sup>と設定した。詳細 は解説を参照。

# 3. 試験方法

3-1. 一般

試験は、JIS A1901 に基づき、3-2.の「試験体の選定方法並びに試験片の作製方法」に 従って作製した試験片によって行う。

3-2. 試験体の選定方法並びに試験片の作製方法

対象資材からの試験体の選定は、原則として各建材の JIS に基づき行う。また、試験片の作製方法は、JIS A1902-1、JIS A1902-2、JIS A1902-3、JIS A1902-4 に従って行う。

- 3-3. 試験条件
  - 試験条件は、3-1に規定した規格による他、次のとおりとする。
    - ①試験片の数:1条件につき、2体とする。
    - ②試料負荷率:標準として 2.2 m<sup>2</sup>/m<sup>3</sup>

ただし、接着剤の場合は 0.4 m²/m³を選択しても良い。

③空気捕集間隔:試験開始後1日目、3日目及び7日目とする

3-4. 試験結果

試験結果については、JIS A1901 に規定する項目及び 3-2. ~3-3. で定めた事項を報告する。

# 3-5. 報告書

試験報告書には、JIS A1901 の 13 報告書で定める事項を記載する。

# 付属書 (参考)

# 基準適合の証明・表示

当基準に基づく適合性の証明・表示をする際は、各機関の既存制度との整合を図ると共 に、次の原則事項により行うことが望ましい。

1. 引用規格

- JIS Q1000:2005 適合性評価―製品規格への自己適合宣言指針
- JIS Q17030:2004 適合性評価-第三者適合マークに対する一般要求事項
- 2. 表示内容の基本事項

当基準に適合している旨の表示を行なう際には、原則として次の事項を記載する。

- 基準適合性を保証する機関名と認証等の交付日及び連絡先
- 2) 基準名(建材からの VOC 放散速度基準…建材からの VOC 放散速度基準化研究会)
- 3) 基準適合している旨の記述又は記号
- 4) 建材名
- 5) 商品名
- 6) 製造者名及び連絡先
- 3. 適合証明·表示区分

基準適合の形態区分は、次のいずれか又は組み合わせがある。

1) 自己証明

製造者が試験データ等により自己責任で基準適合性を証明するもの。

2)試験報告書

試験した建材のサンプルが、基準に適合していることを試験機関が証明するもの。

3) 仕様書等による発注者基準の適合性証明

建築工事仕様書、設計図書等で、当該基準を引用し、建材受け入れ・使用許諾の判 断に資するもの。この際の、受け入れ及び許諾建材の判断は、引用機関の定めによる。

4) 証明・マーク

第三者が建材の品質保証として、試験データ、品質管理システム等各機関の証明・ マーク表示許諾基準により、特定の様式・マークにより基準適合性を保証するもの。

- 4. 適合証明・表示の要件
  - 1)自己適合宣言

自己立証により基準適合性を宣言する場合には、JIS Q1000 に基づき行う。

2) 試験報告書

JIS A 1901 箇条 13 報告書に定める事項及び各機関での試験結果の証明及び建材使 用者の判断に関する試験体・試験条件・試験結果等の技術的な必要情報を記述する。 3)発注者基準の基準適合文書 発注者基準の名称、要件等、特定の発注者の制度的要件を満たしていることの表示。 4)証明・マーク

第三者機関がマーク等で当基準が適合していることを保証する際には、JISQ17030 に基づき、証明・表示する。

この際、2. の1)及び2)の事項は、原則としてマーク中に挿入するものとする。 但し、マーク表示の意図する内容が社会的に誤解を生じないように、各機関の責任 のもとで当該基準の適合性が説明可能となる環境を整備するものとする。

# 解説

(基準制定の背景)

建築基準法によるシックハウス対策規制以後、公共住宅等ではホルムアルデヒド以外のVOC について引渡し前の室内濃度測定を要求している。また、住宅の品質確保の促進等に関する法律 の住宅性能表示制度でも、VOCの現場測定が盛り込まれている。

一方で、各種建材からのVOCの放散については試験法 JIS により測定できるものの、測定結 果の判断基準がないため、建材メーカーや設計・施工者、居住者等からは資材からのVOC放散 に関する判断のよりどころとなる基準化を望む声が多く寄せられている。これまでにホルムアル デヒド・VOCに関する JIS 原案作成並びにVOCの測定法等に関する調査研究を行ってきた (財)建材試験センターを事務局として、学識経験者、業界関係者からなる「建材からのVOC放 散速度基準化研究会」が発足した。研究会では基準化に向けて行政担当者をオブザーバーとして 招き意見を頂きつつ、各種団体の自主基準と整合し、同時に先進各国の基準との調和に配慮して 検討した。

(放散基準の社会的性格)

本基準は、製造・販売者並びに使用・購入者が共通の認識で材料を選択・判断できる共通の「も のさし」として、当研究会で自主的に定め、公表・公開したものである。本基準では、放散速度 基準値のほかに、運用にあたり基本となる表示方法、試験方法、判断方法等についても制定した。 なお、本基準は、各種団体の自主基準等において引用可能とする。

この基準値は、以下の算定法により、通常想定される使用状態において、対象VOCの室内濃度が指針値以下となることを目標に定めたものである。

(対象資材の設定根拠)

対象資材は、JIS A1902-1、JIS A1902-2、JIS A1902-3、JIS A1902-4 で定めるサンプル採取、 試験片作製及び試験条件が確定している資材を原則とした。ただし、当該試験方法を準用して適 切に測定ができる場合は、本基準を採用しても良い。

(基準値設定の根拠)

対象VOCについては、JIS A1901 にて測定できる化学物質、公共住宅や住宅性能表示制度に て濃度測定対象としている化学物質、建材に使用されると考えられる化学物質を対象として選定 した。

基準値は、建築基準法のシックハウス対策技術的基準の根拠を参考に、VOC放散の程度、使 用実態等をもとに、次の考え方により計算した。このため、当該基準値は想定条件(28°C)下にお けるひとつの目安であり、高温下等での環境を満たす指針値ではない。

- ・ 想定条件は、建築基準法のシックハウス対策技術的基準の根拠と同様とした。
- 対象資材が室内全面に施工され、床面積の3倍の家具が設置されている状況を想定し、試料 負荷率は3.4(3.4=2.2+0.4×3)m<sup>2</sup>/m<sup>3</sup>として算定した。
- ・ 換気回数は0.5 回/h、気温は28℃を想定した。

化学物質名	指針値※	試料負荷率L	換気回数	放散速度
	$\mu$ g/m $^3$	$m^2/m^3$	1/h	$\mu$ g/m $^2$ h
トルエン	260	2. 2+0. 4*3=3. 4	4 0.5	38
キシレン	870			120
エチルベンゼン	3800			550
スチレン	220			32

放散速度の値は有効数字3桁以下を切り捨てた。なお、測定は安全側での測定となるように、試料負荷率2.2 m<sup>2</sup>/m<sup>3</sup>(接着剤は0.4 m<sup>2</sup>/m<sup>3</sup>を選択しても良い。)にて行う。

指針値※:厚生労働省が示した化学物質室内濃度指針値

(試験方法並びに試験片の作製について)

当基準への適合性を確認する試験方法は、JIS A1901 小形チャンバー法、試験片の作成方法は JIS A1902-1、JIS A1902-2、JIS A1902-3、JIS A1902-4 とした。ただし、本基準に規定する方法 と相関が図れることが確認できれば、本基準に基づく方法と異なる条件の試験体を選定しても構 わない。

(表示方法について)

基準への適合性の確認については、共通のルールに基づく統一的な表示を行うことが重要であ る。しかし、現時点ではホルムアルデヒドの F☆☆☆☆表示等、類似する表示があることや、化 学物質以外の表示も多数あることから、表示の関係者合意を得ることは現状では困難と判断した。 本基準では、表示における基本的な考え方を付属書にて示すに留めた。なお、関連団体が付属書 をふまえた表示制度を適用することを妨げるものではない。

(未制定 JIS の引用について)

当基準を検討した時点にて未制定であった次の JIS については、制定され次第、当基準に盛り 込むこととした。

JIS A1912 建築材料などからの揮発性有機化合物 (VOC), ホルムアルデヒドを除く他の カルボニル化合物放散測定方法-大形チャンバー法

(家具・建具への適用について)

家具、建具については、製品のままでは小形チャンバー法で測ることはできない。このため、 構成部材(ボード類等)について確認することにより、家具、建具への基準適合の判断を行うも のとする。今後大形チャンバー法が JIS 化され、本基準にて位置づけることにより、家具、建具 についての性能を判断することが可能になる。

(本基準の利用・引用について)

本基準を用いて建材のVOC放散性について証明、表明される際には、本基準の名称並びに当 研究会の名称を明示する。また、本基準を仕様書等に引用する場合にも同様とする。研究会はこ の基準がどのように利用・引用されているか把握し、本基準改正の際に迅速に対応できるように する。

ANSI/BIFMA M7.1-2011



The Industry Voice for Workplace Solutions



Standard Test Method for Determining VOC Emissions From Office Furniture Systems, Components and Seating



# **American National Standard**



Approval of an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria have been met by the standards developer.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

The use of American National Standards is completely voluntary; their existence does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

The American National Standards Institute does not develop standards and will in no circumstances give an interpretation of any American National Standard. Moreover, no person shall have the right or authority to issue an interpretation of an American National Standard in the name of the American National Standards Institute. Requests for interpretations should be addressed to the secretariat or sponsor whose name appears on the title page of this standard.

**CAUTION NOTICE:** This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken periodically to reaffirm, revise, or withdraw this standard. Parties interested in American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Published by



Copyright © 2011 All rights reserved

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission by the publisher.

Printed in the United States of America

# ANSI/BIFMA M7.1-2011

### Acknowledgments

The Business and Institutional Furniture Manufacturers Association (BIFMA) International would like to thank the extraordinary group of stakeholders that came together to assist in the revision of this standard:

All Weather Heating & Cooling – Jeanne Sparks

American Air Filter Intl. - Bryan Ligman

American Seating Co. Tom Geyer Brock Hesselsweet Rick Magnuson Dick Santose

Anshen & Allen – Suzanne Drake

Arcadia Chair Co. - Chris Burgess

Artech - Sarah Webb

Artopex - Jean Barbeau

Air Quality Sciences Stephany Mason Scott Steady

Bayer - Bob Wade

Berkeley Analytical Associates Al Hodgson

**BIFMA International** Dick Driscoll Brad Miller Dave Panning Tom Reardon

**Bodycote** Andrew Cameron Greg Kuhun Rocco Rizzo

California Dept. of Public Health – Wenhao Chen

CATAS - Andrea Glavon

Cardinal Environmental - Scott Hansen

Chalmers University of Technology – Ragib Kadribegovic

Community Playthings - Phil Gattis

Danish Technical Institute – Thomas Witterseh

Eco Institute - Frank Kuebart

Environmental Health & Engineering – Theodore Myatt

ESTeSL - Susana Viegas

**Eurofins Scientific, Inc.** Reinhard Oppl Denise Van Valkenburg

Five Winds International - Steven Baer

Forbo Flooring - Tim Cole

Fraunhofer Institute for Wood Research – Harald Schwab Georgia Tech Research Institute – Charlene Bayer

Global Contract Inc. - Karen Worthy

**GREENGUARD Environmental Institute** Henning Bloech Brian Englert

Harden Furniture - Rick Partlow

Harvard University - Shengwei Zhu

Haworth Inc. Tom Lee Dykstra Jim Thompson-Goodchild Anna Wechselberger

Herman Miller Inc. Larry Dykhuis Susan Koole Randy Ruster

HNI Corporation - Scott Lesnet

IKEA of Sweden - Annelise Larsen

InAIR Environmental - Donald Weekes

Intertek - Ralph Buckingham

**Kimball International** John Kaufmann John Shank Steve Trinkel

Kinki University School of Medicine – Kenichi Azuma

Kinnarps - Tomas Ekstrom

Kitchen Cabinet Mfg. Association – Richard Titus

Knauf Insulation - Scott Miller

Lawrence Berkeley National Laboratory – Henry Willem

Leggett & Platt - Anne Boone

Markes International – Elizabeth Woolfenden

MAS Martin Bennett Randy Stapleton

Micom Lab - Michel Comtois

National Institute of Standards – Cynthia Reed

National Research Council Canada – Doyun Won

North Carolina State University – Harvey West

Nucraft Furniture – Bob Walski

OFS Brands - Vanessa Hartke

**Ohio Dept. of Job & Family Services** – Kelly Huskey

R.W. Larson Associates, P.C. – Sarah Ludwig

San Paulo City Hall - Clelia Moraes

Sauder Woodworking - Michael Zimmerman

Scientific Certification Systems (SCS) Stowe Hartridge-Beam Shannon Morris Nicole Munoz

SGS U.S. Testing Co., Inc. - Piyush Shah

Sherwin-Williams - Jeff Mellgren

SP Technical Research Institute of Sweden – Maria Rademar

SpecFurniture - Jed McKie

Steelcase Inc. Kari Allen Randy Carter Jeff Musculus

Syracuse University - Jianshun Zhang

Teknion Doug Hietkamp Ruth Lytle

Tsinghua University, Beijing China – Yinping Zhang

TUV - Christian Schelle

United Stationers Supply Co. – Connie Yandall

University of Gayle - Mikael Bjorling

University of Texas - Stacy Reed

University of Tokyo - Miyuki Noguchi

University of West Macadonia – John Bartzis

U.S. EPA -Mark Mason David Marr Bob Thompson

Virco - Robert Hupe

Weber Knapp - Dan Houle

Woodlore International Inc. – Wayne Donison

# American National Standard for Office Furnishings

# Standard Test Method for Determining VOC Emissions From Office Furniture Systems, Components and Seating

Sponsor BIFMA International 678 Front Avenue NW, Suite 150 Grand Rapids, MI 49504-5368 <u>email@bifma.org</u> www.bifma.org

Approved April 20, 2011 American National Standards Institute



1

# Foreword

The material presented in this standard test method was developed as a result of the efforts of the members of BIFMA International and reviewed by a broad representation of interested parties, government organizations, interior design organizations, and commercial testing and procurement organizations.

The original work on this standard test method was completed in June 2005 by the BIFMA Subcommittee on Furniture Emissions Standards. The original standard was approved by ANSI on September 5, 2007. The revision work on this standard test method was also completed by the BIFMA Subcommittee on Furniture Emissions Standards. This proposed revised standard test method was submitted to the membership of BIFMA International and approved in November 2009. During 2010, BIFMA conducted a public review of this document by interested parties and stakeholders in accordance with the requirements BIFMA maintains as an ANSI accredited standards developer. After completion of the canvass process, the standard test method was subsequently submitted to the American National Standards Institute for approval as an American National Standard. Approval by ANSI was given on April 20, 2011.

Suggestions for the improvement of this standard test method are welcome. The suggestions should be sent to email@bifma.org or BIFMA International, 678 Front Avenue, NW, Suite 150, Grand Rapids, MI 49504-5368.

# A BIFMA STANDARD TEST METHOD FOR DETERMINING VOC EMISSIONS FROM OFFICE FURNITURE SYSTEMS, COMPONENTS AND SEATING

# CONTENTS

<ol> <li>Scope and Limitations.</li> <li>Referenced Standards</li> <li>Definitions.</li> </ol>	5 7
4. Oursemany of Mathead	.10
4. Summary of Method	.13
6 Principles	. 10
	.17
7. Surface Area Requirements and Calculations	.22
8. Facilities and Equipment	.27
9. Selection, Collection and Preparation of the Test Specimen	.30
10. Test Procedures	.33
11. Data Analysis and Interpretation	.42
12. Compliance, Retesting and Timing	.55
13. Laboratory Test Report	.56
14. Quality Control and Quality Assurance	.59
15. Keywords	.61
Appendix 1 An Example of Concentration and Emission Limits in Relevant Rating Syste	ms
and Guides	.62
Appendix 2 – Examples: Calculations and Standard Workstations	.64
Appendix 3 A Typical Timeline for Office Workstation Ordering, Manufacturing, and	
Shipping	.97
Appendix 4 Target Lists of Individual VOCs for Quantification by TD-GC/MS and HPLC.	.99
Appendix 5 VOC Emission Rates as a Function of TimeTypical Trends	104
Appendix 6 Screening Analysis Procedure	109
Appendix 7 Sample Tables for Reporting the Test Results	110
Appendix 8 Sample Timing Constraints	114

# TABLES

Table 7.1 – Required Standard Workstation Surface Areas	.22
Table 8.1 - Required Control Accuracy and Precision for Chamber Operation in a 24-hour	•
Assessment Test	.29
Table 11.1 – Standard Office Environment Parameters	.47
Table 14.1 – Required Accuracy and Precision Limits Parameters	.59
Table A1.1 - Limits of Indoor Air Concentrations Due to Emissions from Systems Furniture	е
and Seating at 168 Hours	.62
Table A1.2 – Individual Furniture Components Maximum Emission Factors at 168	
Hours	.62
Table A1.3 – Individual Volatile Organic Chemical (VOC) Concentration Limits at 336	
Hours	.63
Table A 2.2.1 – Components of a Standard Open Plan <i>Panel-Based</i> Workstation for	
Emission Testing	.90
Table A2.2.2 – Components of a Standard Open Plan Panel-Based Workstation for Emiss	sion
Testing	.91
Table A2.2.3 – Components of a Standard Open Plan Workstation System for Emission	
Testing	.92

3

Table A2.2.5 – Components of a Standard Private Office Freestanding Casegoods         Workstation System for Emission Testing 13.38 m² (144 ft²) Footprint
(μg/m <sup>3</sup> )
Table A7.3 – Calculated Emission Factors for Identified VOCs, TVOCFormaldehydeand Acetaldehyde, and power-law model coefficients112Table A7.4 – Predicted Concentrations in a Standard Office Environment of a Single OfficeWorkstation System (µg/m³)113

# FIGURES

FIGURE 7.1 – EXAMPLES OF CABINETS FOR SURFACE AREA CALCULATIONS2	.4
FIGURE 7.2 – COMPONENT ASSEMBLY EXAMPLE	5
FIGURE A2.2.1 - A STANDARD OPEN PLAN PANEL-BASED WORKSTATION SYSTEM	0
FIGURE A2.2.2 - A STANDARD OPEN PLAN PANEL-BASED WORKSTATION SYSTEM	1
FIGURE A2.2.3 - A STANDARD OPEN PLAN WORKSTATION SYSTEM	2
FIGURE A2.2.4 - A STANDARD OPEN PLAN WORKSTATION SYSTEM THAT CAN BE CONFIGURED	
TO MEET THE AREA REQUIREMENTS OF TABLE 7.19	3
FIGURE A2.2.5 - A STANDARD PRIVATE OFFICE <i>FREESTANDING</i> CASEGOODS WORKSTATION	
SYSTEM9	4
FIGURE A2.2.6 - A STANDARD PRIVATE OFFICE <i>FREESTANDING</i> CASEGOODS WORKSTATION	
SYSTEM9	15
FIGURE A5.1 – EMISSION FACTORS FOR TVOC AND FORMALDEHYDE FOR 4 WORKSTATION	
SYSTEMS (WS)10	5
FIGURE A5.2 – EMISSION FACTORS FOR INDIVIDUAL VOCS EMITTED FROM 4 WORKSTATION	
SYSTEMS (WS)10	6
FIGURE A8.1 – SAMPLE TIMING CONSTRAINTS11	4

# 1. Scope and Limitations

- 1.1 This standard Test Method is intended for determining volatile organic compound (VOCs including aldehydes) emissions from office furniture and seating under environmental and product usage conditions that are typical of those found in buildings.
- 1.2 This standard Test Method is capable of identifying VOCs emitted and determining the emission rates for individual compounds and total VOCs that may be selected for the purpose of product certification, rating, or determination of workstation system, component, or material emission characteristics. This method contains two separate pathways for determining conformance to acceptance criteria; the <u>concentration</u> approach and the <u>emission factor</u> approach. The concentration approach uses product emissions data to model and predict the emission related concentration levels within one or more of three standardized office environments. The emission factor for a product that can be compared to conformance criteria that are based on emission factors which may be defined based on standard environments. The test method also defines three standard environments; open plan, private office and office seating (See Section 11.3.).
- 1.3 This standard Test Method defines standard workstation systems and their components, and describes specific procedures for specimen collection and preparation, pre-conditioning, environmental chamber testing, air sampling and analysis, data interpretation, estimation of the impact of the emissions on the VOC concentrations in a defined standard office environment, and the required contents of the laboratory report.
- 1.4 This standard Test Method covers testing of complete workstation systems, individual pieces of furniture (workstation components or seating), and individual material components of furniture or partitions (fabrics, desktops, panels, etc.). The method describes the use of emission factors determined from these items under specified environmental chamber test conditions in order to estimate the impact of VOC emissions from these items on airborne VOC concentrations in a standard office environment.
- 1.5 This standard Test Method does not specify or recommend limits of emission rates or concentrations in building environments, however the data obtained by using this standard Test Method can be used to determine if the furniture or seating tested meet any applicable acceptance criteria for VOC emissions established elsewhere (some example rating systems and guides for VOC acceptance criteria are listed in Appendix 1). The standard Test Method may be used as part of a certification program(s) and/or claim verification program(s) by manufacturers or third parties.
- 1.6 While this standard Test Method is focused on the office environment, the principles for chamber testing can be applied to furniture used in other environments such as home offices and schools. For some of these applications, a procedure remains to be developed for using the emission data generated to estimate the impact of the furniture on the VOC concentrations in these environments, considering the specific nature of furniture plan, occupant density, room size and ventilation conditions typically encountered in these environments. (See Section 2.3 California 2010 for an example of ANSI/BIFMA M7.1 used for school environments).

- 1.7 This standard test method includes a variety of optional methodologies for determining compliance such as direct scaling, use of a "power law" analytical approach, component screening, etc. Each of these options has its own unique set of advantages and limitations (e.g., Sections 11.2 "Power Law Model", 11.6 "Direct Scaling", and informative Appendix 5). Users of this standard are encouraged to review each of these options and understand their use and restrictions to assure proper application of the methods contained herein.
- 1.8 This standard Test Method does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard Test Method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. This standard Test Method does not address the assessment of potential odors produced by workstation systems or their components.
- 1.9 Materials presented in the appendices are for information only, and are not part of this standard Test Method unless specifically referenced in the main body of this standard Test Method. Note that some of the appendices are listed as Informative.

# 2. Referenced and Background Documents

# 2.1 Referenced ASTM Standards

D1356 Terminology Related to Atmospheric Sampling and Analysis.

- D1914 Practice for Conversion Units and Factors Related to Atmospheric Analysis.
- D5116 Standard Guide for Small Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products.
- D5197 Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology).
- D6196 Practice for the Selection of Sorbents and Pumped Sampling/Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air.
- D6670 Standard Practice for Full-Scale Chamber Determinations of Volatile Organic Emissions from Indoor Materials/Products.
- D7339 Standard Test Method for Determination of Volatile Organic Compounds Emitted from Carpet using a Specific Sorbent Tube and Thermal Desorption / Gas Chromatography.
- D7440 Standard Practice for Characterizing Uncertainty in Air Quality Measurements.
- E741 Test Method for Determining Air Change in a Single Zone by Means of Tracer Gas Dilution.
- E1836 Standard Practice for Building Floor Area Measurements for Facility Management.
- 2.2 Referenced Documents Other

ANSI/BIFMA X5.4 Lounge Seating – Tests, BIFMA International, 678 Front Ave. Suite 150, Grand Rapids MI 49504.

ANSI/BOMA Z65.1 – 1996 Method for Measuring Floor Area in Office Buildings. Building Owners & Managers Association (BOMA) International 1101 15th St., NW, Suite 800, Washington, DC 20005.

- ASHRAE 2007. ASHRAE Standard 62.1-2007. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigerating, and Air-Conditioning Engineers. Atlanta, GA.
- California 2000. California Government Offices Purchase Criteria Environmental Specifications for Office Furniture Systems.

California 2008. California Department of General Services, Procurement Division, Open Office Panel Systems RFP DGS-56275.

- Carter, R.D. and Zhang, J.S. 2007. Definition of standard office environments for evaluating the impact of office furniture emissions on indoor VOC concentrations. ASHRAE Transactions 113(2):466-77.
- CIB (Conseil International du Bâtiment) 2004. Performance Criteria of Buildings for Health and Comfort. CIB Report, Publication 292. ISBN 90-6363-038-7.
- ECA-IAQ (European Collaborative Action) 1997. Indoor Air Quality and Its Impact on Man---Total volatile organic compounds (TVOCs) in indoor air quality investigations. Report No. 19. EUR 17675 EN. Luxembourg: Office for Official Publications of the European Community.
- Hodgson, A.T., Zhang, J.S., Guo, B., and Xu, J. Development and Validation of a Scaling Method for Environmental Chamber Determination of VOC Emissions from Office Furniture. In Healthy Buildings: Proceedings of the 9<sup>th</sup> International Healthy Buildings Conference and Exhibition. Eds.: Santanam, S., Bogucz, E.A., Peters, C., and Benson, T., Healthy Buildings 2009, Syracuse, NY, USA. Paper No: 444.

- ISO/IEC Guide 98-1 August 27, 2009. Uncertainty of measurement Part 1: Introduction to the expression of uncertainty in measurement.
- U.S. EPA TO-1, TO-11, and TO-17. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air. By R.M. Riggin, W.T. Winberry, and N.T. Murphy. Report EPA-600/4-89/017: NTIS-PB90-116989. Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC. June 1988.
- U.S. EPA TO-15. Compendium 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). By W.A. McClenny and M.W. Holdren. Report EPA/625/R-96/010b, Center for Environmental Research Information, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio. January 1999. <u>http://epa.gov/ttn/amtic/files/ambient/airtox/to-15r.pdf</u>
- U.S. EPA/RTI ETV 1999. Large Chamber Protocol for Measuring Emissions of VOCs and Aldehydes from Office Workstations

(http://www.epa.gov/etv/test\_plan.htm#prevention or http://etv.rti.org/iap/documents.cfm).

- USGBC 2009 LEED-CI: Green Building Rating System for Commercial Interiors World Health Organization, 1989. 'Indoor Air Quality: Organic Pollutants.' EURO Reports and Studies No. 111, World Health Organization, Copenhagen, pp. 1-64.
- 2.3 Background Documents (for informational purposes only)
  - ANSI/BIFMA e3-2010. Furniture Sustainability Standard. BIFMA International, 678 Front Ave, NW., Suite 150, Grand Rapids MI 49504.
  - ASHRAE 1995. Clean spaces. ASHRAE Handbook: HVAC Applications. Chapter 15. ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329.
  - BIFMA 2003. White Paper on Office Furniture Test Protocol for Emissions of Formaldehyde, Total Aldehydes, and TVOCs. BIFMA International, 678 Front Ave., NW, Suite 150, Grand Rapids MI 49504.
  - California 2004. Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers (Supersedes previous versions of small-scale environmental chamber testing portion of California Specification 01350), July 15, 2004.

(http://www.dhs.ca.gov/ps/deodc/ehlb/iaq/VOCS/Practice.htm)

California 2010. Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions From Indoor Sources Using Environmental Chambers, Version 1.1 (Emissions testing method for California Specification 01350. Supersedes the previous version of Standard Practice for the Testing of Volatile Organic Emissions From Various Sources Using Small-Scale Environmental Chambers), February 2010.

http://www.cal-iag.org/VOC/CDPH-IAQ StandardMethod V1 1 2010.pdf

- CHPS 2009. Collaborative for High Performance Schools Best Practices Manual Volume III California Criteria for High Performance Schools, 2009. CHPS, 142 Minna Street, Second Floor, San Francisco, CA 94105.
- ISO 16000-9 February 1, 2006. Indoor Air Part 9: Determination of the Emission of Volatile Organic Compounds from Building Products and Furnishing Emission Test Chamber Method.
- NIOSH Method 2016, NIOSH Manual of Analytical Methods, Fourth Edition, Third Supplement (http://www.cdc.gov/niosh/nmam/pdfs/2016.pdf).
- SCS-EC-10.2-2007. Scientific Certification Systems Product Certification Program-Indoor Air Quality Performance. Scientific Certification Systems, 2000 Powell

Street Suite 1350, Emeryville, CA 94608. (<u>http://www.scscertified.com/iaq/SCS-EC10.2-2007.pdf</u>)

- U.S. EPA Emissions Testing Requirements for Office Furniture Procurement, New Headquarters Project, 1996.
- Zhang, J.S., Li, H., Mason, M., Zhang, Z., and Salonvaara, M. On the Power-Law Model for Predicting the VOC Emissions from Office Workstation Systems. Proceedings of the Air and Waste Management Association/U.S. EPA Office of Research and Development International Specialty Conference: Indoor Environmental Quality - Problems, Research and Solutions - July 17-19, 2006 -Durham, NC, USA.
- Zhang, J.S., Mason, M., Hodgson, A.T., Guo, B., Krebs, K., Barry, A., and Peters, B. An Inter-laboratory Comparison Study of the ANSI/BIFMA Standard Test Method M7.1 for Furniture. In Healthy Buildings: Proceedings of the 9<sup>th</sup> International Healthy Buildings Conference and Exhibition. Eds.: Santanam, S., Bogucz, E.A., Peters, C., and Benson, T., Healthy Buildings 2009, Syracuse, NY, USA. Paper No: 693.
- Zhu, J.P.; Zhang, J.S.; Shaw, C.Y. 2001. Comparison of models for describing measured VOC emissions from wood-based panels under dynamic chamber test condition, Chemosphere, 44, (5), August, pp. 1253-1257, August 01.

# 3. Definitions

Unless otherwise specified in this document, the definitions and terms in this document follow those used within ASTM standards. For an explanation of definitions, units, symbols, and conversion factors, refer to ASTM Practice D1914 and ASTM D1356.

- 3.1 **Clean Air Change Rate, N:** The flow rate of clean air (as defined in 8.6) measured in m<sup>3</sup>/h, supplied into the chamber divided by the nominal air volume (m<sup>3</sup>) of the environmental test chamber (i.e., volume of an empty chamber). The clean airflow rate may be measured directly at the clean air supply duct. The clean air change rate can also be determined by conducting a tracer gas test (e.g., a tracer gas decay test) in the chamber per ASTM E741. Note that the air change rate (in units of 1/h) is abbreviated as ACH. Airflow rate in units of liters per second is abbreviated as L/s, and units of cubic feet per minute is abbreviated as cfm.
- 3.2 **Component Approach**: The testing of individual workstation components or individual furniture items for use in determining compliance (see also flowchart Figure 4.1).
- 3.3 **Component assembly, furniture/workstation/seating unit:** A stand-alone single or composite material that is representative of the complete construction of a product used to make up a workstation component, individual furniture item or seating unit (e.g. sections of vertical panels such as particle board with surfacing materials on both sides, frame with stretched fabric, acrylic panels, work surfaces with particle board with laminate faces, drawer front assemblies, seating structures with foam and surface materials, etc.).
- 3.4 **Component material, furniture/workstation/seating unit:** A stand-alone single material that is representative of the partial construction of a product used to make up a workstation component, individual furniture item or seating unit (e.g. individual fabric, fiberglass, particleboard, foam without surface materials, etc.).
- 3.5 **Direct Scaling:** The testing of relatively small test samples of component assemblies proportioned to predict the emission factor or building concentration of a full-sized product or the testing of full-size component assemblies combined to predict the emission factor or building concentration of a full-sized product.
- 3.6 **Direct Scaling Approach:** The implementation of direct scaling when determining compliance (see also flowchart Figure 4.1).
- 3.7 **Emission Factor, E:** The mass of an analyte emitted per unit time and per unit amount of source tested. Depending on the type of source, the emission rate (3.8) of the source may be normalized by its exposed surface area (i.e., an area source such as a fabric or vinyl covered panel surface), its dominant dimension (i.e., a line source such as a caulk or sealant), its mass, or its standard setup (i.e., a "unit" source such as a predefined workstation system or seating unit). As a result, the unit for the emission factor will be  $\mu g/("unit" h)$ ,  $\mu g/(m h)$ ,  $\mu g/(m^2 h)$ ,  $\mu g/(kg h)$ , and  $\mu g/(m^3h)$  for the "unit," line, area, mass, and volume emission sources, respectively.
- 3.8 **Emission Rate, R:** The mass of an analyte emitted from all test specimen(s) present in the space per unit time, (Typically expressed as μg/h).

- 3.9 **Full-scale Chamber:** A room-size chamber that can house the material/product to be tested in its real assembled dimensions, and provide the required environmental conditions (temperature, relative humidity, air mixing, etc.) that are similar to the material/product use in full-scale room conditions (refer to Section 8.2).
- 3.10 **Individual Furniture Item:** A product used in an office environment that is typically "stand-alone", such as seating, tables, easels, mobile pedestals, file cabinets, bookcases, space dividing screens, etc. These items typically do not require use with, or attachment to, other system elements for their function.
- 3.11 **Loading Ratio, L:** The total amount of test specimen in a chamber or building space divided by the nominal air volume of the environmental test chamber in 1/m<sup>3</sup>, m/m<sup>3</sup>, m<sup>2</sup>/m<sup>3</sup>, and m<sup>3</sup>/m<sup>3</sup> for unit, line, area, and volume emission sources, respectively (refer to Section 3.7).
- 3.12 **Lower Limit of Quantitation (LOQ):** A Lower LOQ is quantitatively defined as the analyte mass that produces a response that is 10 times higher than the instrumental noise level or is 10 times the standard deviation for repeated analyses of a low level standard. A Lower LOQ that is higher than this absolute value may be defined based on practical considerations. For this standard test method, the Lower LOQ for individual VOCs appearing on target lists of chemicals of interest is 2 µg m<sup>-3</sup>. If an acceptance criterion requires the reporting of abundant non-listed VOCs, the Lower LOQ for such compounds is 5 µg m<sup>-3</sup>. The Lower LOQ for TVOC<sub>Toluene</sub> is 20 µg m<sup>-3</sup>. The lower LOQ for Total Aldehydes is 5 ppb.
- 3.13 **Manufacture Date:** The date on which all manufacturing steps required to make a product (workstation system, workstation, component, seating unit, or material) are completed and the product is ready for shipment to a distribution warehouse, dealer, or customer site.
- 3.14 **Material Area:** The exposed surface area of component assembly material in the fully assembled product state (described in detail in Section 7.3) used for the direct scaling approach.
- 3.15 **Mid-scale Chamber:** A chamber with sufficient volume for testing individual components of an office workstation system (e.g., a desk, a file cabinet, a partition panel) or a single seating unit that can provide the required environmental conditions (temperature, relative humidity, air mixing, etc.) that are similar to the conditions for product use in a full-scale room (refer to Section 8.3).
- 3.16 **Nominal Chamber Volume (V**<sub>n</sub>): The volume of the empty chamber. This volume is used for the calculation of the nominal clean air change rate and loading ratio. This volume, used for simplicity as the volume occupied by the test specimen(s), is minimal. The calculation of the emission factors in this method is based on the measured area-specific flow rate and hence is not affected by the calculation of chamber volume.
- 3.17 **Seating Unit:** A chair intended for a single-user. Units with multiple seating positions (tandem units, couches, benches, etc.) intended for more than one user are treated as multiple individual seating units with the number of positions (units) defined by the ANSI/BIFMA X5.4 Lounge Seating Standard.
- 3.18 **Small-scale Chamber:** A chamber that is suitable for testing an individual material specimen, and can provide controlled environmental conditions (temperature, relative humidity, air mixing, etc.) (refer to Section 8.4).
- 3.19 **Simplified Area:** The primary or major surfaces of a furniture product; the simplified area refers to the area calculated using a product's nominal dimensions that represent the majority of its external surfaces (described in detail in Section 7). This area is used for the workstation concentration approach and the workstation component/furniture item emission factor approach. For tables and storage the simplified area used for the concentration approach may differ from the simplified area used for the emission factor approach may differ from the simplified area used for the emission factor approach is equivalent or more conservative than the concentration approach.
- 3.20 **Time Zero:** The time when the chamber door is closed and sealed immediately after the test specimens are installed in the chamber.
- 3.21 **Total Volatile Organic Compound (TVOC):** For TVOC definition, see Terminology in ASTM D1356. In this standard Test Method, it is quantified as  $TVOC_{Toluene}$  and is calculated as the integrated concentration of all the captured compounds between n-C<sub>6</sub> and n-C<sub>16</sub> using the response factor of Toluene as measured by the GC/MS total-ion-current (TIC) method.
- 3.22 **Traditional Approach:** The testing of whole workstations or whole seating units for use in determining compliance (see also flowchart Figure 4.1 and Section 11.4). This approach (when limited to estimated building concentration) was the sole means of determining compliance in the original ANSI/BIFMA M7.1-2007.
- 3.23 **Tracer Gas:** A generally non-adsorbing gaseous compound that can be used to determine the mixing characteristics of the test chamber and as a crosscheck of the chamber air change rate. The tracer gas must not be emitted by the test specimen and must not be present normally in the supply air.
- 3.24 **Volatile Organic Compound (VOC):** For VOC definition, see Terminology in ASTM D1356, which includes formaldehyde.
- 3.25 **Workstation System:** A collection of furniture (excluding seating) that forms a complete office workspace for an individual occupant. Workstation systems can be panel based or freestanding (refer to Appendix 2).
- 3.26 **Workstation Component:** A complete workstation assembly that is part of the workstation system as defined (e.g. a work surface, desktop, panel, file cabinet, binder bin, or shelf).

# 4. Summary of Method

- 4.1 This method describes various ways to evaluate the emissions characteristics of products, components and materials. The method can provide data for determining compliance with either emission factor-based or concentration-based criteria depending on the products and/or materials tested, as defined in this method and required by the compliance standard. Complete workstations, individual furniture items (including seating units), or component assemblies may be tested to determine compliance. This method can also be used with component materials for screening/comparative purposes.
- 4.2 Complete workstation system
  - 4.2.1 A complete workstation system is received by the testing laboratory not more than 15 days after the manufacture date of the first workstation component. All components of the system shall be packaged with the most airtight method used by the manufacturer in its normal commercial shipping practice. Upon receipt, all components shall be stored in a conditioned and ventilated room without unpacking. Within 10 days of receiving the last component of a system at the testing laboratory, all system components shall be unpacked and installed in a full-scale chamber. The components will remain in the chamber for 3 days conditioning and 4 days of testing under tightly controlled environmental conditions for a total of 7 days (168 hours). (Appendix 8 provides an overview of the specimen collection, shipping, storage, conditioning and testing schedule).
  - 4.2.2 Duplicate air samples (two or more) are taken from the exhaust or return air duct of the test chamber at the 72nd and 168th hour. Sample tubes from the air samples are analyzed by appropriate methods to identify the various emitted VOCs and to measure the mass of these VOCs collected to calculate the air concentrations within the test chamber.
  - 4.2.3 The chamber concentrations are used to calculate emission rates at the 72nd and 168th hour assuming a quasi steady-state condition. The emission rates for individual VOCs may be used to determine the two parameters of a power-law model, which describes the emission factor as a function of time. The power law model is then used in conjunction with the defined standard office environment to predict the room concentration level at various early-occupancy time points (e.g., 14 days). Alternately, the room concentration level for the standard office environment may be estimated based on the emission rate as measured directly at a given time point.
- 4.3 Individual workstation components, individual furniture items and seating units are treated similarly to workstations with the following exceptions:
  - These items may be tested in either a mid-scale or full-scale environmental chamber (see Section 8.2 and 8.3).
  - Individual workstation components and individual furniture compliance can be determined by either emission factor of the individual component/item (Section 11.5.2) or by using the concentration level of the combined items in a standard workstation (Sections 11.3 and 11.4).
  - Seating unit compliance is determined only by using the concentration level in a standard environment for seating units (also Sections 11.3 and 11.4).

- 4.4 Component assemblies are treated similarly to workstations and individual components except that they may be tested using full-scale, mid-scale or small-scale chambers (see Section 8). The emissions of component assemblies may be evaluated using the "direct scaling" approach to determine the emission factor or concentration of workstations, workstation components, individual furniture items and seating units to determine compliance.
- 4.5 Component materials are tested for comparative/screening purposes and are chosen, handled and evaluated accordingly with those purposes in mind. Component material testing can be used for evaluating material substitutions when determining compliance.

4.6 The following flowchart outlines the various options used within this method for determining compliance to the applicable standard:



Figure 4.1– Options for Determining Compliance

# 5. Significance and Use

- 5.1 Use of Test Method: The calculated VOC concentrations under the standard workstation/seating and office environmental conditions defined in this standard Test Method are intended to be used for determining compliance with emission requirements established by government agencies, other organizations, customers, etc.
- 5.2 Conducting Tests: The tests should be conducted according to the compliance path selected from Section 4 using full-scale, mid-scale or small-scale chambers depending on the specific testing objectives. (see Figure 4.1).
- 5.3 Full Scale Chamber: The test results can be used to determine the VOC emission rates of complete workstation systems, workstation components, component assemblies, individual furniture items and seating units to estimate their impact on the VOC concentration level in a standard office environment or to determine their emission factors.
- 5.4 Mid Scale Chamber: The test results can be used to determine the VOC emission rates of workstation components, individual furniture items, component assemblies and seating units to estimate their impact on the VOC concentration level in a standard office environment or to determine their emission factors for compliance. The mid-scale chamber test results may also be used to demonstrate compliance of a whole workstation system by summing the emission factors or rates of workstation components or component assemblies through the direct scaling approach. It can also be used to determine whether an alternate workstation component or material would significantly impact the workstation system compliance.
- 5.5 Small Scale Chamber: The test results can be used to determine the VOC emission rates of component assemblies through the direct scaling approach for compliance of workstation systems, workstation components, individual furniture items and seating units (Hodgson et al. 2009). Small scale chambers can also be used for quality control, screening, and estimating the impact of alternative materials on the overall emissions from the furniture/workstation/seating components or seating.

**Note:** The direct scaling approach used in this method is based on the conventional small-chamber test results. The direct scaling method tends to be more conservative (i.e., over-estimates the total emissions) in predicting the emission rates of the component or system as compared to the test results for the component or system using mid-scale or full-scale chamber testing (Hodgson et al. 2009). Therefore, the direct scaling method can be used to determine if a component or a system would at least meet a given emission criteria such as that stated in ANSI/BIFMA X7.1. If a product does not meet the emission criteria based on the small chamber tests and direct scaling approach, it does not necessarily mean that it will also fail if a mid-scale or full-scale chamber test is conducted. (see Section 6.8.6).

# 6. Principles

6.1 Determination of Emission Rates. It is assumed in this Method that: (1) the air in the test chamber is perfectly mixed so that the concentration of a VOC at the chamber's exhaust is the same as that inside the chamber; (2) the adsorption of VOCs on the chamber's interior surfaces including recirculation portion of any associated HVAC system (i.e., sink effect) is negligible; (3) there are no chemical reactions or interactions among any of the VOCs present inside the chamber; (4) the chamber is air tight; and (5) the air supplied to the chamber is clean. Under these assumptions, the concentration of any VOC emitted from the test specimen(s) is governed by the following mass balance equation:

$$V\frac{dC(t)}{dt} = AE(t) - QC(t)$$
(6.1)

where,

- V = air volume of the chamber excluding air volume taken by test specimens, m<sup>3</sup>;
- t = time, h;
- C(t) = concentration of the emitted VOC in the air exhausted from the chamber (can be measured in chamber air or at the exhaust air duct), mg/m<sup>3</sup>;
- amount of the source(s), 1, m, m<sup>2</sup>, kg, and m<sup>3</sup>, for "unit," line, area, mass, and volume emission sources, respectively;
- *E(t)* = emission factor of the source(s) in the chamber, mg/h, mg/(m h), mg/(m<sup>2</sup> h), mg/(kg h), and mg/(m<sup>3</sup> h) for "unit," line, area, mass, and volume emission sources, respectively; and
- Q = clean air flow rate supplied to the chamber (measured at inlet air supply duct or determined by a tracer gas test), m<sup>3</sup>/h.

Equation (6.1) states that the rate of change in mass of a VOC in the chamber is equal to the rate of emission from the source minus the rate at which the VOC is removed by ventilation. At steady-state or when the emission rate changes very slowly with time (which is the case for furniture after a certain initial emission/conditioning period), the term on the left hand side of the equation is negligible, resulting:

$$E(t) \approx \frac{Q}{A}C(t) = q_A C(t)$$
(6.2)

where,

 $q_A = Q/A$  is the source specific ventilation rate, m<sup>3</sup>/h, m<sup>3</sup>/(h m), m<sup>3</sup>/(h m<sup>2</sup>), m<sup>3</sup>/(h kg), m<sup>3</sup>/(h m<sup>3</sup>) for "unit," line, area, mass, and volume emission sources, respectively. It is also equal to the clean air change rate ( $N=Q/V_n$ ) divided by the chamber-loading ratio ( $L=A/V_n$ ).

The validity of Equations (6.1) and (6.2) depends on how well the chamber's actual operation meets these assumptions. Therefore, the performance of the chamber must be evaluated against established criteria (see Section 8) in order to obtain reliable and reproducible test results.

For this Test Method, the source specific ventilation rate is set between 6.0 and 10.0 L/s (12.7-21.2 cfm) per workstation system. This range approximates the range of 4.0 L/s (8.4 cfm) defined for the "standard open plan office environment of a single workstation system" and 9.6 L/s (20.4 cfm) defined for the "standard private office environment of a single workstation system." (see Section 6.5). The specified range of flow rate for testing is to facilitate accurate control and measurement of the flow rate in different sizes of chambers, while considering the fact that the back-pressure effect on the emission rate of dry materials is relatively small, and concentrations can be measured with the same level of accuracy if they are within the same range (a factor of two for the flow range specified).

In principle, the same range of the source specific ventilation rate should be applied to testing individual workstation components or seating units. However, the resulting concentration in the chamber could be too low to be quantified accurately, and it may pose difficulty in providing relatively large airflows in a mid-scale chamber if the flow rate is too high. See Section 8 for information on the source specific ventilation rate that should be used for an individual workstation component or seating unit.

6.2 Variables Affecting Emission Rates. Variables affecting emission rates include those related to the materials/products themselves (emitting source variables), those related to the environment within which they are used or tested (environmental variables) as described in ASTM D6670, and those associated with VOC sampling and analysis.

To the extent possible, emitting source variables including chemical composition, manufacturing process, material heterogeneity, density, thickness, internal structure, surface characteristics, and ways materials are applied, should be controlled. These variables may be most easily controlled by standardizing sample selection, application and preparation. Additionally, because the physical and chemical properties of manufactured products may change over time, it is necessary to know the age of materials or products being tested and the conditions under which they have been stored. Ideally, when comparing different products or materials of the same type all test specimens would be the same approximate age and have the same history of exposure to environmental conditions. Environmental variables including temperature, relative humidity, air motion (velocity and turbulence), and VOC concentrations in the ambient air should also be controlled. The ventilation rate in test chambers and the loading should be standardized as appropriate.

The environmental variables are standardized and controlled in order to reduce uncertainty. It may be helpful to conduct an estimation of uncertainty (See Section 14.8). For estimating the impact of the workstation systems or seating on the VOC concentration in an office environment, assumptions are made regarding the size and volume of the office environment containing the workstation, the size of the workstation and the number of seating units, clean air flow rate per system, temperature, relative humidity, and air velocities over emitting surfaces.

6.3 Definition of Standard Workstation Systems. This Test Method defines a Standard Workstation System as one of the systems described in Section 6.5, 7, 11.3, and Appendix 2. The standard workstation systems are used as reference cases for standard testing, for comparing the emissions from different workstation systems, and for estimating their contributions to the VOC concentrations in a standard office environment.

- 6.4 Effect of Product Age. Since VOC emission rates of office workstations typically decrease with time, the age of the workstation system or seating (i.e., time elapsed from its packaging date following manufacture) is controlled considering the typical timelines for delivery and occupancy. It is assumed 10 days typically are required between manufacturing and onsite delivery. Seven and fourteen days following delivery and on site assembly of the workstation system are defined as the times of interest for early occupancy (Appendix 3).
- 6.5 Definition of Standard Office Environments. For the purpose of estimating the impact of furniture on the VOC concentrations in office spaces, a standard open plan office environment and a standard private office environment are defined based on research (*Carter, R.D. and Zhang, J.S. 2007. Definition of standard office environments for evaluating the impact of office furniture emissions on indoor VOC concentrations. ASHRAE Transactions 113(2): 466-77).* These accommodate one workstation system for a single occupant. The areas include traffic area and support space for copiers, files, storage, etc. The outdoor or clean air ventilation rate for each environment is the minimum required outdoor ventilation rate per ASHRAE Standard 62.1-2007, which specifies a minimum ventilation rate of 5 cfm per person plus 0.06 cfm per square foot of floor area. See Section 7.1 and Section 11.3.
- 6.6 Calculation of VOC Concentrations in a Standard Office Environment due to Emissions from a workstation system (this is an example; the same principles apply to individual workstation components and seating). The emission factor determined from the chamber testing can be used to calculate an associated airborne concentration for a standard office environment. Assuming the emission factor only changes very slowly with time, the following equation is used to estimate the concentrations in a standard office environment at the time of interest for early occupancy [i.e., t= 168 or 336 h (7 or 14 days) after the workstation is installed]:

$$C_{t} \approx \frac{A_{o}E_{t}}{Q_{o}} \tag{6.3}$$

where,

- $C_t$  = concentration in the defined office environment at the time of early occupancy (7 or 14 days after the installation), mg/m<sup>3</sup>;
- A<sub>o</sub> = source amount in the office environment (e.g., number of workstation units, and is equal to 1 in this case);
- $E_t$  = estimated emission factor at t= 168 or 336 h (7 or 14 days) from Time Zero based on chamber testing, mg/h per workstation unit;
- $Q_o$  = clean air ventilation rate in the office environment for the standard open plan or private office environments as defined in Section 11.3.

**Note:** For this Test Method, the power-law model is only used to predict the emission factor at 14 days or less for decaying sources.

6.7 General Emission Characteristics of Office Furniture and Seating. Many VOCs found indoors may potentially be emitted from office furniture and seating (Appendix 4). The emission rate as a function of time can be very different among the VOCs emitted, depending on the component materials used and the way the materials are assembled. Typically, the emission rates for VOCs in the outermost layer of a furniture component decrease from a peak value after the start of a test. Emission rates of VOCs in the inner layers typically increase to a peak value shortly after the

workstation systems/components are placed in the chamber for testing, and then slowly decrease over time. The time at which the emission rates reach the peak value differs among the VOCs emitted from the same workstation system and among different workstation systems/components, but is typically less than 72 hours from the start of testing. Emission rates that decay after reaching peak values typically can be well represented by a power law function (Appendix 5).

- 6.8 Other Considerations. The goal of this Test Method is to achieve consistent, accurate, reliable and repeatable test results while making the test procedure practical for implementation. Other important considerations include:
  - 6.8.1 Conditioning. The 72-hour period between initiation of a test and the collection of the first samples is considered to be conditioning. This relatively long period is specified to reduce the variability in the test results that might result from differences in shipping and storage conditions.
  - 6.8.2 Sampling Period. This Test Method focuses on the determination of emission rates at the time of interest for early occupancy (i.e., 7 or 14 days after the installation). It only requires air samples to be collected at 72 and 168 hours while allowing air samples to be collected at 14 days (336 h) and other times depending upon study objectives.
  - 6.8.3 Prediction Model. The emission factors determined at 72 and 168 hours can be directly compared to criteria specified for these time points. They are also used to determine the coefficients of the power-law model. For a decaying source, the power-law model is used to predict the emission factor at any time point between 72 hours and 14 days.
  - 6.8.4 Duplicate air samples are required at each time point to reduce sampling and analysis uncertainty and to flag significant experimental errors.
  - 6.8.5 Target VOCs. Selection of specific VOCs to be measured is dictated by the acceptance criteria established by relevant government agencies, certification and other organizations, customers, etc. (e.g., ANSI/BIFMA X7.1, ANSI/BIFMA e3, etc.). This Test Method specifies sampling and analysis methods for VOCs that typically are included in such criteria.
  - 6.8.6 Direct Scaling. The direct scaling approach adopted in this Method tends to be conservative in predicting the emission rates of a workstation system or component based on a recently completed study (Hodgson et al. 2009). The data indicate that small chamber tests should focus on the measurement of VOC emissions from component assemblies rather than from isolated surfaces because sealing of a primary face can alter the emission characteristics of some compounds. Also, relatively detailed knowledge of material construction is required to select the most appropriate items for testing in small scale. Using such techniques, the study demonstrated that the direct scaling of VOC emissions from the small-scale tests to the full system and to its major components either produced comparable projections or over-predicted the emissions for the system and units tested in the mid-scale and large-scale chambers. Only for one compound group (the analytically difficult butanols) in one comparison was the projected value more than 15% less than the actual measured value. With respect to standards such as ANSI/BIFMA X7.1, VOC emissions were not significantly underestimated.

6.8.7 Principles of Component Testing & Direct Scaling - When using the component approach or direct scaling approaches covered in this method it is important that tests used to determine compliance adequately characterize the end-product emissions. Individuals performing testing using the component or direct scaling approach should very carefully consult Appendices A2.1.1 – A2.1.5. These sections of the test method highlight key examples that illustrate how components and materials for testing should be selected.

# 7. Surface Area Requirements and Calculations

7.1 Definition of standard workstation systems based on simplified surface area: **Note:** these requirements are only applicable to determinations of compliance for whole workstations.

The workstation systems are used as reference cases for standard testing, comparing the emissions from different workstation systems, and for estimating their contributions to the VOC concentrations in a standard office environment. Appendix 2, A2.2 shows representative open plan and private office workstation system configurations. Alternative system configurations may be defined for specific purposes.

	Vertical			Total
Workstation	Surface/Panel	Work Surface	Storage Total	Workstation
System Type	Area	Area	External Area	Area
Open Plan	11.08 m <sup>2</sup>	6.10 m <sup>2</sup>	4.57 m <sup>2</sup>	21.75 m <sup>2</sup>
	(119.3 ft <sup>2</sup> )	(65.7 ft <sup>2</sup> )	(49.1 ft <sup>2</sup> )	(234.1 ft <sup>2</sup> )
Private Office	7.63 m <sup>2</sup>	6.73 m <sup>2</sup>	10.55 m <sup>2</sup>	24.91 m <sup>2</sup>
	(82.2 ft <sup>2</sup> )	(72.5 ft <sup>2</sup> )	(113.6 ft <sup>2</sup> )	(268.3 ft <sup>2</sup> )

# Table 7.1 Required Standard Workstation Surface Areas

Using the simplified area calculation (see definition 3.17), the total surface area of each workstation parameter shall be within  $\pm 5\%$  of the values listed and the total Workstation Area, defined as the total of Panel Area, Work Surface Area, and Storage Area, shall also be within  $\pm 5\%$  of the total workstation areas shown above. The open plan areas specified include the surface area of office furniture (excluding seating) present in general office common space outside of open plan workstations (see Section A.2.3).

7.2 Calculation of simplified area

The surface areas for the products/components shall be provided by the manufacturer and may be subject to verification by the test lab or third-party certifier.

7.2.1 To Calculate Vertical Surface/Panel Area:

Total the surface of both faces of panels, ignore edges, assume all panel surface is exposed. For freestanding workstation types with desk and casegood furniture, treat modesty panels, desk screens, gables, and end panels of desks/returns as panels. For tables, treat support structures as panel area. Table support structure(s) shall be included in the area calculation unless the structure(s) are constructed of very low or non-emitting materials such as powder coated metal, glass, aluminum, etc.

7.2.2 To Calculate Work surface Area:

Total the surface area of the top and bottom of work surfaces, ignore edges and treat all surfaces as exposed.

- 7.2.3 To Calculate Storage Total External Area:
  - 7.2.3.1 Concentration Approach

For overhead storage cabinets and bookcases with doors, drawer pedestals, lateral files, and wardrobe cabinets total the external surface area by treating the assembly as a box with six faces but ignoring edges. For drawer pedestals or lateral files where the top surface is covered by work surface, subtract the area of the pedestal or lateral top, i.e., treat the assembly as a box with five faces. For individual hanging shelves, cabinets with open shelves, bookcases without doors, etc., count the total exposed horizontal surface area (top and bottom) without edges, including end panel structures or supports.

#### 7.2.3.2 Emission Factor Approach

**Note:** The simplified area for storage furniture items is calculated differently for the emission factor approach. This difference is to ensure compliance determined for workstation components or individual furniture items alone is at least as conservative (may overstate emissions) as when determining compliance for storage products following the traditional workstation concentration approach. When this method was first developed, simplified area was only used to determine which furniture sizes to include fully assembled in the test chamber, therefore it was not necessary to calculate the area of all potential emitting surfaces internal to storage units.

When calculating storage total external area to determine compliance using the emission factor approach, treat cabinets and bookshelves with one open face, i.e., without doors, as a box with six faces or as if a door was present. See Figure 7.1. For cabinets, carts, bookshelves, or other storage elements with two or more open faces (i.e., without doors or back panel), treat the storage element as a combination of shelves (top and bottom surface areas), vertical panels (both sides), and horizontal work surface areas (top and bottom surface areas). For products that have a combination of open and closed faces, treat each 'section' as a separate product (for example, one section as a box having six sides, the other as having two open faces). See Appendix 2 for additional examples of surface area calculations.



Figure 7.1 – Examples of Cabinets for Surface Area Calculations

For emissions factor storage surface area calculations, treat the surface area of both cabinets in Figure 7.1 as the example on the right (i.e., when only one face of the cabinet is open, omit the area of internal surfaces and assume the opening is covered by a door).

- 7.3 Calculation of the material area of component assemblies for the direct scaling approach.
  - 7.3.1 Identify and catalog each unique component assembly (i.e., each emitting piece) based on emissions characteristics of the core material and surface treatment. Comprehensive knowledge of product construction, all materials used, and their dimensions are required for these detailed calculations. Detailed information for the products/components shall be provided by the manufacturer and may be subject to verification by the test lab or third-party certifier.
  - 7.3.2 For each assembly identified above, calculate the amount of each material by determining its total emitting surface area. For each material, also determine the amount of each emitting surface area type that is "blocked" from emitting in its assembled state. If the amount of blocked surface area is less than 10% of the total emitting surface area for the affected surface area type, the blocked area may be ignored, i.e., treated as if it is exposed.
  - 7.3.3 For component assembly material edges, determine the surface area of each type of edge that is exposed in the assembled state, as edges, particularly bare composite wood, may have substantially different emissions than finished faces. For component assembly materials of planar, "sandwich" construction, where both major surfaces are fully exposed when assembled, the ratio of the exposed surface area for each edge type to the exposed surface area of the major planar surfaces may be calculated. This "edge-to-face" ratio may be used to determine a representative small-scale sample of the component assembly material for testing, in accordance with Section 9.1, 9.3, and 11.6.

7.3.4 The following example illustrates the application of Sections 7.3.2 and 7.3.3. Assume the analysis of a product identifies a component assembly whose surfaces have varied emissions, as shown in Figure 7.2.



Figure 7.2 – Component Assembly Example

The example shown in Figure 7.2 is a flat panel and is typical of a work surface, desk modesty panel, file cabinet side panel, or other planar component assembly. The construction of this example assembly is a planar "sandwich" type with a wood core, a finished veneer face on one side (surface A), an unfinished veneer face on the opposite side (surface B), three edge banded surfaces (C, D and E) and one unfinished edge (surface F). This assembly is considered as having four surface types:

- major face A finished veneer, 0.45 m<sup>2</sup>
- major face B unfinished veneer, 0.45 m<sup>2</sup>
- three edge banded surfaces (C, D, and E), 0.0382 m<sup>2</sup> total
- unfinished edge (F) exposed area, 0.0089 m<sup>2</sup>.

The edge-to-face ratio of the edge-banded surfaces is 0.043, calculated by summing the area of the three banded edges and then dividing by the total area of both major faces, (i.e., 0.0382 / 0.9).

The emissions of this component assembly may be determined with two small-scale tests, as follows.

Test 1 - a sample is cut from the component assembly with face A exposed, face B exposed, a portion of edge-banded surface exposed, and all cut edges sealed (see Section 9.3). The edge-banded surface is exposed in the ratio of 0.043 when compared to the total area of face A and B. Thus, the emission factor from test one represents faces A, B, and the edge-banded surfaces, in appropriate proportion, and can be scaled in accordance with Section 11.6.2 step 2) and equation 11.15.

Test 2 - a sample identical to the sample from Test 1 is used, but with an unfinished edge also exposed. Therefore, the results of Test 1 can be subtracted from the results of Test 2 and the remainder represents the emissions from the unfinished edge, in accordance with Section 9.3.2.

Alternatively, the emissions of this example may be determined with three small-scale tests, as follows:

Test 1 – a sample with only A, B, and an unfinished edge exposed Test 2 – a sample with only A, B, and an edge-banded surface exposed Test 3 – a sample with only A and B exposed, all edges sealed

Subtracting the results of Test 3 from Test 1 yields the unfinished edge emissions, and Test 2 minus Test 1 yields the edge-banded emissions (see Section 9.3.2).

To illustrate direct scaling when areas are blocked, assume 0.2  $m^2$  of the unfinished veneer (Face B) is covered by powder-coated steel structural supports (these could be under-worksurface supports, or structure to support file drawers if the component assembly was the side panel of a file cabinet, etc.). In this case a fourth test would be necessary to determine the emissions from the finished veneer (Face A) surface when Face B is blocked. The emissions from Face A would be treated as two types; the portion of A where B also emits, and the portion of A where B is blocked.

# 8. Facilities and Equipment

- 8.1 General Considerations for Chamber System Design, Construction and Performance Testing. Refer to ASTM D5116 and D6670. This section describes the specific requirements pertaining to the design, construction and performance testing of chambers. The operation of a chamber is described in Section 10.1.
- 8.2 Full-scale Chamber. The volume of a full-scale chamber shall range from 20 to 55 m<sup>3</sup> (706 to 1,942 ft<sup>3</sup>). The floor area shall be at least 8.4 m<sup>2</sup> (90 ft<sup>2</sup>), and the height shall be approximately 2.4 m (8 ft). This chamber size is intended to contain a standard office workstation system that has a 1.8 m by 1.8 m (6 ft. by 6 ft.) footprint or the furniture used in a 3.7 m by 3.7 m (12 ft. x 12 ft.) private office. The chamber shall be designed to supply a source specific ventilation rate between 6.0 and 10.0 L/s (12.7-21.2 cfm) for all chambers within the specified size range. Full-scale chambers can also be used to test products such as workstation components, individual furniture items or seating units as long as the unit-specific flow rate is within the range of the value specified in Section 8.3. If component assemblies are tested in a full-scale chamber the area-specific flow rate shall be within the range specified in Section 8.4.
- 8.3 Mid-scale Chamber. The volume of a mid-scale chamber shall range from 3.0 to less than 20.0 m<sup>3</sup> (106 to 706 ft<sup>3</sup>). The minimum volume of 3 m<sup>3</sup> is intended to contain a relatively small seating unit without significant obstruction to air recirculation and mixing in the chamber. The chamber shall be designed to supply a source specific ventilation rate between 0.8 and 2.0 L/s (1.6 to 4 cfm) for all chambers within the specified size range. Mid-scale chambers can also be used to test products such as workstation components, individual furniture items or seating units as long as the unit-specific flow rate is within the range of the value specified.
- 8.4 Small-scale Chamber. A small-scale chamber is intended for testing individual material specimens and shall be designed to provide environmental conditions (temperature, relative humidity, area specific air flow rate, and air mixing) that are similar to material/product use at full-scale room conditions. The volume of a small chamber shall range from 0.05 to 1.0 m<sup>3</sup> (1.76 to 35.31 ft<sup>3</sup>). The chamber shall be operated at the area-specific flow rate of 1.0 to 2.5 m<sup>3</sup>/hr/m<sup>2</sup> (0.3 to 0.7 L/s/m<sup>2</sup>). For a chamber operating at 1.0 ACH, this corresponds to a loading ratio of 0.4 to 1.0 m<sup>2</sup>/m<sup>3</sup>.
- 8.5 Construction. Chamber interior materials shall be Type 304 or 316 stainless steel. Chambers shall have No. 4 finishing (a general purpose polished finish) as a minimum to minimize the chamber sink effect. Other chamber interior materials are acceptable only if they are shown to be equivalent through the chamber validation process. The chambers and their ducts for air recirculation (if any) shall be airtight with a total leakage rate of less than 3.0% of the testing ventilation rate under 10 Pa pressure differential across the chamber envelope.

- 8.6 Clean Air Supply and Conditioning System shall be able to satisfy the following background concentration criteria:
  - TVOC<sub>Toluene</sub>  $\leq 20 \ \mu g/m^3$
  - Total aldehydes ≤ 5 ppb
  - Each individual target VOC  $\leq 2.0 \ \mu g/m^3$

The background compliance for  $TVOC_{toluene}$ , total aldehydes, and individual VOCs shall be verified prior to every test (Section 10.1.2).

In addition, compliance with the following criteria shall be verified at the initial commissioning and again if the chamber system or surrounding environment changes in a way that may affect these values:

- Particulates  $\leq$  35200 particles/m<sup>3</sup> of 0.5 µm diameter or larger, and <0.5 µg/m<sup>3</sup> in mass concentration; and
- Ozone and other potentially reactive species (NOx, SOx, etc.) <10 μg/m<sup>3</sup>
- 8.7 Air Flow Rate, Distribution and Mixing. Air mixing mechanisms (air diffusers or mixing fans) shall be provided to ensure that the air mixing level as defined in ASTM D6670 is higher than 80%, which corresponds to a concentration non-uniformity of less than 5% in the chamber. For a full-scale chamber, the mixing test shall be conducted with a mock-up of the workstation panels and work surfaces shown in any of the example workstations in Appendix 2 in place. For a mid-scale chamber, the mixing test shall be conducted with a mock-up of the desk shown in Figure A2.2.5 in place (the desk dimensions, excluding height, may be modified to accommodate chamber size as necessarv). The mock-up can be the actual furniture system components or constructed with plywood or other suitable materials as long as the geometries and dimensions are represented within ±2.0 cm. Air speed at 1.0 cm from the specimen surfaces shall be less than 0.3 m/s, avoiding a direct air jet on any of the furniture components. Air speed can be measured using a hand-held hot-wire or hot-sphere The inlet airflow rate and the chamber ventilation rate shall be anemometer. measured at standard temperature and pressure conditions per Table 8.1.
- 8.8 Control Accuracy and Precision. Refer to ASTM D6670 for determination of the control accuracy and precision of the chamber system in terms of airflow rate, temperature, relative humidity, and pressure. For this Test Method, the control accuracy and precision of the chamber system shall meet the criteria in Table 8.1 during the entire test period with a minimum measurement frequency of four samples per hour (i.e., a 15-minute maximum sampling interval).

Parameter	Standard Test Condition	Control Accuracy, $\Delta$ (expressed as bias)	Control Precision, Γ (expressed as standard deviation, STD)
Temperature, °C	23.0	±0.5	±1.0
Relative humidity, %	50.0	±5	±5
Chamber pressure**, Pa	10.0 to 25.0	±10% of the set point or ±5 Pa, whichever is greater	±5 Pa
Airflow rate,	Large-scale chamber: 6.0 to 10.0 L/s Mid-scale chamber: 0.6 – 2.0 L/s Small-scale chamber: 0.3- 0.7 L/s/m <sup>2</sup>	±3% of the set point	±5% of the mean value

# Table 8.1 Required Control Accuracy\* and Precision\* for Chamber Operation in a 24-Hour Assessment Test

Control Accuracy is defined as the deviation of the 24-hour mean value from the reference point (standard test condition). Control Precision is defined as the standard deviation of the measured value from the mean value (ASTM D6670 Section 8.3).

- \*\* Static chamber pressure referenced to the air pressure outside the chamber.
  - 8.9 Evaluation of Overall Chamber Performance Using a Standard Source. The overall performance of the chamber system shall be assessed by using a standard source whose emission rate is measured independently from the chamber testing method. For one acceptable procedure, refer to ASTM D6670 for the standard source testing applicable to full-scale chambers, in which a pool of pure liquid VOC (e.g., decane, dodecane) contained in a petri dish is used as a reference emission source. The reference source is placed in the test chamber and its weight loss due to evaporation/emission is measured by an electronic balance to determine the reference emission rate,  $R_r(t)$ . The concentration of the VOC measured at the chamber exhaust is used to determine the emission rate, R(t), as is typically done in environmental chamber testing. The overall performance of the environmental chamber is quantified by the relative difference,  $\delta(t)$ , between R(t) and  $R_r(t)$ :

$$\delta(t) = \frac{R(t)}{R_r(t)} - 1 \tag{8.1}$$

The time average of  $\delta(t)$  shall be within ±15% and the standard deviation of  $\delta(t)$  shall be within ±10% as recommended by ASTM D6670.

**Note:** the above procedure applies to full-scale and mid-scale chambers. The emission rate from a standard source can be adjusted based on the chamber volume and flow rate. For small-scale chambers, evaluation may be performed using pre-calibrated/certified permeation tubes or equivalent as a standard emission source.

# 9. Selection, Collection and Preparation of the Test Specimen(s)

- 9.1 Selection of test samples.
  - 9.1.1. Representative (Worst-case) specimens shall be selected for testing.
  - 9.1.2 To demonstrate compliance for a specific product(s), only that product shall be tested.
  - 9.1.3 Compliance of a broad set of products may be demonstrated by using the results from a limited number of representative models. A range, series or category of products with varying characteristics may be grouped together for testing purposes if the products can be expected to perform similarly during testing (i.e., having the same general construction, materials, and manufacturing processes).
  - 9.1.4 If test results are to be considered representative of a group of products or materials, a representative specimen that has the potential to have the highest VOC emissions shall be selected from the group. A case-by-case product line analysis by the manufacturer in consultation with the laboratory(ies) and/or certification body(ies) is required, taking into consideration any special attributes, materials, methods of manufacture/construction, etc. See Section 7 and Appendix 2 for additional requirements for product configurations and size.
  - 9.1.5 For evaluations using the direct scaling approach, the determination of the representative worst-case product shall be based on the individual component assembly emissions and product construction. Component assemblies may be either pre-assembly components of a product or may be deconstructed assemblies taken from a completed product as long as they are consistent and representative of final product emissions. Selection and preparation of component assembly samples for direct scaling should account for breaching of lower emitting surface materials to expose potentially higher emitting substrates (e.g., drilled holes or cut-outs in work surfaces constructed of laminate on composite wood materials such as particleboard).
  - 9.1.6 For evaluations using the emission factor approach the product with the minimum amount of simplified surface area in combination with the maximum overall product emissions (in terms of resulting chamber concentration) shall be used as the representative worst-case product. Note that the largest product size may not necessarily be representative of the worst-case emitting condition for a given product line. Although some surfaces may be excluded or ignored when calculating simplified area, the emissions of all product surfaces shall be considered when determining total product emissions during testing.

30

- 9.2 Test Specimen Collection, Packaging, Transportation, and Storage (time schedule).
  - 9.2.1 The complete test item all components or component assemblies of a workstation system, workstation component, or seating unit must be received by the testing laboratory not more than 15 days after the date of manufacture of the first workstation component. The manufacturer shall attempt to minimize the total elapsed time from manufacture to receipt of the sample at the lab in a way that best represents their standard manufacturing, packaging and shipping processes. The manufacturer's most airtight packaging option for that workstation component, component assembly, or seating unit shall be used unless the manufacturer prefers to use a more airtight means of packaging<sup>1</sup>.
  - 9.2.2 When testing component materials for screening purposes, the material samples shall be packaged at the time of sample collection, and shall be sealed or packed in a fashion to limit emissions (e.g., double-layer aluminum foil wrap with shiny side out and placed in a polyethylene bag, or directly placed in a Mylar or Tedlar bag and sealed). Samples shall remain in their packaging until prepared and placed in a test chamber. Sample collection shall occur within 24 hours of manufacture.
  - 9.2.3 Each system, component, or material shipped must be accompanied by a chain-of-custody (COC) form that contains the full identification of the item, the dates of manufacture, collection and shipping, and individuals handling the item.
  - 9.2.4 Upon receipt, the test specimen shall be stored in a conditioned and ventilated room of 23±3 °C and not to exceed 60% RH without unpacking, or unpacked and immediately installed in the conditioned chamber for testing. The test specimen must be unpacked and installed for testing within 25 days of the manufacture date of the first sample (see Appendix 8). The concentrations of TVOC, individual VOCs and particles in the storage room shall be controlled by limiting indoor sources using appropriate filtering (e.g. granulated activated carbon filter and high efficiency particle filter) on the HVAC system. Compliance with the following criteria shall be verified at the initial commissioning and again if the storage area or surrounding environment changes in a way that may affect these values.
    - TVOC<sub>Toluene</sub>  $\leq 100 \ \mu g/m^3$ ;
    - any individual compound to be measured in the chamber  $\leq 10.0 \,\mu\text{g/m}^3$ ;
    - particulates  $\leq$  35,200 particles/m<sup>3</sup> of 0.5 µm diameter or larger, and <0.5 µg/m<sup>3</sup> in mass concentration; and
    - ozone and other potentially reactive species (NOx, SOx, etc.) <10 μg/m<sup>3</sup>.

<sup>&</sup>lt;sup>1</sup> Typically the most airtight packaging will fully-encase the product in plastic coverings (polybags, shrink-wrap, etc.). Corrugated (cardboard) packaging materials, even if combined with shrink-wrap that does not fully enclose the product, are generally less airtight than fully encasing plastic materials. Blanket wrapping is generally not considered to be airtight and is discouraged for use as a packaging material for the purpose of emissions testing. More airtight means of packaging may be preferred to prevent the potential for cross-contamination during shipping if such contamination is suspected.

- 9.3 Test Specimen Preparation for Component Assemblies and Component Materials. Protocol differs for workstation systems, workstation components, and component materials.
  - 9.3.1 Individual component assemblies and component materials shall be cut into a predefined standard size that results in an area-specific flow rate between 0.3 and 0.7 L/s/m<sup>2</sup> for testing in a small chamber in accordance with ASTM D5116. All edges of the test specimen that are to be excluded from the emissions measurement (see Section 7.3.4) shall be sealed by sodium silicate, aluminum foil tape, paraffin wax (or equivalent means). The overlay of the edge-sealing material on each surface of the specimen shall be less than or equal to 6.4 mm (0.25 in.) from the edge. Potential emissions from the sealing material used shall be measured; values in excess of chamber background requirements are not acceptable. The sealing method shall be documented in detail.
  - 9.3.2 Estimating the emission factors for normally exposed edges may be determined by sealing all but the edge of interest when making the evaluation, however, this approach may significantly overstate the emissions factor from these edges. The recommended method of estimating the emission factors associated with a normally exposed edge of a component assembly or material is to determine the difference between samples with edges of interest sealed and unsealed. The differences between the emission rates of the specimens (edge unsealed and edge sealed) divided by the unsealed edge surface area of the specimen is the estimated emission factor of the unsealed specimen edge. Using the difference between the emission factor of the edge emission rates that may be caused by the sealing of relatively large sample surface areas (i.e., the faces of the specimens).
    - 9.3.2.1 Alternatively, for planar component assemblies, the emissions associated with normally exposed edges may be determined in combination with the emissions of the exposed major faces when the representative "worst-case" ratio of exposed edge-to-face surface area can be determined and duplicated with test samples. This approach allows the use of one test to determine the emissions of multiple surfaces (see the example in Section 7.3.4).

#### 10. Test Procedures

- 10.1 Chamber Operation
  - 10.1.1 Chamber Test Parameters. All tests are conducted under tightly controlled and constant environmental conditions of 23.0±1.0 STD °C, 50%±5% STD RH, and 10.0 to 25.0±5 STD Pa of positive pressure relative to the surrounding area. These control parameters shall be monitored and maintained throughout the test period. The ventilation airflow rate depends upon the scale of the chamber that is used to perform the test.
    - 10.1.1.1 For a workstation system tested in a full-scale chamber, set the ventilation airflow at a constant rate in accordance with Section 8.2.
    - 10.1.1.2 For workstation components, individual furniture items or seating units tested in mid-scale or full-scale chambers, set the ventilation airflow at a constant rate in accordance with Section 8.3.
    - 10.1.1.3 For component assemblies tested in small-scale, mid-scale, or full-scale chambers, set the ventilation airflow at a constant rate in accordance with Section 8.4.
    - 10.1.2 Measuring Background VOC Concentrations. Measure chamber background VOC concentrations within one week prior to the initiation of a test. The chamber shall be configured and operated exactly as it will be operated for the corresponding test, but without the test specimen. Before collecting the background samples, start the data acquisition system and operate the chamber at the specified test conditions for a minimum of three full air changes. This removes approximately 95% of the background contamination that may have been introduced when the chamber door was open, stabilizes test parameters, and creates a near steady-state condition for the collection of air samples. Following this purge, collect air samples for the analysis of VOCs and aldehydes using procedures identical to those used for the collection of test samples (Section 10.2) except that it is acceptable to use single samples rather than duplicate samples. Analyze the samples (Section 10.3) and confirm that chamber background VOC concentrations meet the criteria specified in Section 8.6. If background concentrations exceed these criteria, investigate the cause, eliminate the source(s) of contamination, and repeat the background measurement before proceeding with the test. The measured background concentration of any compound is denoted as C<sub>bk</sub>, and is used in data analysis in Section 11.1. Operate the chamber continuously after the background sample is collected and prior to initiating the test. Monitor chamber conditions with the data acquisition system throughout this period.

- 10.1.3 Unpackaging and Transfer of Test Piece to Chamber. The objective is to remove the test piece from its factory packaging, perform any specimen preparation and assembly operations, and transfer the test piece into the chamber as quickly as possible. Maintain supply airflow into the chamber during transfer to reduce intrusion of laboratory air. The required dimensional measurements (Section 7 and 9.3) may be made at this time if they can be accomplished within the specified time limit or the measurements may be made at the conclusion of the test. The sequence and details of these operations depend upon the scale of the test.
  - 10.1.3.1 For a workstation system, unpackage the workstation components outside the chamber and then immediately move them into the chamber for assembly. Complete the entire assembly process within 6 hours or less. During this time, operate the chamber at the specified airflow rate and temperature/humidity conditions recognizing that opening of the chamber door and the presence of workers in the chamber will alter these conditions. Installers shall not use greasy tools and shall wear disposable, clean-room booties to minimize contamination.
  - 10.1.3.2 For workstation components, individual furniture items and seating, unpackage the test piece outside the chamber. Perform all required assembly operations within one hour or less and then immediately place the piece into the chamber.
  - 10.1.3.3 Prepare the specimen of a component assembly or component material within one hour as described in Section 9.3.
- 10.1.4 Placement of Test Piece in Chamber. For workstations, workstation components, individual furniture items, component assembly, component material, and seating units, assemble the test piece following the manufacturer's instructions so that its components and parts are in their correct orientations and relative positions. Locate the test piece in the center of the full- or mid-scale chamber so that air inlets and outlets are not obstructed and there is at least a 0.4 m air space between the piece and chamber walls. Set adjustable feet on components so the bottom edges are approximately 2 cm above the chamber floor. Place seating in an upright position with feet resting on the chamber floor. Close all workstation and component doors and drawers. For small-scale chamber tests, place the prepared specimen inside the chamber. Support the piece on a stainless steel stand (e.g., three supports each 0.64 cm diameter or less) or rack minimizing the contact area so that all intended emitting surfaces are exposed to chamber air. Photographically record the installation.
- 10.1.5 Time Zero. Close and seal the chamber door immediately after installing/loading the test piece. Record the time; this is used as the Time Zero for the test.

10.1.6 Sampling Schedule. Collect duplicate VOC samples and duplicate aldehyde samples at 72 and 168 hours elapsed time after the initiation of a test as described in Section 9.2. Additional air samples may be taken during or beyond the seven-day elapsed time period to meet other objectives. For example, if a test is conducted to determine if a workstation system would comply with emission criteria specified at the 14th day, it is acceptable to extend the test period to 14 days.

#### 10.2 Air Sampling

- 10.2.1 Two different methods for air sampling and chemical analysis of VOCs are utilized. Air samples for the analysis of TVOC and individual VOCs including higher molecular weight aldehydes are collected on sorbent tubes and are analyzed by thermal desorption Gas Chromatography/Mass Spectrometry (TD-GC/MS). Air samples for the analysis of low molecular weight aldehydes (e.g., formaldehyde and acetaldehyde) are collected on chemically treated cartridges and are analyzed by High Performance Liquid Chromatography (HPLC).
- 10.2.2 Air sampling devices
  - 10.2.2.1 VOC Sorbent Samplers. Utilize a VOC sampling system that is capable of quantitatively collecting VOCs with a wide range of functional groups and volatilities approximately ranging from n-hexane through nhexadecane (n-C<sub>6</sub> to n-C<sub>16</sub>). Collect VOCs, excluding formaldehyde, acetaldehyde and other very volatile compounds, using stainless steel or glass tubes packed with Tenax-TA as a single sorbent or with multiple sorbents (i.e., a multi-sorbent samplers) consisting of Tenax-TA backed by one or more carbonaceous sorbents in series as described in USEPA Methods TO-1 and TO-17, respectively. The use of multi-sorbent samplers is recommended to minimize losses of the most volatile compounds due to breakthrough. Sorbent sampler dimensions are dictated by the requirements of the laboratory's thermal desorption apparatus. Each sampler is identified by a permanent unique ID number. Clean and condition sorbent samplers by thermal desorption before each use. Store conditioned samplers at reduced temperature in a refrigerator or freezer.
  - 10.2.2.2 Aldehyde Samplers. Collect air samples for the analysis of formaldehyde, acetaldehyde and other very volatile aldehydes on cartridges containing silica gel coated with an acid solution of the derivatizing reagent 2,4-dinitrophenylhydrazine (DNPH) as described in ASTM D5197. Note that this sampling system also is capable of quantitatively collecting higher molecular weight aldehydes and ketones. Cartridges meeting the requirements of ASTM D5197 are commercially available. Cartridges supplied with a certificate of analysis stating the background masses of formaldehyde and other carbonyl compounds are preferred. Background masses must be sufficiently low that the maximum allowed background concentration of  $\leq 2.0 \ \mu g/m^3$  per compound is not exceeded. Store unused sampling cartridges at reduced temperature in a refrigerator or freezer.

- 10.2.3 Sampling Flow Rates and Volumes
  - 10.2.3.1 Sampling flow rates for sorbent samplers and aldehyde samplers are established to provide an acceptable pressure drop across the sampler and to minimize losses of target VOCs due to breakthrough. Typical sampling flow rates are about 100 cm<sup>3</sup>/min for sorbent samplers and about 1 Lpm for aldehyde samplers. Sampling volumes (i.e., the product of sampling rate and sampling duration) are established to prevent overloading of sampling devices and analytical instrumentation and to limit breakthrough losses to less than 5% while providing a lower limit of quantitation of  $\leq 2 \mu g m^{-3}$  for individual VOCs. Generally, the sampling volume shall be equal to or less than the safe sampling volume (SSV) for the least retained VOC on the target list as described in ASTM D6196. For aldehyde samplers, do not allow the original amount of DNPH in the sampler to be depleted by more than approximately one-half by reaction with carbonyl compounds in the air sample in order to prevent breakthrough. In some cases, it may be necessary to collect samples with different volumes at a given time point to satisfy these requirements.
  - 10.2.3.2 In the case of small-scale chambers, limit the maximum sampling flow rate so that the total flow rate for simultaneously collected samples does not exceed 80% of the chamber inlet flow rate.
- 10.2.4 Sampling Apparatus. The air sampling apparatus consists of the sampling media with an air flow controller and a vacuum pump located downstream of the media. In some cases, the media is connected to a sampling manifold attached to the chamber air exhaust. Sampling flow rates are regulated with electronic mass flow controllers, or similar devices, with an accuracy of ±2% full scale, or better, and capable of continuously measuring and controlling the flow.

**Note:** Standard conditions for flow calibration are  $25^{\circ}$  C and 101.3 kPa (1 atm.) pressure. The sampling flow rate is to be determined for  $23^{\circ}$  C and 101.3 kPa (1 atm.) pressure conditions. During sampling, maintain the airflow rate to within  $\pm 5\%$  of the specified value. Minimize system components in the flow path between the chamber and the sampling media so that sampling manifolds and sampling tubing are no greater than 0.4 m in length. Construct such components of stainless steel, glass or polytetrafluoroethylene (PTFE). If all samplers are to be connected to the same manifold, position the ports for aldehyde samplers downstream of the ports for sorbent samplers. Purge all sampling manifolds and tubing a minimum of five air changes before collection of samples. Alternately, for mid- and full-scale chambers air samples may be collected directly from chamber air without any components upstream of samplers by inserting samplers through specially constructed airtight ports in the chamber wall. With direct sampling of chamber air, position sampler inlets at least 0.5 m away from the source.

- 10.2.5 Sampling Procedures
  - 10.2.5.1 Air samples are collected so that they do not alter the positive pressure within the chamber relative to its surrounding environment. For largescale and mid-scale chambers, collect all samples (e.g., duplicate VOC samples plus duplicate aldehyde samples) simultaneously. Center the temporal mid point for the collection of each air sample so that it is within  $\pm 2\%$  of the specified collection time (e.g.,  $72 \pm 1.4$  hours and 168  $\pm$  3.4 hours). The actual time of sample collection shall be recorded, and used in the determination of the coefficients of the power-law Limit the maximum sampling duration for both VOC and model. aldehyde samples to four hours. Equilibrate samplers taken from refrigerated storage and VOC samplers taken directly from thermal desorption equipment to room temperature prior to use. Record the start and stop times and the average air flow rate for the sampling Assign each air sample a unique interval for each air sample. laboratory identification number. Following collection, seal air samples in clean airtight containers and store them at reduced temperature in a refrigerator or freezer dedicated to the storage of air samplers. Analyze samples as soon as practical and within 30 days after collection.
  - 10.2.5.2 For small-scale chambers, it may be necessary to collect some samples sequentially so that chamber pressure is not affected and the restriction on the total sampling air flow rate as a percentage of the chamber inlet flow rate is not exceeded (Section 10.2.3.2).
- 10.3 Chemical Analysis
  - 10.3.1 VOC sorbent samplers are analyzed for individual VOCs and total VOCs (TVOC) by two-stage, thermal desorption GC/MS (TD-GC/MS). Aldehyde samplers are analyzed for formaldehyde, other individual aldehydes and total aldehydes by HPLC. Generally, the VOCs (including aldehydes) of interest are those organic chemicals in the volatile range that either are used in the production of furniture or are present as residuals in component materials. Selection of the specific chemicals or chemical classes to be measured is dictated by acceptance criteria for furniture VOC emissions, for example the criteria specified in ANSI/BIFMA X7.1. Other criteria may be established by government agencies, certification bodies, customers, etc. For example, Appendix 4, Table A4.1 lists VOCs targeted by a government agency for determining the acceptability of furniture system emissions (CA Dept General Services, 2008). Appendix 4, Table A4.2 lists VOCs typically found in the indoor environments (ECA-IAQ, 1997) including VOCs known to be emitted from furniture systems and seating.
  - 10.3.2 Thermal Desorption-Gas Chromatograph/Mass Spectrometer (TD-GC/MS) System and Methods. Optimize the TD-GC/MS system and associated analytical method for the quantitative recovery and analysis of individual VOCs of interest within a volatility range bounded, at a minimum, by n-hexane and n-hexadecane (C6-C16). Note that some criteria may require the analysis of VOCs over a different volatility range. The MS shall be an electron impact ionization (70 eV) instrument operated in the scanning mode over a mass range of at least m/z 35-450 at ≤ 0.5 Hz. The system and method shall have sufficient sensitivity to quantify chamber concentrations of target analytes ≥ 2 μg m<sup>-3</sup>. Use ASTM D7339 and U.S. Environmental Protection Agency (EPA) Methods TO-1 and TO-17, or equivalent methods, as the basis for configuring the instrument and establishing instrument-operating parameters.

- 10.3.2.1 Identification of Individual VOCs by TD-GC/MS. An individual VOC is identified by comparing the chromatographic retention time and mass spectrum of the unknown peak to the corresponding parameters for the pure compound analyzed using the same instrument and method. For a confirmed identification, the retention times of the unknown and the standard must agree within 0.25%, or better, of the total run-time and the match quality of mass spectrum of the unknown to the mass spectrum of the standard must be  $\geq$  90%. All VOCs specifically named in an acceptance criterion and present in samples shall be positively identified (e.g., Appendix 4, Table A4.1). If confirmation is not obtained, the unknown spectrum is compared to spectra contained in the NIST electronic library. A trained analyst shall decide if the identification is likely based on the match quality and the reasonableness of the retention time. Typically, a match quality  $\geq 85\%$  is sufficient for tentative identification. If no such identification is obtained, label the compound as an unknown.
- 10.3.2.2 Tuning of TD-GC/MS System. Tuning and mass standardization of the MS is performed using perfluorotributylamine (PFTBA) as the calibrant. Adjust the instrument parameters to achieve target relative ion abundances such as given in ASTM D7339. Tune the MS as needed to achieve relative ion abundances that are repeatable from day to day.
- 10.3.2.3 Internal Standard. The use of one or more internal standard is recommended. An internal standard serves to adjust the MS instrument response for small run-to-run and day-to-day variations. Toulene-d8 and 1-bromo-4-fluorobenzene are commonly used as internal standards. An identical amount of the internal standard is added at the time of analysis to both samples and standards.
- 10.3.2.4 Calibration of TD-GC/MS System for Target VOCs. Standard calibration curves are required for all VOCs specifically named in an acceptance criterion. Initially, the TD-GC/MS system shall be calibrated using pure compounds with a minimum of five calibration levels spanning the anticipated mass ranges of the individual target VOCs. Prepare calibration levels by injecting aliquots of standard solutions or known volumes of calibration gas mixtures onto clean VOC sorbent samplers. The calibration standards should not exceed the capacities of the sorbent sampler, the analytical column or the MS detector. Analyze the spiked samplers using parameters identical to use for the analysis of chamber air samples. If using an internal standard, analyze at least one calibration check standard with each batch of samples analyzed. If not using an internal standard, perform at least a three-level calibration with each batch of samples.

- 10.3.2.4.1 Processing of calibration standard and sample data files requires the extraction of characteristic ions from the totalion-current (TIC) chromatograms for each VOC. Use one quantitative (i.e., primary) ion and at least one confirming (i.e., secondary) ion for each compound including any internal standard. The extracted ion peaks are integrated. The ratio of the area of each confirming ion peak to the area of the quantitative ion peak for a VOC is determined. These ratios and peak retention times serve to provide positive identification of target VOCs. Refer to USEPA TO-15, Table 2 for characteristic primary and secondary ions for some common air contaminants.
- 10.3.2.4.2 The calibration curve for a VOC is constructed using the peak area responses of its quantitative ion in the standards. Apply a linear least squares fit or an average response factor fit to a plot of peak area versus mass of compound injected. If the response is not linear, a quadratic fit may be required. Assuming a zero intercept and linear response, the slope of the plot is the response factor in area/mass injected. When using an internal standard, the response factor is normalized by the internal standard mass and the peak area response of the quantitative ion for the internal standard.
- 10.3.2.5 Quantification of Non-target VOCs. If reporting of non-target VOCs is required by an acceptance criterion, such VOCs that can be positively identified shall be quantified using pure compound calibrations. If a VOC cannot be positively identified, its Total Ion Current (TIC) peak area response shall be quantified based using toluene as the surrogate standard. Initially, construct a multi-point (≥ five points) calibration for toluene using the TIC areas of toluene in the standards as the response. For routine control, analyze a single-point calibration for toluene for every batch of air samples. Normalize the calibration if an internal standard is used. Calculate the response factor and use this to make semi-quantitative estimates of the masses of tentatively identified and unidentified peaks in a sample. VOCs quantified by this surrogate method shall be clearly indicated in reports.
- 10.3.2.6 Quantification of TVOC<sub>Toluene</sub>. For the purposes of this method, TVOC<sub>Toluene</sub> is defined as the combined, toluene-equivalent mass of all VOCs in a sample eluting on a non-polar polydimethylsiloxane analytical column over a volatility range bounded by n-hexane and n-hexadecane. If a more polar analytical column is used, the equivalent volatility range shall be utilized. First, determine the TIC areas of all chromatographic peaks within the defined range using appropriate parameters that achieve baseline-to-baseline integration and then sum these areas. Using a toluene TIC response factor (Section 10.3.2.4), estimate the toluene-equivalent mass represented by this summed area.

- 10.3.3 High Performance Liquid Chromatography (HPLC) System and Methods. Optimize the HPLC system and associated analytical method for the quantitative recovery and analysis of formaldehyde and other low molecular weight aldehydes of interest. Base the method on ASTM D5197, or an equivalent method. The HPLC system shall be equipped with a UV detector operating at 360 nm and a C18 reverse phase analytical column providing full resolution of the formaldehyde hydrazone derivative from unreacted DNPH in a sample. The system and method shall have sufficient sensitivity to quantify chamber concentrations of analytes  $\geq 2 \ \mu g \ m^{-3}$ . Note that unsaturated low molecular weight aldehydes such as acrolein are not accurately determined by this method unless special procedures are used. Higher molecular weight aldehydes approximately beginning with butanal can be analyzed by TD-GC/MS (Section 10.3.2).
  - 10.3.3.1 Identification of Individual Aldehydes by HPLC. The aldehydes in a sample are identified by comparing their retention times with those of standard DNPH derivatives analyzed using the same instrument and method. The retention times of the unknown and the standard must agree within 0.25%, or better, of the total run-time.
  - 10.3.3.2 Calibration of HPLC System for Target Aldehydes. A calibration standard stock solution is prepared with accurately weighed amounts of each individual DNPH-aldehyde derivative. Purified crystals or solutions of DNPH-aldehyde derivatives are available from commercial sources. Calculate stock solution concentrations as the mass of free aldehyde per unit volume. Prepare calibration standards (at least five levels) spanning the anticipated response ranges of interest by dilution of the stock solution. Construct the calibration curve for an aldehyde by plotting the peak area responses of the standards versus their DNPH-aldehyde concentrations. Apply a linear least squares fit to the plot to obtain the response factor. Analyze at least one mid-level standard with each batch of samples.
  - 10.3.3.3 Quantification of Total Aldehydes. The criteria specified in ANSI/BIFMA X7.1 require the measurement of Total Aldehydes. For the purposes of this method. Total Aldehydes is defined as the sum of the molar volume concentrations of all normal aldehydes from formaldehyde through nonanal plus benzaldehyde. Analyze formaldehyde and acetaldehyde by HPLC. The remaining aldehydes shall be analyzed by TD-GC/MS as this method has the advantage of providing positive peak identification. For individual compounds that can be clearly identified and accurately quantified by HPLC those values can be used in place of the corresponding values measured by GC/MS.10.4 Performance Criteria for Sampling and Chemical Analysis. This method establishes performance requirements for sampling times (Section 10.2.5.1), air sampling flow rates (Section 10.2.3), chamber background concentrations of VOCs (Section 10.1.2), lower limits of quantification (LOQ), and combined sampling and analytical precision. Additionally, laboratories shall develop procedures for demonstrating analytical proficiency and for quantifying overall recoveries of analytes from chambers as follows.

- 10.4 Data Requirements
  - 10.4.1 Lower LOQ. See Section 3.1.2.
  - 10.4.2 Precision: Chamber air samples for a test (i.e., 72-h and 168-h samples) are required to be collected and analyzed in duplicate. Chamber VOC concentrations determined for these duplicate samples are used to evaluate sampling and analytical precision. Precision is calculated as the absolute difference of the two concentrations divided by the mean in percent, i.e., the relative difference.

The data quality objective is for the relative difference to be  $\leq 15\%$ . All concentrations with a relative difference > 15% and  $\leq 45\%$  shall be clearly indicated in reports. Generally, a relative difference of > 45% for a listed component of an acceptance criterion at the time point of interest (e.g., 168 h) is not acceptable. The test shall be repeated if this large difference may potentially affect the outcome with respect to the tested piece passing or failing the performance criterion. If the outcome of the test, even considering the >45% relative difference, is well below or above the performance criterion, the cause of the difference shall be investigated. If a systematic problem with the analysis is found, the test shall be repeated following corrective action. Otherwise, the test outcome is considered to be acceptable. (Acceptance of a variation of >45% in limited cases is intended to accommodate large percentage relative differences that can occur near the lower limits of quantitation.)

10.4.3 Analytical Proficiency. At least annually, the laboratory shall conduct analytical proficiency tests (PT) for individual compounds of interest or a set of representative analytes using blinded reference standards supplied by a qualified external vendor. These standards typically are in form of solutions that the laboratory spikes onto sampling media. The measure of PT analytical accuracy for a compound is defined as the relative difference between the measurement result and the concentration of the compound in the reference standard. In the absence of other requirements, the acceptable PT accuracy is ±30%. Implement corrective actions if the result does not meet the acceptance criterion.

# 11. Data Analysis and Interpretation

#### 11.1 Basic Calculations

- 11.1.1 Chamber Air Concentration
  - 11.1.1.1 Individual VOC (including individual aldehydes) and TVOC chamber concentrations are calculated by:

$$C_{chamber}(t_i) = \frac{m(t_i)}{V_s} - C_{bk}$$
(11.1)

Where,

 $C_{chamber}(t_i)$  = chamber concentration of the compound at time  $t_i$ ,  $\mu g/m^3$ ;

- $m(t_i)$  = mass amount measured, µg;
- $t_i$  = elapsed time from Time Zero, and equal to the average of the start and end time of the sampling period ( $t_1$  = 72 h, and  $t_2$  = 168 h);
- $V_s$  = sampling volume (equal to the air sampling airflow rate times the air sampling period), m<sup>3</sup>; and
- $C_{bk}$  = background concentration of the compound in the chamber measured before the test,  $\mu g/m^3$ .

The concentrations at  $t_1 = 72$  h and  $t_2 = 168$  h are calculated as the averages of the duplicate air samples, and denoted as  $C(t_1)$  and  $C(t_2)$ , respectively. Refer to Section 10.4.2 to determine whether the duplicate samples are acceptable.

11.1.1.2 Total Aldehydes Chamber Concentrations. Using equation 11.1, calculate the chamber concentration for each aldehyde specified in Section 10.3.3.3 and then convert each to ppb (parts-per-billion) by:

$$C_{chamber}(t_i)_{ppb} = \frac{C_{chamber}(t_i) \times 24.45}{MW}$$
(11.2)

Where,

 $C_{chamber}(t_i)_{ppb}$  = chamber concentration of the compound at time  $t_i$ , ppb;

- $C_{chamber}(t_i)$  = chamber concentration of the compound at time  $t_i$ , (equation 11.1),  $\mu g/m^3$ ;
- 24.45 = molar volume of air at standard conditions (1 atm pressure, 25° C), L/mol;
- *MW* = molecular weight (molar mass) of the respective compound, µg.

Total Aldehydes chamber concentration is the sum of the ppb chamber concentrations of individual aldehydes.

11.1.2 Chamber Source Emission Rate.

Workstation systems, workstation components, individual furniture items (including seating units) and their materials can be treated as sources with a constant or near-constant emission rate after the initial (72 h) conditioning period.

11.1.2.1 Individual VOC and TVOC Calculation of Emission Rate. The chamber source emission rates at  $t_1$  and  $t_2$  are calculated by:

$$R_{chamber}(t_i) = Q_{chamber} \times C_{chamber}(t_i)$$
(11.3)

Where,

R <sub>chamber</sub> (t <sub>i</sub> )	= chamber source emission rate at time $t_i$ ( <i>i</i> =1 and 2, $t_1$ = 72 h
	and $t_2 = 168$ h), µg/h.;
<b>Q</b> <sub>chamber</sub>	= chamber clean air supply flow rate, m <sup>3</sup> /h; and
· · · ·	

 $C_{chamber}(t_i)$  = concentration of the compound at time  $t_i$ , (equation 11.1),  $\mu g/m^3$ .

This calculation applies to individual aldehydes, including formaldehyde.

11.1.2.2 Total Aldehydes Calculation of Emission Rate. Calculate emission rates for each aldehyde using equation 11.3 and then convert each to µmol/h by:

$$R_{chamber}(t_i)_{\mu mol} = \frac{R_{chamber}(t_i)}{MW}$$
(11.4)

Where,

R <sub>chamber</sub> (t <sub>i</sub> ) <sub>µmol</sub>	= chamber source emission rate at time $t_i$ ( <i>i</i> =1 and 2), $\mu$ mol/h.;
R <sub>chamber</sub> (t <sub>i</sub> )	= chamber source emission rate at time t <sub>i</sub> (i=1 and 2), μg/h.; and
MW	<ul> <li>molecular weight (molar mass) of the respective compound, μg.</li> </ul>

Total Aldehydes emission rate is the sum of the  $\mu$ mol emission rates of the individual aldehydes specified in Section 10.3.3.3.

#### 11.1.3 Chamber Emission Factor

11.1.3.1 Individual VOC (including individual aldehydes) and TVOC chamber emission factors are calculated by:

$$E(t_i) = \frac{R_{chamber}(t_i)}{A_{chamber}}$$
(11.5)

where,

- *E*(*t<sub>i</sub>*) = emission factor at time t<sub>i</sub> (*i* = 1 and 2), μg/("unit" h), μg/(m h), μg/(m<sup>2</sup> h), μg/(m<sup>3</sup> h), and μg/(kg h) for unit, line, area, volume and mass sources, respectively;
- $R_{chamber}(t_i)$  = chamber source emission rate at time  $t_i$  (equation 11.3),  $\mu g/h$ .; and
- A<sub>chamber</sub> = amount of materials/products tested in the chamber, unit, m, m<sup>2</sup>, m<sup>3</sup>, and kg for unit, line, area, volume, or mass emission sources, respectively.
- 11.1.3.2 Total Aldehydes Calculation of Emission Factor. Calculate emission factors for each aldehyde using equation 11.5 and then convert each to µmol per appropriate units by:

$$E(t_i)_{\mu m ol} = \frac{E(t_i)}{MW}$$
(11.6)

Where,

- *E*(*t<sub>i</sub>*)<sub>μmol</sub> = emission factor at time t<sub>i</sub> (*i*=1 and 2), μmol/("unit" h), μmol/(m h), μmol/(m<sup>2</sup> h), μmol/(m<sup>3</sup> h), and μmol/(kg h) for unit, line, area, volume and mass sources, respectively;
- E(t<sub>i</sub>) = emission factor at time t<sub>i</sub> (equation 11.5), μg/("unit" h), μg/(m h), μg/(m<sup>2</sup> h), μg/(m<sup>3</sup> h), and μg/(kg h) for unit, line, area, volume and mass sources, respectively; and
- MW = molecular weight (molar mass) of the respective compound,  $\mu g$ .

Total Aldehydes chamber emission factor is the sum of the  $\mu$ mol chamber emission factors of the individual aldehydes specified in Section 10.3.3.3.

#### 11.2 Power Law Model

11.2.1 Calculation of Power Law Coefficients. The emission factors for individual VOCs (including individual aldehydes) from  $t_1 = 72$  h and  $t_2 = 168$  h may be used to determine the two coefficients of a power-law model, which describes the emission factor as a function of time at any point from 72 h to 336 h (14 days). Alternately, the emission factor may be based on the emission rate as measured directly at a given time point. To use the power law model, calculate the *a* and *b* coefficients by:

$$b = \frac{\ln E(t_1) - \ln E(t_2)}{\ln t_2 - \ln t_1}$$
(11.7)

$$a = E(t_1)t_1^{\ b} = E(t_2)t_2^{\ b}$$
(11.8)

Where,

- $E(t) = \text{emission factor at time } t_1 \text{ or } t_2 \text{ (equation 11.5), } \mu g/(\text{"unit" h}), } \mu g/(\text{m h}), \\ \mu g/(\text{m}^2 \text{ h}), \\ \mu g/(\text{m}^3 \text{ h}), \\ \text{and } \mu g/(\text{kg h}) \text{ for unit, line, area, volume and mass sources, respectively;}$
- $t_1 = 72, h; and$
- $t_2 = 168, h.$
- **Note:** The simplified procedure described above is adopted in this standard Test Method because it is simpler to use and provides sufficient accuracy. If more air samples are taken between 72 and 168 hours, regression analysis can also be used to determine *a* and *b*. Users shall refer to ASTM D6670 for the detailed calculation procedure.
- 11.2.2 Decaying or Increasing Sources. Using equation 11.7, if coefficient b is < -0.15 or > 0.15 then the emission source is not considered constant and the predicted emission factor for the relevant VOC shall be calculated by:

$$E(t) = at^{-b} \tag{11.9}$$

Where,

- *E(t)* = predicted emission factor at time *t*, μg/("unit" h), μg/(m h), μg/(m<sup>2</sup> h), μg/(m<sup>3</sup> h), and μg/(kg h) for unit, line, area, volume and mass sources, respectively;
- t = any time point from 72 to 336 h (14 days);
- a = coefficient from equation 11.8; and
- b = coefficient from equation 11.7.

11.2.3 Constant Sources. Using equation 11.7, if -0.15 < b < 0.15 then the emission source is considered constant and the predicted emission factor for the relevant VOC shall be the average of the emission factors from 72 and 168 h, calculated by:

$$E(t) = \frac{E(t_1) + E(t_2)}{2}$$
(11.10)

Where,

- E(t) = predicted emission factor at time t,  $\mu g/("unit" h)$ ,  $\mu g/(m h)$ ,  $\mu g/(m^2 h)$ ,  $\mu g/(m^3 h)$ , and  $\mu g/(kg h)$  for unit, line, area, volume and mass sources, respectively;
- $t_1 = 72, h;$

 $t_2 = 168$ , h, and

- t = any time point from 72 to 336 h (14 days).
- **Note:** The above simplified calculation procedure is valid, in general, assuming that the measurement of the concentrations  $C(t_1)$  and  $C(t_2)$  are accurate, and  $E = at^{-b}$  is a valid representation of the emission factor. The current air sampling and chemical analysis techniques can provide a precision of about  $\pm 10\%$  (relative standard deviation), or better, based on current research (Hodgson et al., 2009). Thus, the average of the duplicate air samples will improve the precision by a factor of  $2^{0.5}$  to about  $\pm 7.1\%$ . Assuming a worst case scenario in which the measured E(t=72 h) is 7.1% higher and E(t=168 h) is 7.1% lower than an emission factor that is supposed to be constant, it can be shown that the measurement uncertainty would result in b = 0.15. Similarly, the limited precision in concentration measurement could also result in b =  $\pm 0.15$  for a constant emission source. As a result, emission factors with -0.15 < b < 0.15 shall be reported as constant.

11.3 Definition of Office Building Room Scenarios for Mass Balance Modeling

Determinations of compliance for workstations, workstation components or individual furniture items shall be made using the open plan and/or private office standard environments, depending on the product type, application, and intended use. Determinations of compliance for seating units shall be made using the seating standard environment. The choice of which standard environment(s) to use for compliance is specified by the requestor (typically the product manufacturer).

The parameters of the standard office environments for estimating the impact of workstations, workstation components (including seating units), and individual furniture items on the VOC concentrations in office spaces are summarized in Table 11.1.

Parameter	Open Plan Workstation	Private Office Workstation	Seating
Floor Area per Workstation with Common Area (m <sup>2</sup> ) Modeled Building/Room Volume (m <sup>3</sup> ) Modelled Air Flow, Q, (m <sup>3</sup> /h)	5.95 16.3 15.02	23.78 65.2 34.68	24.8*
Workstation Components Panel Vertical Area (m <sup>2</sup> ) Work Surface Horizontal Area (m <sup>2</sup> ) Storage External Surface Area (m <sup>2</sup> )	11.08 6.10 4.57	7.63 6.73 10.55	
Total Potential Emitting Surface Area (m <sup>2</sup> )	21.75	24.91	Largest of represented product(s)

# Table 11.1. Standard Office Environment Parameters

\*Calculated as the average for open plan and private office workstations.

These standard open plan and private office conditions define representative "worstcase" conditions and combine high density (90<sup>th</sup> percentile) furniture loading conditions with minimum allowable outdoor (clean) air ventilation rates (Carter, Zhang, 2007). Surface areas of workstation components and whole workstations are based on simplified area and are repeated here for convenience. Reference Section 3.17, Section 7, and Appendix 2 for details.
## 11.4 Estimated Building Concentration Compliance Approach

11.4.1 Full Workstation or Seating Unit. The estimated building concentration of each relevant VOC (including individual aldehydes, total aldehydes, and TVOC) for a complete standard workstation or complete seating unit tested in whole shall be calculated by:

$$C_{bldg}(t) = \frac{A_o E(t)}{Q_o} \tag{11.11}$$

Where,

$C_{bldg}(t)$	= estimated building concentration of the compound at time $t$ , $\mu g/m^3$
t	= any time point between 72 h and 336 h, including 72 and 336 h;
Ao	= 1 workstation or seating unit;
E(t)	= calculated by Equation 11.5 (direct measurement), 11.9 (power law-
	not constant source), or 11.10 (power law-constant source);
$Q_o$	= 15.02 m <sup>3</sup> /h (i.e., 4.17 L/s or 8.84 cfm) for the standard open plan office
	environment, or $Q_o$ = 34.68 m <sup>3</sup> /h (i.e., 9.63 L/s or 20.4 cfm) for the

standard private office environment, or  $Q_o = 24.8 \text{ m}^3/\text{h}$  (i.e., 6.89 L/s or 14.6 cfm) for a seating unit as defined in Section 11.3.

Alternately,  $C_{bldg}(t)$  may be calculated per Section 11.6.1 using the direct scaling approach.

11.4.1.1 The estimated building concentrations of formaldehyde shall be converted to ppb using equation 11.2. The estimated building concentrations of Total Aldehydes shall be calculated using equation 11.11, where E(t) is calculated per Section 11.1.3.2.

11.4.2 Workstation Components. The estimated building concentration of each relevant VOC (including individual aldehydes, total aldehydes, and TVOC) for a standard workstation, where one or more of the workstation components are tested independently, shall be calculated by:

$$C_{bldg}(t) = \frac{\sum_{i=1}^{n} A_{i,o} E_i(t)}{Q_o}$$
(11.12)

Where,

 $C_{bldg}(t)$  = estimated building concentration of the compound at time t, µg/m<sup>3</sup>

- t = any time point between 72 h and 336 h, including 72 and 336 h;
- *n* = the number of workstation components in the standard workstation;
- A<sub>i,o</sub> = the number of *i* workstation components used in the standard workstation system (e.g., one file cabinet is tested but workstation contains two identical file cabinets, so A<sub>i,o</sub> = 2 "units");
- $E_i(t)$  = is calculated by Equation 11.5 (direct measurement), 11.9 (power lawnot constant source), or 11.10 (power law-constant source), for each *i* workstation component; and
- $Q_o$  = 15.02 m<sup>3</sup>/h (i.e., 4.17 L/s or 8.84 cfm) for the standard open plan office environment, or  $Q_o$  = 34.68 m<sup>3</sup>/h (i.e., 9.63 L/s or 20.4 cfm) for the standard private office environment, as defined in Section 11.3.

Alternately,  $C_{bldg}(t)$  may be calculated per Section 11.6.1 using the direct scaling approach. The direct scaling approach may be used on all workstation components or on a subset of workstation components. For example, workstation panel and storage components may be tested fully assembled in a mid-scale chamber and the results combined with work surface emissions determined using the direct scaling approach.

11.4.2.1 The estimated building concentrations of formaldehyde shall be converted to ppb using equation 11.2. The estimated building concentrations of Total Aldehydes shall be calculated using equation 11.12, where E(t) is calculated per Section 11.1.3.2.

- 11.5 Emission Factor Compliance Approach
  - 11.5.1 General Calculation of Emission Factor Limits. When VOC emissions compliance requirements are specified as maximum concentration limits under standard conditions (i.e., airflow rates and standard source quantities in "units", surface area, volume, or mass), the concentration limits may be converted to emission factor limits by:

$$E\max_{t} = \frac{Q_{std} \times C\max_{t}}{A_{std}}$$
(11.13)

where,

- *E max<sub>t</sub>* = Emission Factor Limit at time *t*, μg/("unit" h), μg/(m h), μg/(m<sup>2</sup> h), μg/(m<sup>3</sup> h), and μg/(kg h) for unit, line, area, volume and mass sources, respectively;
- $Q_{std}$  = standard airflow (ventilation) rate defined with  $C_t$ , m<sup>3</sup>/h;
- $C max_t$  = required concentration of the compound under standard conditions at time t,  $\mu$ g/m<sup>3</sup>; and
- $A_{std}$  = standard source amount defined with  $C \max_{t}$  "unit", m, m<sup>2</sup>, m<sup>3</sup>, and kg for "unit", line, area, volume, and mass sources, respectively.
- 11.5.2 Emission Factor Calculations for Compliance.
  - 11.5.2.1 When determining compliance using the emission factor approach for workstations, workstation components, or individual furniture items tested in whole, the emission factors for individual VOCs (including individual aldehydes) and TVOC shall be calculated by:

$$E_{product}(t) = \frac{R_{chamber}(t)}{A_{simplified}}$$
(11.14)

where,

- *E*<sub>product</sub>(*t*) = emission factor at time t, μg/("unit" h), μg/(m h), μg/(m<sup>2</sup> h), μg/(m<sup>3</sup> h), and μg/(kg h) for unit, line, area, volume and mass sources, respectively;
- $R_{chamber}(t)$  = chamber source emission rate at time *t* (equation 11.3),  $\mu$ g/h.; and
- $A_{simplified}$  = simplified area calculated per Section 7 for the workstation, workstation component, or individual furniture item, m<sup>2</sup>.

Equation 11.14 (above) is used for direct measurement situations. Equations 11.9 (power law-not constant source), or Equation 11.10 (power law-constant source) may also be used to calculate  $E_{product}(t)$  but in each case, the source amount *A* shall be the simplified area calculated per Section 7 for the workstation, workstation component, or individual furniture item. Alternately,  $E_{product}(t)$  may be calculated per Section 11.6 using the direct scaling approach. The direct scaling approach may be used on all workstation components or on a subset of workstation components. 11.5.2.2 Calculate the emission factor for Total aldehydes by first converting the emission factor from Section 11.5.2.1 for each individual aldehyde to µmol per appropriate unit using Equation 11.6. The sum of the converted emission factors for the individual aldehydes specified in Section 10.3.3.3 is the Total Aldehydes Emission Factor used for determining compliance.

- 11.6 Direct Scaling Approach From Component Assemblies
  - 11.6.1 Small-scale (or larger) chamber test results of component assemblies may be used to determine if a workstation system, workstation components, or individual furniture items (including seating units) are compliant with the VOC emissions concentration or emission factor requirements of a given standard such as ANSI/BIFMA X7.1.
  - 11.6.2 The following procedure shall be used:
    - Analyze the design, materials, and construction of the product to identify all component assemblies of the product and the exposed material area, *A<sub>material</sub>*, source amount (Section 3.14) of each component assembly in the finished product state, per Sections 7.3, 9.1.5 and 9.3.
    - 2) Test a representative sample of each component assembly and determine the emission factor, *E(t)* in accordance with Section 11.1 (chamber / direct measurement) and 11.2 (power law) for each compound and for the identified source type (i.e., face, edge, etc.) of each component assembly. For this calculation of emission factor the source amount, *A*, shall be the amount of the source type of interest present and exposed in the test chamber.

For example, a component assembly has a material area of  $1.2 \text{ m}^2$  when fully assembled into a product, but the sample tested in chamber has only 0.04 m<sup>2</sup> area, therefore use 0.04 m<sup>2</sup> to calculate the emission factor *E*(*t*). See the example in Section 7.3.4.

3) Calculate the emission rate for each component assembly in the fully assembled product state by:

$$R_{ca}(t) = E(t) \times A_{material}$$
(11.15)

where,

 $R_{ca}(t)$  = emission rate of the component assembly in the fully assembled product state for the compound of interest at time *t*, µg/h or µmol/h;

E(t) = emission factor from step 2, above; and

 $A_{material}$  = material area from step 1, above.

When demonstrating compliance for a workstation using the building concentration approach, the material areas shall be for the workstation components identified when establishing the standard workstation(s) as shown in Table 11.1.

4) For each compound of interest, calculate the sum of the emission rates from all component assemblies in the product (i.e., workstation, workstation component, individual furniture item, or seating unit), as the total emission rate of the product, R<sub>tot</sub>; in µg/h or µmol/h. 5) Direct scaling with the building concentration approach. (For emission factor approach, use step 6).

Determine compliance for a workstation, workstation component, or seating unit by calculating the estimated building concentration for each compound of interest by:

$$C_{bldg}(t) = \frac{R_{tot}(t)}{Q_o}$$
(11.16)

where,

- $C_{bldg}(t)$  = estimated building concentration for the compound of interest at time *t*,  $\mu g/m^3$ ;
- $R_{tot}(t)$  = total emission rate of the product from step 4, above; and
- $Q_o$  = 15.02 m<sup>3</sup>/h (i.e., 4.17 L/s or 8.84 cfm) for the standard open plan office environment, or  $Q_o$  = 34.68 m<sup>3</sup>/h (i.e., 9.63 L/s or 20.4 cfm) for the standard private office environment, or  $Q_o$  = 24.8 m<sup>3</sup>/h (i.e., 6.89 L/s or 14.6 cfm) for a seating unit as defined in Section 11.3.

The estimated building concentration for each compound of interest from a workstation shall be the total of the concentrations for each workstation component in the standard workstation. Formaldehyde and Total Aldehyde concentrations shall be reported in ppb.

6) Direct scaling with the emission factor approach.

Determine compliance for a workstation, workstation component, or individual furniture item by calculating the emission factor for each compound of interest emitted from the assembled product (i.e., workstation, workstation component, individual furniture item, or seating unit) by:

$$E_{product}(t) = \frac{R_{tot}(t)}{A_{simplif \ ied}}$$
(11.17)

where,

- $E_{product}(t)$  = emission factor for the compound of interest from the workstation, workstation component, or individual furniture item at time t,  $\mu g/(m^2 h)$ ;  $R_{tot}(t)$  = total emission rate of the product from step 4, above; and
- $A_{simplified}$  = simplified surface area for the workstation, workstation component, or individual furniture item calculated per Section 7, m<sup>2</sup>.

The emission factor for Total Aldehydes shall be reported in  $\mu$ mol/(m<sup>2</sup> h) consistent with Section 11.1.3.2.

## 11.7 Substitution of Component Assemblies or Materials

11.7.1 Emission test results for component assemblies may be used to assess if an alternative component assembly would result in a significant change of the emissions from a product (i.e., workstation, workstation component, individual furniture item, or seating unit). Assuming that a product has an emission rate of R(t), and a component assembly is replaced by an alternative component assembly, the VOC concentrations due to emissions from the revised product with the alternative assembly may be calculated by:

$$C_{alternate}(t) = \frac{R(t) - A_{original}E_{original}(t) + A_{alternate}E_{alternate}(t)}{Q_o}$$
(11.18)

where,

$C_{alternate}(t)$	= estimated building concentration due to the workstation, workstation component, individual furniture item, or seating unit, using the alternate component assembly, ug/m <sup>3</sup> :
R(t)	<ul> <li>emission rate of the original complete workstation, workstation component, individual furniture item, or seating unit, calculated by equation 11.3, 11.4, 11.15 or Section 11.6 step 4, µg/h;</li> </ul>
A <sub>original</sub>	= amount of the original component assembly material used in the complete furniture or seating unit, m <sup>2</sup> ;
E <sub>original</sub> (t)	<ul> <li>emission factor of the original component assembly material, calculated by Equation (11.5), μg/(m<sup>2</sup> h);</li> </ul>
A <sub>alternate</sub>	<ul> <li>amount of the alternative component assembly material used in the complete furniture component or seating unit, m<sup>2</sup>;</li> </ul>
$E_{alternate}(t)$	<ul> <li>emission factor of the alternative component assembly material, calculated by Equation (11.5), μg/(m<sup>2</sup> h), and</li> </ul>
$Q_0$	= 15.02 m <sup>3</sup> /h for the standard open plan office environment, or $Q_o$ = 34.68 m <sup>3</sup> /h for the standard private office environment, or $Q_o$ = 24.8 m <sup>3</sup> /h for a seating unit as defined in Section 11.3.

**Note:** When using Equation 11.18, it is recommended that the original component assembly be tested independently at the same time the product is tested to minimize material variations, however samples of original component assemblies may be tested at a later time if the materials have not changed. The same test procedure used for testing the original component assembly shall also be used for testing the alternative component assembly.

11.7.2. The approach defined in 11.7.1 may be used for screening of component materials (such as fabric, fiberglass, foam, particleboard with or without surface finish, etc.) to identify the relative potential impact of alternative component materials on the emissions of the product or component assembly. The results of this approach may be used to identify which component material may be tested as part of a product or component assembly to represent more than one possible alternative material. For determinations of compliance, if the alternative component material exhibits higher emissions than the original material, verification of the impact of the alternative component material shall be conducted per Section 11.4 or 11.5.

# 12. Compliance, Retesting and Timing

- 12.1 This standard Test Method is designed so that compliance may be evaluated against a variety of acceptance criteria such as the emission requirements in ANSI/BIFMA X7.1 and ANSI/BIFMA e3 as well as those set by the USGBC, requirements based on the U.S. EPA/RTI ETV 1999 method, the State of California, and Conseil International du Bâtiment (CIB). Equivalence to other test methods should be evaluated on a case-by-case basis. Example concentration or emission limits are listed in Appendix 1.
- 12.2 The emissions test results can be considered valid and useful for supporting claims of low emitting product for as long as the materials and components, manufacturing processes, and packaging methods remain the same. Significant changes to one or more of these factors should be evaluated for possible effects on emission characteristics. If it is possible that the product emissions will increase as a result of the change being considered or implemented, a new test should be conducted. Changes in material specification or manufacture of components such as finish materials, adhesives, core materials, plastic materials, and cushioning materials must be considered and evaluated for potential adverse impacts on VOC emissions. Evaluations may be conducted by engineering calculations from supporting data or may require, at a minimum, screening level emission testing. Other sources of variability to be considered include the range of in-plant process parameters, differences associated with multiple suppliers of a single component, uncertainties associated with emissions characteristics of recycled materials, etc.
- 12.3 A formally documented quality system or quality system registered to ISO 9000 requirements and/or specific internal requirements specifying product emissions levels are indicators of stable manufacturing systems.
- 12.4 Certification by the manufacturer confirming ongoing validity of the results are acceptable, however, emissions testing results must be revalidated by testing at an interval not to exceed a time period established in the certification program for which the test is conducted. The required frequency of testing may depend on the typical product change cycle and frequency in changing material suppliers as well as the general trend of emissions over years.

# 13. Laboratory Test Report

- 13.1 A separate cover letter should be provided, summarizing the test purpose, identifying the products tested, and stating if the product meets the pre-selected performance criteria.
- 13.2 The report shall include the following information:
  - (1) a title (i.e., "Test Report");
  - (2) name and address of the laboratory;
  - (3) unique identification of the report (such as serial number);
  - (4) unique page numbers (i.e., Page  $\underline{X}$  of  $\underline{Y}$ );
  - (5) name and address of the customer (where applicable);
  - (6) description and unambiguous identification of the item(s) tested;
  - (7) dates of manufacture, collection, and shipment of the item(s). Attach copies of Chain of Custody forms;
  - (8) characterization and condition of the test item;
  - (9) date of receipt of the test item;
  - (10) date(s) of the performance of test;
  - (11) identification of the test method used, including the testing approach in accordance with Section 13.4.3;
  - (12) any additions to, deviations from, or exclusions from the test method (such as environmental conditions);
  - (13) a signature and title, or an equivalent identification of the person(s) accepting responsibility for the content of the report;
  - (14) date of issue of the report;
  - (15) test conditions (see Section 13.3);
  - (16) test results (see Section 13.4);
  - (17) a statement that the report shall not be reproduced, except in full, without the written approval of the laboratory;
  - (18) A statement that all data, including but not limited to raw instrument files, calibration fits, and quality control checks used to generate the test results is available to the customer upon request.
- 13.3. Test conditions shall include chamber dimensions, volume, clean air supply flow rate, temperature, humidity, amount and dimensions of the test specimen and a photograph of the test specimen under the condition while in the test chamber. Any deviation from the standard test conditions shall be reported.
- 13.4 Test results shall include the following information (See Appendix 7 for example tables).
  - 13.4.1 Measured Chamber Concentrations:
    - Table(s) containing chamber concentrations of VOCs between C6 and C16 measured by the GC/MS analysis. The table(s) shall include: names of VOCs (Chemical Abstracts Service (CAS) numbers are also recommended) identified from the air samples taken at 72 and 168 hours; measured concentrations in individual samples at 72 and 168 hours; mean concentrations and relative deviations. A note may be provided describing the type of sorbent tubes used for air sampling, the sampling volumes, and the GC/MS operating conditions and calibration information.

- 2) Table(s) containing chamber concentrations of Formaldehyde and Acetaldehyde measured by HPLC analysis. The table(s) shall include: names of Formaldehyde and Acetaldehyde identified from the air samples taken at the 72<sup>nd</sup> and 168<sup>th</sup> hours; measured concentrations in individual samples at the 72<sup>nd</sup> and 168<sup>th</sup> hours; mean concentrations and relative deviations. A note may be provided describing the cartridges used for air sampling, the sampling volume, and the HPLC operating conditions and calibration information. See Appendix 7 for a sample table format.
- 13.4.2 Calculated Chamber Emission Factors:

Table(s) containing the following data columns:

- 1) names of the target parameters of interest, (e.g., formaldehyde, total aldehydes, 4-PCH, TVOC<sub>toluene</sub> criteria given in ANSI/BIFMA X7.1, and/or the compounds required in ANSI/BIFMA e3 Section 7.6 Low Emitting Furniture),
- 2) chamber emission factors calculated from the mean values at the 72<sup>nd</sup> and 168<sup>th</sup> hour by equations 11.5 and 11.6, and
- 3) values of coefficients *a* and *b* of Equations 11.7 and 11.8, if the customer has requested the testing address criteria where these are applicable.
- 13.4.3 Estimated Building Concentrations and/or Product Emission Factors.

**Note:** If estimated building concentrations and/or product emission factors are included in the laboratory report, the following information (items #1 through #4 below) shall be included.

If the test laboratory report provides only chamber concentrations and/or chamber emission factor information, (and does not include estimated building concentrations and/or product emission factors), then calculating and providing the following information (items #1 through #4 below) in the laboratory report is optional. This information is typically used for purposes of determining compliance to emissions standards (e.g., ANSI/BIFMA X7.1, etc.) and may be performed by a certification body (see Section 12).

Table(s) containing the following data:

- 1) names of the target parameters of interest.
- 2) estimated building concentrations at t=72 and 168 hours and potentially at 336 hours. Concentrations at the 72nd and 168th hour are based on the measured chamber emission factors (per Section 11.1.3) while those at 336 h are determined in accordance with Section 11.4.
- 3) Calculated emission factors and associated surface areas used per Section 11.5.
- 4) A note shall be provided clearly identifying the scenario from Section 11.3 used (e.g., open plan or private office) to calculate the estimated building concentrations and/or product emission factors in the report, whether direct scaling, testing of whole products, or some combination was used, and identifying which approach (e.g., traditional, component, direct scaling) was used for each product.

- 13.5 References to this Standard Test Method and others as appropriate.
- 13.6 Report all values in SI units unless specified otherwise.

#### 14. Quality Control and Quality Assurance

- 14.1 Quality Assurance/Control (QA/QC) Plan. A QA/QC plan shall be designed and implemented to ensure the integrity of the measured and reported data obtained during product evaluation studies. This plan shall encompass all facets of the measurement program from sample receipt to final review and issuance of reports. Refer to ASTM D5116 and ASTM D6670 for additional guidance.
- 14.2 Data Quality Objectives/Acceptance Criteria. The QA/QC plan shall be based on established data quality objectives and acceptance criteria that will depend on the purpose of the testing and the capability of the laboratory (equipment and personnel) to conduct the test procedures. Data quality objectives shall be established for the following parameters prior to initiating the testing program:
  - 14.2.1 Test Material/Product Transfer Time and Environmental Conditions. Tolerance limits for the elapsed time from production to testing are as follows:

The time between the manufacture date of the first workstation component and receipt of the last component by the lab must not be more than 15 days.

14.2.2 Test Chamber Conditions and Test Results. Precision and accuracy limits shall be established for each parameter in Table 14.1. Initial commissioning and annual maintenance/verification of the chamber system shall be conducted to verify the accuracy and precision of the test chamber conditions.

Parameter	Accuracy (as bias)	Precision
Temperature, °C	±0.5	±1.0
Relative humidity, %	±5	±5
Air flow rate, %	±3	±5
Area of the testing surface of the specimen, %	±1.0	±1.0
Time, %	±1.0	±2.0
Organic concentration, % RSD*		±15.0
Emission factor, % RSD*		±20.0

 Table 14.1. Required Accuracy and Precision Limits Parameters

\*RSD = Relative standard deviation =  $(s/m) \times 100\%$ , where, s = estimate of the standard deviation; and m = mean. For the concentration, RSD is calculated from replicate air samples taken at the medium of the chamber concentration observed during the test period. For the emission factor, the RSD is calculated from replicate standard source tests described in Section 8.9 using the constant source procedure.

14.2.3 Accuracy certifications are supplied by the manufacturers of the sensors, flow meters, and other measurement devices who calibrate them against National Institute of Standards and Technology (NIST)-traceable primary sources.

- 14.2.4 Accuracy checks shall be performed with independent sensors calibrated against NIST-traceable primary standards. Precision measurements are obtained in the laboratory by continuous recording of the parameters. Non-compliance requires immediate correction and/or replacement of sensors. Calibrated replacements shall be retained in the laboratory. Experience shows that routine calibration and tracking of precision can prevent non-compliance.
- 14.2.5 Record Keeping and Logs. Various documentation requirements shall be implemented for all test parameters including environmental chamber and analytical performance. Refer to ASTM D5116. Additionally, the identity of persons conducting each procedure shall be recorded. All devices used, date and time of tests, and the test data shall be part of the QA/QC recording process. Complete records are required.
- 14.3 Calibration. Calibration must be frequent enough to ensure performance of the system within specified parameters. Frequency of calibration should be determined prior to the test, and periodic equipment checks using a second source (other than that used for the calibration) shall be used to verify acceptable performance. All calibration and verification measurements shall be recorded including the time, equipment description, and measurement data.
- 14.4 Accuracy Determinations. Accuracy determinations require measurements of a known emission source (e.g., permeation tubes, spiked samples, gravimetric method) or test gas. These measurements shall be made prior to establishing the project data quality objectives, and shall be consistent with the overall testing objectives. The procedures and materials used for establishing the accuracy of the measurement system shall be recorded.
- 14.5 Precision. Precision determinations require replications sufficient to establish the systematic variation associated with all measurements. When multiple chambers are used as part of an experiment, duplicate samples shall be used. Variation in test data from a single chamber and among chambers can be established by use of standardized sources such as permeation tubes for determining organic concentrations and calculated emission rates.
- 14.6 Duplicate Analysis. All primary chamber air samples are collected and analyzed in duplicate. The results of such analyses shall be recorded and assessed to determine the adequacy of the total system performance relative to the testing objectives. Relative deviations >15% between results for individual VOCs in duplicate samples shall be indicated.
- 14.7 Charting. Charting QC data will allow analysis of system performance and observation of anomalistic or unacceptable deviations

14.8 Estimation of Uncertainty. When conformity to acceptance criteria is evaluated based on VOC emission measurements, the uncertainty of the test results should be determined. This often is best accomplished by a "bottom-up" approach using the law of propagation of error to determine an expanded uncertainty accounting for all major contributing components as described in ISO Guide to the Expression of Uncertainty in Measurement (GUM) (ISO Guide 98) and ASTM D7440. It is recommended that laboratories attempt to identify all the major components of uncertainty occurring in the laboratory and, using actual data, develop an uncertainty budget and make an estimate of expanded uncertainty.

#### 15. Keywords

Environmental chamber testing, furniture emissions, indoor air quality, organic emissions, indoor materials, indoor products.

# Appendix 1. An Example of Concentration and Emission Limits in Relevant Rating Systems and Guides

The U.S. Green Building Council (USGBC)'s "Green Building Rating System For Commercial Interiors" (LEED CI 2009) has the following criteria (Table A1.1) for receiving "EQ Credit 4.5 Low-Emitting Materials, Systems Furniture and Seating":

# Table A1.1 Limits of Indoor Air Concentrations Due to Emissionsfrom Systems Furniture and Seating at 168 Hours.\*

Chemical Contaminant	Emissions Limits	Emissions Limits	
	Systems Furniture	Seating	
TVOC <sub>toluene</sub>	≤ 0.5 mg/m <sup>3</sup>	≤ 0.25 mg/m <sup>3</sup>	
Formaldehyde	≤ 50 ppb	≤ 25 ppb	
Total Aldehydes	≤ 100 ppb	≤50 ppb	
4-Phenylcyclohexene	≤ 0.0065 mg/m <sup>3</sup>	≤ 0.00325 mg/m <sup>3</sup>	

\* These limits apply to Option B for receiving the "EQ Credit 4.5" in LEED CI, which requires emission testing using the EPA/RTI ETV (1999) test protocol and to Option C, which requires emission testing using the ANSI/BIFMA M7.1 standard test method. These requirements were also recommended by the GREENGUARD certification program.

TVOC<sub>toluene</sub> is the method of measuring TVOC using the response factor of toluene.

In addition to the LEED criteria above, the ANSI/BIFMA e3-2010 Furniture Sustainability Standard has the following optional criteria (Table A1.2) for receiving one point per Section 7.6 Low-Emitting Furniture.

<b>Table A1.2 Individual Furniture Components I</b>	Maximum Emission Factors at 168 Hours.
---	--

	ANSI/BIFMA M7.1	ANSI/BIFMA M7.1
	Open Plan Workstation	Private Office Workstation
Formaldehyde, (µg/m <sup>2</sup> hr)	42.3	85.1
TVOC, (µg/m² hr)	345	694
Total Aldehydes, (µmol/m² hr)	2.8	5.7
4-Phenylcyclohexene, (µg/m² hr)	4.5	9.0

Section 7.6 of the ANSI/BIFMA e3-2010 Furniture Sustainability Standard also includes additional optional criteria for receiving one point if furniture emissions do not exceed the individual Volatile Organic Chemical (VOC) concentration limits listed in Table A1.3 at 336 hours (14 days) or sooner when determined in accordance with the ANSI/BIFMA M7.1 standard test method. These criteria are based on California EPA's OEHHA's reference exposure VOC limits in the 2004 California Standard Practice for the Testing of Volatile Organic Emissions from Various Sources using Small-Scale Environmental Chambers, as applied in the 2008 California open plan office furniture bid specification. Users are encouraged to reference ANSI/BIFMA e3 for the most current limits, for example, the acetaldehyde number in the following table does not represent the current CREL established by OEHHA in December 2008.

# ANSI/BIFMA M7.1-2011

# Table A1.3 Individual Volatile Organic Chemical (VOC) Concentration Limits at 336 Hours.

				Workstation	Seating	Individual (	Components
Compound Name	CASRN	MW	CREL	Maximum Allowable Conc. (μg/m³)	Maximum Allowable Conc. (µg/m <sup>3</sup> )	Open Plan Maximum Allowable Emission Factor (µg/m <sup>2</sup> h)	Private Office Maximum Allowable Emission Factor (µg/m <sup>2</sup> h)
Ethylbenzene	100-41-4	106.2	Ý	1000	500	689	1392
Styrene	100-42-5	104.2	Υ	450	225	310	627
p-Xylene	106-42-3	106.2	Υ	350	175	241	487
1,4-Dichlorobenzene	106-46-7	147	Y	400	200	276	557
Epichlorohydrin	106-89-8	92.52	Y	1.5	0.75	1.0	2.1
Ethylene Glycol	107-21-1	62.1	Υ	200	100	138	278
1-Methoxy-2-propanol (Propylene glycol monomethyl ether)	107-98-2	90.12	Y	3500	1750	2413	4874
Vinyl Acetate	108-05-4	86.1	Υ	100	50	68.9	139
m-Xylene	108-38-3	106.2	Y	350	175	241	487
Toluene	108-88-3	92.1	Y	150	75	103	209
Chlorobenzene	108-90-7	112.56	Y	500	250	345	696
Phenol	108-95-2	94.1	Y	100	50	68.9	139
2-Methoxyethanol	109-86-4	76.1	Y	30	15	21	42
Ethylene glycol monomethyl ether acetate	110-49-6	118.13	Y	45	22.5	31	63
n-Hexane	110-54-3	86.2	Y	3500	1750	2413	4874
2-Ethoxyethanol	110-80-5	90.1	Υ	35	17.5	24	49
2-Ethoxyethyl acetate	111-15-9	132.2	Y	150	75	103	209
1,4-Dioxane	123-91-1	88.1	Y	1500	750	1034	2089
Tetrachloroethylene	127-18-4	165.8	Υ	17.5	8.75	12.1	24.4
Formaldehyde	50-00-0	30.1	Y	16.5	8.25	11	23
Isopropanol	67-63-0	60.1	Υ	3500	1750	2413	4874
Chloroform	67-66-3	119.4	Y	150	75	103	209
N,N-Dimethyl Formamide	68-12-2	73.09	Y	40	20	28	56
Benzene	71-43-2	78.1	Υ	30	15	21	42
1,1,1-Trichloroethane	71-55-6	133.4	Y	500	250	345	696
Acetaldehyde	75-07-0	44.1	Υ	9	4.5	6	13
Methylene Chloride	75-09-2	84.9	Y	200	100	138	278
Carbon Disulfide	75-15-0	76.14	Y	400	200	276	557
Trichloroethylene	79-01-6	131.4	Y	300	150	207	418
1-Methyl-2- Pyrrolidinone	872-50-4	99.13	Ν	160	80	110	223
Naphthalene	91-20-3	128.2	Y	4.5	2.25	3	6
o-Xylene	95-47-6	106.2	Υ	350	175	241	487

Reference: State of CA Department of General Services IFB 55756 - Open Office Panel Systems

# Appendix 2 – Examples: Calculations and Standard Workstations

This appendix contains examples intended to clarify the application of the M7.1 test method.

The following is a list of the examples provided:

#### A2.1.1 WORKSTATION SYSTEM EXAMPLE

- CASE #1: Evaluate the Entire Workstation Using the Concentration Approach (testing a fully assembled workstation in chamber)
- CASE #2: Evaluate the Entire Workstation Using the Emission Factor Approach (testing a fully assembled workstation in chamber)
- CASE #3 Evaluate the Entire Workstation Using the Concentration Approach (using direct scaling)

#### A2.1.2 WORKSTATION COMPONENT EXAMPLE

**Evaluate Workstation Component Using the Emission Factor Approach** *(using direct scaling)* 

#### A2.1.3 CONFERENCE TABLE EXAMPLE

CASE #1:	Evaluate the Conference Table using the Emission Factor Approach
	and testing a fully assembled table in chamber.

- CASE #2: Evaluate the Conference Table Using Direct Scaling From <u>Full Size</u> Samples of Component Assemblies
- CASE #3: Evaluate the Conference Table Using Direct Scaling From <u>Small-</u> <u>scale</u> Samples of Component Assemblies

#### A2.1.4 STORAGE CABINET EXAMPLE

- CASE #1: Calculate the simplified area for the workstation concentration approach.
- CASE #2: Calculate the simplified area for the individual component emission factor approach.
- CASE #3: Calculate the material area for direct scaling.

#### A2.1.5 EASEL EXAMPLE

- CASE #1: Calculate the simplified area for the workstation concentration and emission factor approach.
- CASE #2: Calculate the material area for direct scaling.

# A2.1.1 WORKSTATION SYSTEM EXAMPLE

# CASE #1: Evaluate the Entire Workstation Using the Concentration Approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). Case #1 follows the left half of the flowchart with the "traditional" testing approach.



## Step 1 – Evaluate the product line for "worst-case" emitting materials

As defined by Section 7, 9, 11.7 and Appendix 6, identify the potential emitting materials for all options in the product line. Once those items are identified, further narrow down the list to only the highest emitting material for each option. *This may require some small chamber testing of materials to determine the worst-case materials for each compound.* 

## Step 2 – Determine representative "worst-case" workstation

Once the worst-case materials are identified, create the representative "worst case" standard workstation as per Section 9.1. This requires solving the puzzle of what combination of products and sizes are available from the manufacturer that can be combined to meet the simplified surface area targets defined in Section 7.1. The simplified surface areas of the workstation panel, storage, and work surface totals are calculated per Section 7. This example uses the standard workstation defined in A2.2 (shown below for convenience), but many other combinations are possible.



			Simplified		
	Qty	Surface Type	area (m <sup>2</sup> )		
	1	Work Surface, Rectangular, 0.610 m x 0.610 m (24 in. x 24 in.)	0.74		
e		Work Surface, Extended Corner, 0.610 m x 0.762 m x 1.83			
urfa	1	m x 1.22 m (24 in x 30 in. x 72 in x 48 in.)			
rksı	1	Round Table, 1.07 m (42 in.) diameter	1.79		
٨٥		Total Worksurface Area:	6.04		
	1	Panel, 0.601 m wide x 1.68 m high (24 in. x 66 in.)	2.04		
	1	Panel, 1.22 m wide x 1.68 m high (48 in. x 66 in.)	4.09		
	1	Panel, 0.601 m wide x 1.37 m high (24 in. x 54 in.)	1.67		
ē	1	Panel, 1.22 m wide x 1.37 m high (48 in. x 54 in.)	3.34		
Pan		Total Panel Area:	11.15		
		Overhead Storage Bin, 1.22 m wide x 0.401 m high x 0.406			
	1	m deep (48 in. wide x 15.8 in. high x 16 in. deep)			
	1	Shelf, 0.601 m wide x 0.356 deep (24 in. x 14 in.)	0.43		
rage	1	Pedestal File, 0.762 m deep x 0.686 m high x 0.381 wide (30 in. deep x 27 in. high x 15 in. wide)	1.84		
O   Total Storage Area:   4.1					
TOT	TOTAL WORKSTATION SIMPLIFIED AREA: 21.75				

# Step 3 – Determine the testing approach

In this case, use the traditional approach defined in Section 11.4 and test the full workstation. The results for formaldehyde at t=168 h are as follows:

	Chamber		Chamber Clean Air
	Concentration	Chamber Emission	Supply Flow Rate,
Component	(µg/m³)	Factor (µg/m² h)	Q <sub>chamber</sub> (m <sup>3</sup> /h)
Entire Workstation	51.2	58.9	25.0

# Step 4 – Calculate the Concentration for Open Plan Conditions

As per Section 11.4.1, the Estimated Building Concentration is calculated as follows:

$$C_{bldg} = \frac{A_o E(t)}{Q_o} = \frac{21.75*58.9}{15.02} = 85.4 \, \frac{\mu g}{m^3}$$

where the open plan workstation standard air flow rate, Q equals 15.02 m<sup>3</sup>/h (per 11.3).

If the concentration limit for formaldehyde at 168 hours is 50ppb or 61.5  $\mu$ g/m<sup>3</sup>, then this workstation does not meet the criteria.

# CASE #2: Evaluate the Entire Workstation Using the Emission Factor Approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). Case #2 follows the right half of the flowchart, with the "traditional" testing approach.



Using the workstation from Case #1, steps 1 through 3 are the same as in Case #1.

# Step 4 – Calculate the emission rate for the assembled workstation

As per Equation 11.3, the chamber source emission rate at t=168 h is calculated as follows:

$$R_{chamber}(t) = Q_{chamber} * C_{Chamber}(t) = \left(25.0 \frac{m^3}{h}\right) * (51.2 \frac{\mu g}{m^3}) = 1280 \frac{\mu g}{h}$$

## Step 5 – Calculate the emission factor for the assembled workstation

As per Equation 11.14, the Emission Factor is calculated for compliance as follows:

$$E_{product}(t) = \frac{R_{chamber}}{A_{simplified}} = \frac{1280}{21.75} = 58.9 \frac{\mu g}{m^2 h}$$

Refer to Table A1.2 and A1.3 for example emission factor compliance criteria.

If the emission factor limit for formaldehyde at 168 hours is 42.3  $\mu$ g/m<sup>2</sup> h for an open plan workstation, then this workstation does **not** meet the criteria.

If the emission factor limit for formaldehyde at 168 hours is 85.1  $\mu$ g/m<sup>2</sup> h for a private office scenario, then this workstation does meet the criteria.

Please note, using the emission factor approach yields the same results as using the concentration approach, as can be seen by comparing Case #1 and Case #2.

# CASE #3: Evaluate the Entire Workstation Using the Concentration Approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). Case #3 follows the left half of the flowchart, with the "direct scaling" approach.



Using the workstation from Case #1, steps 1 and 2 are the same as in Case #1.

# Step 3 – Determine the testing approach

In this case, use the direct scaling approach under the concentration approach as defined in sections 11.6. For this example, the table tops and worksufaces are particle board core encapsulated (top, bottom and edges) with laminate; the table legs, system work surface support legs, panel shelf and the file cabinet are powder coated metal; the upper storage cabinet is powder coated metal with a wood veneer door; and the panels are a fabric-covered tackable construction. Because the table tops and work surfaces are of identical construction, one set of tests will represent both. The upper storage cabinet door and vertical panels will each be tested. All finished metal components are powder-coated steel and are therefore considered non-emitting.

First, the round table and system work surfaces and their supports are evaluated using direct scaling under the concentration approach, per Section 7.3 and 11.6.2 (2). The direct scaling approach is an alternate option to testing the assembled table or assembled system work surfaces in a mid-scale (or larger) chamber.

For the round table, system work surfaces, and their supports there are five component assemblies; the table's work surface and the table's base, two work surfaces on the panel system, and the legs supporting one of the system work surfaces. The work surfaces have three emitting source types; the work surface top, work surface bottom, and work surface edge. The amount of blocked area on the bottom of the work surfaces is less than 10% of the total area and is therefore treated as if exposed (per 7.3.2).

As defined by Section 7.3.4 and 11.6.2.2, two small-scale samples of the work surfaces are tested to determine the emission factors for the top/bottom of the work surface and the edges of the work surface. Test 1 is a sample of work surface with the top, bottom, and edge exposed, but all cut edges sealed. Test 2 is a sample of work surface with the top and bottom exposed, but all edges sealed. Subtracting the chamber emission rate of Test 2 from the chamber emission rate of Test 1 and dividing by the exposed edge surface area of the

Test 1 sample yields the emission factor of the work surface edge, as described in Section 9.3.2.

Test 1 and Test 2 both use square samples cut from the work surface, 17.78 cm (7.0 inches) by 17.78 cm (7.0 inches) and 5.08 cm (2.0 inches) thick<sup>2</sup>. Focusing on formaldehyde at t=168 h, the emission rate of Test 1 is 0.844  $\mu$ g/h. The emission rate of Test 2 is 0.436  $\mu$ g/h. Subtracting the emission rate of Test 2 from that of Test 1 yields 0.408  $\mu$ g/h. The exposed edge surface area of the Test 1 sample is 0.009 m<sup>2</sup>. Therefore, the emission factor of the exposed edge is 0.408 divided by 0.009, which yields 45.2  $\mu$ g/m<sup>2</sup> h. The emission factor of the work surface top and bottom is 0.436 divided by 0.0632, which yields 6.90  $\mu$ g/m<sup>2</sup> h.

The results for formaldehyde at t=168 h are as follows:

Component	Material Area (m²)	Emission Factor (ug/m <sup>2</sup> h)
Table work surface top and bottom	1.79	6.90
Table work surface edges	0.170	45.2
Table base	Non emitting	
System work surface support legs	Non emitting	
System work surfaces top and bottom	4.25	6.90
System work surfaces edges	0.348	45.2

The storage cabinet door is tested using the direct scaling approach with a single small-scale test with appropriate edge-to-face ratio evaluation (see Sections 7.3.4 and 9.3.2.1, also shown in example A2.1.3 case #3 step #3) with the following results:

Component	Material Area (m²)	Emission Factor (ug/m <sup>2</sup> h)
Storage cabinet wood veneer door front and back	0.978	222.4

Finally, the panels are tested using the direct scaling approach in a mid-scale chamber. If all of the panels were identical, the component approach could be used for the panels, per Section 11.4.2. In this example the panel sizes vary, therefore direct scaling is used. The panel trim is powder-coated metal, therefore the fabric-covered surfaces of the panels are expected to be the source of all potential emissions. A single assembled panel is tested to determine the emission factor, which is then used to determine the emission rate from all of the panels in the work station. The formaldehyde emissions at t=168 h are as follows:

Component	Material Area (m <sup>2</sup> )	Emission Factor (ug/m <sup>2</sup> h)
Work station panels (fabric-covered tackable)	11.15	89.7

<sup>&</sup>lt;sup>2</sup> The size of the small-scale sample chosen may vary based on test chamber size and airflow rates (see Section 9). The actual size should be determined in consultation with the testing laboratory.

# Step 4 – Calculate the workstation total emission rate from all component assemblies

As per Section 11.6.2 (3), (4), and Equation 11.15, the Emission Rates are calculated as follows:

Table Work Surface Top/Bottom:

$$R_{ca}(t) = E(t) * A_{material} = \left(6.9 \frac{\mu g}{m^2 h}\right) * (1.79m^2) = 12.35 \frac{\mu g}{h}$$

Table Work Surface Edges:

$$R_{ca}(t) = E(t) * A_{material} = \left(45.2 \frac{\mu g}{m^2 h}\right) * (0.17m^2) = 7.68 \frac{\mu g}{h}$$

System Work Surfaces Top/Bottom:

$$R_{ca}(t) = E(t) * A_{material} = \left( \frac{6.9 \, \mu g}{m^2 h} \right) * (4.25m^2) = 29.33 \, \frac{\mu g}{h}$$

System Work Surfaces Edges:

$$R_{ca}(t) = E(t) * A_{material} = \left(45.2 \frac{\mu g}{m^2 h}\right) * (0.348m^2) = 15.73 \frac{\mu g}{h}$$

Storage Cabinet Wood Veneer Door:

$$R_{ca}(t) = E(t) * A_{material} = \left(\frac{222.4 \,\mu g}{m^2 h}\right) * (0.978m^2) = 217.5 \,\frac{\mu g}{h}$$

Workstation Panels:

$$R_{ca}(t) = E(t) * A_{material} = \left(\frac{89.7 \,\mu g}{m^2 h}\right) * (11.15m^2) = 1000 \,\mu g/h$$

Total Workstation Emission Rate:

$$R_{tot}(t) = 12.35 + 7.68 + 29.33 + 15.73 + 217.5 + 1000 = 1283 \frac{\mu g}{h}$$

#### Step 5 – Calculate the estimated building concentration for the workstation

Focusing on the results for formaldehyde at t=168 h and following Section 11.6.2 (5) and Equation 11.16, the estimated building concentration for the workstation is calculated as follows:

$$C_{bldg}(t) = \frac{R_{tot}(t)}{Q_o} = \frac{1283}{15.02} = 85.4 \, \frac{\mu g}{m^3}$$

# A2.1.2 WORKSTATION COMPONENT EXAMPLE

# Evaluate Workstation Component Using the Emission Factor Approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the right half of the flowchart with the "direct scaling" testing approach.





This example demonstrates the emission factor approach, focusing on just one component of the workstation evaluated in Case #1, the 1.07 m (42 inch) diameter round table.

## Step 1 – Evaluate the product line for "worst-case" emitting materials

As defined by Section 7, 9, 11.7 and Appendix 6, identify the potential emitting materials for all options in the product line. Once those items are identified, further narrow down the list to only the highest emitting material for each option. *This may require some small chamber testing of materials to determine the worst-case materials for each compound.* 

## Step 2 – Determine "worst-case" table options

Determine the representative "worst case" configuration of the emitting components of the round table, using the highest ratio of the worst case emitting materials (see Section 9.1).

## Step 3 – Determine the testing approach

In this case, the round table is evaluated using direct scaling under the Emission Factor approach, per Section 7.3 and 11.6.2 (2). Direct scaling is an alternate option to testing the assembled table in a mid-scale (or larger) chamber.

For this example there are two component assemblies; the table work surface and the base. The table base is powder coated steel and is therefore essentially non-emitting. The table work surface has three emitting source types, the work surface top, work surface bottom, and work surface edge. The amount of blocked area on the bottom of the table surface is less than 10% of the total area and is therefore treated as if exposed (per 7.3.2).

As defined by Section 7.3.4 and 11.6.2, two small-scale samples of the table work surface are tested to determine the chamber emission factors for the top/bottom of the work surface and the edges of the work surface. Test 1 is a sample of work surface with the top, bottom, and edge exposed, but all cut edges sealed. Test 2 is a sample of work surface with the top and bottom exposed, but all edges sealed. Subtracting the chamber emission rate of Test 2 from the chamber emission rate of Test 1 and dividing by the edge surface area of the Test 2 sample yields the emission factor of the work surface edge, as described in Section 9.3.2. Test 1 and Test 2 both use square samples cut from the work surface, 17.78 cm (7.0 inches) by 17.78 cm (7.0 inches) and 5.08 cm (2.0 inches) thick. Focusing on formaldehyde at t=168 h, the emission rate of Test 1 is 0.844 µg/h. The emission rate of Test 2 is 0.436 µg/h. Subtracting the emission rate of Test 2 from that of Test 1 yields 0.408 µg/h. The exposed edge surface area of the Test 2 sample is 0.009 m<sup>2</sup>. Therefore, the emission factor of the exposed edge is 0.408 divided by 0.009, which yields 45.2 µg/m<sup>2</sup> h.

The results for formaldehyde at t=168 h are as follows:

Component	Material Area (m²)	Chamber Emission Factor (µg/m² h)	
Table Work Surface Top and Bottom	1.79	6.9	
Table Work Surface Edges	0.17	45.2	
Base	Non emitting		

# Step 4 – Calculate the emission rates for the table work surface component assembly

As per Section 11.6.2 (3) and Equation 11.15, the Emission Rate is calculated as follows:

Table Work surface Top/Bottom:

$$R_{ca}(t) = E(t) * A_{material} = \left(6.9 \frac{\mu g}{m^2 h}\right) * (1.79m^2) = 12.35 \frac{\mu g}{h}$$

Table Work surface Edges:

$$R_{ca}(t) = E(t) * A_{material} = \left(45.2 \frac{\mu g}{m^2 h}\right) * (0.17m^2) = 7.68 \frac{\mu g}{h}$$

Because the table base is non-emitting, the total emission rate,  $R_{tot}(t)$  for the table is equal to the total emission rate of the table work surface.

# Step 5 – Calculate the emission factor for the table

The combined emission factor for the round table is calculated as per Section 11.6.2 (6) using Equation 11.17. In this case the simplified area for the table is the same as the material area for the work surface top and bottom.

$$E_{product}(t) = \frac{R_{tot}(t)}{A_{simplified}} = \frac{(12.35) + (7.68)}{1.79} = 11.19 \, \frac{\mu g}{m^2 h}$$

Refer to Table A1.2 and A1.3 for example emission factor compliance criteria.

If the emission factor limit for formaldehyde at 168 hours is 42.3  $\mu$ g/m<sup>2</sup> h for an open plan workstation, then this workstation component does meet the criteria.

If the emission factor limit for formaldehyde at 168 hours is  $85.1\mu g/m^2$  h for a private office scenario, then this workstation component does meet the criteria.

**Note:** All workstation components of the full workstation could be evaluated independently following this approach. If all representative worst-case components were compliant, the workstation system would also be compliant.

Alternatively, the emissions of the table work surface top, bottom, and edge could have been determined by one small-scale test, using the edge-to-face ratio as described in Section 7.3.3, 7.3.4, and 9.3.2.1. Another testing option would be to conduct two tests; one with only the table work surface top and bottom exposed and one with only the work surface edges exposed, as described in Section 9.3.2.

# A2.1.3 CONFERENCE TABLE EXAMPLE

# CASE #1: Evaluate the Conference Table using the Emission Factor Approach and testing a fully assembled table in chamber

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the right side of the flowchart with the "component" testing approach.



# Step 1 – Evaluate the product line for worst-case emitting materials

As defined by Section 7, 9, 11.7 and Appendix 6, identify the potential emitting materials for all options in the product line. Test materials for which you have no existing data and compare against other material options/results for the conference table to determine the highest emitting options.

## Step 2 – Determine worst-case sample configuration/surface area

Choose the worse case configuration of the conference table components (base + top, etc) – to yield the highest ratio of emitting materials, per Section 7, 9, and 11.

Furniture description:

Conference Table with Three Cylinder Bases

Key features:

Bases have glides, column supports are closed (surface area of the column bottoms is included as an emitting surface), there is no permanent open access to column interior<sup>3</sup> The two halves of the work surface butt tightly together when the table is fully assembled, there are no cutouts in the table top for cabling. The bases tightly seal to the bottom of the work surface.

<sup>&</sup>lt;sup>3</sup> If column has interior access that is permanently exposed, the interior surface area of each of the columns shall be added to the total surface area.

Key dimensions: Work surface - 122 cm (48.0 in.) x 366 cm (144 in.) x 4.00 cm (1.6 in.) Base - 40.6 cm dia. (16.0 in.) x 68.6 (27 in.) high bases

Calculate simplified surface areas per Section 7. There are two types of simplified surface area to calculate:

Work surface area, all top and bottom =  $2(\pi 61.0^2 + [122 \text{ x} (366 - 122)]) = 82,917 \text{ cm}^2$ =  $8.29 \text{ m}^2$ 

Vertical surface/panel area:  $(3 \times [68.6 \times 40.6\pi] + [6 \times \pi 20.3^2]) = 34,017 \text{ cm}^2 = 3.40 \text{ m}^2$ 

Total Simplified Product Area =  $8.29 + 3.40 = 11.69 \text{ m}^2$ .

If the bases were constructed of powder-coated steel or a similar very-low or non-emitting material, the column surface would not be included if using the total surface area to determine the table emissions factor.

## Step 3 – Determine the testing approach

Test the fully assembled table in a chamber. The following focuses on one single compound from the results:

Component	Surface Area (m²)	Emission Factor (ug/m <sup>2</sup> h)
Conference Table	11.69 (simplified)	14

Because a full conference table was tested, there is no need to do any further calculations. The resulting emission factors for the table can be used for determination of compliance against the emission factor criteria (for example the maximum emission factors for each compound listed in Table A1.2 and A1.3).

#### CASE #2: Evaluate the Conference Table Using Direct Scaling From <u>Full Size</u> Samples of Component Assemblies

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the right side of the flowchart with the "direct scaling" testing approach.



Using the information from Case #1, steps 1 and 2 are the same as in Case #1.

**Step 3 –** Test the full-size table work surface independently from the full size bases in midscale (or larger) chambers. The area on the bottom of the work surface that would be blocked by the columns must be sealed during the chamber test. Likewise, the top surface of the columns that would be blocked by the work surface when assembled must also be sealed during the chamber test.

Calculate the exposed emitting surface area for each surface type. Subtract the blocked area from the bottom of the work surface.

41,458.5 cm<sup>2</sup> -  $[3 \times \pi 20.3^2] = 37,575$  cm<sup>2</sup> = 3.76 m<sup>2</sup> exposed on bottom of work surface.

Calculate exposed work surface edge area =  $0.52 \text{ m}^2$ Total work surface area exposed in chamber =  $4.15+3.76+0.52 = 8.43 \text{ m}^2$ .

Calculate the exposed surface area of the bases. Subtract the blocked area of the top of each base.

 $(3 \times [68.6 \times 40.6\pi] + [3 \times \pi 20.3^2]) = 30,133 \text{ cm}^2 = 3.01 \text{ m}^2$ 

Focusing on the results for formaldehyde at t=168 h for this example:

Component	Material Area Exposed in Chamber (m <sup>2</sup> )	Chamber Emission Factor (µg/m <sup>2</sup> h)		
Worksurface	8.43	12		
Bases	3.01	23		

## Step 4 – Calculate the Emission Rates for each component assembly

Per Equation 11.15, the work surface Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left(\frac{12 \,\mu g}{m^2 h}\right) * (8.43m^2) = 100 \,\mu g/h$$

The table bases Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left(23 \frac{\mu g}{m^2 h}\right) * (3.01m^2) = 69 \frac{\mu g}{h}$$

#### **Step 5 – Calculate the Product Emission Factor**

$$E_{product}(t) = \frac{R_{tot}(t)}{A_{simplified}} = \frac{100+63}{11.69} = 14 \frac{\mu g}{m^2 h}$$

Compare the resulting Emission Factor to the maximum emission factor requirements to determine compliance (e.g. Table A1.2).

## CASE #3: Evaluate the Conference Table Using Direct Scaling From <u>Small-scale</u> Samples of Component Assemblies

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the right side of the flowchart using the "direct scaling" testing approach.



Using the information from Case #1, steps 1 and 2 are the same as in Case #1.

## Step 3 – Determine the testing approach

In this case, the conference table is evaluated using the **Direct Scaling Approach** per Section 7.3 and 11.6. The direct scaling approach is an alternative to testing the assembled table in a mid-scale (or larger) chamber.

For this example there are two component assemblies; the work surface and the base. The work surface has three emitting source types, the work surface top, work surface bottom, and work surface edge. The amount of blocked area on the bottom of the table surface is greater than 10% of the total area and therefore must be accounted for per Section 7.3.2. Therefore the emissions of the work surface top face must be determined independently from the emissions of the work surface bottom face.

The emissions of the work surface edges can be accounted for using the edge-to-face ratio approach, per Section 7.3.3 and 7.3.4. Calculate the edge-to-face ratio for the work surface edge relative to the top surface as follows:

Work surface edge area / Work surface top face area =  $0.52 \text{ m}^2$  /  $4.15 \text{ m}^2$  = 0.125

Four small-scale tests are conducted as follows:

- 1. Work surface with top face and finished edge exposed, bottom face and cut edges sealed.
- 2. Work surface with top, bottom, and finished edge exposed, all cut edges sealed.
- 3. Base vertical material with outer surface exposed, all other surfaces sealed.
- 4. Base bottom material with bottom surface exposed, all other surfaces sealed.

For both Test 1 and Test 2, the small-scale sample must have the exposed edge-to-top ratio of 0.125 (this can be accomplished by sealing a portion of the finished edge). The results

from Test 1 are subtracted from the results of Test 2 to determine the emissions of the work surface bottom face alone.

Component	Material Area (m²)	Emission Factor (µg/m <sup>2</sup> h)
Work Surface Top Face and Work Surface Edge	4.15 <sup>a</sup>	8.4
Worksurface Bottom Face	3.76	16
Base Columns Vertical Face	2.62	19
Base Columns Bottom	0.388	50

Focusing on the results for just formaldehyde at *t*=168 h:

<sup>a</sup>Work surface top face area used for direct scaling because edge emisssions are included in the associated emission factor, determined from Test 1. This assumes the reported chamber emission factor is calculated using only the exposed top face area. If the chamber emission factor is calculated using the top face and edge area, then the corresponding material area must be used, which in this case is 4.15 + 0.52 = 4.67.

## Step 4 – Calculate the Emission Rates for each component assembly

Per Equation 11.15, the work surface top and edge Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left(8.4 \frac{\mu g}{m^2 h}\right) * (4.15m^2) = 35 \frac{\mu g}{h}$$

The work surface bottom face Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left(16\frac{\mu g}{m^2 h}\right) * (3.76m^2) = 60\frac{\mu g}{h}$$

The base columns vertical face Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left(19 \frac{\mu g}{m^2 h}\right) * (2.62m^2) = 50 \frac{\mu g}{h}$$

The base columns bottom face Emission Rate is calculated as follows:

$$R_{ca}(t) = E(t) * A_{material} = \left( 50 \frac{\mu g}{m^2 h} \right) * (0.388m^2) = 19 \frac{\mu g}{h}$$

# Step 5 – Calculate the emission factor for the table

The combined emission factor for the conference table is calculated as per Section 11.6.2 (6) using Equation 11.17. The simplified area for the table is calculated in Case #1.

$$E_{product}(t) = \frac{R_{tot}(t)}{A_{simplified}} = \frac{35 + 60 + 50 + 19}{11.69} = 14 \frac{\mu g}{m^2 h}$$

Refer to Table A1.2 and A1.3 for example emission factor compliance criteria.

If the emission factor limit for formaldehyde at 168 hours is  $42.3\mu g/m^2$  h for an open plan workstation, then this workstation does meet the criteria.

If the emission factor limit for formaldehyde at 168 hours is  $85.1\mu g/m^2$  h for a private office scenario, then this workstation does meet the criteria.

# A2.1.4 STORAGE CABINET EXAMPLE

Only the calculation for Simplified Area and Material Area are shown. Calculations for the compliance approaches and for direct scaling would be consistent with the previous examples shown.

Furniture description:	Storage cabinet with drawers, doors, and shelves
Key features:	Glides under unit, two open shelves, three doors, door covering
	storage area (surface area of the bottom included as an emitting
	surface),
Key dimensions:	170 cm (67.0 in.) x 109 cm (43 in.) x 65 cm (25.75 in.)



## CASE #1: Calculate the simplified area for the workstation concentration approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the left side of the flowchart with the "component" testing approach.



Per Section 7.2.3, treat the cabinet as a five-sided box + shelves + drawer fronts + exposed interior "bookcase areas".

Qty	Simplified Surface Type	Length (cm)	Depth (cm)	Area (cm²)	
2	Outer surface of Side Panels	163	64	20,864	
2	Outer surface of Top and Bottom Panel	109	65	14,170	
2	Shelves (both top and bottom surfaces)	84	64	21,504	
3	Drawer Headers (outer surface)	85	23	5,865	
1	Door (outer surface)	24	159	3,816	
1	Inner exposed surface of Back Panel	90	84	7,560	Simplified
2	Inner exposed surface of Side Panel	90	64	11,520	Area
1	Outer surface of Back Panel	152	109	16,568	Total
2	Top of Drawers Case & underside of top	84	64	10,752	(m²)
			TOTAL	112,619	11.26
#### CASE #2: Calculate the simplified area for the individual component emission factor approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows the right side of the flowchart with the "component" testing approach.



Per Section 7.2.3, treat the cabinet as a six-sided box, as if doors enclose the shelves.

Qty	Туре	Length (cm)	Depth (cm)	Area (cm²)	_
2	Outer surface of Side Panels	163	64	20,864	
2	Outer surface of Top and Bottom Panel	109	65	14,170	Total
2	Outer surface of Back Panel, Drawers, Doors	152	109	33,136	(m <sup>2</sup> )
			TOTAL	68,170	6.82

The reason for calculating simplified area differently for the emission factor approach is to ensure storage components that are compliant alone will also always be compliant when used in a standard workstation scenario.

For example, the maximum allowed emission factors shown in Table A1.2 and A1.3 were established using the standard workstation scenarios shown in Table 7.1, where the total workstation surface area is based in part on simplified storage external surface area.

In the original version of this test method, emission factor compliance was not an option. The simplified surface area calculations were intended to define what size and configuration of fully assembled workstation components would be tested in a chamber. At that time it was not necessary to measure the detailed, inner surface areas of closed storage cabinets, as the parts would be present when testing the assembled product in the chamber. Also, it was initially believed that the emissions from the inner portions of a normally closed storage cabinet or file would have minimal effect on the chamber (or building) concentrations. Subsequent research (Hodgson et.al. 2009) revealed the inner materials of a closed cabinet have a greater affect on room concentrations for VOCs than was initially thought.

Because compliance was traditionally based on concentration limits for whole workstations, and the workstation area was defined by conventions adopted for the research defining standard workstations (Carter, Zhang 2007), storage components are treated as closed boxes for the emission factor approach to be consistent with the established compliance precedents. If material area of storage components was used when determining compliance using the emission factor approach, the emission factor limits in Table A1.2 and A1.3 would no longer be consistent with the original workstation concentration approach.

#### CASE #3: Calculate the material area for direct scaling

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows both sides of the flowchart up to the "direct scaling" approach.



Per Section 7.3, treat the storage cabinet as a combination of component assemblies.

This is a relatively simple example as it does not include any unfinished edges and multiple cabinet parts are made from common materials. This example assumes four types of component assemblies:

- A. Overall Case Structure
- B. Shelves
- C. Drawer Headers and Door
- D. Drawer Bodies (not shown)

Each of these planar, sandwich construction component assemblies is assumed to have identical finishes on both faces, and consistent edge banding on all parts. This is simplified, as many storage cabinets contain component assemblies with combinations of banded and unfinished edges. Particular care must be taken to account for unfinished edges, especially when the core substrate is a composite wood material. For this example, blocked surfaces are treated as exposed.

Qty	Туре	Length (cm)	Depth (cm)	Area - 2 sides (cm <sup>2</sup> )	Tot (cm <sup>2</sup> )	Total Material Area (m <sup>2</sup> )	
6	Side Panels (includes vertical divider)	163	64	62,592			
2	Top and Bottom Panel	109	65	28,340	134,820	13.5	A. FACES
1	Back Panel	152	109	33,136			
1	Top of Drawers Case	84	64	10,752			
					2,374	0.237	A. EDGES
2	Shelves	84	64	21,504	21,504	2.2	B. FACES
					341	0.034	B. EDGES
3	Drawer Headers	85	23	11,730	19,362	1.9	C. FACES
1	Door	24	159	7,632			
					2,059	0.206	C. EDGES
6	Drawer body Side Panels	61	22	16,104		EQ	
3	Drawer bottoms	84	61	30,744	57,936	<b>J.</b> 0	D. FACES
3	Drawer backs	84	22	11,088			
					1,887	0.189	D. EDGES
					TOTAL	24.07	

#### A2.1.5 EASEL EXAMPLE

Only the calculation for Simplified Area and Material Area are shown. Calculations for the compliance approaches and for direct scaling would be consistent with the previous examples shown.



Furniture description:	"A-frame" easel with shelves
Key features:	Ceramic marker board upper on one side, tackboard covering entire opposite side, two painted metal shelves, one plastic tray, glides
Key dimensions:	189 cm (74.5 in.) x 91 cm (36 in.) x 46 cm (18 in.)

# CASE #1: Calculate the simplified area for the concentration and emission factor approach

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows both sides of the flowchart up to the "component" approach.



Per Section 7.2, treat the easel as a combination of panel (vertical) and work surface or shelf (horizontal) area.

Qty	Туре	Length (cm)	Depth/Width (cm)	Area (cm²)	Simplified Area (m <sup>2</sup> )
2	Vertical panels	183	91	66,612	
1	Upper shelf	91	29	5,278	]
1	Lower shelf	91	64	11,648	
1	Tray shelf	91	8	1,456	
2	Upper shelf end cap/supports	29	8	928	
			•	85,922	8.59

#### CASE #2: Calculate the material area for direct scaling

Refer to Figure 4.1 – Options for Determining Compliance (Flowchart). This example follows both sides of the flowchart up to the "direct scaling" approach.



Per Section 7.3, treat the easel as a combination of component assemblies.

For this example assume the following:

Two types of emitting surfaces:

- Lower face: Surface C (two sided):
- Tackable face: D (two-sided, not shown)

Five types of non-emitting surfaces (these areas are not shown in the table below because the emission rates are zero for these component assemblies):

- Upper face: Surface A (metal with ceramic surface)
- Tray: Surface B (aluminum)
- Shelves: Surfaces F & G (painted metal)
- Frame: Surface E (anodized aluminum)
- Casters: Surface H (hard plastic)

Qty	Туре	Length (cm)	Depth/Width (cm)	Number of faces or edge surfaces	Area (cm²)	Material Area (m <sup>2</sup> )
	Vertical panel (tackable					
1	surface)	183	91.44	2	33,467	3.3
1	Edges of tackable surface	549	1.91	1	1049	0.105
1	Lower face (face c)	91	76.2	2	13,868	1.4
1	Edges of lower face	335	1.91	1	640	0.064
					49,024	4.9

#### A2.2 Representative Open Plan and Private Office Workstation System Configurations

Figure A2.2.1 illustrates a representative Open Plan - *Panel Based* workstation system with its components and quantity listed in Table A2.2.1. These component sizes and combinations represent one example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1 and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.1 A Standard Open Plan *Panel-Based* Workstation System

Table A2.2.1 Components of a Standard Open Plan *Panel-Based* Workstation for Emission Testing

Quantity	Description with Nominal Dimensions	Configuration During Test
1	Work Surface, Rectangular, 0.610 m x 0.610 m (24 in. x 24 in.)	Assembled
1	Work Surface, Extended Corner, 0.610 m x 0.762 m x 1.83 m x 1.22 m (24 in x 30 in. x 72 in x 48 in.)	Assembled
1	Round Table, 1.07 m (42 in.) diameter	Assembled
1	Panel, 0.601 m wide x 1.68 m high (24 in. x 66 in.)	Assembled
1	Panel, 1.22 m wide x 1.68 m high (48 in. x 66 in.)	Assembled
1	Panel, 0.601 m wide x 1.37 m high (24 in. x 54 in.)	Assembled
1	Panel, 1.22 m wide x 1.37 m high (48 in. x 54 in.)	Assembled
1	Overhead Storage Bin, 1.22 m wide x 0.401 m high x 0.406 m deep (48 in. wide x 15.8 in. high x 16 in. deep)	Assembled, Door Closed
1	Shelf, 0.601 m wide x 0.356 deep (24 in. x 14 in.)	Assembled
1	Pedestal File, 0.762 m deep x 0.686 m high x 0.381 wide (30 in. deep x 27 in. high x 15 in. wide)	Assembled Under Work Surface, Drawers Closed

#### ANSI/BIFMA M7.1-2011

Figure A2.2.2 illustrates a representative Open Plan - *Panel Based* workstation system with its components and quantity listed in Table A2.2.2. These component sizes and combinations represent a second example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1 and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.2 A Standard Open Plan *Panel-Based* Workstation System

Table A2.2.2
Components of a Standard Open Plan Panel-Based Workstation for Emission Testing

Quantity	Description with Nominal Dimensions	Configuration During Test
2	Work Surface, Rectangular, 0.762 m x 1.52 m (30 in. x 60 in.)	Assembled
1	Work Surface, Rectangular, 0.610 m x 0.914 m (24 in. x 36 in.)	Assembled
1	Panel, 1.52 m wide x 1.68 m high (60 in. x 66 in.)	Assembled
1	Panel, 0.762 m wide x 1.37 m high (30 in. x 54 in.)	Assembled
1	Panel, 0.914 m wide x 1.37 m high (36 in. x 54 in.)	Assembled
1	Panel, 0.762 m wide x 1.067 m high (30 in. x 42 in.)	Assembled
1	Overhead Storage Bin, 1.52 m x 0.401 m x 0.406 m (60 in. x 15.8 in. x 16 in.)	Assembled, Door Closed
1	Pedestal File, 0.762 m deep x 0.686 m high x 0.381 wide (30 in deep x 27 in high x 15 in wide)	Assembled under Work Surface, Drawers Closed

Figure A2.2.3 illustrates a representative Open Plan - workstation system with its components and quantity listed in Table A2.2.3. These component sizes and combinations represent a third example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1. and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.3 A Standard Open Plan Workstation System

Table A2.2.3
Components of a Standard Open Plan Workstation System for Emission Testing

Quantity	Description with Nominal Dimensions	Configuration During Test
1	Rectangular Table/Desk 0.762 m x 1.22 m (30 in. x 48 in.)	Assembled
1	Rectangular Table/Desk 0.762 m x 1.07 m (30 in. x 42 in.)	Assembled
1	Corner Table/Desk 1.22m x 1.22 m x 1.07 m (48 in. x 48 in. x 30 in.)	Assembled
1	Mobile Storage Cabinet, 0.508 m x 0.762 m x 1.07 m (20 in. x 30 in. x 42 in.)	Assembled, Drawers and Doors Closed
1	Desk Mounted Storage Unit, 0.406 m x 0.406 m x 0.610 m (16 in. x 16 in. x 24 in.)	Assembled, Doors Closed
2	Mobile Screen / Panel, 1.22 m x 1.63 m (48 in. x 64 in.)	Assembled
1	Mobile Screen / Panel, 0.914 m x 1.63 m (36 in. x 64 in.)	Assembled

Figure A2.2.4 illustrates a representative Open Plan workstation system that represents a fourth example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1 and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.4 A Standard Open Plan Workstation System That Can be Configured to Meet the Area Requirements of Table 7.1

Figure A2.2.5 illustrates a representative Private Office *Freestanding Casegoods* workstation system with its components and quantity listed in Table A2.2.5. These component sizes and combinations represent one example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1 and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.5 A Standard Private Office *Freestanding* Casegoods Workstation System

# Table A2.2.5Components of a Standard Private Office Freestanding Casegoods WorkstationSystem for Emission Testing 13.38 m² (144 ft²) Footprint

Quantity	Description with Nominal Dimensions	Configuration During Test
- 1 1 1 1	Single Pedestal Desk: Work surface, 1.83 m x 0.914 m (72 in. x 36 in.) Pedestal, 0.457 m x 0.762 x 0.686 m (18 in. x 30 in. x 27 in.) Modesty Panel, 1.37 m x 0.686 m (54 in. x 27 in.) End Panel, 0.914 m x 0.686 m (36 in. x 27 in.)	Assembled, Drawers Closed
- 1 1 1 1	Single Pedestal Credenza: Work surface, 1.83 m x 0.610 m (72 in. x 24 in.) Modesty Panel, 0.914 m x 0.686 m (36 in. x 27 in.) Lateral File, 0.914 m x 0.610 m x 0.686 m (36 in. x 24 in. x 27 in.) End Panel, 0.610 m x 0.686 m (24 in. x 27 in.)	Assembled, Drawers Closed
1	Bridge Unit Work surface, 0.610 m x 0.914 m (24 in. x 36 in.)	Assembled
-	Hutch Storage Unit w/Doors:	
1	Storage Area, 1.83 m x 0.381 m x 0.457 m (72 in. x 15 in. x 18 in.)	Assembled,
2	End Panel, 0.381 m x 0.508 m (15 in. x 20 in.)	Doors Closed
1	Back Panel, 1.83 m x 0.508 m (72 in. x 20 in.)	
1	Mobile Pedestal, 0.457 m wide x 0.584 m deep x 0.686 m high	Assembled,
	(18 in. wide x 23 in. deep x 27 in. high)	Drawers Closed

#### ANSI/BIFMA M7.1-2011

Figure A2.2.6 illustrates a representative Private Office *Freestanding* workstation system with its components and quantity listed in Table A2.2.6. These component sizes and combinations represent a second example that can be used to achieve the total surface area requirements specified in Table 7.1. Other combinations are acceptable if they result in surface areas for each workstation parameter that are within  $\pm 5\%$  of the requirements specified in Table 7.1 and if the total area is within  $\pm 5\%$  of the requirements specified in Table 7.1.



Figure A2.2.6 A Standard Private Office *Freestanding* Casegoods Workstation System

Table A2.2.6
Components of a Standard Private Office Freestanding Casegoods Workstation
System for Emission Testing 13.38 m <sup>2</sup> (144 ft <sup>2</sup> ) Footprint

Quantity	Description with Nominal Dimensions	Configuration During Test
1	Peninsula Work Surface, 1.83 m x 0.914 m (72 in. x 36 in.)	Assembled
1	End Panel Support, 0.914 m x 0.686 m (36 in. x 27 in.)	Assembled
1	Bridge Work Surface, 1.067 m x 0.610 m (42 in. x 24 in.)	Assombled
1	Back Panel Support, 1.067 m x 0.686 m (42 in. x 27 in.)	Assembled
1	Credenza Work Surface, 1.83 m x 0.610 m (72 in. x 24 in.)	
1	Back Panel, 0.914 m x 0.686 m (36 in. x 27 in.)	Assembled
1	End Panel, 0.610 m x 0.686 m (24 in. x 27 in.)	Drawore Closed
1	Lateral File, 0.914 m wide x 0.686 m high x 0.457 m deep	Diawers Closed
	(36 in. wide x 27 in. high x 18 in. deep)	
1	Lateral File, 0.914 m wide x 1.35 m high x 0.457 m deep	Drowers Cleased
I	(36 in. wide x 53 in. high x 18 in. deep)	Drawers Closed
1	Hutch, 0.965 m high x 1.83 m wide x 0.381 m deep	Dooro closed
I	(38 in. high x 72 in. wide x 15 in. deep)	Doors closed

#### A2.3 Rationale for Standard Workstation System Sizes and Modeled Air Flow Rate

The following information is summarized from the Carter, Zhang 2007 research paper.

A2.3.1. Floor Area per Workstation, including allocated office common area:

This value was determined from a BIFMA statistical analysis of 30 randomly selected North American office building floor plans chosen from a cross section of customers from seven major office furniture manufacturers. The analysis of these floor plans included over 5,000 office workstations.

In each case the floor area "footprint" of each office was measured and combined with a relatively sized portion of the general office common area. The general office common area typically included informal open plan conference or meeting areas, copy machine/printer areas, or aisle space between open plan workstations. This general office space was allocated to all adjoining occupiable areas (i.e. conference rooms, private offices, refreshment areas, cafeterias, floor-to-ceiling corridors, etc.) unless the adjoining areas were part of the building area common to all tenants and/or were separated from the open plan office area by floor-to-ceiling walls and doors that would normally be closed. Building atria, reception areas, storage rooms, elevators, stairwells, building vertical penetrations, electrical/mechanical rooms, and restrooms were typically excluded from allocations of the general office common area. This analysis of floor area was intended to be consistent with the definitions and practices of ASHRAE 62.1 2007, ANSI/BOMA Z65.1-1996, and ASTM E 1836-01.

A2.3.2. Modeled Air Flow Rate (cfm):

This value is based on the required minimum outdoor air flow rate specified in ASHRAE 62.1-2007, using the floor area per workstation value from A2.3.1 to determine the occupant density of the office area and assuming that each workstation is intended for one person.

Occupant Density = 1 / Floor Area per Workstation

Using Table 2 in ASHRAE 62.1-2007 and equation 6-1, the required outdoor air flow rate is determined as follows:

Modeled Air Flow Rate (cfm) = 5 (cfm) + 0.06 (cfm/sq. ft.) x Floor Area/Workstation (sq. ft.)

#### A2.3.3. Required Potential Emitting Surface Area (sq. ft.):

The representative amount of total potential emitting surface area was calculated based on the representative worst-case surface areas of panels, work surfaces, and storage components determined in the BIFMA statistical analysis of over 5,000 workstations as described above. The surface area of all elements present in each office and in the surrounding general office common areas were totaled and divided by the number of workstations present. The resulting frequency distribution, weighted by number of building workstations affected, was used to determine the representative worst-case value for Panel, Work surface, Storage, and Total Area. Additional detail is available from BIFMA International.

#### Appendix 3 Informative - A Typical Timeline for Office Workstation Ordering, Manufacturing, and Shipping

The chart below is a review of lead-time elements for made-to-order workstations for the installation of 100 new workstations in a room. Time ranges are based on standard 8-hour workdays and totals are adjusted to "weeks" including non-working weekends<sup>4</sup>.

<u>Timelir</u>	ne Review		Typical Time Ranges
CT1	Dealer Receives Workstation	n Order	1 day
CT2	Factory Receives Workstatio	n Order	1-5 days
CT3	Factory Floor, Multiple Manu	facturing Orders	1-56 days
CT4	(Factory lead of wait time) Manufacture (10-20 different (actual floor time)	processes)	1-4 days
CT5	Package & Move to Warehou	use	1-2 days (2)
CT6	Consolidate & Ship Order		1-10 days (5)
CT7	Shipping Transit Time to Cus	stomer	1-5 days (3) max)
CT8	Installer labor unwrap and as	semble furniture	7-21 days
CT9	Electricity and data cabling		7-14 days
CT10	Telephone and computers		7-14 days
CT11	Furniture cleaned, floor vacu	umed	1-5 days
CT12	Office worker occupancy		1-5 days
		Minimum (CT5-CT8)	10 davs
		Maximum (CT5-CT8)	38 days
		Minimum (CT9-CT12)	16 davs
		Maximum (CT9-CT12	) 38 days

# A3.1 Rationale for preparation, shipping and storage times prior to preconditioning/testing in the chamber

For emission testing, the office workstation systems or their components are prepared and shipped to the testing laboratory according to the similar procedure as used for customers except usually only one workstation system (or a set of its components) is shipped at a time to the laboratory. To reduce the variation in emission test results, the age of the test specimen (time elapsed from the product packaging prior to the conditioning/testing in the chamber) should be controlled within 25 days, which is the slightly more than the average of the minimum and maximum time from the packaging to receiving by the customer in a typical ordering and shipping process (i.e., CT5-CT8 shown in the above chart). The emission rate at the 72-hour time point can be used to model a worst-case scenario for short-term impact in an office setting.

<sup>&</sup>lt;sup>4</sup> The data were based on the experience and past records of BIFMA members in furniture manufacture at multiple locations, staging, order consolidation, and delivery.

#### A3.2 Rationale for conditioning/testing period

The conditioning/testing period starts when the test specimen is unwrapped and placed in the chamber under a controlled environmental and ventilation condition, during which the VOCs are emitted. Ideally, the end of the test period should represent the condition of occupancy when a batch of workstations are ordered and installed in the office space as in the above chart. California (2000) recommends a 14-day conditioning/testing period, which is close to the minimum time between the completion of installation and the occupancy shown in the above chart (16 days). However, analyses of the furniture emission characteristics and past test data suggest that it is adequate to use 7-day test data to predict the VOC emission rates at the 14th day (Appendix 5). Reducing the conditioning/testing period to 7 days significantly reduces the turn-around time.

## Appendix 4 -- Target Lists of Individual VOCs for Quantification by TD-GC/MS and HPLC

Table A4.1 lists the individual VOCs of potential concern and their maximum allowable concentrations ( $\mu$ g/m<sup>3</sup>) in an office workspace at a 336-hour time point as specified in Section 5.7; Indoor Air Quality (IAQ) Requirements; California Department of General Services, Procurement Division; Open Office Panel Systems RFP DGS-56275; March 3, 2008. These VOCs are analyzed by TD-GC/MS and HPLC as indicated. Not all of these compounds are known to be emitted from office furniture systems and seating.

Table A4.2 lists individual VOCs analyzed by TD-GC/MS that typically may be found in indoor air (ECA-IAQ, 1997). Also indicated are those VOCs that have been identified in previous testing as commonly emitted from office furniture systems and seating.

Table A4.1. List of target individual VOCs of potential concern analyzed by TD-GC/MS and HPLC (California Department of General Services, 2008)

Chemical Class / Compound Name	CAS #	MW	CREL?** (Y/N)	Maximum Allowable Conc. <sup>†</sup> (µg/m³)
Aromatic Hydrocarbons				
Benzene	71-43-2	78.1	Y	30
Toluene	108-88-3	92.1	Y	150
Ethylbenzene	100-41-4	106.2	Y	1,000
m-Xylene	108-38-3	106.2	Y	350
p-Xylene	106-42-3	106.2	Y	350
o-Xylene	95-47-6	106.2	Y	350
Styrene	100-42-5	104.2	Y	450
Naphthalene	91-20-3	128.2	Y	4.5
Aliphatic Hydrocarbons				
n-Hexane	110-54-3	86.2	Y	3,500
Alcohols				
Isopropanol	67-63-0	60.1	Y	3,500
Phenol	108-95-2	94.1	Y	100
Glycols/Glycol Ethers				
Éthylene Glycol	107-21-1	62.1	Y	200
2-Methoxyethanol	109-86-4	76.1	Y	30
2-Ethoxyethanol	110-80-5	90.1	Y	35
1-Methoxy-2-propanol	107-98-2	90.1	Y	3,500
Aldehydes				
Formaldehyde*	50-00-0	30.03	Y	16.5
Acetaldehyde*	75-07-0	44.1	Y	9.0
Halocarbons				
Epichlorohydrin	106-89-8	92.5	Y	1.5
Methylene Chloride	75-09-2	84.9	Y	200
Chloroform	67-66-3	119.4	Y	150
Trichloroethylene	79-01-6	131.4	Y	300
1,1,1-Trichloroethane	71-55-6	133.4	Y	500
Tetrachloroethylene	127-18-4	165.8	Y	17.5
Chlorobenzene	108-90-7	112.6	Y	500
1,4-Dichlorobenzene	106-46-7	147.0	Y	400
Esters				
Vinyl acetate	108-05-4	86.1	Y	100
Ethylene glycol monomethyl	110-49-6	118.1	Y	45
ether acetate				
2-Ethoxyethyl acetate	111-15-9	132.2	Y	150
Ethers				
1,4-Dioxane	123-91-1	88.1	Y	1,500
Other				
Carbon Disulfide	75-15-0	76.1	Y	400
N,N-Dimethylformamide	68-12-2	73.1	Y	40
1-Methyl-2-pyrrolidinone	872-50-4	99.1	N	160

\*Analyzed by HPLC; all other VOCs analyzed by TD-GC/MS

\*\*Chronic Reference Exposure Level, California Office of Environmental Health Hazard Assessment
\*Specified in California Department of General Services, Procurement Division, Open Office Panel Systems RFP DGS-56275 (2008)

Table A4.2. VOCs frequently encountered in indoor air and analyzed by TD-GC/MS (ECA-IAQ, 1997)

Chemical Class / Compound Name	CAS#	Boiling Point (°C)	Identified as Emitted from Furniture Systems & Seating
Aromatic Hydrocarbons			
Benzene	71-43-2	80.1	
Toluene	108-88-3	111	[1][2][3][4]
Ethylbenzene	100-41-4	136.2	[3]
m/p-Xylene	108-38-3 &	139.1 &	[2][3][4]
	106-42-3	138.3	
o-Xylene	95-47-6	144	
n-propylbenzene	103-65-1	159	
1,2,4-Trimethylbenzene	95-63-6	169.4	
1,3,5-Trimethylbenzene	108-67-8	165	
2-Ethyltoluene	611-14-3	165.2	
Styrene	100-42-5	145.2	
Naphthalene	91-20-3	218	
4-Phenylcyclohexene	31017-40-0	251-3 <sup>1</sup>	
Aliphatic Hydrocarbons (n-C <sub>6</sub>	to n-C₁₀)		
n-Hexane	110-54-3	69	[3]
n-Heptane	142-82-5	98.4	
n-Octane	111-65-9	125.7	
n-Nonane	111-84-2	150.8	
n-Decane	124-18-5	174.1	[4]
n-Undecane	1120-21-4	196	[3]
n-Dodecane	112-40-3	216.3	[1][3][4]
n-Tridecane	629-50-5	235.4	
n-Tetradecane	64036-86-3	253.7	[1]
n-Pentadecane	629-62-9	270.6	
n-Hexadecane	544-76-3	287	
2-Methylpentane	107-83-5	60.3	[3]
3-Methylpentane	96-14-0	63.3	
1-Octene	111-66-0	121.3	
1-Decene	872-05-9	170.5	
Cycloalkanes			
Methylcyclopentane	96-37-7	71.8	
Cyclohexane	100-82-7	81	[3]
Methylcyclohexane	108-87-2	101	

Chemical Class / Compound Name	CAS #	Boiling Point (°C)	Identified as Emitted from Furniture Systems & Seating
Terpenes			
3-Carene	13466-78-9	167	
α-Pinene	80-56-8	156	[1][2][4]
β-Pinene	181172-67-3	164	
Limonene	138-86-3	170	[2][3][4]
Alcohols			
2-Propanol	67-63-0	82.4	
1-Butanol	71-36-3	118	[2][4]
2-Ethyl-1-hexanol	104-76-7	182	[4]
Glycols/Glycol Ethers			
2-Methoxyethanol	109-86-4	124.6	
2-Ethoxyethanol	110-80-5	135	
2-Butoxyethanol	111-76-2	171	[4]
1-Methoxy-2-propanol	107-98-2	118	
2-Butoxyethoxyethanol	112-34-5	231	
Aldehydes			
Butanal	123-72-8	76	[2][4]
Pentanal	110-62-3	103	[3][4]
Hexanal	66-25-1	129	[1][2][3][4]
Nonanal	124-19-6	93	[4]
Benzaldehyde	100-52-7	179	[2]
Ketones			
Methylethylketone	78-93-3	780	
Methylisobutylketone	108-10-1	116.8	
Cyclohexanone	108-94-1	155.6	[4]
Acetophenone	98-86-2	202	
Halocarbons			
Trichloroethene	79-01-6	87	
Tetrachloroethene	127-18-4	121	
1,1,1-Trichloroethane	71-55-6	74.1	[3][4]
1,4-Dichlorobenzene	106-46-7	173	
Acids			
Hexanoic acid	142-62-1	202	
Esters			
Ethyl acetate	141-78-6	77	
Butyl acetate	123-86-4	126.5	
Isopropyl acetate	108-21-4	85	
2-Ethoxyethyl acetate	111-15-9	156.4	
2,2,4-Trimethyl-1,3- pentanediol diisobutyrate (TXIB)	6846-50-0		
Other			
2-Pentylfuran	3777-69-3		
Tetrahydrofuran	109-99-9	67	

<sup>1</sup> Value of 1-phenyl-cyclohexene.

- [1] At least occurred in 5 of the 17 sets of furniture and seating emission data at the 96<sup>th</sup> hour of the test per the GREENGUARD protocol, representing top 11 out of 187 VOCs reported. Data were provided by BIFMA.
- [2] At least occurred in 5 of the 15 sets of furniture and seating emission data at the 24<sup>th</sup> hour following a 10 day conditioning period of the test per California (2000) protocol, representing top 9 out of the 213 VOCs reported. Data were provided by BIFMA.
- [3] Most frequently occurring 12 VOCs based on 32 workstation tests conducted in the period 1990-1998, representing 15 manufacturers. Data was provided by BIFMA.
- [4] Reported in "Table 1 potential VOC and aldehyde emissions from office furniture" as compounds occurring in >50% of the data analyzed. "Environmental Technology Protocol Verification Report—Emissions of VOCs and Aldehydes from Commercial Furniture", by Research Triangle Institute, RTP, NC. The table information was provided by Dr. Marilyn Black of Air Quality Sciences, Inc.

#### Appendix 5 - Informative – VOC Emission Rates as a Function of Time-Typical Trends

Long-term emission data for workstation systems are very limited. As examples, Figure A5.1 and A5.2 show the VOC emission factors as functions of time for four workstation systems. Data were provided by Mark Mason of the EPA from an Air Quality Science report to the EPA, and were presented in the proceedings of the EPA-A&WMA Engineering Solutions to IAQ Problems conference in 1995 in a paper entitled "Evaluation of a source management strategy for a large building", by Mark Mason and Marilyn Black. One set of the data is the same as one of the 10 sets of long term emission test data provided by BIFMA in 2004. It is noted that the workstations were at times placed in a conditioned room instead of remaining in the full-scale chamber for the entire test period, which may account for some of the variability in the data.

Figure A5.1 shows that the TVOC (reference to Toluene) emission factor can be modeled by the power-law (E = a  $t^{-b}$ ) very well (R<sup>2</sup>>0.9) except for WS 4 in which R<sup>2</sup> = 0.674 (marginally correlated). The relative poor correlation for WS 4 may be attributed to the large variation in the measured data points at t=310 h and t=550 h.

The formaldehyde (HCHO) emission factors appear to be less well modeled by the powerlaw, and very poorly modeled in the case of WS 2 (Figure A5.1). This could be attributed to a different emission behavior for formaldehyde, but the main reason appears to be the relatively small change of emission factor at low emission level at which experimental uncertainty is comparable to the real change of the emission factor. Therefore, if the change of emission factor over time is smaller than that which could be caused by experimental uncertainty, it is simpler to present the emission factor as a constant value.



Figure A5.1 Emission Factors for TVOC and Formaldehyde for 4 workstation systems (WS 1-4)

The formaldehyde emission factor increased over time for WS 4 (Figure A5.1), which might be associated with the curing process of the specific finish (acid catalyzed) used for the work surfaces. Well-cured work surfaces would not typically have such emission behavior.

Figure A5.2 shows that the emission factors over time for individual VOCs can be well modeled by the power-law in general when the elapsed time (t) is larger than the peaking time of the emission factors. In the case of WS 1 and WS 2, the maximum emission factors occurred at t<24 hour. For WS 3 and WS 4, emission factors for most VOCs did not start to decrease until t>=48 or 72 hours, depending on the compounds. Relatively less satisfactory model performance ( $R^2$ <0.8) can also be seen for WS 3 for hexanal and limonene 1 (Figure A5.2). This may be attributed to the experimental uncertainty at the low emission level.

The data sets provided by BIFMA in 2004 also show similar emission trends as discussed above. The power-law appears to be capable of modeling the emission factors over time.



Figure A5.2 Emission factors for individual VOCs emitted from 4 workstation systems (WS 1-4).

If the variation over time is within the experimental uncertainty, a constant emission factor should be assumed. Reducing the experimental uncertainty would result in better sensitivity of the model and reduce the prediction error. Duplicate air samples can be taken (as

required in this standard) to reduce the experimental uncertainty in the data points to be used in determining the model parameters.

In 2007 and 2008, BIFMA sponsored additional research with the objective to:

- develop a method for predicting emission rates of volatile organic compounds (VOCs) from an office workstation system and workstation components using small chamber testing of individual component materials; and
- 2) validate this method for direct scaling from materials to furniture objects by conducting tests in small-, mid- and full-scale chambers.

The initial results were presented at the 2009 Healthy Buildings conference (see Section 2.2 Hodgson et.al, 2009 for details). Additional analysis was subsequently conducted and is provided in Table A5.1, below. These results indicate that the projection of VOC emissions from small-scale tests of materials is a conservative approach for determining if a furniture system complies with emission standards.

VOC emission rates from seven small-scale chamber tests of component materials were projected to 336 h by applying a power-law model to the measured duplicate 72- and 168-h data points following the procedures specified in the 2011 version of the M7.1 Standard Method. These small-scale, projected emission rates were then summed as required based on the number of component materials (n = 1, 5, or 7) to predict the emission rates for the workstation components and the full workstation system. The small-scale summed results (M71-Predicted) are compared to the emission rates at 336 h (336-h Measured) for the components and system measured in mid- and large-scale chambers in Table A5.1, below.

			22	a h Emissio	n Data (wa)	b)		
		- ·			n Rate (µg/	(1)	o	
Component/		Formal-	Acetald-		Isobutyl		C <sub>3</sub> Alkyl	
System	Butanols	dehyde	dehyde	Hexanal	Acetate	Xylenes	benzenes	TVOC
Worksurface								
M71-Predicted (n=1)	307	656	32.2	83.2	48.7	12.8	72.3	1,250
336-h Measured	234	484	7.8	20.8	23.0	7.7	45.0	590
(Pred/Meas)-1	+31%	+36%	+312%	+300%	+112%	+67%	+61%	+113%
Pedestal								
M71-Predicted (n=5)	187	423	87.6	157	32.6	6.0	9.7	670
336-h Measured	132	404	51.0	183	15.4			631
(Pred/Meas)-1	+41%	+5%	+72%	-14%	+112%			+6%
Pedestal Desk								
M71-Predicted (n=7)	800	1,630	201	390	131	34.1	99.3	3,880
336-h Measured	741	1,210	113	273	77.8	15.3	78.7	1,330
(Pred/Meas)-1	+8%	+35%	+78%	+43%	+69%	+123%	+26%	+191%
Full System								
M71-Predicted (n=7)	2,240	5,140	592	1,380	411	117	271	13,400
336-h Measured	1,300	3,240	343	898	162	36.8	192	5,920
(Pred/Meas)-1	+103%	+59%	+73%	+54%	+153%	+219%	+41%	+127%

## Table A5.1 Predicted versus measured 336-h emission rates of VOCs for components and full workstation system – power law using measured 72- and 168-h points

The full experimental data set, which included duplicate measurements at 168 h, was used to create the results in Table A5.2, shown below. For this analysis, the power-law projections were made using the measured duplicate 72-, 168-, and 336-h data points and no averaging of data points for plots with low decay coefficients. The same comparisons are made, i.e., the small-scale summed results are compared to the 336-h emission rates measured in mid-

and full-scale chambers. Table A5.2 was originally presented as Table 2 in the Hodgson et.al., 2009 paper and is shown here with the addition of the number (n) of small chamber tests used for each prediction.

			33	6-h Emissio	n Rate (uo/h	1)		
Component/		Formal-	Acetald-		Isobutvl	')	C₂ Alkvl	
System	Butanols	dehvde	dehvde	Hexanal	Acetate	Xvlenes	benzenes	TVOC
Worksurface	Batanolo	dengae	uonyuo	Tiostaria	, lootato	, tylenee	0011201100	
Predicted (n=1)	289	658	30.6	82.2	45.6	12.0	70.5	917
Measured	234	484	7.8	20.8	23.0	7.7	45.0	590
(Pred/Meas)-1	+23%	+36%	+290%	+290%	+98%	+56%	+57%	+55%
Pedestal	. 20 /0	.0070	.20070	.20070	.0070	.0070	.01 /0	.0070
Predicted (n=5)	162	400	93.8	160	30.3	59	82	667
Measured	132	404	51.0	183	15.4			631
(Pred/Meas)-1	+23%	-1%	+84%	-12%	+97%			+6%
Podostal Dosk	.2070	170	.0470	1270				.070
Predicted (n=7)	505	1 330	161	337	100	26.4	86.6	2 210
Monsured	741	1,330	113	272	77.9	15.3	79.7	1 2 2 0
	741	1,210	113	273	11.0	15.5	/0./	1,330
(Pred/Meas)-1	-20%	+10%	+42%	+23%	+29%	+73%	+10%	+00%
Full System								
Predicted (n=7)	2,180	4,730	623	1,320	368	102	257	8,480
Measured	1,300	3,240	343	898	162	36.8	192	5,920
(Pred/Meas)-1	+68%	+46%	+82%	+47%	+130%	+180%	+34%	+43%

Table A5.2 Predicted versus measured 336-h emission rates of VOCs for components and full workstation system – power law using measured 72-, 168-, and 336-h points

#### Appendix 6 - Informative - Screening Analysis Procedure

In testing a new type of product, a screening analysis is usually needed to identify VOCs emitted by the product, set proper operating conditions for the analytical instruments such as TD-GC/MS and TD-GC/FID, and/or HPLC systems, select target VOCs, and to determine a proper air sampling volume for subsequent sampling at defined time points (ASTM D6670). While not mandatory in this standard Test Method, the screening analysis can be conducted within the conditioning period (72 hours) (see Section 9.1).

A6.1 Screening samples should be collected after the environmental test chamber has been supplied with clean air for at least 5 air changes at the standard air flow rate (i.e., 5 hours if the air change rate is  $1.0 \text{ h}^{-1}$ ) so that over 99% of the background VOCs introduced during loading the specimen have been removed.

A6.2 When analyzing the screening samples, different GC operating parameters (columns and temperature program) or HPLC operating parameters may be tested to obtain a good separation of emitted VOCs if necessary. The results can be used to determine a proper set of GC or HPLC operating parameters for subsequent environmental chamber testing. Samples for other analytes may also be taken from the environmental test chamber if necessary. The selection of major VOCs for subsequent environmental chamber testing depends on the objective of the testing. Appendix 1 provides a list of VOCs and their concentration limits for several relevant indoor air quality guidelines.

A6.3 Multiple air samples may be taken using sorbent tubes or cartridges with different air sampling volumes ranging from low to high (e.g. 1,2 and 5 L for sorbent tubes and 20, 50 and 100L for DNPH cartridges). Results from the screening samples can be used to determine the proper air sampling volume for subsequent environmental chamber testing so that the amount of VOC mass is within the calibration range.

A6.4 Air samples taken during the 0 to 72 hour period can also provide additional data to investigate the trend of VOC emission rates as a function of time.

#### Appendix 7 – Informative - Sample Tables for Reporting the Test Results

Table A7.1 Concentrations of VOCs between  $n-C_6$  and  $n-C_{16}$  measured by GC/MS ( $\mu$ g/m<sup>3</sup>)

VOC name		72 <sup>nd</sup>	hour		168 <sup>th</sup> hour			
	#1	#2	Mean	% diff.	#1	#2	Mean	% diff.
Aromatic								
Hydrocarbons								
Toluene								
Aliphatic								
Hydrocarbons								
n-Decane								
Cycloalkanes								
Cyclohexane								
Terpenes								
alpha-Pinene								
Alcohols								
1-Butanol								
Aldehydes								
Hexanal								
Ketones								
Cyclohexanone								
Halocarbons								
1,1,1-								
Trichloroethane								
Acids								
Hexanoic acid								
Easters								
Others								
TVOC <sub>sum</sub>								

Sorbent tube and media: Stainless steel tube with Tenax-TA; Sampling Volume: 5 L; GC/MS operating conditions and calibration info:

#### Table A7.2

#### Concentrations of Formaldehyde and Acetaldehyde by HPLC Analysis ( $\mu$ g/m<sup>3</sup>)

VOC name	72 <sup>nd</sup> hour				168 <sup>th</sup> hour			
	#1	#2	Mean	% diff.	#1	#2	Mean	% diff.
Formaldehyde								
Acetaldehyde								

Sampling cartridges: silica gel coated with DNPH; Sampling Volume: 10 L; HPLC operating conditions and calibration info:

# Table A7.3Calculated Emission Factors for Identified VOCs, TVOCCalculated Em

VOC name	Emission Factor		Power-law Model Coefficients for		
			E=a t <sup>-D</sup>		
	72 <sup>nd</sup> hour	168 <sup>th</sup> hour	а	b	
Aromatic					
Hydrocarbons					
Toluene					
Aliphatic					
Hydrocarbons					
n-Decane					
Cycloalkanes					
Cyclohexane					
Terpenes					
alpha-Pinene					
Alcohols					
1-Butanol					
Aldehydes					
Hexanal					
Ketones					
Cyclohexanone					
Halocarbons					
1,1,1-					
Trichloroethane					
 A alida					
ACIOS					
Hexanoic acio					
 Eastara					
Easters					
 Othoro					
ouners					
Formaidenyde					
Acetaidenyde					

**Note:** the power law is valid only for the period from 72 to 336 hours unless additional data are available to validate the model for an extended period of time.

#### Table A7.4

#### Predicted Concentrations in a Standard Office Environment of a Single Office Workstation System\* (µg/m<sup>3</sup>)

(\*Assuming a ventilation rate of 4.17 L/s (8.84 cfm) for a standard open plan environment or 9.63 L/s (20.4 cfm) for a standard private office environment as defined in Section 6.5)

VOC name	Based on the measured		Based on the Power-law Model		
	da	ita	Pre	diction	
	72 <sup>nd</sup> hour	168 <sup>th</sup> hour	336	<sup>th</sup> hour	
	(3 days)	(7 days)	(14	days)	
Aromatic					
Hydrocarbons					
Toluene					
Aliphatic					
Hydrocarbons					
n-Decane					
Cycloalkanes					
Cyclohexane					
Terpenes					
alpha-Pinene					
Alcohols					
1-Butanol					
Aldehydes					
Hexanal					
Ketones					
Cyclohexanone					
Halocarbons					
1,1,1-					
Trichloroethane					
Acids					
Hexanoic acid					
Easters					
Others					
TVOC <sub>sum</sub>					
<b>TVOC</b> <sub>Toluene</sub>					
Formaldehyde					
Acetaldehyde					



#### **Appendix 8 -- Sample Timing Constraints**

Figure A8.1 Sample Timing Constraints Time Line

**Note:** The seven days in chamber will not require measuring emissions concentration during a weekend if time zero begins on a Monday, Tuesday, or Friday.

### END OF DOCUMENT

### STANDARD METHOD FOR THE TESTING AND EVALUATION OF VOLATILE ORGANIC CHEMICAL EMISSIONS FROM INDOOR SOURCES USING

#### **ENVIRONMENTAL CHAMBERS**

VERSION 1.1

(Emission testing method for **California Specification 01350**. Supercedes the previous version of Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers)

#### **PREPARED BY:**

Indoor Air Quality Section Environmental Health Laboratory Branch Division of Environmental and Occupational Disease Control California Department of Public Health

FEBRUARY 2010



California Department of Public Health DR. MARK HORTON, Director

California Health and Human Services Agency KIM BELSHÉ, Secretary



State of California ARNOLD SCHWARZENEGGER, Governor

#### FOREWORD

It has been five years since the Indoor Air Quality Program issued the *Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers (Standard Practice)* on behalf of the California Sustainable Building Task Force. We recognized from the start that maintenance of this document would be required to keep up with changes in the field and to track current health standards. Limitations in staff resources have delayed this effort till now. It is our intention that the update of the *Standard Practice* will be a continuous process, and this document presents an initial effort.

The major changes to the prior document in this draft include:

- The title has been changed to *Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources using Environmental Chambers* as the document addresses both practice and method as well as testing using chambers of various sizes.
- Adoption of OEHHA's new CRELs to set allowable emission limits. For formaldehyde, it is recommended to continue using one-half of the prior CREL  $(33 \ \mu g \ m^{-3})$  until December  $31^{\text{th}}$ , 2011, and the new full CREL  $(9 \ \mu g \ m^{-3})$  starting January  $1^{\text{st}}$ , 2012.
- Incorporation of the ANSI/BIFMA M7.1-2007 test and power-law model prediction method as the recognized test method for pupil desks and chairs, open-plan office furniture and office seating, provided that test results meet all the requirements described in this method at 336 hr (14 days).
- Revision of exposure model parameters for the standardized school classroom and the typical office environments, including reference to ASHRAE Standard 62.1-2007 for the outdoor ventilation flow rates.
- Addition of general guidelines to manufacturers and certification/verification organizations for the use of this standard method as the basis for a product-wide claim.
- Revision of specimen collection, preparation and environmental chamber testing in accordance with current best practices.
- Addition of a section on quality management and measurement uncertainty.
- General document clean up.
- Addition of an informative appendix to document a preliminary new single-family residence scenario for IAQ concentration modeling.

#### Background

In 1990, the California legislation directed the Indoor Air Quality (IAQ) Program to develop guidelines for the reduction of exposure to volatile organic compounds (VOCs) from building construction materials in newly constructed or remodeled office buildings. The IAQ Program issued the report, *Reducing Occupant Exposure to Volatile Organic Compounds (VOCS) From Office Building Construction Materials: Non-Binding Guidelines.* This 1996 report provided a simple technical approach for evaluating, selecting, and installing building construction materials in order to minimize occupant exposures to VOCs emitted from these materials.

In 1999, the California Integrated Waste Management Board (CIWMB) initiated a multistakeholder process to develop "sustainability" criteria for office furniture which could be used in the pending State contract. CIWMB staff convened State agencies to address energy efficiency (lighting), material recycled content and recyclability, and enhanced IAQ, and they hired several consultants to help draft the *Special Environmental Specifications for Office Furniture*. In it, we adopted the IAQ Program's approach to low-VOC emitting materials, drawing from testing protocols and the limited set of allowable VOC limits used for the San Francisco Public Library. The Office Furniture contract was successfully bid in 2000.

At the same time, another multi-agency group, the California Sustainable Building Task Force, was formed to direct State "green building" requirements, which were notably applied in the design and construction of the State's Capitol Area East End Complex, completed in 2002-03. The *Special Environmental Specifications* for the CAEEC required material testing for VOC emissions and expanded the health-based exposure limits to all volatile organic chemicals with Chronic Reference Exposure Levels (CREL) issued by Office of Environmental Health Hazard Assessment (OEHHA). The CAEEC specifications were rewritten in Construction Specification Institute (CSI) format, and they became known under the moniker of their CSI section: 01 35 00 General Requirements - Special Project Procedures) or simply "Section 01350". The Collaborative for High Performance Schools (CHPS) subsequently adopted the specifications for their Low-emitting Material IEQ credit in 2002.

Section 01350 received wide acceptance from numerous manufacturers of building materials due to its flexibility, relative low cost, and the fact that it is the only health-based building material specification. As laboratories started to implement the VOC testing requirements within Section 01350 on a wider scale, it became apparent that certain sub-sections of this specification needed to be expanded. In 2004, the Program issued its Standard Practice for the Testing of Volatile Organic Emissions from Various Sources Using Small-Scale Environmental Chambers (Standard Practice). Its highlights were the more detailed requirements given for testing and the allowable emission limits tied explicitly to health-based exposure levels. Notably, the Standard Practice addressed testing, exposure modeling and allowable limits for modeled indoor air concentrations at 14 days, based on the chemicals of concern listed by Cal-EPA (notably, chemicals with established Chronic Reference Exposure Levels or CRELs).

Subsequently, the health-based criteria of the *Standard Practice* were incorporated into the State of California *Open Office Panel Systems* 2007-2008 purchasing criteria issued by the Department of General Services. The State of Minnesota government similarly adopted these environmental purchasing criteria. A variety of other product certification programs have adopted or adapted the *Standard Practice*; these include the *Leadership in Energy and Environmental Design* (*LEED*) *Indoor Environmental Quality criteria*; the National Green Building Standard; Business and Institutional Furniture Sustainability Standard (for the health-based criteria); Carpet and Rug Institute (CRI) Green Label Plus (GLP); Scientific Certification Systems (SCS) Indoor Advantage Gold; Resilient Floor Covering Institute (RFCI) FloorScore; and GREENGUARD Children & Schools.

#### Author/Acknowledgements

The California Department of Public Health (CDPH), Indoor Air Quality (IAQ) Section, prepared this document, and CDPH approved its release on March 4, 2010. Dr. Wenhao Chen was the primary author, and Mr. Robert Miller crafted updates for Sections 2 and 3. Dr. Jed Waldman and Mr. Leon Alevantis (CDPH Senior Mechanical Engineer) provided Departmental technical review. In addition, numerous individuals outside CDPH contributed invaluable suggestions and recommendations during the public review process, which were essential for final document development. Appendix A lists stakeholders who submitted written comments (or oral comments in public meetings).

#### Disclaimer

The *Standard Practice* and *Standard Method* are in the public domain, and the State has no financial interest in their use or application. The mention of commercial products or services, their source, or their use in connection with material presented in this report is not to be construed as actual or implied endorsement of such products or services by the State of California.

### **TABLE OF CONTENTS**

F	OREW	/ORD	2
1	BA	CKGROUND INFORMATION	7
	1.1 1.2 1.3	Scope References Terminology	7 8 10
2	CO SAN	LLECTION, PACKAGING, SHIPMENT, & DOCUMENTATION OF PRODUC	CT 14
	2.1 2.2 2.3 2.4 2.5 2.6	Product Sample Collection Packaging and Shipment of Samples Chain-of-Custody Documentation Rejection of Samples by Laboratory Receipt of Samples by Laboratory Storage of Samples by Laboratory Prior to Testing	14 18 18 19 19
3	LAI CA	BORATORY SAMPLE PREPARATION, TESTING, CHEMICAL ANALYSES LCULATIONS	AND 20
	3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 3.10	Test Specimen Preparation Preparation of Paint Test Specimens Preparation of Adhesive Product Test Specimens Preparation of Caulking Product Test Specimens Selection and Preparation of Dry Product Test Specimens Preparation of Dry Product Test Specimen Assemblies Conditioning of Test Specimens Environmental Chamber Testing Chemical Analyses Calculations	20 21 22 23 24 24 24 26 30 32
4	TAI CO	RGET CHEMICALS, MAXIMUM ALLOWABLE CONCENTRATIONS, AND NCENTRATION MODELING	IAQ 35
	4.1 4.2 4.3	Target VOCs Maximum Allowable Concentrations for Target VOCs. IAQ Concentration Modeling	35 35 36
5	QU	ALITY ASSURANCE AND QUALITY CONTROL	41
	5.1 5.2 5.3	Mandatory Practices on Quality Management Mandatory Laboratory Practices Measurement Uncertainty	41 41 42
6	REC	QUIRED ELEMENTS OF THE LABORATORY TEST REPORT	43
	6.1	Required elements of the Laboratory Test Report	43
7	TES	TING OF FREESTANDING FURNITURE	45
---	-------------------	---	----------------
	7.1 7.2 7.3	Test Method for Freestanding Furniture Concentration Modeling for Furniture and Office Seating Compliance with Maximum Allowable Concentrations	45 45 46
8	GUI PRC	DELINES FOR USE OF STANDARD METHOD AS BASIS FOR A BUILDING DUCT CLAIM	47
	8.1	Manufacturer and Third-Party Claims	47
	8.2	Laboratory Selection	47
	8.3	Breadth of Claim	47
	8.4	Modifications of Method	47
	8.5	Acceptable Alternative to Method	48
	8.6	Quality Control	48
	8.7	Product Sample Selection	48
	8.8	Retesting	49
A	PPENE	DIX A LIST OF STAKEHOLDER REVIEWERS	50
A	PPEND	DIX B NEW SINGLE-FAMILY RESIDENCE SCENARIO	51

### TABLES

Table 2-1	Sample collection and testing chronology for products	15
Table 3-1	Chamber conditions for 96-h test period	27
Table 4-1	Target CREL VOCs and their maximum allowable concentrations	37
Table 4-2	Definition of standard school classroom	38
Table 4-3	Product quantities and specific air flow rates to be used for estimation of VOC	
	concentrations in standard school classroom	38
Table 4-4	Definition of standard private office	39
Table 4-5	Product quantities and specific air flow rates to be used for estimation of VOC	
	concentrations in a standard private office	39
Table 5-1	Guidelines for measurement uncertainty and precision of chamber conditions ar	nd
	VOC measurements	42
Table 7-1	Standard open-plan office defined in ANSI/BIFMA M7.1-2007	46
Table 7-2	Product quantities and specific air flow rates to be used for estimation of VOC	
	concentrations in a standard open-plan office	46
Table B-1	Definition of new single-family residence	51
Table B-2	Product quantities and specific air flow rates to be used for estimation of VOC	
	concentrations in standard new single-family residence	52

# **1 BACKGROUND INFORMATION**

#### 1.1 Scope

- 1.1.1 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, wallcoverings, floor coverings, acoustical ceilings, wood paneling, wall and ceiling insulation used in public and commercial office buildings, schools, residences and other building types.
- 1.1.2 This method applies to freestanding furniture used in schools and offices by incorporation of an American National Standard Method for furniture VOC emissions. For open-plan office furniture, this method adopts the open-plan office defined in an American National Standard Method for furniture VOC emissions. Private office workstations are not addressed within the current scope of this Standard Method.
- 1.1.3 This method applies to newly manufactured products before they are used in construction, finishing and furnishing of buildings.
- 1.1.4 The standard does not apply to structural building products, janitorial products, air fresheners, electronic air cleaners, and other electronic equipment.
- 1.1.5 This method establishes the procedures for product sample collection, emission testing, indoor concentration modeling, and documentation requirements associated with quantifying the emissions of volatile organic chemicals from various sources using environmental chambers.
- 1.1.6 This method defines scenarios for a standardized school classroom (including pupil desks and chairs) and a typical private office environment (for building products other than office furniture). These scenarios include the dimensions, occupancy and ventilation characteristics of the space and the amounts of major products contained within the space.
- 1.1.7 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.
- 1.1.8 This method includes requirements on laboratory quality management system and measure uncertainty estimation.
- 1.1.9 The indoor concentration modeling scenarios and the performance criteria may be applied to emission test results obtained from other recognized test methods.
- 1.1.10 This method may be utilized as the basis for product claims and for certification/verification programs. General guidelines are provided for incorporation of the method into such programs.
- 1.1.11 This method specifies target chemicals and their maximum allowable concentrations. However, this method does not purport to address all of the safety, health, comfort (e.g.,

odor) and performance concerns, if any associated with its use. Users of this method may establish additional safety, health, comfort and other performance conditions and determine the applicability of regulatory requirements prior to use.

#### 1.2 References

#### 1.2.1 ASTM Standards

- D 1356-05 Standard Terminology Relating to Sampling and Analysis of Atmospheres
- D 5116-06 Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products
- D 5197-03 Standard Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology)
- D 6196-03 Standard Practice for Selection of Sorbents, Sampling and Thermal Desorption Analysis Procedures for Volatile Organic Compounds in Air
- D 6345-98 (2004) Standard Guide for Selection of Methods for Active, Integrative Sampling of Organic Compounds in Air
- D 6670-01 (2007) Standard Practice for Full-Scale Determination of Volatile Organic Emissins from Indoor Materials/Products
- D 7339-07 Standard Test Method for Determination of Volatile Organic Compounds Emitted from Carpet using a Specific Sorbent Tube and Thermal Desorption / Gas Chromatography

#### 1.2.2 **Other Documents**

- ANSI/ASHRAE Standard 62.1-2007. *Ventilation for Acceptable Indoor Air Quality*, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA
- ANSI/ASHRAE Standard 62.2-2007. Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA
- ANSI/BIFMA M7.1-2007. Standard Test Method for Determining VOC Emissions from Office Furniture Systems, Components and Seating, BIFMA International, Grand Rapids, MI
- BIFMA e3-2008. *Furniture Sustainability Standard*, BIFMA International, Grand Rapids, MI. Standard is accessible at: <u>http://levelcertified.org/wp-content/uploads/2009/06/2009-02-20%20SASe3.pdf</u>
- Cal/EPA, ARB list of Toxic Air Contaminants (TACs). The current version of this list is accessible at <u>http://www.arb.ca.gov/toxics/id/taclist.htm</u>
- Cal/EPA OEHHA Safe Drinking Water and Toxic Enforcement Act or 1986 (Proposition 65). The current versions of these lists are accessible at <u>http://www.oehha.ca.gov/prop65/prop65\_list/newlist.html</u>
- Cal/EPA OEHHA list of chemicals with noncancer chronic Reference Exposure Levels (RELs). The current version of this list is accessible at <u>http://www.oehha.ca.gov/air/chronic\_rels/AllChrels.html</u>

- Carter, R.D and J.S. Zhang. 2007. Definition of Standard Office Environments for Evaluating the Impact of Office Furniture Emissions on Indoor VOC Concentrations. *ASHRAE Transactions*, Volume 113, Part 2, pp 466-477.
- CHPS 2009 Criteria. CHPS Best Practice Manual Volume III California Criteria for High Performance Schools (2009 Edition), Collaborative for High Performance Schools, San Francisco, CA
- ISO 14021:2001. Environmental labels and declarations. Self-declared environmental claims (*Type II environmental labeling*), International Organization for Standardization, Geneva, Switzerland.
- ISO 16000-9:2006. Indoor Air Part 9: Determination of the Emission of Volatile Organic Compounds from Building Products and Furnishing - Emission Test Chamber Method, International Organization for Standardization, Geneva, Switzerland.
- ISO 16000-11:2006. Indoor Air Part 11: Determination of the Emission of Volatile Organic Compounds from Building Products and Furnishing - Sampling, Storage of Samples and Preparation of Test Specimens, International Organization for Standardization, Geneva, Switzerland.
- ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories, International Organization for Standardization, Geneva, Switzerland.
- ISO/IEC Guide 65:1996 General Requirements for Bodies Operating Product Certification Systems, International Organization for Standardization, Geneva, Switzerland.
- Jenkins, P.L., T.J. Phillips and J. Waldman, 2004. Environmental Health Conditions in California's Portable Classrooms. Report is accessible at http://www.arb.ca.gov/research/indoor/pcs/pcs.htm
- Offermann, F.J., 2009. Ventilation and Indoor Air Quality in New Homes. Report is accessible at <u>http://www.arb.ca.gov/research/apr/past/indoor.htm</u>.
- U.S. Census Bureau. 2008. Housing and Household Economic Statistics Division, Hagerstown, MD. Accessible at <u>http://www.census.gov/const/C25Ann/sftotalmedavgsqft.pdf</u>
- U.S. DOE. 2008. Buildings Energy Data Book. Chapter 2.2 Residential Sector Characteristics. U.S. Department of Energy, Energy Efficiency and Renewable Energy, Washington DC. Accessible at <u>http://buildingsdatabook.eren.doe.gov/</u>
- U.S. EPA. Method TO-1. 1984. Method for the Determination of Volatile Organic Compounds in Ambient Air Using Tenax Adsorption and Gas Chromatography/Mass Spectrometry (GC/MS). *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition* (EPA/625/R-96/010b). This method is accessible at http://www.epa.gov/ttn/amtic/airtox.html
- U.S. EPA. Method TO-17. 1997. Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling Onto Sorbent Tubes. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition* (EPA/625/R-96/010b). This method is accessible at <a href="http://www.epa.gov/ttn/amtic/airtox.html">http://www.epa.gov/ttn/amtic/airtox.html</a>

#### 1.3 Terminology

#### 1.3.1 Acronyms and Abbreviations

- ARB Air Resources Board, Cal/EPA
- ANSI American National Standards Institute
- ASHRAE American Society of Heating Refrigerating and Air Conditioning Engineers
- ASTM American Society for Testing and Materials
- BIFMA Business and Institutional Furniture Manufacturer's Association International
- CDPH California Department of Public Health
- Cal/EPA California Environmental Protection Agency
- CHPS Collaborative for High Performance Schools
- CIWMB California Integrated Waste Management Board, Cal/EPA
- DNPH 2,4-Dintrophenylhydrazine
- DOE U.S. Department of Energy
- EF Emission factor
- EPA U.S. Environmental Protection Agency
- GC/MS Gas chromatography/mass spectrometry
- HAP Hazardous Air Pollutant
- HPLC High performance liquid chromatography
- IAQ Indoor air Quality
- ISO International Standards Organization
- LEED Leadership in Energy and Environmental Design Green Building Rating System<sup>TM</sup>
- LOQ Limit of quantitation, lower
- MDF Medium density fiberboard
- MFC Mass flow controller
- MSDS Material safety data sheet
- NAHB National Association of Home Builders
- OEHHA Office of Environmental Health Hazard Assessment, Cal/EPA
- OSB Oriented strand board
- QMS Quality management system
- REL Reference exposure level
- RH Relative humidity in percent
- TAC Toxic Air Contaminant
- TD-GC/MS Thermal desorption GC/MS

- TIC Total ion-current chromatogram
- TVOC Total volatile organic compounds
- UV Ultraviolet wavelength
- VCT Vinyl composition tile
- VOC Volatile organic compound

#### 1.3.2 **Definitions**

- Air change rate Ratio of volume of conditioned air brought into the emission test chamber or building space per unit time to the chamber or building space volume
- Air flow rate Air volume entering the emission test chamber per unit time
- Air velocity Air speed over the surface of the test specimen
- Aldehydes Formaldehyde, acetaldehyde and other carbonyl compounds detectable by derivatization with DNPH and analysis by HPLC
- Area specific flow rate Ratio of the inlet air flow rate to the nominal surface area of the product or the product test specimen
- Background concentration VOC concentrations in emission test chamber in the absence of a product test specimen
- Chain-of-custody Document providing written evidence of transfer of a product sample, air sample, or another document from one organization to another organization or from one individual to another individual within the same organization. Document is signed and dated by each party involved in the transfer
- CREL Noncancer chronic reference exposure level developed by Cal/EPA OEHHA. These are 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 other than cancer.
- Concentration Mass of VOC per unit air volume expressed at standardized conditions for temperature and pressure (i.e., 298° K, 101.3 kPa)
- Data acquisition system System used to monitor, acquire and store data defining the environmental conditions for an emission test
- Emission factor Mass of VOC emitted from a specific unit area of product surface per unit time. Other unit measures such as product mass or length may be used as appropriate
- Emission rate Mass of VOC emitted by an entire product or test specimen per unit time
- Emission test chamber Non-contaminating enclosure of defined volume with controlled environmental conditions for inlet air flow rate, temperature and humidity used for determination of VOC emissions from product test specimens
- Loading factor Ratio of the nominal exposed surface area of the product or the test specimen to the volume of the building space or the emission test chamber

- Manufacturer's identification number Unique product identifier from which a manufacturer is able to determine the product name, product category or subcategory, manufacturing location, date of manufacture, production line, and/or other pertinent identifying information for the product
- Mass flow controller Electronic device based on principle of thermal conductivity used to control the flow rate of air entering the emission test chamber and the flow rate of air passing through a sampling device
- Product category General group of similar products intended for a particular application and performance, such as VCT, laminated wood flooring, broadloom carpet, sheet vinyl flooring, plywood, OSB, interior paint, etc.
- Product subcategory Group of products within a product category having similar chemistry, construction, weight, formulation and manufacturing process and which may have a similar VOC emissions profile
- Representative product sample A product sample that is representative of the product manufactured and produced under typical operating conditions
- Sampling interval Time over which a single air sample is collected
- Sampling period Established time for collection of air sample from emission test chamber
- Scan mode Operation of an electron impact GC/MS to continually and repeatedly scan masses between m/z 35 350, or some other range
- Sorbent tube Solid phase sampling device through which a sample of chamber exhaust air at controlled flow rate is passed to capture VOCs. Device typically contains Tenax-TA, or equivalent, as primary sorbent material backed up by higher surface area sorbent material to quantitatively capture the most volatile VOCs
- Specific emission rate Emission rate normalized to the area, mass or length of a product (i.e., equivalent to emission factor)
- Test specimen Portion of representative sample prepared for emission testing in an emission test chamber following a defined procedure
- Total-ion-current (TIC) chromatogram Chromatographic representation of a GC/MS analysis produced as the sum of all of the scanned masses between m/z 35 350, or some other range
- TVOC Sum of the concentrations of all identified and unidentified VOCs between and including 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

Ventilation rate – Same as air change rate

VOCs - Carbon-containing compounds (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates and ammonium carbonate) with vapor pressures at standard conditions approximately ranging between those for n-pentane through n-heptadecane. For the purposes of this method, formaldehyde and acetaldehyde are considered to be VOCs

Zero time – Time establishing the beginning of an emission test

# 1.3.3 Symbols and Units

Symbol	Description	Units
Α	Projected surface area	m <sup>2</sup>
N <sub>ACH</sub>	Air change rate	$h^{-1}$
Ci	Concentration of VOC <sub>i</sub>	μg m <sup>-3</sup>
EFA	Emission factor, area specific	$\mu g m^{-2} h^{-1}$
EF <sub>P</sub>	Emission factor, unit specific	µg h <sup>-1</sup> per unit
L	Product loading factor	$m^2 m^{-3}$
Q	Air flow rate	$m^3 h^{-1}$
q <sub>A</sub>	Area specific flow rate	$m^{3} h^{-1} m^{-2} (m h^{-1})$
<b>q</b> P	Unit specific flow rate	$m^3 h^{-1}$ per unit
t	Time after start of test	h or day
V	Volume	m <sup>3</sup>

# 2 COLLECTION, PACKAGING, SHIPMENT, & DOCUMENTATION OF PRODUCT SAMPLES

#### 2.1 Product Sample Collection

#### 2.1.1 Purpose

Guidelines are established for the collection, handling and documentation of product samples to ensure the samples being tested are reliable, uncontaminated, and well preserved. The guidelines are generally consistent with ISO 16000-11:2006.

#### 2.1.2 **Personnel**

- 2.1.2.1 Personnel in charge of sample collection must perform the task carefully and conscientiously. If the sampling is done improperly, the sample is in error and any subsequent analysis is invalid.
- 2.1.2.2 Because of the importance of proper sampling, individuals engaged in sample collection and handling must be qualified by training and experience and possess a thorough understanding of the relevant practices and techniques or, at a minimum, be under the direct supervision of such an individual.

#### 2.1.3 **Representative Sample**

Samples selected for testing shall be representative of the product manufactured and produced under typical operating conditions. See Section 8.7 for additional guidelines.

#### 2.1.4 Sample Preservation

Due to the adsorptive and absorptive nature of most products being tested, special care shall be taken to prevent contamination of the product sample from any external source, such as solvent-containing products, prior, during and subsequent to the sample collection procedure. Samples must be stored immediately after collection in airtight, moisture-proof containers/packaging to prevent contamination and to preserve their chemical integrity by preventing subsequent VOC emission losses.

#### 2.1.5 Location of Sampling

The product type and manufacturing process determine the optimal sampling location as described in the sampling procedures. The sampling location/site shall be selected to allow for reproducible, easy access to a representative cross section of the product category. The location shall be documented.

#### 2.1.6 Sample Age

- 2.1.6.1 With the exception of containerized products, samples shall be collected at the point of production as soon as possible after the normal manufacturing process. Samples shall be collected within 24 hours of production with the exceptions specified in Sections 2.1.9.2, 2.1.10.3 and 2.1.11.2 for individual product categories. Containerized products (i.e., paints, sealants, adhesives, and other wet products) shall be collected and shipped within three months of production.
- 2.1.6.2 Samples shall be shipped to the laboratory within 24 hours of actual collection.
- 2.1.6.3 Timing of sample collection shall be coordinated between the manufacturing facility and the testing laboratory to ensure that testing of samples can commence within 5 weeks of the actual production date, except for containerized products for which testing of samples shall commence within 4 weeks of receipt at the laboratory (maximum 4 months from actual production date).
- 2.1.6.4 The schedule for sample collection, shipping, specimen preparation, and testing is summarized in **Table 2-1**.

Event	Schedule
Dry Products (e.g., resilient flooring, carpet, wallcovering, etc.)	
Manufacturing date	Production date establishes initial time
Sample collection	Within 24 hours of production (see specific exceptions in Sections 2.1.9.2, 2.1.10.3 and 2.1.11.2)
Shipment to laboratory	Within 24 hours of sample collection
Commence laboratory testing	Within 5 weeks of production
Containerized products (e.g., adhesive, sealant, paint, etc.)	
Manufacturing date	Production date establishes initial time
Shipment to laboratory	No more than 3 months after production
Commence laboratory testing	No more than 4 months after production

**Table 2-1** Sample collection and testing chronology for products

2.1.7 If cutting or other preparation of a test specimen at a testing laboratory is exceptionally difficult or requires highly specialized equipment, a fully prepared test specimen may be fabricated by the manufacturer and shipped to the laboratory following all other applicable procedures. Such fabrication procedures shall be fully documented and reported. All cutting and other tools used to prepare the test specimen shall be cleaned properly to avoid sample contamination.

#### 2.1.8 Sample Collection Procedures – General Considerations

- 2.1.8.1 Samples shall be collected directly from the manufacturing or packing line within 24-hours of production unless otherwise specified below in Sections 2.1.9.2, 2.1.10.3 and 2.1.11.2. Products meeting the specific requirements described in Sections 2.1.9.2, 2.1.10.3 and 2.1.11.2 for individual product categories may be collected within 7 days of actual production. Sample size shall be determined based on the surface area needed for testing. Seal the samples with two layers of heavy-duty aluminum foil so the air space within the package is minimized and the seams are crimped to create an airtight seal. Use clear packaging tape to assure that the package is airtight. Label the foil package and place in a clear polyethylene or Mylar bag. No more than one hour shall elapse between collection and packaging.
- 2.1.8.2 A sample label, listing the manufacturer, sample ID, product name, and date and time of sample collection, shall be affixed to both the outside of the foil-wrapped product package and the outside of the bag.

# 2.1.9 Sample Collection Procedures - Tile, strip, panel and plank products less than or equal to 2-feet wide including VCT, resilient floor tile, linoleum tile, wood floor strips, parquet flooring, laminated flooring, modular carpet tile, etc.

- 2.1.9.1 A minimum of four representative tiles, strips or planks, each with a surface area that is greater than the surface area needed for testing, shall be collected. The tiles, strips or planks shall be stacked tightly together for packaging (normally face to back). Package the stack of samples as described in Sections 2.1.8.
- 2.1.9.2 Samples may be collected from consumer packages up to 7 days from the actual product completion date only if these packages contain tightly stacked pieces. A package containing stacked pieces shall be opened and a sufficient number of pieces shall be selected and withdrawn from the center of the stack to prepare the sample as described in Section 2.1.9.1.

# 2.1.10 Sample Collection Procedures – Sheet and roll goods greater than 2-feet wide including broadloom carpet, sheet vinyl, sheet linoleum, carpet cushion, wallcovering, fabric, etc.

- 2.1.10.1 A strip approximately one-foot wide (or wider depending on surface area needed for testing) shall be cut across the width of the roll. At least one foot shall be discarded from each end of the strip. The remaining material shall be cut into squares. A minimum of four squares is required. The squares shall be stacked tightly together face to back, and packaged as described in Section 2.1.8.
- 2.1.10.2 Wallcovering and other fabric may be collected as a full or partial production roll. In this case, the roll shall have at least 10 layers of material. Package samples as described in Sections 2.1.8.
- 2.1.10.3 Samples may be collected from tightly wound rolls up to 7 days from the actual production completion date by unrolling a minimum of 2 m or at least two full roll circumferences (i.e., roll diameter x 3.14 x 2) from the end of the roll.

# 2.1.11 Sample Collection Procedures – Rigid panel products greater than 2-feet wide including gypsum board, other wall paneling, insulation board, OSB, MDF, plywood, particleboard, etc.

- 2.1.11.1 For large panel products, the sample shall be taken at least 6 inches away from all edges of a panel. Within this boundary, the panel shall be cut into squares. A minimum of four squares is required. The squares shall be stacked tightly together face to back, and packaged as described in Sections 2.1.8.
- 2.1.11.2 Samples may be collected from stacks of panels without spacers up to 7 days from the actual production completion date by selecting a panel that is positioned at least three panels down from the top of the stack.

#### 2.1.12 Sample Collection Procedures – Insulation products

- 2.1.12.1 Batt and roll insulation products Remove one or two pieces of insulation from the center of a newly produced consumer package. Cut four 2-foot long sections across the width of the batt or roll. These may be cut into smaller sizes, 12-in by 12-in or larger, depending upon chamber size. Stack four pieces together, compress them to reduce the air volume and wrap them in two layers of heavy-duty aluminum foil. Package as described in Sections 2.1.8. It may be necessary to package thick insulation as two separate stacks. Alternately, an unopened consumer package may be shipped to the laboratory.
- 2.1.12.2 Blowing wools and loose fill insulation products Collect insulation directly from the production line or from a newly produced consumer package. Remove enough material from the center of the package to produce at least one-cubic foot or more of installed insulation depending upon chamber size. Compress the material and package in one or two batches as described for batt and roll products. Alternatively, an unopened consumer package may be shipped to the laboratory.
- 2.1.12.3 Boards and rigid foam insulation products Collect a board directly from the production line or from a newly produced consumer package. If removed from a consumer package, select a board from the center of the stack. Cut individual pieces at random, 12-in by 12-in or larger depending upon chamber size, from the board. Stack four pieces together and package as described for batt and roll products.
- 2.1.12.4 Spray foam insulation Closed cell and open cell spray foam insulation test samples are prepared at the manufacturer's location following the product specifications. For a substrate, use a 12-in by 12-in piece of clean cardboard, or larger depending upon chamber size, and wrap with one layer of aluminum foil. Spray foam onto the substrate covering the large majority of the surface. Closed cell foam is sprayed to a thickness of 2 inch. Open cell foam is sprayed to a thickness of 4 inch or 6 inch depending upon application. Record the product names and lot numbers of the A- and B-side materials and the relevant equipment parameters (temperatures, pressures, etc.) for the application. For open cell foam, scarf the sample (i.e., remove the skin) one hour after application to a minimum thickness of 3.5 inch or 5.5 inch with a clean knife or saw (do not use a hot knife). Create two identical samples. Wrap each sample in two layers of aluminum foil and package as described for batt and roll products.

# 2.1.13 Sample Collection Procedures – Containerized products including adhesives, sealants, paints, other coatings, primers and other "wet" products.

- 2.1.13.1 Paints, other coatings and primers can be supplied in original, standard 1-quart or 1-gallon consumer containers.
- 2.1.13.2 Adhesives can be supplied in their consumer packaging such as an applicator tube or can if these are small (i.e., less than 1 gallon). Alternately, the samples of adhesives can

be collected in clean, unused paint cans (1-pint or 1-quart size). Special care is required to assure these samples are representative of the larger batches from which they are collected. Containers shall be filled so there is minimal unfilled headspace above or below the adhesive. The collection procedure shall be documented.

- 2.1.13.3 Samples of containerized products sent to a laboratory shall be accompanied by a Material Safety Data Sheet (MSDS) and a specification sheet that describes the products, lists the major chemical ingredients, identifies the intended uses, describes the application methods and coverage rates.
- 2.1.13.4 If specialized tools are required to apply a containerized product to a substrate (e.g., a specific notched trowel not readily obtainable in a hardware store) these tools also shall be supplied to the laboratory.
- 2.1.13.5 A sample label, listing the manufacturer, sample ID, and date and time of sample collection, shall be affixed to the outside of the product container.
- 2.1.13.6 Testing laboratories shall have the right to return the unused portion of any containerized product to the organization supplying the product for testing.

#### 2.2 Packaging and Shipment of Samples

- 2.2.1 Product samples shall be carefully packaged in a cardboard box or other shipping container suitable for air shipment so that the sealed polyethylene or Mylar bag and the foil layers will not be damaged or punctured during shipment.
- 2.2.2 Only one product shall be placed in a shipping container.
- 2.2.3 The product sample shall be shipped in a manner to meet the timetable set in Table 2.1.
- 2.2.4 A chain of custody form described below (Section 2.3) shall be prepared for each sample. The form shall be completed, signed and attached to the outer bag containing the packaged sample using a clear plastic window envelope or equivalent method.

#### 2.3 Chain-of-Custody Documentation

- 2.3.1 A completed and signed chain of custody form shall accompany each product sample
- 2.3.2 The chain-of-custody shall be executed every time the product sample moves between organizations or between physical facilities within an organization prior to be tested.
- 2.3.3 The chain of custody form shall be printed as a multi-layered carbonless copy form or if a single-layered form is used, each signatory shall sign, date and transmit the original and retain a photocopy for their record.
- 2.3.4 The chain of custody form shall include, at a minimum, the following information:
- 2.3.4.1 *Manufacturer/Company Details* Name, Street Address, City, State/Province, Country, Zip/Postal Code
- 2.3.4.2 *Contact Details* Contact Name, Title, Phone Number, E-mail Address
- 2.3.4.3 *Sample Details* Sample ID, Product Category, Product Subcategory (if applicable), Product Name, Manufacturers Identification Number, Date Manufactured, Sample Collection Location, Sample Collection Date and Time, Sample Collected By, Number of Sample Pieces
- 2.3.4.4 *Shipping Details* Packed By, Shipping Date, Carrier, Airbill Number (Carrier and Airbill Number may be filled in by Laboratory upon receipt)

- 2.3.4.5 *Ship to Laboratory* Name, Street Address, City, State/Province, Country, Zip/Postal Code, Phone Number, Fax Number
- 2.3.4.6 *Laboratory Receiving Details* Received By, Received Date, Condition of Shipping Package, Condition of Sample, Assigned Laboratory Material tracking Number
- 2.3.4.7 *Packaging Details* Types of Air-tight Containers or Seals
- 2.3.4.8 *Signature Tracking Details* Relinquished By, Received By, Signature, Company, Date and Time

#### 2.4 Rejection of Samples by Laboratory

- 2.4.1 A testing laboratory shall have the right to reject a product sample for testing due to, but not limited to, any of the following reasons: damaged shipping or product packaging; incomplete or missing Chain of Custody; or sample receipt occurs too late to accommodate the last possible testing initiation date as stated in Section 2.1.6.3.
- 2.4.2 When a product sample is rejected, the testing laboratory shall inform the manufacturer within two days of the decision and provide the reason for rejection.
- 2.4.3 The manufacturer has the right to collect a new sample and resubmit it for testing, subject to the conditions described within this method. All costs for recollection and shipment shall be the responsibility of the manufacturer.

#### 2.5 Receipt of Samples by Laboratory

- 2.5.1 As soon as practical after a package is received from the shipping company, the laboratory's sample custodian or other authorized personnel shall inspect the package and product container for visible signs of damage that could potentially affect the integrity of the product sample.
- 2.5.2 The product container (i.e., external bag, foil package, can, tube, etc) shall not be opened at this time.
- 2.5.3 The sample custodian shall note the condition of the package and container on the chainof-custody form and sign and date the form.
- 2.5.4 If a package or container is significantly damaged or the other criteria are not met, the laboratory shall reject the sample as described in Section 2.4.
- 2.5.5 Valid samples shall be assigned a unique laboratory ID number. The sample information and the ID number shall be entered into the laboratory's sample-tracking database.

#### 2.6 Storage of Samples by Laboratory Prior to Testing

Prior to testing, samples shall be stored in their original unopened containers in a conditioned space at typical indoor conditions. The samples shall be protected from chemical contamination and exposure to temperatures in excess of  $25^{\circ}$ C and relative humidity in excess of 65%. Samples shall not be refrigerated or stored at reduced temperature.

### 3 LABORATORY SAMPLE PREPARATION, TESTING, CHEMICAL ANALYSES AND CALCULATIONS

#### 3.1 Test Specimen Preparation

- 3.1.1 For product assemblies (e.g., wall paint primer and finish coat, wallcoverings, and floor systems where the finish material is applied to a substrate, with or without the use of adhesives), the individual products comprising the assembly shall be tested separately. If all individual products meet the emissions criteria established herein, no further testing is required. For assemblies where one component, such as an adhesive, does not meet the criteria, the products may be tested together with assembly preparation following the manufacturer's recommended procedures. If the products are tested as an assembly, test results are only applicable to this particular assembly configuration.
- 3.1.2 Products manufactured to arrive on site preassembled (e.g., adhesive impregnated wallpaper, adhesive applied floor tiles, or raised floor panels of sandwich construction with adhesive between layers) shall be tested as an a single unit, that is, the manufacturer is not required to submit separate samples of the primary material and adhesive for testing.
- 3.1.3 The dimensions shall be optimized for small-scale test chambers with volumes of 50 L to  $1 \text{ m}^3$  operating at  $1 \pm 0.05$  air change per hour to achieve the loading factor of  $0.3 1.0 \text{ m}^2 \text{ m}^{-3}$  as specified in Table 3.1. See also Section 3.8.2 for more information.
- 3.1.4 For products not covered in this specification, it may be necessary to develop alternate procedures for preparation of test specimens. If procedures other than described in this section are used, they shall be fully described and reported.
- 3.1.5 A fraction of the specimens shall be prepared in duplicate from the same product sample. See Section 3.8.5.5 for the required fraction of duplicates.
- 3.1.6 Completion of specimen preparation and placement of the test specimen in the conditioning environment shall be regarded as the starting time for the VOC emission test (i.e., zero time).
- 3.1.7 If special substrates and/or edge sealing materials (i.e., gypsum board and aluminized tape) are required for specimen preparation, appropriate tests shall be conducted to determine background concentrations of VOCs for these materials. They shall not emit VOCs above the limits specified for the chamber background. Additionally, an attempt shall be made to use materials that do not emit measurable amounts of any target VOC of concern. In some cases, it may be acceptable to perform background tests for batches or lots of substrate materials and subtract background values from test values.
- 3.1.8 Use clean, stainless steel plates or trays for single-sided sample tests. Samples requiring multiple side exposure should be suspended within the chamber. Special substrates, such as gypsum board, shall be conditioned at  $23 \pm 2^{\circ}$ C,  $50 \pm 10$  % RH while ventilated with clean air for twenty-four hours before use.

#### **3.2** Preparation of Paint Test Specimens

- 3.2.1 Apply "flat" and "eggshell" wall paints to conditioned standard 5/8" thick gypsum board (e.g., USG Sheetrock brand or equivalent). The substrate size shall be appropriate to achieve the specified loading factor (Table 3.1). Just prior to painting, accurately weigh (±0.1 g) substrate, mask borders ¼" on all sides with tape (e.g., 3M Scotch-Blue<sup>TM</sup> Painter's masking tape, or equivalent) to avoid paint dripping on edges. Accurately measure (±2 mm) the dimensions of the area to be painted. Alternative approaches for protecting the edges may be acceptable and shall be reported if used.
- 3.2.1.1 Apply paint using a standardized roller procedure that simulates application of paint in a building by this technique. For most wall paint applications, use a 4" wide 3/8" nap roller intended for smooth surfaces. Alternate methods shall be reported if used.
- 3.2.1.2 Thoroughly stir paint in the container and transfer 100 mL of paint to a heavy-duty aluminum foil disposable tray, or equivalent.
- 3.2.1.3 Completely saturate roller cover with paint by running roller back and forth in tray.
- 3.2.1.4 Apply paint to substrate using four strokes, two in vertical direction and two in horizontal direction, so the entire area is uniformly covered. For most wall paints, use a single loaded roller application.
- 3.2.1.5 Remove tape mask from substrate and re-weigh substrate. Difference in weight before and after painting determines mass of applied paint and coverage in grams of wet paint per square meter of substrate surface. The measured mass amount shall be compared with the desired mass of paint to be applied to substrate. This comparison is used to check whether the paint has been properly applied to the substrate. The desired mass is calculated as the paint product density (g/L) divided by the manufacturer's recommended paint coverage (m<sup>2</sup>/L) and then multiplied by the painted area of test specimens. Unless otherwise specified, use a coverage of 350 ft<sup>2</sup>/gal (or 8.6 m<sup>2</sup>/L).
- 3.2.1.6 Place substrate on a piece of sheet stainless steel to cover entirely the back surface. Attach substrate to stainless steel with strips of aluminized tape emitting no VOCs so only the painted surface is exposed. (*Note: a variety of aluminized tapes are available including tapes manufactured specifically for cleanroom use. As specified in Section* 3.1.7, appropriate background tests shall be performed to demonstrate selected tape is not a source of VOC contamination. Also note that it may be more convenient to seal the back and edges of the substrate prior to applying paint.) For a blank specimen, similarly prepare an unpainted piece of gypsum board. Alternate procedures to cover unpainted surfaces of gypsum board may be acceptable and shall be reported if used.
- 3.2.1.7 Immediately transfer specimen to conditioning environment and record the time.
- 3.2.1.8 Where multiple coats of paint, which may include primer, are being tested, apply paints as described above and follow manufacturers' instructions for minimum or optimal drying time between coats. Report weight of test specimen prior to and after each coat of paint is applied. Hold specimen in conditioning environment between coats. The test period begins immediately after application of final coat.
- 3.2.2 Apply "semi-gloss" and "gloss" paint to a clean stainless steel sheet metal following the procedure described above. Mask edges of substrate as described to create the appropriate exposed area. Substrate shall be weighed immediately before and after painting.

3.2.3 Some types of finishes are designed for specific substrates. One category of specialized finishes consists of dyes, sealers, hardeners and toppings for concrete floors. Such products require a porous surface for proper application and curing. If gypsum board or stainless steel sheet metal is an inappropriate substrate for a specialized finish, an alternate substrate may be used. The laboratory shall provide full description of the substrate in the test report if any alternate substrate is used. Condition the substrate prior to use as discussed in Section 3.1.8.

#### 3.3 Preparation of Adhesive Product Test Specimens

- 3.3.1 Apply adhesive to clean stainless steel sheet metal plate unless product is specifically designed to be applied to gypsum board. If the choice of substrate is optional, a sheet metal plate shall be used. If substrate is gypsum board, condition as described in Section 3.1.8.
- 3.3.1.1 Accurately weigh (±0.1 g) substrate before applying adhesive. If substrate is gypsum board, mask boarders with tape as described for paint application (Section 3.2.1). Accurately measure (±2 mm) the dimensions of the area to which the adhesive will be applied.
- 3.3.1.2 Thoroughly mix adhesive in container and apply to entire surface of substrate or masked area with a notched trowel, nap roller or spray applicator based on manufacturer's recommendations, closely matching the dimensions of manufacturer's specified tool. Record the details of the applicator used (i.e., dimensions of the trowel).
- 3.3.1.3 Re-weigh substrate after removing tape mask from substrate, if applicable. Difference in weight before and after application is used to determine mass of applied adhesive and coverage in grams of wet adhesive per square meter of substrate surface. The measured mass amount shall be compared with the desired mass of adhesive to be applied. This is used to check whether the adhesive has been properly applied to the substrate. The desired mass is calculated as the adhesive product density (g/L) divided by manufacturer's recommended coverage (m<sup>2</sup>/L) and then multiplied by the area of the test specimen.
- 3.3.1.4 If substrate is porous material, complete preparation of test specimen by covering back and cut edges as described in Section 3.2.1.6.
- 3.3.1.5 Immediately transfer specimen to conditioning environment and record the time.

#### 3.4 Preparation of Caulking Product Test Specimens

- 3.4.1 Apply caulks, sealants, adhesives and other products supplied in tube applicators or containers into a metal channel (aluminum, brass or stainless steel). The width and height of the metal channel shall match the intended diameter of the caulk bead, i.e., either <sup>1</sup>/<sub>4</sub>" or 3/8" and shall be 6" to 10" in length (or as appropriate for chamber size).
- 3.4.1.1 Accurately weigh  $(\pm 0.1 \text{ g})$  and measure  $(\pm 2 \text{ mm})$  metal channel before applying caulk.
- 3.4.1.2 Insert the container into a caulk gun. Cut the applicator tip to produce the desired bead width. Dispense approximately 100 g from the container and discard. Then, fill the metal channel with caulk using a single, smooth stroke of the gun. Wipe any excess caulk from the exterior of the channel.

- 3.4.1.3 Re-weigh the channel after applying the caulk. Difference in weight before and after application determines mass of applied caulk and coverage in grams of wet caulk per linear meter of a defined-size bead.
- 3.4.1.4 Immediately transfer specimen to conditioning environment and record the time.

#### **3.5** Selection and Preparation of Dry Product Test Specimens

- 3.5.1 The period of time between unpacking a product sample and preparation of the test specimen shall be as short as practical, one-hour or less, with exceptions reported. The time of placement of the specimen in the conditioning environment shall be recorded.
- 3.5.2 All surface dimensions of specimens shall be accurately measured (±2 mm) after they are cut. It also may be necessary to measure the thickness of the specimen. The actual exposed surface dimensions of the specimen shall be measured. Exclude any portion of the surface that is masked with aluminized tape or otherwise covered.
- 3.5.3 Selection of test specimen from package containing stacked pieces of the product samples: Open the packaging containing the product sample. Select a piece from the center of the stack in a random manner, i.e., do not purposefully select the piece based on any appearance characteristic. Cut the specimen from the center of the selected piece at least 1" away from the previously cut edges. Exceptions are products for which it may be important to incorporate a factory-finished edge into the VOC emission test (e.g., laminate counter top, acoustical ceiling panel, etc.) For these products, cut the specimen from the selected piece leaving one factory-finished edge.
- 3.5.4 Selection of test specimens from sample rolls (e.g., wallcoverings and other fabrics): Open the package containing the product sample. Discard at least the outer two layers of the roll. Cut the test specimen from the remaining material at least 4" away from the factory-finished edges.
- 3.5.5 **Dry specimen preparation techniques:** Depending on the product being tested, there are a few variations in preparation technique. Some products, such as resilient flooring, are cut to size and placed on a stainless steel plate with either edge taping or in a stainless steel tray that conceals the edges. Carpet is cut to size and placed in a stainless steel tray that provides tight fit at edges. Insulation specimens are normally prepared and tested as tray-fitted specimens since insulation products are typically used where only one side is exposed or facing toward the occupied space. Any alternate specimen preparation procedures, such as for insulation products with more than one surface exposed, shall be fully described.
- 3.5.5.1 **Stainless steel plate with edge-taping:** Cut a square to the appropriate size and place on a clean stainless steel plate. Attach the specimen to the plate using strips of low VOC aluminized tape so that the edges are masked by at least <sup>1</sup>/<sub>4</sub> inch. Composite wood products, gypsum boards and similar rigid wall panels, sheet and tile resilient flooring and wallcovering products are tested with this preparation.
- 3.5.5.2 **Tray-fitted specimens:** Cut the specimen to fit snugly within a clean, stainless steel tray. Broadloom carpet, carpet cushion and carpet tile are tested with this preparation. Sheet and tile resilient flooring may be tested with this preparation. For batt and roll insulation products, cut the specimen to fit an appropriately-sized stainless steel tray, e.g., 3.5-in deep for many wall applications and 6-in deep for many ceiling and floor

applications. A product facing material, if present, is exposed to chamber air. For blowing wools and loose fill insulation products, the mass of blowing wools and loose fill insulation to be added to an appropriately-sized tray is calculated based on the manufacturer's recommended installed density. Weight this amount and pour/pack it into the tray. For spray foams and other rigid insulation products, samples are trimmed to size and placed into an appropriately-sized tray. Weigh spray foam specimens and calculate product density.

- 3.5.5.3 **Specimens not requiring substrate:** Cut the specimen to the appropriate size and place in the conditioning environment. The exposed area for calculation of emission factors and room concentrations is considered to be the area of the primary face. Acoustical ceiling panels, woven and nonwoven fabrics not used as wallcovering (e.g., upholstery fabric) are tested using this preparation.
- 3.5.5.4 **Special considerations:** (a) Acoustical Ceiling Panels include one factory finished edge when preparing the specimen and test with both sides exposed. Use the primary face area for the concentration modeling calculation.

#### 3.6 Preparation of Dry Product Test Specimen Assemblies

- 3.6.1 Products tested as assemblies are generally either adhered to a substrate or glued directly to a stainless steel plate or tray.
- 3.6.2 Assemblies shall utilize the manufacturer's recommended adhesive and procedures.

#### 3.6.3 Specific Requirements

- 3.6.3.1 **Tile and broadloom carpeting applied with adhesives:** Fit into a stainless steel tray that provides tight fit at edges.
- 3.6.3.2 Laminates or wood veneers applied with adhesives: Use no-added formaldehyde medium density fiberboard (MDF) as a substrate; Seal the edges as described in Section 3.5.5.1. Alternately, if a specimen of appropriate size is produced by a manufacturer specifically for VOC emission testing, it is recommended that the core be fully encapsulated so all six sides are covered with the finish material.
- 3.6.3.3 **Sheet and tile resilient flooring applied with adhesives:** Adhere directly to a stainless steel plate. Seal the edges as described in Section 3.5.5.1.
- 3.6.3.4 **Wallcoverings applied with adhesives:** Wallcoverings are adhered to a conditioned, gypsum board substrate. Seal the edges as described in Section 3.5.5.1.

#### 3.7 Conditioning of Test Specimens

3.7.1 **Principle:** The principle of conditioning is to maintain test specimens in clean air at controlled conditions of temperature and RH for a defined period of 10 days before initiating a 96-hour test in a small-scale test chamber at more precisely controlled conditions. In this manner, the final VOC measurements determining the suitability of a product are made after the specimen has been exposed for a total of 14 days. Fourteen days represents an early, but realistic, time for first occupancy after new building construction or major renovation. At the 14-day time point, the emissions of VOCs from most products primarily will be dependent upon the characteristic diffusion rate of the VOCs within the material and the concentration of the VOCs in the bulk material and should change slowly from day to day and from week to week. Thus, minor differences in product sample age at the time of collection should be partially or wholly compensated

for by use of a 10-day conditioning period and any minor surface contamination not directly related to the content of VOCs in the bulk material should be eliminated. Also, the potential effect of external mass transfer resistance on the emission rates of most VOCs should be diminished substantially after 10 days of conditioning. Incorporation of conditioning into a product testing method is described in ISO 16000-9:2006, Section 12.3.

- 3.7.2 **Apparatus:** Conditioning can be accomplished by different approaches using different apparatus. Product specimens can be maintained for the entire 14-day period in the emission test chambers. A potentially less expensive approach utilizes a specially constructed facility. This facility is based on an isolated room constructed entirely with low emitting and low sorbing interior surfaces such as stainless steel sheet metal. The room is supplied with acceptably clean air and maintained at controlled temperature and RH conditions. The test specimens are maintained in separate metal containers with ventilation air drawn into each container from the room.
- 3.7.2.1 **Emission test chambers:** If the emission test chambers are used for conditioning, the apparatus and procedures described in Section 3.8 shall apply.
- 3.7.2.2 Separate containers for conditioning specimens: Specimens shall be placed in individual clean metal containers with a volume of at least 10-L. Containers shall be kept in a conditioned environment (room). The conditioned room shall be operated with a clean air supply at a minimum of 2 air changes per hour. Containers shall be of sufficient size so air freely circulates through the container and all emitting surfaces of prepared specimens are exposed to circulating air. Air shall be drawn through the containers with a vacuum system at a flow rate that provides an area specific flow rate nearly equivalent (i.e., within  $\pm 20\%$ ) to the area specific flow rate achieved in the emission test chamber. Alternatively, the containers may be operated at the same flow rate with clean air supplied at the inlet by a pressurized source.
- 3.7.3 **Clean air supply:** The air used to supply the conditioning environment shall contain low levels of VOCs and shall be filtered for particulate matter. The supply air, if not from gas cylinders, shall pass through an active filtration system consisting of a bed of granulated activated carbon (or other methods specifically designed for removing organic compounds) and a particle filter. The VOC content of the supply air shall not exceed 5  $\mu$ g/m<sup>3</sup> for any individual compound including formaldehyde and 25  $\mu$ g/m<sup>3</sup> for TVOC.
- 3.7.4 **Temperature and relative humidity control:** The temperature and humidity of the air to which specimens are exposed during the conditioning period shall be maintained within ranges of  $23 \pm 2^{\circ}$  C and  $50 \pm 10\%$  RH.
- 3.7.5 Verification of conditions: The airflow rates to a conditioning room and to individual containers used for conditioning shall be measured and recorded on a periodic basis according to the laboratory's quality management system. The temperature and relative humidity of a conditioning room or of emission test chambers used for conditioning shall be continuously monitored and recorded using temperature/RH probes and a data acquisition system. The air used for conditioning periodically shall be sampled and analyzed for VOCs, aldehydes and TVOC on at least a monthly basis according to the laboratory's quality management system.

3.7.6 **Time:** Placement of a test specimen in the conditioning environment establishes the beginning of the test period. This critical time shall be recorded and all subsequent times for transfer of the specimen to the test chamber and collection of air samples from the chamber shall be scheduled relative to this initial zero time. A  $\pm 2\%$  deviation in transfer time and sampling times is allowed. Thus, transfer from the conditioning environment to the test chamber shall occur at an elapsed time of 10 days  $\pm 5$  hours.

#### 3.8 Environmental Chamber Testing

- 3.8.1 **Principle**: The principle of the test is to determine the specific emission rates of VOCs emitted from prepared specimens of building products. The test is conducted in a small-scale environmental chamber at specified constant conditions of temperature, relative humidity, ventilation rate and product loading factor. The chamber is considered to be a constantly stirred tank reactor. As the air in the chamber is fully mixed, VOC concentrations measured at the chamber exhaust are representative of air concentrations in the chamber. From the airflow rate into the chamber, the VOC concentration, and the exposed surface area of the specimen, an area-specific emission rate or emission factor is calculated using the steady-state form of the mass-balance model. The chamber test is conducted following the guidance of ASTM Standard D 5116-06. ISO 16000-9:2006 provides additional guidance.
- 3.8.2 **Test Conditions**: The test shall be conducted at the conditions and within the limits specified in **Table 3-1**. Standard conditions for the purpose of calibrating flow measurement devices and calculating all flow rates shall be  $25^{\circ}$  C ( $298^{\circ}$  K) and one atmosphere pressure (101.3 kPa). The chamber volume shall be between 50 L and 1 m<sup>3</sup>. The chamber shall be ventilated at  $1 \pm 0.05$  air changes per hour. The loading factor shall be optimized to produce an area specific flow rate approximately equal to the area specific flow rate for the product in the modeled scenarios (Section 4.2). For example, a value of 0.5 m<sup>2</sup> of exposed specimen surface area per m<sup>-3</sup> chamber volume results in an area specific flow rate of 2 m<sup>3</sup> h<sup>-1</sup> m<sup>-2</sup> (m h<sup>-1</sup>), which is close to the value for many materials in both the classroom and private office scenarios. A loading factor of 0.3 to 1.0 m<sup>2</sup> m<sup>-3</sup> is allowed for all materials. Specimen sizes are to be adjusted according to the chamber volume to achieve the specified loading factors.

Parameter	Symbol	Units	Value
Chamber volume	V	m <sup>3</sup>	0.05 - 1.0
Loading factor <sup>1</sup>	L	$m^2 m^{-3}$	0.3 – 1.0
Air change rate	а	$h^{-1}$	$1.0 \pm 0.05$
Area specific flow rate	$q_{\rm A}$	$m h^{-1}$	1.0 – 3.3
Temperature	Т	°C	$23 \pm 1^{2}$
Relative humidity	RH	%	$50 \pm 5^{2}$

#### **Table 3-1**Chamber conditions for 96-h test period

1. Specimen sizes are to be adjusted according to the chamber volume to achieve the specified loading factor range. See Sections 3.1.3 and 3.8.2

2. Values must be within range for at least 90% time throughout the 96-h test, and within range during sampling and for three air changes prior to sampling. See section 3.8.4.

- 3.8.3 **Duration**: The chamber test shall last 96 hours. Sealing of the chamber lid/door following insertion of the product specimen into the chamber establishes the starting time for the chamber test, following 10 days of conditioning.
- 3.8.4 **Apparatus and Facilities**: The apparatus and facilities shall be constructed to maintain the test specimen at the specified conditions within a non-contaminating and low sorption environment.
- 3.8.4.1 **Clean air supply and flow control:** A clean air generator or high purity air cylinders shall be used to supply pressurized clean, dry air. The flow rate of the supply air to a chamber shall be regulated and monitored with electronic mass flow controllers (MFCs), or equivalent, with an accuracy of  $\pm 2$  % of full scale, or better, and capable of continuously maintaining the flow within  $\pm 5$  % of the specified value. The supply air flow rate shall be maintained within  $\pm 5$  % of the specified value throughout the 96-hr test. MFCs shall be calibrated periodically according to the Laboratory's quality management system. At a minimum, flow measurement devices shall be calibrated on an annual basis against NIST traceable standards. As the humidity of the supply air is maintained by mixing dry and saturated gas streams, two mass flow controllers may be required per chamber (i.e., one for the dry stream and one for the wet stream). The dry and wet streams shall be mixed before the supply air enters the chamber.
- 3.8.4.2 **Chamber and materials:** The chamber volume shall be between 50 L and 1 m<sup>3</sup>. The chamber shall be constructed of stainless steel. Stainless steel chambers shall have electro-polished, or equivalent, interior surfaces. Either rectangular or cylindrical shapes are acceptable. The chamber shall be designed as a single-pass system without recirculation of chamber air. The chamber shall be operated at a slight positive pressure relative to the room to prevent the entrainment of room air. The chamber inlet and exhaust shall be positioned and designed to ensure complete mixing of chamber air. The chamber lid/door shall have a non-contaminating, non-sorbing gasket and a closure mechanism to create an airtight seal. Other materials introduced into to the chamber (e.g., racks and probes) shall be constructed of non-contaminating materials such as stainless steel.

- 3.8.4.3 **Background concentrations** in the empty chamber ventilated at 1.0 air changes per hour shall not exceed  $2 \mu g m^{-3}$  for any individual VOC, and  $25 \mu g m^{-3}$  for TVOC.
- Temperature and humidity control: The temperature of the chamber shall be 3.8.4.4 maintained within the range of  $23 \pm 1^{\circ}$ C for at least 90% time throughout the 96-hr test, and within range during sampling and for three air changes prior to sampling. In no case shall the temperature range exceed  $23 \pm 2^{\circ}$ C. All surfaces of the chamber shall be held at the same temperature so that the temperature inside the chamber is uniform. Typically, this is accomplished by placing the chamber inside a temperature-controlled environment such as an incubator or a dedicated room. The humidity of the chamber air shall be maintained within the range of  $50 \pm 5\%$  RH for at least 90% time throughout the 96-h test, and within range during sampling and for three air changes prior to sampling. In no case shall the relative humidity range exceed  $50 \pm 10\%$  RH. As wet products (e.g., water-based paints) will have 10 days of prior conditioning, the RH of the chamber air should be nearly equivalent to the RH of the inlet air. Thus, the humidity can be established by controlling the humidity of the inlet air. Generally, this is accomplished by mixing equivalent flows of dry and water saturated air streams. Water used in bubblers to saturate gas streams shall be free of organic solvents and contaminants (i.e., HPLC grade or equivalent).
- 3.8.4.5 **Monitoring and data acquisition:** The temperature and relative humidity for a chamber shall be measured continuously and independently of the systems for controlling temperature and humidity. The measurements shall be made inside the chamber or immediately at the chamber exhaust using electronic probes. The probes shall be calibrated periodically according to the laboratory's quality management system. At a minimum, these probes shall be calibrated on an annual basis against NIST traceable standards. Chamber inlet flow rates, temperature and relative humidity shall be recorded using a computer-based data acquisition system. At a minimum, these data shall be recorded at 5-minute intervals.

#### 3.8.5 **Procedures**

- 3.8.5.1 **Chamber cleaning and preparation:** Prior to reuse, the chamber shall be fully disassembled and washed. At a minimum, the chamber and components shall be washed with a dilute solution of laboratory detergent in warm water, thoroughly rinsed with clean water and dried. Alternative cleaning methods may be used provided that the background chamber concentrations can meet the requirements specified in section 3.8.4.3. The clean chamber shall be operated at the test conditions for a minimum of three full air changes prior to making a background measurement or introducing a test specimen.
- 3.8.5.2 **Background measurement:** Chamber background measurements shall be made on a regular basis according to the laboratory's quality management system. At a minimum, the background of VOCs and aldehydes shall be determined prior to each third use of a chamber. VOC and aldehyde samples are to be collected as described in Section 3.8.6 to provide lower quantitation limits of at least  $2 \ \mu g \ m^{-3}$  for individual VOCs and  $25 \ \mu g \ m^{-3}$  for TVOC.
- 3.8.5.3 **Specimen loading:** Test specimens shall be taken directly from the conditioning facility and placed in a cleaned test chamber minimizing the time the specimen is exposed to laboratory air. Generally, this time shall not exceed 15 minutes. In a rectangular chamber with flat surfaces, the specimen may be placed directly on the floor of the

chamber without additional support. In a horizontally oriented cylindrical chamber, a wire rack shall be used to hold the specimen near the midpoint of the chamber. A wire rack may also be used in a rectangular chamber. There shall be sufficient space for chamber air to circulate freely around the exposed face of the specimen. The specimen loading factor shall be  $0.3 - 1.0 \text{ m}^2 \text{ m}^{-3}$ .

- 3.8.5.4 **Chamber air leakage:** The air leakage of the chamber shall be determined immediately after loading a test specimen. This is accomplished by measuring the flow rate at the chamber exhaust and comparing this to the supply airflow rate. The flow measurement device shall have low pressure drop. Bubble flow meters and low-pressure drop rotameters are suitable for use. The exhaust flow rate shall be within 10% of the inlet flow rate by this method.
- 3.8.5.5 **Replicate chamber tests:** A fraction of the tests shall be conducted in replicate using specimens prepared from the same product sample. The fraction of replicates is determined by the laboratory's quality management system, but at least one replicate is required for every twenty tests.

#### 3.8.6 Air Sampling

- 3.8.6.1 **Sampling schedule:** Chamber air samples shall be collected at average elapsed times of 24, 48 and 96 hours after initiating the chamber test.
- 3.8.6.1.1 At 24 and 48 hours, only samples for formaldehyde and TVOC analyses are required to be collected. These first measurements, when compared to the corresponding 96-h measurements, are used to determine whether the chamber concentrations remained relatively constant or declined slowly throughout the test. Temporal variations or fluctuations outside of the normally expected range (e.g.,  $\pm 25\%$ ) likely indicate that a test parameter was uncontrolled or an analysis was incorrect. In this case, the cause of the variations shall be determined and the test repeated if necessary.
- 3.8.6.1.2 At an average time of  $96 \pm 2$  hours after initiating the test, samples for the full characterization of VOC emissions shall be collected.

#### 3.8.6.2 Sampling media

- 3.8.6.2.1 **VOC sampling media** for individual VOCs and TVOC shall consist of thermally desorbed, solid-phase sorption tubes. Refer to ASTM Standards D6196-03 and D 6345-98 (2004), and U.S. EPA Methods TO-1 and TO-17 for guidance. The samplers shall be capable of quantitatively collecting VOCs with a broad range of functional groups and volatilities approximately within the volatility range of n-pentane through n-heptadecane ( $C_5 C_{17}$ ). Minimal losses of analytes (i.e., <5%) due to breakthrough shall occur. This can be accomplished by the use of sampling tubes containing two or more sorbent materials in series, with the highest surface area material used as the backup to prevent the breakthrough of the most volatile compounds. Typical sorption tubes contain Tenax-TA as the primary sorbent backed up by carbonaceous sorbent(s). Before use, samplers shall be conditioned by thermal desorption. Samplers taken from refrigerated storage shall be warmed to room temperature prior to use.
- 3.8.6.2.2 **Sampling media** for formaldehyde, acetaldehyde and other low molecular weight aldehydes through butanal (C4 aldehydes) shall consist of cartridges containing a solid support material (e.g., silica gel) treated with an acid solution of 2,4-dinitrophenylhydrazine (DNPH) as a derivatizing reagent. Refer to ASTM Standard D 5197-03 for guidance. Samplers shall be warmed to room temperature prior to use.

- 3.8.6.3 **Flow control:** Sampling flow rates shall be regulated with electronic mass flow controllers, or equivalent, with an accuracy of  $\pm 2\%$  of full scale, or better, and capable of continuously maintaining the flow during sampling within  $\pm 5\%$  of the specified value.
- 3.8.6.4 **Sampling procedures:** Air samples shall be collected directly from the chamber exhaust at the specified elapsed times. A short manifold with multiple ports and a maximum length of 6 in (15 cm) may be used at the exhaust to allow simultaneous collection of multiple samples. No other tubing is allowed between the chamber exhaust and the sampler inlet. The DNPH cartridge is placed downstream of the VOC sorption tubes to reduce the chance of VOC sample contamination with residual acetontrile that may be present in the DNPH cartridge. The total sampling flow rate at any time shall not exceed 75% of the inlet flow rate. The start and stop times and the sampling flow rates shall be recorded. A unique identification number shall be assigned to each air sample.
- 3.8.6.5 **Duplicate air samples:** A fraction of the samples shall be collected in duplicate. The fraction of duplicates is determined by the laboratory's quality management system, but at least one duplicate is required for every ten samples.
- 3.8.6.6 **Sampler storage:** Following collection, air samples shall be sealed in clean airtight containers and stored at reduced temperature in a dedicated refrigerator or freezer. Samples shall be analyzed as soon as practical after collection. Use unexposed samplers as storage blanks.

#### **3.9** Chemical Analyses

3.9.1 **Principle**: Chamber air samples are analyzed using instrumental methods that are capable of positively identifying individual VOCs and quantifying them using multi-point calibrations prepared using pure standards. The methods provide sufficient sensitivity and accuracy to reliably quantify individual VOCs at concentrations of  $2 \,\mu g \,m^{-3}$ , or less.

#### 3.9.2 Analytical Instruments

- 3.9.2.1 VOCs and TVOC: Sorbent tube samples for individual VOCs and TVOC shall be analyzed by thermal desorption GC/MS (TD-GC/MS). The thermal desorber desorption and inlet parameters shall be optimized to obtain quantitative recovery of VOCs in the range defined in Section 3.8. The GC column and oven temperature parameters shall be optimized for the analysis of volatiles. The MS shall be an electron impact instrument operated in the scanning mode over a mass range of at least m/z 35-350.
- 3.9.2.2 Formaldehyde, acetaldehyde and other low molecular weight aldehydes: Aldehyde samples shall be analyzed by HPLC equipped with a UV detector and an analytical column providing full resolution of the formaldehyde hydrazone derivative from unreacted DNPH in a sample.

#### 3.9.3 Methods for Individual VOCs

- 3.9.3.1 The analytical methods for individual VOCs shall be based on ASTM Standard D 6196-03, ASTM Standard D 7339-07, and U.S. EPA Methods TO17 and TO-1, or equivalent methods. Standards and chamber samples shall be analyzed using identical conditions.
- 3.9.3.2 The analytical methods for formaldehyde, acetaldehyde and other low molecular weight aldehydes shall be based on ASTM Standard D 5197-03, or an equivalent method. It is

recognized that unsaturated low molecular weight aldehydes such as acrolein are not accurately determined by this method. Aldehydes with molecular weights equal or greater than that of butanal can be analyzed by TD-GC/MS.

#### 3.9.4 **TVOC Method**

- 3.9.4.1 Because the TVOC results are dependent upon the details of the analytical method and because there are substantial variations in the TIC response of VOCs with different chemical functionality, the analysis of TVOC is a semi-quantitative measure that is inherently less accurate than the calibrated measurement of individual VOCs. Formaldehyde and acetaldehyde are not included in TVOC calculations.
- 3.9.4.2 The TVOC method shall span a retention time interval consistent with the analysis of individual VOCs. Per definition of TVOC used in this Method, the mass range is n-pentane through n-heptadecane (i.e.,  $C_5 C_{17}$ ). Use toluene as the reference compound for calculating TVOC mass.
- 3.9.4.2.1 The integrated TIC areas in a sample less the TIC area of the internal standard are summed over the retention time interval. The ratio of summed area to the area of the internal standard is calculated. This value is multiplied by the internal standard mass to obtain the internal standard equivalent sample mass.
- 3.9.4.2.2 When using toluene- $d_8$  as the internal standard, the toluene-equivalent sample mass is calculated as the internal standard equivalent sample mass times the ratio of the density of toluene to toluene-d8 (i.e., 0.860/0.943).
- 3.9.4.2.3 When using another internal standard (e.g., 1-bromo-4-fluorobenzene), determine the Toluene /internal standard TIC response factor by analyzing at least two toluene calibration standards within the linear response range for toluene. For each level, the TIC response of the internal standard and the TIC response of toluene are divided by their corresponding masses in nanograms to produce normalized area-per-unit mass responses. Then area/mass relative responses are determined by dividing the normalized values for toluene by the normalized value for the internal standard. The relative response from each calibration level are averaged to produce an average toluene response factor. The internal standard equivalent sample mass is then divided by this average toluene response factor to produce a toluene-equivalent sample mass.
- 3.9.4.3 Alternate TVOC test methods (e.g., use of  $C_6 C_{16}$  as the mass range) may be used. The laboratory shall provide full method description in the test report if any alternate TVOC method is used.

#### 3.9.5 Identification of Individual VOCs

- 3.9.5.1 The identification of an individual VOC by GC/MS shall be determined by comparing the chromatographic retention time and mass spectrum of the unknown to the corresponding parameters for the pure compound analyzed on the same instrument using identical methods. Matching retention times and mass spectra provide positive, confirmed identifications. All VOCs of concern occurring on the referenced list (Section 4.1) that can be analyzed by this method shall be positively identified.
- 3.9.5.2 If no high quality match is obtained, the unknown spectrum is compared to spectra contained in the latest version of the NIST electronic database. A trained analyst shall decide if the identification is likely based on the match quality and the reasonableness of the retention time. Compounds identified by this procedure shall be clearly

indicated. If no highly probable match is obtained, the compound shall be labeled as an unknown.

3.9.5.3 Aldehyde hydrazone derivatives analyzed by HPLC shall be identified by matching the chromatographic retention times of the unknowns with the retention times of derivatives of the pure compounds analyzed on the same instrument using identical methods.

#### 3.9.6 Analytical Calibrations

- 3.9.6.1 All target VOCs of concern shall be quantified by GC/MS based on multi-point calibrations prepared using pure compounds. If possible, other positively identified VOCs shall be quantified by the same method. An internal standard calibration method is recommended. A minimum of four points shall be used. Target analytes shall be introduced onto sorbent tubes as gas or liquid standards and then analyzed using methods identical to those used for the analysis of chamber samples. Analyze at least one calibration standard with each batch of samples. Perform full calibrations at least once every three months or more frequently to ensure accuracy for the analyses.
- 3.9.6.2 Individual VOCs not positively identified by GC/MS shall be quantified using toluene as the reference compound for calculating compound mass. Fully describe the method. VOCs quantified by this surrogate method shall be clearly indicated.
- 3.9.6.3 Aldehydes analyzed by HPLC shall be quantified based on multi-point calibrations prepared from hydrazone derivatives of the pure compounds. Standards and samples shall be analyzed using identical methods. At least one standard shall be analyzed with each batch of samples.

#### 3.9.7 Lower Limits of Quantitation (LOQ)

- 3.9.7.1 A lower LOQ often is quantitatively defined as the analyte mass that produces a response that is 10 times higher than the instrumental noise level or is 10 times the standard deviation for repeated analyses of a low level standard. A lower LOQ that is higher than this absolute value may be defined based on practical considerations.
- 3.9.7.2 The lower LOQ for TVOC shall be  $25 \ \mu g \ m^{-3}$ , or better.
- 3.9.7.3 The lower LOQ for VOCs appearing on list of chemicals of concern (see Section 4.1) shall be  $2 \mu g m^{-3}$ , or better.
- 3.9.7.4 The lower LOQ for non-listed VOCs (see Section 4.1) shall be  $2 \mu g m^{-3}$ , or better.
- 3.9.8 A LOQ verification sample shall be analyzed after each calibration. Target analytes shall be introduced onto sorbent tubes as gas or liquid standards at or below the level of quantitation and then analyzed using methods identical to those used for the analyses of chamber samples.

#### 3.10 Calculations

#### 3.10.1 Calculation of Emission Factors

- 3.10.1.1 Since the chamber measurements are made starting on the 11<sup>th</sup> day and ending on the 14<sup>th</sup> day after preparation of the test specimen when chamber concentrations are expected to change slowly with time, the steady state form of the mass-balance equation shall be used for analysis of the chamber data (ASTM Standard D 5116-06).
- 3.10.1.2 The area specific emission rate or emission factor,  $EF_{Ai}$  (µg m<sup>-2</sup> h<sup>-1</sup>), at a given time, *t* (h), after placing a test specimen in the chamber shall be calculated using Equation 3.1:

$$EF_{Ai} = Q \times (C_{it} - C_{i0}) / A_C$$
 (Eq. 3.1)

The inlet flow rate, Q (m<sup>3</sup> h<sup>-1</sup>), is the measured flow rate of air into the chamber. The chamber concentration,  $C_{it}$  (µg m<sup>-3</sup>), is the concentration of a target VOC<sub>i</sub>, formaldehyde and other carbonyl compounds measured at time *t*. The chamber background concentration,  $C_{i0}$  (µg m<sup>-3</sup>), is the corresponding concentration measured with the chamber operating without a test specimen or with an appropriate substrate. The exposed projected surface area of the test specimen in the chamber,  $A_C$  (m<sup>2</sup>), is determined from the measurements made at the time of specimen preparation.

3.10.1.3 Volume, length, mass or unit specific emission rates or emission factors,  $EF_V$ ,  $EF_L$  or  $EF_M EF_P$  (µg m<sup>-3</sup> h<sup>-1</sup>, µg m<sup>-1</sup> h<sup>-1</sup>, µg kg<sup>-1</sup> h<sup>-1</sup> or µg h<sup>-1</sup>per unit), can be calculated using Equation 3.1 by substituting the appropriate parameter used to quantify the material specimen (i.e., volume in cubic meters, length in meters, mass in kilograms or number of products tested).

#### 3.10.2 Calculation of Estimated Building Concentrations

- 3.10.2.1 Building concentrations can be calculated on a case-by-case basis using input parameters for the amount of installed product, the size of the space and the air change rate (or air flow rate) that are specific to the architectural project under consideration. In order to evaluate and compare products for use in a wide range of building products, concentrations also can be calculated for selected building scenarios as described below.
- 3.10.2.2 Building concentrations are estimated based on the measured VOC emission factors, the amount of material to be installed in the building and flow rate of outside air used for ventilation. Steady state conditions with respect to emission rates and building ventilation shall be assumed in making the prediction. Additional assumptions are zero outdoor concentrations, perfect mixing within the building and no net losses of VOC from air due to other effects such as irreversible or net sorption on surfaces (i.e., net sink effects) and chemical reactions.
- 3.10.2.3 The projected surface area of an installed material by product category and the building parameters to be used in the calculation of estimated VOC concentrations are established by this method for three standard model building scenarios, a school classroom, an office and a single family residence (Section 4.2).
- 3.10.2.4 The estimated building concentration,  $C_{iB}$  (µg m<sup>-3</sup>), of a target VOC<sub>i</sub> shall be calculated using Equation 3.2a or 3.2b.

For products that have the area specific emission factor,  $EF_A$  (µg m<sup>-2</sup> h<sup>-1</sup>), Equation 3.2a shall be used:

$$C_{Bi} = (EF_{Ai} \times A_B) / Q_B = EF_{Ai} / (Q_B / A_B) = EF_{Ai} / q_A$$
(Eq. 3.2a)

The area specific emission rate  $EF_A$  at 336 hours (14 days) total exposure time is divided by the area specific flow rate,  $q_A$  (m h<sup>-1</sup>). The area specific flow rate,  $q_A$ , is calculated as the ratio of the flow rate of outside ventilation air,  $Q_B$  (m<sup>3</sup> h<sup>-1</sup>), to the exposed surface area of the installed material in the building,  $A_B$  (m<sup>2</sup>).

For products that only have the unit specific emission factor,  $EF_P$  (µg h<sup>-1</sup> per unit), Equation 3.2b shall be used:

$$C_{Bi} = (EF_{Pi} \times N_B) / Q_B = EF_{Pi} / (Q_B / N_B) = EF_{Pi} / q_P \qquad (Eq. 3.2b)$$

The unit specific emission rate  $EF_P$  at 336 hours (14 days) total exposure time is divided by the unit specific flow rate,  $q_P$  (m<sup>3</sup> h<sup>-1</sup> per unit). The unit specific flow rate,  $q_P$ , is calculated as the ratio of the flow rate of outside ventilation air,  $Q_B$  (m<sup>3</sup> h<sup>-1</sup>), to the number of the installed products in the building, N<sub>B</sub>.

3.10.2.5 In some cases, it may be necessary to calculate the results using the volume, length or mass of a product to be installed in a building and the corresponding volume, length or mass specific emission rate.

### 4 TARGET CHEMICALS, MAXIMUM ALLOWABLE CONCENTRATIONS, AND IAQ CONCENTRATION MODELING

#### 4.1 Target VOCs

- 4.1.1 VOCs emitted by products appearing on State of California lists of toxic substances (see below) are considered to be *chemicals of concern* and shall be included as "Target VOCs" for the testing of emissions under this method.
- 4.1.2 *Chemicals of concern* include known or probable human carcinogens, reproductive/ developmental toxins, and systemic toxins with noncancer chronic effects contained in the latest published editions of the following lists:
  - Cal/EPA OEHHA list of chemicals for which non-cancer Chronic Reference Exposure Levels (CRELs). CRELs are 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). CREL values are continuously updated by OEHHA (see http://www.oehha.ca.gov/air/chronic\_rels/AllChrels.html).
  - Cal/EPA OEHHA Safe Drinking Water and Toxic Enforcement Act of 1986 (*Proposition 65*) lists of known or probable human carcinogens and reproductive/developmental toxins. These lists are accessible at <u>http://www.oehha.ca.gov/prop65/prop65\_list/newlist.html</u>.
  - **Cal/EPA ARB list of Toxic Air Contaminants (TACs).** The TAC list includes all substances on the EPA list of Hazardous Air Pollutants plus additional compounds. This list is accessible at <u>http://www.arb.ca.gov/toxics/id/taclist.htm</u>.
- 4.1.3 The VOCs emitted from tested products shall be quantified using pure standards as described in Section 3. Many VOCs approximately within the volatility range of n-pentane through n-heptadecane ( $C_5 C_{17}$ ) can be analyzed by TD-GC/MS and low molecular weight aldehydes through butanal can be analyzed using HPLC.
- 4.1.4 Non-listed VOCs that are abundant in the emissions from a product specimen shall also be quantified. At a minimum, the ten VOCs having the highest emission factors (most abundant VOCs), which may include listed compounds, shall be quantified. If pure standards are not readily available, abundant, non-listed VOCs are quantified using a surrogate (see Section 3.9).
- 4.1.5 Chemical substances (on the CREL or other lists) that are *not* VOCs (e.g., metals, acids and pesticides) are not required to be analyzed under this Standard Method

#### 4.2 Maximum Allowable Concentrations for Target VOCs.

4.2.1 Target VOCs *except formaldehyde*. Multiple sources of individual VOCs are often present in a building. To ensure indoor air concentrations are within allowable limits, each individual product category is capped at no more than *one-half* of the CREL for each chemical in a building type. To determine acceptability of the emission results, the estimated building VOC concentrations are compared to one-half their corresponding CRELs (except formaldehyde, which is discussed below). The CRELs are currently

published at <u>http://www.oehha.ca.gov/air/chronic\_rels/AllChrels.html</u>. The specific VOCs on the CREL list that are required to be included in this assessment (i.e., those VOCs that can be analyzed by the sampling and analytical methods specified herein) are identified in **Table 4-1**.

- 4.2.2 Formaldehyde. The allowable limit for emissions of formaldehyde corresponds to an indoor air concentration not to exceed the full CREL of 9 μg m<sup>-3</sup> commencing January 1, 2012. Until that date, one-half of 33 μg m<sup>-3</sup> (i.e., 16.5 μg m<sup>-3</sup>, the value given for formaldehyde in the Standard Practice 2004 document) will continue to be used as the allowable concentration limit.
- 4.2.3 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 (**Table 4-1**) shall continue to apply until these changes are published in a revised version of this document.

#### 4.3 IAQ Concentration Modeling

- 4.3.1 **Principle**: The purpose of IAQ concentration modeling is to convert the *measured VOC emission rates* into *estimated airborne concentrations* that are relevant to potential indoor inhalation exposures of building occupants. The calculation is accomplished using a steady-state mass-balance model with several simplifying assumptions described in Section 3.10. The calculation requires inputs for the emission factor of a VOC emitted by a product and the flow rate of outdoor air per unit amount of product.
- 4.3.2 **Area-specific air flow rate:** For a product with a given VOC emission factor, the relationship that determines, to a first-order approximation, the gas-phase VOC concentration in a test chamber and in a built environment is the flow rate of outdoor ventilation air per unit area of product. This parameter is termed the area-specific air flow rate and has units of  $m^3 h^{-1} m^{-2} (m h^{-1})$ . It is also obtained from the ratio of the air change rate to the loading factor (sometimes described as N/L) with the same units.
- 4.3.3 **Standardized scenarios:** Typical product categories (e.g., floor coverings, wall coverings, paint, acoustical ceilings, etc.) are specified with respect to their loading in each building environment (i.e., school classrooms and private offices in public/commercial buildings) and the flow rate of outdoor air.
- 4.3.4 School classroom scenario: The school classroom model is based on the dimensions of a typical re-locatable classroom; the classroom size also is generally representative of site-built classrooms for K-12 schools (Jenkins, Phillips and Waldman, 2004). The parameters that define the standard school classroom to be used with this method are listed in Table 4-2. The surface areas of major product categories and unit quantities of pupil desks and seating in the school classroom are presented in Table 4-3 along with the calculated correspondent area-specific air flow rates or unit-specific air flow rates.

NI-	Commence de Norma	CACN	Allowable Conc. <sup>a</sup>
INO.	Compound Name	CAS NO.	(µg/m <sup>3</sup> )
1	Acetaldehyde	75-07-0	70
2	Benzene	71-43-2	30
3	Carbon disulfide	75-15-0	400
4	Carbon tetrachloride	56-23-5	20
5	Chlorobenzene	108-90-7	500
6	Chloroform	67-66-3	150
7	Dichlorobenzene (1,4-)	106-46-7	400
8	Dichloroethylene (1,1)	75-35-4	35
9	Dimethylformamide (N,N-)	68-12-2	40
10	Dioxane (1,4-)	123-91-1	1,500
11	Epichlorohydrin	106-89-8	1.5
12	Ethylbenzene	100-41-4	1,000
13	Ethylene glycol	107-21-1	200
14	Ethylene glycol monoethyl ether	110-80-5	35
15	Ethylene glycol monoethyl ether acetate	111-15-9	150
16	Ethylene glycol monomethyl ether	109-86-4	30
17	Ethylene glycol monomethyl ether acetate	110-49-6	45
18	Formaldehyde	50-00-0	16.5 <sup>b</sup>
19	Hexane (n-)	110-54-3	3,500
20	Isophorone	78-59-1	1,000
21	Isopropanol	67-63-0	3,500
22	Methyl chloroform	71-55-6	500
23	Methylene chloride	75-09-2	200
24	Methyl <i>t</i> -butyl ether	1634-04-4	4,000
25	Naphthalene	91-20-3	4.5
26	Phenol	108-95-2	100
27	Propylene glycol monomethyl ether	107-98-2	3,500
28	Styrene	100-42-5	450
29	Tetrachloroethylene	127-18-4	17.5
30	Toluene	108-88-3	150
31	Trichloroethylene	79-01-6	300
32	Vinyl acetate	108-05-4	100
33-35	5 Xylenes, technical mixture	108-38-3,	350
	(m-, o-, p-xylene combined)	95-47-6,	
		106-42-3	

 Table 4-1
 Target CREL VOCs and their maximum allowable concentrations

a) Refer to <u>http://www.oehha.ca.gov/air/chronic\_rels/AllChrels.html</u>. All maximum allowable concentrations are one-half the corresponding CREL adopted by Cal/EPA OEHHA with the exception of formaldehyde. For any future changes in the CREL list by OEHHA, values in Table 4.1 shall continue to apply until these changes are published in the Standard Method.

b) Formaldehyde has a CREL of 9  $\mu$ g/m<sup>3</sup> (December 2008); guidance value established by this Standard Method at 16.5  $\mu$ g/m<sup>3</sup> before Dec 31<sup>th</sup>, 2011 and at 9  $\mu$ g/m<sup>3</sup> starting from Jan 1<sup>st</sup>, 2012. See Section 4.3.2.

Parameter	Unit of Measure	Parameter Value
Length (40 ft)	m	12.2
Width (24 ft)	m	7.32
Floor (ceiling) area	$m^2$	89.2
Ceiling height (8.5 ft)	m	2.59
Volume	m <sup>3</sup>	231
Windows (4 ft x 4 ft and 4ft x 8 ft)	m <sup>2</sup>	4.46
Door (3 ft x 7 ft)	m <sup>2</sup>	1.89
Net wall area	m <sup>2</sup>	94.6
Occupancy	Unit	27
Outdoor air flow rate <sup>1</sup>	m <sup>3</sup> /h	654
Adjusted outdoor air flow rate <sup>2</sup>	m³/h	191
Effective outdoor air change rate <sup>2</sup>	1/h	0.82

**Table 4-2**Definition of standard school classroom

 Based on ASHRAE 62.1-2007, Table 6-1, for classrooms occupied by pupils, ages five and up. The minimum ventilation requirement is 5 L/s-person (10 cfm/person) and 0.6 L/s-m<sup>2</sup> floor area (0.12 cfm/ft<sup>2</sup>). The code minimum total flow rate of outdoor air is then 654 m<sup>3</sup> h<sup>-1</sup> (182 L/s or 385 cfm). This produces a ventilation rate of 2.8 h<sup>-1</sup> for occupied hours.

2. As documented in various reports, classroom HVAC systems sometimes do not deliver the required amount of outdoor air for a variety of reasons including poorly designed or overridden controls and lack of maintenance. In addition, HVAC systems may not be started sufficiently early in the school day to achieve a fully ventilated condition prior to the start of class. Therefore for use in this method, average the ventilation over a 168-h week assuming 40 hours of operation at 654 m<sup>3</sup> h<sup>-1</sup> (2.8 h<sup>-1</sup>) and 128 hours of operation with ventilation of only 0.2 h<sup>-1</sup> due to infiltration. This yields an average ventilation rate of 0.82 h<sup>-1</sup> and an average flow rate of 191 m<sup>3</sup> h<sup>-1</sup> (53.1 L/s or 112 cfm).

Product Type	Area or Quantity		Area- or Unit-Specific Air Flow Rate	
Flooring (all types)	$m^2$	89.2	m/h	2.14
Ceiling (all types)	$m^2$	89.2	m/h	2.14
Wall paint & wallcoverings <sup>1</sup>	$m^2$	94.6	m/h	2.02
Thermal insulation				
Ceiling	$m^2$	89.2	m/h	2.14
Wall	$m^2$	94.6	m/h	2.02
Ceiling & Wall	$m^2$	183.8	m/h	1.04
Wall base (10-inch)	$m^2$	9.68	m/h	19.7
Visual aid boards <sup>2</sup>	$m^2$	11.9	m/h	16.1
Desk (pupil)	Unit	27 ea	m <sup>3</sup> /h	7.07
Seating (pupil)	Unit	27 ea	m <sup>3</sup> /h	7.07

**Table 4-3**Product quantities and specific air flow rates to be used for estimation of VOC<br/>concentrations in standard school classroom

The net wall area is 94.6 m<sup>2</sup> based on the total wall area minus the area of one door and two windows.
 Area of visual aid boards is assumed to be 1.22 m by 9.75 m (4 ft by 32 ft) based on typical classroom layouts and traditional markerboard/chalkboard materials. Unique, specialty visual aid board products (e.g. with multimedia projection capabilities, etc.) that are restricted in size by the manufacturer may justify different area values. Any deviations from the area specified in Table 4.3 shall be stated in reports and public claims of compliance.

4.3.5 Private office scenario: The private office model is based on assumed dimensions of an enclosed office in a public/commercial building that is occupied by a single individual. The parameters that define the standard private office to be used with this method are listed in Table 4-4. The surface areas of major product categories are presented in Table 4-5 along with the calculated correspondent area-specific air flow rates. This private office scenario applies to building materials and products other than office furniture or seating units. Private office workstations are not addressed within the current scope of this Standard Method. For office seating, refer to Section 7.

Parameter	Unit of Measure	Parameter Value
Length (12 ft)	m	3.66
Width (10 ft)	m	3.05
Floor (ceiling) area	m <sup>2</sup>	11.15
Ceiling height (9 ft)	m	2.74
Volume	m <sup>3</sup>	30.6
Window (4 ft x 4 ft)	m <sup>2</sup>	1.49
Door (3 ft x 7 ft)	$m^2$	1.89
Net wall area	m <sup>2</sup>	33.4
Occupancy	Unit	1
ASHRAE Outdoor air flow rate <sup>1</sup>	m <sup>3</sup> /h	20.7
Effective outdoor air change rate <sup>1</sup>	1/h	0.68

**Table 4-4**Definition of standard private office

 Based on ASHRAE 62.1-2007, Table 6-1, for offices. The minimum ventilation requirement is 2.5 L/sperson (5 cfm/person) and 0.3 L/s-m<sup>2</sup> floor area (0.06 cfm/ft<sup>2</sup>). The minimum total flow rate of outdoor air is then 20.7 m<sup>3</sup> h<sup>-1</sup> (5.76 L/s or 12.2 cfm). This produces a ventilation rate of 0.68 h<sup>-1</sup> for occupied hours.

Table 4-5	Product quantities and specific air flow rates to be used for estimation of VOC
	concentrations in a standard private office

Product Type	Area		Area-Specific Air Flow Rate	
Flooring (all types)	$m^2$	11.1	m/h	1.86
Ceiling (all types)	$m^2$	11.1	m/h	1.86
Wall paint &	$m^2$	33.4	m/h	0.62
wallcoverings <sup>1</sup>				
Thermal insulation				
Ceiling	$m^2$	11.1	m/h	1.86
Wall <sup>2</sup>	$m^2$	ND	m/h	ND
Ceiling & Wall <sup>2</sup>	$m^2$	ND	m/h	ND
Wall base (4-inch)	$m^2$	1.27	m/h	16.3
Door & other millwork	m <sup>2</sup>	1.89	m/h	11.0
Window treatments	$m^2$	1.49	m/h	13.9

1. The net wall area is  $33.4 \text{ m}^2$  based on the total wall area minus the area of one door and one window.

2. The material area for thermal insulation in walls has not been fully defined (ND).

4.3.6 **Modeling parameters for products not specifically addressed in data tables**: There are a number of products for which data on standard applications are not readily available; many adhesives, caulks, sealants, and wallboard finishing products fall into this category. For these products, the loading shall be determined based on (a) the surface area of the system (i.e., ceiling, wall, or floor) in the selected standard environment (i.e., classroom, private office, or single-family residence), where the product is applied, and (b) the product's standard application specifications. For example, flooring adhesive shall be modeled using the entire floor area of the space and the manufacturer's published application rate for that adhesive (e.g., g m<sup>-2</sup>). Parameters used to establish the loading shall be made part of the test report record and made available through the certification report if the modeling parameters are defined by a certification/verification organization (Section 6.1.4).

# 5 QUALITY ASSURANCE AND QUALITY CONTROL

#### 5.1 Mandatory Practices on Quality Management

- 5.1.1 Laboratories conducting testing and evaluation of VOC emissions shall be maintained under a *Quality Management System* (QMS).
- 5.1.2 At the minimum, the QMS shall include the following elements:
  - Quality system objectives and policies, plus conflicts of interest, ethics, etc.
  - Laboratory organization management.
  - Personnel qualifications and training.
  - Document review and management.
  - Sample management, including handling and chain of custody.
  - Reagent and standard preparation.
  - Maintenance and calibration of instrumentation and measurement systems.
  - Quality assurance/quality control (QA/QC) plan for laboratory operations.
  - Data and records management.
  - Performance and system audits.
  - Corrective actions request systems.
- 5.1.3 QMS performance shall be audited on an annual basis according to ISO/IEC 17025:2005.
- 5.1.4 Documentation of the QMS and annual laboratory audits shall be available for review by clients and certification bodies.

#### 5.2 Mandatory Laboratory Practices

- 5.2.1 Laboratory's QMS and applicable test procedures shall be conducted in accordance with ISO/IEC 17025:2005.
- 5.2.2 Laboratories shall devise and implement methods for verifying the overall accuracy or bias of their chamber testing performance. Known, realistic concentrations of compounds of interest in chamber air should be generated by procedures that are independent of the sampling and analytical methods used for chamber tests. The possibilities include certified gas mixtures, gravimetrically calibrated diffusion and permeation sources, and injection and vaporization of liquid mixtures. The overall bias for a compound is defined as the relative or statistical difference between the measured air concentration and the independently determined, or theoretical, air concentration of the compound.
- 5.2.3 Laboratories shall participate in proficiency test (PT) programs. These PT programs may be in the form of interlaboratory studies with a sufficient number of participants to allow statistical analysis of the results. Custom PT programs may be developed using an
accredited supplier of VOC standards in various forms such as calibration gas cylinders and spiked thermal desorption tubes.

# 5.3 Measurement Uncertainty

- 5.3.1 Measurement uncertainty (accuracy) and precision limits for test chamber conditions and test results are listed in **Table 5-1**.
- Table 5-1
   Guidelines for measurement uncertainty and precision of chamber conditions and VOC measurements

Parameter	Measurement Uncertainty	Precision
Temperature, <sup>o</sup> C	±0.5	±1.0
Relative humidity, %	±5	±5
Air flow rate, %	±3	±5
Exposed area of test specimen, %	±1	±2
Time, %	±1	±2
VOC Concentration, %RSD <sup>1</sup>		±15
VOC Emission factor, %RSD <sup>1</sup>		±20

1. %RSD= Relative standard deviation = estimate of the standard deviation / mean x 100%.

- 5.3.1.1 The measurement uncertainty and precision of parameters such as temperature, relative humidity and air flow rate shall be maintained and verified by periodic performance checks and calibration of instrumentation according to the laboratory's QMS.
- 5.3.1.2 Precision for VOC measurements shall be determined from a laboratory's continuous assessment of duplicate VOC samples collected during tests. Precision for VOC emission factors shall be estimated based on propagation of the precisions of the individual measurements used to calculate emission factors. Alternately, precision for VOC emission factors can be estimated from an assessment of duplicate tests of product specimens.

# 6 REQUIRED ELEMENTS OF THE LABORATORY TEST REPORT

# 6.1 Required elements of the Laboratory Test Report

6.1.1 **Laboratory identification**: Name, address, phone number and other contact information for the laboratory.

# 6.1.2 Manufacturer, product and sample identification:

- Manufacturer and manufacturer contact name address and phone number
- Product name, product number, product category and subcategory (if applicable)
- Other manufacturer's identification numbers (if applicable)
- Manufacturing location, manufacturing date, collection date, shipment date and date of arrival at laboratory
- Laboratory sample ID or tracking number.
- 6.1.3 **Test methods and conditions**: Chamber volume, inlet air flow rate, average temperature and range, average relative humidity and range, exposed area of test specimen (or other relevant test specimen measurement parameter), chamber loading factor, test specimen preparation details, conditioning period start date and duration, and test period start date and duration, and sampling and analytical methods (including TVOC method).
- 6.1.4 **Data analysis procedures**: Equations and procedures used to derive emission factors from measured chamber concentrations; Equations, procedures and parameters used to calculate building concentrations from the emission factors including: the selected standardized building scenario(s), the assumed product area (or other relevant product measurement parameter), and the area- or unit-specific air flow rate. For products not specifically addressed in data tables (e.g., adhesives and caulks), also attach the manufacturer's published application specifications used to estimate VOC concentrations (Section 4.3.6).
- 6.1.5 **Test results**: For the 96-h results, list of all target VOCs (individual toxic and abundant VOCs, including formaldehyde and acetaldehyde see Section 4.1) and TVOC quantified in the chamber with their chamber concentrations and corresponding emission factors. For the 24-h and 48-h results, list only the formaldehyde and TVOC quantified in the chamber with their chamber concentrations and corresponding emission factors.

Provide the following information:

- CAS numbers for individual VOCs
- Indicate which non-listed VOCs were quantified using surrogate compounds in lieu of pure compounds.
- Identify those VOCs with CRELs and those VOCs on the other lists of toxic substances (Section 4.1).
- Provide estimated concentration for the selected standardized building scenario(s) for all listed and non-listed compounds.

- 6.1.6 **Photographs:** Include a photographic image of each test specimen.
- 6.1.7 **Additional information:** Report any additional facts and deviations, which may have influenced the test results. These include but are not limited to the following:
  - Dates of most recent internal and external audits, proficiency evaluation(s) and corrective actions taken, if any
  - Product sample manufacturing dates, collection dates, and shipment dates
  - Any deviations from method and specified parameters and values
  - Details of specimen preparation not covered above (e.g., application methods for paints and adhesives or preparation of assemblies)
  - Mass quantity and coverage (g m<sup>-2</sup>) of paint and adhesive
  - Any other relevant observations.
- 6.1.8 **Chain of Custody:** Attach a copy of the completed and signed chain-of-custody (COC) form with the laboratory report.
- 6.1.9 **Certification of the Report:** Name, position, signature and date of authorized laboratory personnel attesting to accuracy of provided information.

# 7 TESTING OF FREESTANDING FURNITURE

# 7.1 Test Method for Freestanding Furniture

ANSI/BIFMA M7.1-2007 test method (including specimen collection and preparation, chamber testing, and air sampling) and the power-law modeling procedure described in that method are hereby recognized as the test method for pupil desks and chairs, office furniture and office seating unless otherwise specified below. Testing of furniture items shall meet the following requirements for the determination of the emissions of the VOCs of concern defined in Section 4.1.

- 7.1.1. Tests of pupil desks and chairs, office furniture and office seating units are to be conducted in mid- and full-scale chambers according to ANSI/BIFMA M7.1-2007. Office workstation components (i.e., panel, work surface and storage) may be tested individually in mid-scale chambers or combined in a full-scale chamber. As defined in BIFMA e3-2008, small chamber testing of component pieces of workstations per the ANSI/BIFMA M7.1-2007 method is acceptable if there is third-party oversight in selecting representative components and in applying the calculations in ANSI/BIFMA M7.1-2007 (Section 10.6.1 and 10.6.2) to estimate the emission factor of a product.
- 7.1.2. Air samples are to be analyzed for individual VOCs following procedures that are equivalent to the procedures described in Section 3.9.
- 7.1.3. VOC emission factors per furniture unit are calculated from chamber concentrations measured at 72 h and 168 h. VOC emission factors at 14 days (336 h) are projected by application of the power-law model to the measured data. The 72-h and 168-h emission factors are averaged if the decay coefficient, b, is >-0.2 and <0.2 (BIFMA e3-2008).
- 7.1.4. Alternatively, tests can be conducted over 336-h in mid- and full-scale chambers with full speciation of VOCs in the duplicate samples collected at 336-h to directly obtain the required emission factors.

# 7.2 Concentration Modeling for Furniture and Office Seating

- 7.2.1 **Pupil desks and chairs:** Classroom pupil furniture consisting of desk units and seating units are modeled for the standard classroom scenario defined in Section 4.3.4. The specific air flow rate for a pupil desk unit and for a pupil seating unit is specified in **Table 4-3**.
- 7.2.2 Open-plan office workstations: Single-occupant open plan office workstations are modeled to the open-plan office environment defined in ANSI/BIFMA M7.1-2007. The parameters that define the standard open-plan office are listed in Table 7-1. The area specific air flow rates for the standard workstation and its components are presented in Table 7-2. These parameters shall be used to calculate estimated indoor VOC concentrations attributable to a workstation or its components for a standard open-plan office environment. If office workstation components are tested individually, the contributions of the components may be summed to estimate the indoor VOC concentration for the full workstation.

Parameter	Unit of Measure	Parameter Value
Length	m	2.44
Width	m	2.44
Floor (ceiling) area $(64 \text{ ft}^2)^1$	$m^2$	5.94
Ceiling height $(9 \text{ ft})^1$	m	2.74
Volume	m <sup>3</sup>	16.3
Occupancy <sup>1</sup>	unit	1
ASHRAE Outdoor air flow rate <sup>1</sup>	m <sup>3</sup> /h	15.0
Effective outdoor air change rate	1/h	0.92

**Table 7-1**Standard open-plan office defined in ANSI/BIFMA M7.1-2007

 Based on research conducted for BIFMA (Carter and Zhang, 2007), the typical open-plan office environment for a single occupant is defined as a space without walls with a 5.94 m<sup>2</sup> (64-ft<sup>2</sup>) floor area and a 2.74-m (9-ft) ceiling. It contains a single workstation system. The minimum required outdoor ventilation rate calculated from ASHRAE 62.1-2007, Table 6-1 is 15.0 m<sup>3</sup> h<sup>-1</sup> (4.17 L/s or 8.84 cfm).

Table 7-2	Product quantities and specific air flow rates to be used for estimation of VOC
	concentrations in a standard open-plan office

Product Type	Area or Quantity		Area- or U Air Flo	nit-Specific w Rate
Open-plan workstation <sup>1</sup>	$m^2$	21.76	m/h	0.69
Vertical panel	$m^2$	11.08	m/h	1.35
Work surface	$m^2$	6.103	m/h	2.46
Storage	m <sup>2</sup>	4.569	m/h	3.36

 The standard open-plan workstation defined in ANSI/BIFMA M7.1-2007 (Appendix 2, Table A2.1) is used. It consists of vertical panel, work surface and storage components. The total workstation surface area is 21.76 m<sup>2</sup> apportioned as 11.08 m<sup>2</sup> panel, 6.103 m<sup>2</sup> work surface, and 4.569 m<sup>2</sup> storage areas (refer to ANSI/BIFMA M7.1 for area calculation conventions). These areas are based on 90<sup>th</sup> percentile furniture surface area conditions.

- 7.2.3 **Private office workstations:** Private office workstations are not addressed within the current scope of this Standard Method.
- 7.2.4 **Office seating units:** ANSI/BIFMA M7.1-2007 specifies one seating unit with an air flow rate of 24.8 m<sup>3</sup> h<sup>-1</sup>. For this method, assume two (2) identical seating units and utilize the average air flow rate for seating defined in ANSI/BIFMA M7.1. Thus, the unit specific air flow rate for each seating unit is 12.4 m<sup>3</sup> h<sup>-1</sup>. This is consistent with the credit criteria for seating in CHPS 2009 and BIFMA e3-2008.

# 7.3 Compliance with Maximum Allowable Concentrations

To be compliant with the method, the modeled concentration for a tested furniture item (i.e., a pupil desk unit, a pupil seating unit, an office workstation, or an office seating unit) shall not exceed the maximum allowable concentrations established in Section 4.3.

# 8 GUIDELINES FOR USE OF STANDARD METHOD AS BASIS FOR A BUILDING PRODUCT CLAIM

In the past, product manufacturers have used test results as the basis for a single-attribute claim regarding one or a group of their products (i.e., a low VOC emissions product claim). Claims certification and verification organizations have also deemed to use these test results as part of their own process for substantiating manufacturers' claims. Whenever this *Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers* is to be used to make, certify or verify a building product claim, the following guidelines are recommended to ensure the integrity of the process.

# 8.1 Manufacturer and Third-Party Claims

- 8.1.1 Claims made by manufacturers regarding their own products shall be made following the principles of ISO 14021 (2001) for self-declared environmental labels and declarations. These requirements include that such claims be: based on scientific evidence; accurate; verifiable; and updated if circumstances alter their accuracy. Information on the procedures, criteria and data used to support such claims shall be made available to interested parties upon request.
- 8.1.2 Certification/verification organizations involved in substantiating manufacturers' claims shall operate in accordance with ISO Guide 65 (1996). Program documentation, quality manuals, and information on the procedures, criteria and data used to substantiate manufacturers' claims shall be made available to interested parties upon request.

# 8.2 Laboratory Selection

Manufacturers or certification/verification organizations shall utilize only laboratories demonstrating competency to perform the method as described in Section 5. Laboratories shall be independent entities with no direct connection to the manufacturer or potential conflict of interest with respect to the manufacturer.

# 8.3 Breadth of Claim

- 8.3.1 A claim that extends beyond the individual product that is tested shall only be made if there is clear evidence justifying that tested items are representative of this product or related products. Such evidence shall be documented and the documentation shall be made available to interested parties upon request (see Section 8.7 and 8.8).
- 8.3.2 For products that meet the 9  $\mu$ g m<sup>-3</sup> requirement for formaldehyde earlier than January 1, 2012, a claim of "*compliance with 9 \mug m<sup>-3</sup> formaldehyde CREL*" may be made together with the claim of compliance with the Standard Method.

# 8.4 Modifications of Method

While certification/verification organizations may modify some of the procedures described in this method to meet their program objectives, modifications that alter essential compliance, undercut, or otherwise weaken the objectives of the method shall not be made.

- 8.4.1 Certification/verification organizations may require additional procedures or measurements not addressed by the method.
- 8.4.2 In order for a certification/verification organization to make a claim of essential compliance with the method, modifications shall be documented, including detailed evidence of the basis. This documentation shall be made readily available to program participants, the public and any other interested parties.

# 8.5 Acceptable Alternative to Method

Test results meeting all the requirements described in this Method at no less than 168 hours (7 days) instead of the 336 hour (14-day) testing required by this Method are acceptable provided that: (a) the specimen remains in the same chamber for the duration of the 168-hr test; (b) samples for formaldehyde and TVOCs are collected and their corresponding chamber concentrations and emission factors are reported at a minimum of three time points between 24 and 120 hours, spaced at least 24 hours apart (e.g., 24, 48, 72, 96 and 120-hr); (c) full speciation of VOCs is performed at 168-hr according to the requirements described in this method; (d) chamber concentrations of VOCs of concern are determined to be constant or declining with time at 168 hour.

# 8.6 Quality Control

The manufacturer shall have a documented quality control (QC) plan for the production of the selected building product. This QC plan shall be under the supervision of a member of the manufacturer's senior management team. The manager shall ensure that the QC plan provides for adequate supervision and control to be exercised at all stages and locations of manufacture so that the finished units are consistently produced. It may be necessary for the manufacturer to conduct in-plant quality control testing and/or perform other documented procedures to demonstrate continuing compliance.

# 8.7 Product Sample Selection

- 8.7.1 Guidelines are established herein for the selection of test samples by manufacturers and certification/verification organizations that intend to use the test results as the basis for a product-wide claim.
- 8.7.1.1 The manufacturer and certification/verification organization shall have a pre-defined, written sampling plan.
- 8.7.1.2 The manufacturer and certification/verification organization, as applicable, shall select the test sample from typical production operations. The sample shall be randomly selected from a production lot that is large enough to ensure that it is representative of the processes involved and of the quality that the manufacturer routinely introduces into the market.
- 8.7.1.3 The sample shall be in the condition in which it is offered for sale and shall not be a pre-production model or a sales sample.
- 8.7.1.4 If there are significant differences in manufacturing (e.g., different suppliers, variations among different plants, etc.) that may affect the emissions of VOCs from a product, then the sample shall be selected from the lot or group expected to give the worst results for the test. Preliminary testing may be needed to make this "worst-case" determination.

- 8.7.1.5 A range of product models, brands and/or styles with varying characteristics may be grouped together for testing purposes if the products can be expected to have virtually the same performance during testing and use. A test group shall only include models which are made using the same production methods and are comprised of the same product ingredients (formulation). The test sample shall be selected from the model in the group that can be expected to give the worst results for the test taking into consideration special attributes, materials, methods of manufacturing, suppliers, etc.
- 8.7.1.6 The manufacturer and/or a certification/verification organization, if applicable, shall document and maintain a record of the procedures used to select the test sample and, if applicable, the procedures used for the selection of a worst-case lot, group, or model in the form of calculations, test results, formulations, written explanations and other supportive data.

# 8.8 Retesting

The manufacturer or certification/verification organization shall establish the schedule for routine laboratory retesting of samples appropriate to provide representative products. Often, the minimum frequency is dictated by building rating systems that award credits for using products with low VOC emissions. Biennial or even annual retesting often is required. The full retesting of samples may be less frequent if a certification/verification organization implements a robust routine quality control testing program and demonstrates its equivalency to full test for the purpose of substantiating manufacturers' claims. Detailed evidence of such equivalency shall be documented. The documentation shall be available to program participants, the public and any other interested parties. In addition, changes in formulation, manufacturing process, or supplier that can alter the VOC emissions characteristics of a product shall trigger additional retesting to maintain the validity of a claim based on the method.

# APPENDIX A LIST OF STAKEHOLDER REVIEWERS

# Name

# Affiliation

Martin Bennett	Materials Analytical Services, LLC (MAS)
Anthony Bernheim	AECOM
Robert Blaisdell	Office of Environmental Health Hazard Assessment (OEHHA)
Charles D. Byers	USG Corporation
Randal Carter	Steelcase Inc.
Amy Costello	Armstrong World Industries, Inc.
Larry Dykhuis	Herman Miller
William Freeman	Resilient Floor Covering Institute (RFCI)
Phil Gattis	Community Playthings
Ken Gould	Owens Corning
Stowe Hartridge-Beam	Scientific Certification Systems (SCS)
Doug Hensel	California Dept. of Housing and Community Development
Al Hodgson	Berkeley Analytical
Pat Hooper	Hooper Associates
Frank Hurd	Carpet and Rug Institute (CRI)
Josh Jacobs	GREENGUARD Environmental Institute (GEI)
Peggy Jenkins	California Air Resources Board (CARB)
Richard Lam	Office of Environmental Health Hazard Assessment (OEHHA)
Tom Lent	Healthy Building Network
Hal Levin	Building Ecology Research Group
Stephany I. Mason	Air Quality Sciences, Inc. (AQS)
Ken McIntosh	Carpet and Rug Institute (CRI)
Reinhard Oppl	Eurofins Product Testing A/S
Bill Orr	Collaborative for High Performance Schools (CHPS)
Steve Pfeiffenberger	Armstrong World Industries, Inc.
Tom Phillips	California Air Resources Board (CARB)
Bruce Ray	Johns Manville (JM)
Robert Raymer	California Building Industry Association
Jan Stensland	Inside Matters
Raja Tannous	Berkeley Analytical
Steven Trinkel	Kimball International
Denise Van Valkenburg	MASCO RetailCabinetGroup
Anna Wechselberger	Haworth Inc
Stan Wolfersberger	Owens Corning

# APPENDIX B NEW SINGLE-FAMILY RESIDENCE SCENARIO

This is an informative appendix and not part of the required portion of this Standard Method. It is the intent of the CDPH-IAQ to further review and develop the Single Family Residence Scenario for inclusion in final form in Version 2.0 of the Standard Method.

Lack of residential scenario(s) is a major gap in the application of *Standard Practice* (2004). A preliminary new single-family residence model has been developed. It is based on the assumed dimensions of a median size new detached single-family home. The parameters that define the standard new single-family residence are listed in **Table B-1**. The surface areas of major product categories and unit quantities of other components in the standard new-single family residence are given in **Table B-2** along with the calculated correspondent area-specific air flow rates.

Parameter	Unit of Measure	Parameter Value
Floor area $(2,272-\text{ft}^2)^1$	m <sup>2</sup>	211
Ceiling height $(8.5 \text{ ft})^2$	m	2.59
Volume	m <sup>3</sup>	547
ASHRAE Outdoor air flow rate <sup>3</sup>	m <sup>3</sup> /h	127
Effective outdoor air change rate <sup>3</sup>	1/h	0.23
No. Bedrooms <sup>4</sup>	Unit	4
No. Full Baths <sup>4</sup>	Unit	2
No. Other Rooms <sup>4</sup>	Unit	3

**Table B-1**Definition of new single-family residence.

According to the NAHB consumer preference survey conducted in 2007, the 2.44-m (8-ft) and 2.74m (9-ft) ceiling height are most preferred by consumers. A 2.59-m (8.5-ft) average height is therefore assumed yielding a volume of 547 m<sup>3</sup> (19,310 ft<sup>3</sup>). Summary of the 2007 NAHB consumer preference survey results is accessible at <a href="http://www.nahb.org/fileUpload\_details.aspx?contentTypeID=3&contentID=51299&subContentID=137">http://www.nahb.org/fileUpload\_details.aspx?contentTypeID=3&contentID=51299&subContentID=137</a>

332.
3. The measured median outdoor air change rate (24-hr measurement) for homes without mechanical outdoor air ventilation systems is 0.26 h<sup>-1</sup> in a recent study with a randomly selected sample of 108 new CA homes (Offermann , 2009). The ventilation flow rate requirement is 127 m<sup>3</sup> h<sup>-1</sup> (75 cfm) using Table 4.1a or 102 m<sup>3</sup> h<sup>-1</sup> (60 cfm) using Equation 4.1a of ASHRAE Standard 62.2-2007. The higher value of 127 m<sup>3</sup> h<sup>-1</sup>, correspondent to an outdoor air change rate of 0.23 h<sup>-1</sup>, is used. It is close to the measured median outdoor air change rate for new CA homes.

4. Due to incomplete data, it is necessary to estimate the home configuration. The most frequent number of bedrooms is three, but many floor plans for homes of this size contain a fourth bedroom or a bedroom/den. Thus, the home is assumed to consist of four bedrooms, two full baths and three other rooms.

Statistics on new homes completed in the U.S. are published by the U.S. Census Bureau (U.S. Census Bureau, 2008). For 2008, the median size for new detached single-family homes is 206 m<sup>2</sup> (2,215 ft<sup>2</sup>). The Buildings Energy Data Book, Table 2.2.10 (U.S. DOE, 2008) summarizes data from the National Association of Home Builders (NAHB) on the materials used in the construction of a 211 m<sup>2</sup> (2,272-ft<sup>2</sup>) single family home in 2000. The home in 2000 is selected for this scenario since it has associated material quantities and is nearly identical to the median 2008 home.

Product Type	Area or Quantity <sup>1</sup>		Area Specific Air Flow Rate	
Flooring (all types) <sup>2</sup>	$m^2$	211	m/h	0.602
Ceiling	$m^2$	217	m/h	0.585
Walls & wallcoverings	$m^2$	562	m/h	0.226
Interior wallboard paint <sup>3</sup>	$m^2$	779	m/h	0.163
Thermal insulation <sup>4</sup>	$m^2$	284	m/h	0.447
Acoustic insulation	$m^2$	343	m/h	0.370
(comprehensive acoustic				
upgrade) <sup>5</sup>				
Windows <sup>6</sup>	unit/m <sup>2</sup>	19/38.0	m/h	3.34
Exterior doors <sup>7</sup>	unit/m <sup>2</sup>	4/7.56	m/h	16.8
Interior doors <sup>8</sup>	unit/m <sup>2</sup>	12/37.2	m/h	3.41
Closet doors <sup>9</sup>	unit/m <sup>2</sup>	6/44.6	m/h	2.85

**Table B-2**Product quantities and specific air flow rates to be used for estimation of VOC<br/>concentrations in standard new single-family residence.

1. Material areas or quantities are taken from the Buildings Energy Data Book (U.S. DOE, 2008) accessible at <u>http://buildingsdatabook.eren.doe.gov/</u>.

- 2. In reference to this interim update, 100% coverage (211 m<sup>2</sup>) shall be used as the default parameter for modeling residential floorings. We recognize that some stakeholders have proposed that representative coverage rates may be appropriate to account for partial coverage of specific flooring types. For example, product usage data has been published by NAHB (NAHB 2008 Builder Practices Report); the material quantities used in the construction of new homes in 2008 (as a percentage of total finished floor areas) are given for carpets (52%), hardwood (20%), ceramic tile (16%), vinyl (9%) and other flooring types. Material areas for specific flooring types and their impact on indoor concentration will be evaluated and considered in the next update.
- 3. The value is calculated as sum of ceiling and wall area.
- 4. 284 m<sup>2</sup> is sum of ceiling and wall thermal insulations. Material area for ceiling insulation and material area for wall insulation will be listed separately as subcategories in next document update if there are published scientific literatures to determine these numbers.
- 5. For optional comprehensive acoustic upgrade only. The value is calculated as sum of insulation required for partition walls and floors.
- 6. The surface area is estimated for a window-to-floor area ratio of 18%, assuming the total window area is three times of the openable window area and using the measured median openable window area/floor area of 0.06 taken from the recent CA home study (Offermann, 2009).
- 7. The surface area is estimated for  $1.89 \text{ m}^2/\text{door}$  (one side), interior surface exposed.
- 8. The surface area is estimated for  $1.55 \text{ m}^2/\text{door}$  (one side), both faces exposed.
- 9. The surface area is estimated for  $3.72 \text{ m}^2/\text{door}$  (one side), both faces exposed.
- 10. Usage of 15 kitchen cabinets and 5 other cabinets is also reported in the Buildings Energy Data Book (U.S. DOE, 2008), which corresponds to unit specific flow rate of 8.47 m<sup>3</sup>/h and 25.4 m<sup>3</sup>/h for kitchen cabinets and other cabinets, respectively. Material areas and area specific flow rates for cabinetry will be determined in next document update.



# 中华人民共和国国家标准

GB 18584—×××× 代替 GB 18584-2001

# 木家具中挥发性有机物质及重金属迁移限 量

Limit of volatile organic compounds and migration of heavy metal of wood based furniture

点击此处添加与国际标准一致性程度的标识

(报批稿)

(本稿完成日期: 2014-06-10)

xxxx-xx-xx发布

××××- ××- ××**实**施

# 中华人民共和国国家质量监督检验检疫总局 发布 田国家标准化管理委员会 发布

# 目 次

前	言	Ι
1	范围	
2	规范性引用文件	
3	术语和定义	
4	要求	
5	试验方法	
6	检验规则	
附	录A(规范性附录) 木家具外形轮廓体积计算	
参	考文献	

言 前

本标准的第4章、第5章为强制性,其余为推荐性。

本标准按照GB/T 1.1-2009给出的规则起草。

本标准代替GB 18584-2001《室内装饰装修材料 木家具中有害物质限量》,与GB 18584-2001相比, 主要技术变化如下:

一一修改了木家具中甲醛释放量的限量要求及试验方法;

——增加了苯、甲苯、二甲苯、TVOC 的限量要求及试验方法;

——修改了可迁移元素的试验方法;

——增加了附录 A;

——增加了参考文献。

请注意本文件的某些内容可能涉及专利。本文件的发布机构不承担识别这些专利的责任。

本标准由中国轻工业联合会提出。

本标准由全国家具标准化技术委员会(SAC/TC 480)归口。

本标准主要起草单位:上海市质量监督检验技术研究院、深圳市计量质量检测研究院、国家家具及 室内环境质量监督检验中心、成都市产品质量监督检验院、浙江省家具与五金研究所、广东产品质量监 督检验研究院、广东联邦家私集团有限公司、深圳市华源轩家具股份有限公司、深圳市圆方园实业发展 有限公司、上海菲林格尔木业股份有限公司、亚振家具股份有限公司、湖南星港家居发展有限公司、深 圳市大富豪实业发展有限公司。

本标准参加起草单位:清华大学、浙江圣奥家具制造有限公司、北京黎明文仪家具有限公司、廊坊 华日家具股份有限公司、成都市全友家私有限公司、好孩子儿童用品有限公司、上海科绿特环境科技有 限公司、广东巴德士化工有限公司、深圳天诚家具有限公司、上海杰天装饰材料有限公司、博洛尼家居 用品(北京)有限公司、吉林森林工业股份有限公司、左尚明舍家居用品(上海)有限公司、班尔奇家 具(上海)有限公司、索菲亚家居股份有限公司、佛山市南海金富轩家具有限公司、君子兰化工(上海) 有限公司、佛山市南海区狮山百川涂料制造有限公司、广州市永特耐木胶贸易有限公司、佛山市金天拓 家私有限公司。

本标准主要起草人: 张晓杰、古鸣、罗菊芬、张淑艳、罗炘、李隆平、梁米加、张莺红、姚晨岚、 海凌超、周山林、陈碧煌、庄日光、李松、曹永宏、徐建民、张寅平、何循证、倪良正、黎胜国、周旭 恩、张友全、邹宇、张福基、严修才、郑书胜、叶建兵、钱立民、刘泽华、吴伟杰、程少阶、王庆生、 黄显明、朱金水。

本标准代替标准历次版本发布情况为:

-----GB 18584-2001.

# 木家具中挥发性有机物质及重金属迁移限量

## 1 范围

本标准规定了木家具中甲醛、苯、甲苯、二甲苯、TV0C等挥发性有机物和重金属迁移限量要求、试验方法和检验规则。

本标准适用于室内用木家具中挥发性有机物和可迁移重金属的检测和评价。

## 2 规范性引用文件

下列文件对于本文件的应用是必不可少的。凡是注日期的引用文件,仅注日期的版本适用于本文件。 凡是不注日期的引用文件,其最新版本(包括所有的修改单)适用于本文件。

GB 6675.4-2014 玩具安全 第4部分:特定元素的迁移GB/T 31106-2014 家具中挥发性有机化合物的测定GB/T 31107 家具中挥发性有机物化合物检测用气候舱通用技术条件

#### 3 术语和定义

GB/T 31106-2014、GB/T 31107界定的以及下列术语和定义适用于本文件。

#### 3.1

#### 气候舱舱容 volume of test chamber

气候舱空载时,舱内参与空气交换的总容积。用v表示。注:舱内照明设备、传感器等所占空间不计。

3.2

**体积承载率 volume loading factor** 木家具外形轮廓体积与气候舱舱容的比值。 用*a*表示。

# 3.3

**背景浓度** background concentration 气候舱空载时,舱内空气的甲醛和苯、甲苯、二甲苯、TVOC浓度。

3.4

**空气交换率** air exchang rate 单位时间内进入气候舱的清洁空气量与气候舱舱容的比。 用加表示。

# 3.5

# 空气流速 air velocity

气候舱空载时,舱内空气的流动速度。

#### 3.6

# 甲醛释放量 Formaldehyde emission by the chamber method

按本标准第5章规定的气候舱法测定的木家具试件向空气中释放的甲醛浓度。

# 3.7

# **可迁移重金属含量** soluble heavy metal's content 木家具表面涂层中通过规定的试验方法测得的可迁移元素铅、镉、铬、汞重金属的含量。

# 4 要求

# 4.1 木家具中甲醛和苯、甲苯、二甲苯、TVOC 限量

应符合表1的规定。

表1 木家具中甲醛和苯、甲苯	🖞、二甲苯、 IVOC 限量
----------------	----------------

项目	限量值(mg/m³)
甲醛释放量	≪0.10
苯	≪0.11
甲苯	≪0. 20
二甲苯	≤0.20
TVOC	≪0.60

# 4.2 木家具中可迁移重金属限量

应符合表2的规定。

# 表2 木家具中可迁移重金属限量

项目	限量值 (mg/kg)
铅	≪90
镉	≤75
铬	≤60
汞	≤60

# 5 试验方法

#### 5.1 试验原理

#### 5.1.1 木家具中甲醛和苯、甲苯、二甲苯、TVOC 试验原理

将样品按照规定的体积承载率放入气候舱内,模拟样品使用环境条件进行试验。当达到规定时间后, 采集舱内空气,通过规定的试验方法测定其甲醛和苯、甲苯、二甲苯、TVOC浓度。

#### 5.1.2 木家具中可迁移重金属含量试验原理

用机械刮削方法从样品表面刮取涂层,将涂层溶解在酸性溶液中,模拟涂层材料在吞咽后与胃酸发 生反应,通过化学分析方法测定溶液中可迁移铅、镉、铬、汞的含量。

# 5.2 试验设备

#### 5.2.1 气候舱

应符合GB/T 31107的规定。

# 5.2.2 采样仪器和设备

应符合 GB/T 31106-2014 中 4.1.3 的规定。

# 5.2.3 可迁移重金属试验试剂和仪器

应符合GB 6675.4-2014中第6章的规定。

#### 5.3 试验程序

#### 5.3.1 甲醛及苯、甲苯、二甲苯、TVOC 试验

#### 5.3.1.1 计算样品外形轮廓体积

按附录 A 的规定计算样品外形轮廓体积。当样品可调时,按样品可调体积的最小值计算。

5.3.1.2 预处理

试验前,组装产品、折叠产品、可调产品应按最有利于有害物质释放的样式进行组装、打开、调节, 一般按产品整件进行预处理,产品的所有部件表面应尽可能暴露在预处理环境中。

预处理时间为(120±2)h。

预处理环境条件为:

- ——温度(23±2)℃;
- ——相对湿度(45±10)%;
- ——样品间的距离不小于 300mm;
- ——样品间的甲醛浓度≤0.10mg/m<sup>3</sup>, TVOC≤0.60mg/m<sup>3</sup>。

# 5.3.1.3 气候舱选择

气候舱的体积承载率应满足(0.075~0.3)的范围,并按体积承载率最接近0.15的原则选择合适的 气候舱。设定样品体积承载率等于0.15时,空气交换率为1(即1h内进入气候舱的清洁空气量与气候舱 容积相等);当样品体积承载率不等于0.15时,按下列公式计算空气交换率: 式中:

- *n*——空气交换率,精确至0.01;
- Q——单位时间(h)内进入气候舱的清洁空气量,单位为立方米(m<sup>3</sup>/h);
- V ——气候舱舱容, 单位为立方米 (m<sup>³</sup>);

a——样品体积承载率。

#### 5.3.1.4 背景浓度的测定

应在样品放入气候舱前1h内采集舱内空气,按GB/T 31106-2014中的规定进行测定并记录甲醛和苯、 甲苯、二甲苯、TVOC的浓度。背景浓度应满足:甲醛≤0.006mg/m<sup>3</sup>,苯、甲苯、二甲苯均≤0.005mg/m<sup>3</sup>,TVOC ≤0.05mg/m<sup>3</sup>。

#### 5.3.1.5 甲醛和 VOC 的采集

样品预处理后,应在1h内放入气候舱内开展试验。组装产品、折叠产品、可调产品应按最有利于有 害物质释放的样式进行组装、打开、调节,一般按产品整件进行测试,产品所有活动部件表面应尽可能 暴露在气候舱内。

试验期间,气候舱内试验条件应满足:

- ----温度(23±2)℃;
- ----相对湿度(45±5)%;
- ----空气交换率, 按式(1)计算;
- ----空气流速(0.1~0.3)m/s;

----进给空气中甲醛和苯、甲苯、二甲苯、TVOC浓度:甲醛≤0.006mg/m<sup>3</sup>,单个VOC≤0.005mg/m<sup>3</sup>,TVOC ≤0.05mg/m<sup>3</sup>;

样品放入气候舱内(20±0.5)h后,按GB/T 31106-2014中的规定进行空气采样,1h内完成。

#### 5.3.1.6 甲醛和苯、甲苯、二甲苯、TVOC 的测定

应按GB/T 31106-2014中的规定进行。仲裁检验时,甲醛分析采用该标准中规定的酚试剂分光光度法。

#### 5.3.2 可迁移重金属试验

#### 5.3.2.1 涂层部位的选择

应从样品表面选择涂层部位。如有多种颜色的涂层,每一种涂层都应进行试验,以每种可迁移重金 属检出最大值进行分析校正。

# 5.3.2.2 涂层部位的制备和提取

按GB 6675.4-2014中8.1的规定。

#### 5.3.2.3 可迁移重金属含量测定

按GB 6675.4-2014中第9章的规定。

#### 5.4 试验结果的表示

#### 5.4.1 甲醛释放量

样品的甲醛释放量按下列公式计算:

$$C_f = C_{f_c} - C_{0f} \quad \dots \qquad (2)$$

式中:

 $C_{f}$ ——样品的甲醛释放量,单位为毫克每立方米 (mg/m<sup>3</sup>);

 $C_{fc}$ ——试验后气候舱内空气中的甲醛浓度,单位为毫克每立方米 (mg/m<sup>3</sup>);

 $C_{0f}$ ---甲醛背景浓度,单位为毫克每立方米 (mg/m<sup>3</sup>)。

# 5.4.2 VOC 释放量

样品的VOC释放量按下列公式计算:

 $C_{\nu} = C_{\nu c} - C_{0\nu}$  (3)

式中:

 $C_n$ ——样品的苯、甲苯、二甲苯、TVOC释放量,单位为毫克每立方米 (mg/m<sup>3</sup>);

 $C_{vc}$ ----试验后气候舱内空气中的苯、甲苯、二甲苯、TVOC浓度,单位为毫克每立方米 (mg/m<sup>3</sup>);  $C_{0v}$ --- 苯、甲苯、二甲苯、TVOC背景浓度,单位为毫克每立方米 (mg/m<sup>3</sup>)。

# 5.4.3 可迁移重金属含量分析校正

样品的可迁移重金属含量结果的分析校正应符合 GB 6675.4-2014 中 4.2 的规定。

# 6 检验规则

#### 6.1 试验顺序

应先进行甲醛和苯、甲苯、二甲苯、TVOC试验,然后进行可迁移重金属试验。

# 6.2 检验结果的判定

当按照第4章所列项目检验合格时,判定该项目合格;全部项目合格时,判定该样品的有害物质限 量合格。如果存在任何一项不合格,判定该样品有害物质限量不合格。

#### 6.3 复验

木家具中甲醛和VOC检验不应复验。

当对可迁移性重金属检验结果存在异议时,可进行复验。应对原样品进行复验,在检验报告中注明 "复验合格"或"复验不合格"。

# 附 录 A (规范性附录) 木家具外形轮廓体积计算

#### A.1 测量仪器

钢直尺或卷尺,精确度不低于1mm。如采用面积测定仪,精确度应不低于1mm<sup>2</sup>。

# A.2 各类木家具外形轮廓体积计算方法

#### A.2.1 柜类家具

测量柜类家具的最大水平投影面积和最大外形高度,计算两者的乘积作为柜类家具的外形轮廓体积。

#### A.2.2 桌类家具

测量桌类家具的最大水平投影面积和最大外形高度,计算两者的乘积作为桌类家具的外形轮廓体积。

#### A.2.3 椅类家具

测量座面的最大水平投影面积和座面最大高度,计算两者的乘积作为椅类家具的外形轮廓体积。椅背和扶手的体积忽略不计。

# A.2.4 凳类家具

测量凳面的最大水平投影面积和凳面最大高度,计算两者的乘积作为凳类家具的外形轮廓体积。

# A.2.5 床类家具

测量床铺面的最大水平投影面积和铺面高度,计算两者的乘积作为床类家具的外形轮廓体积。高出 铺面的床板体积忽略不计。

# 参考文献

[1] ISO 16000-9: 2004 Indoor air-Part 9:Determination of the emission of volatile organic compounds from building products and furnishing-Emission test chamber method

[2] ENV 717-1: 2004 Wood-based panels-Determination of formaldehyde release-Part 1:Formaldehyde emission by the chamber method

[3] ASTM E1333:1996(2002) Standard test method for determining formaldehyde concentrations in air and emission rates from wood products using a large chamber

[4] RAL-UZ38:2002 Low-emission wood products and wood-base products

[5] BIFMA M7.1-2005 Standard test method for determining VOC emissions from office furniture systems, components and seating