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Compilation and Analysis of Types and Concentrations of Airborne Chemicals Measured in Various Indoor and Outdoor Human Environments

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Running head: Airborne Chemical Concentrations Indoors and Outdoors

Abstract

The main purpose of this article is to summarize and illustrate the results of a literature search on the types, levels, relative concentrations, concentration spread of individual chemicals, and number of airborne compounds (mostly volatile organic compounds, VOCs) that have been found, measured, and reported both indoors and outdoors. Two broad categories of indoor environments are considered: 1) Home/School, and 2) Commercial spaces. Also, two categories of outdoor environments are considered: 1) Non-industrial and 2) Industrial (the latter represented by the vicinity of a pig farm and the vicinity of an oil refinery). The outcome is presented as a series of graphs and tables containing the following statistics: geometric mean, arithmetic mean, median, standard deviation, variance, standard error, interquartile distance, minimum value, maximum value, and number of data (data count) for the air concentration of each reported compound in a given environment. A Supplementary Table allows interested readers to match each single value included in this compilation with its corresponding original reference.

Keywords: Environmental Chemical Exposures - Volatile Organic Compounds (VOC) – Home/School VOC Concentrations – Commercial Buildings VOC Concentrations – Outdoor VOC Concentrations

1. Introduction

Humans are exposed to a wide variety of airborne chemicals both indoors and outdoors. Acute awareness of such exposures often arises from chemosensory sensations, principally odor, nasal chemesthesis (i.e., nasal pungency or irritation), and ocular chemesthesis (i.e., eye irritation). These human chemosensations are the focus of our research interest (Cometto-Muniz and Abraham, 2008, 2010a; Cometto-Muñiz et al., 2010), with special emphasis on the search for quantitative structure-activity relationships in terms of detection thresholds (Abraham et al., 2003; Abraham et al., 2007, 2012; Abraham et al., 2010; Cometto-Muniz and Abraham, 2010b; Cometto-Muniz et al., 2005). In general, no matter what the particular focus might be for the study of environmental chemical exposures, previous knowledge of the kind and levels of airborne compounds that have been found in different types of broad environments constitute an important piece of information. This reasoning led us to mine the scientific literature for data on the types and concentration-ranges of airborne chemicals that have been found and measured in indoor and outdoor environments. The questions addressed include: What compounds have been found in various types of indoor and outdoor environments? At what concentrations where they found? Which compounds are common to different indoor environments and which to different outdoor environments? Which compounds are common between indoor and outdoor environments? For compounds common to two environments, in which are they higher and by what concentration ratio? What spread of concentrations have been reported for a given compound within and across these various environments? This compilation presents the gathered data in the form of illustrative graphs and tables and can serve as a useful and practical information guide for a wide range of investigators interested in the many aspects of the topic.

2. Materials and Methods

Two main databases were used to collect data: PubMed (<http://www.ncbi.nlm.nih.gov/pubmed>) and Web of Knowledge (<https://apps.webofknowledge.com>). The search terms entered alone and in combination included, among others: “Air Pollution”, “Air Pollution, Indoor”, “Volatile Organic Compounds”, “Environmental Exposure”, “VOC levels”. Some of these terms were searched on PubMed via the MeSH (Medical Subject Headings) from the NLM (National Library of Medicine) controlled vocabulary thesaurus. From this literature search, 47 references were selected by focusing on those articles tracking a large number of volatiles, typically more than a dozen, and by filtering the results by “Species: Humans”. The set contained quantitative data on the concentration and identity of volatile organic compounds (VOCs), and other airborne chemicals, present in a variety of indoor and outdoor environments. The geographical distribution of the studies was very broad. It included areas and cities in the United States, European Union (north, central and south countries), Japan, China (Hong Kong), Taiwan, Korea, Australia and Argentina (La Plata). The references are listed at the end of this article under the title “Data Sources References”, but readers interested in consulting the specific citation for each single value used in this compilation can do so in a Supplementary Table accessible on the web. These papers constituted the source to calculate the following statistics: geometric mean, arithmetic mean, median, standard deviation, variance, standard error, interquartile distance, minimum value, maximum value, and number of data (data count) for the air concentration of each reported compound in a given environment. The values presented immediately below are geometric means across studies that measured a particular compound in a specific environment (Tables 1 to 4, and Figures 1 to 6). In fact, as a rule, each value reported in a given study was itself an average of a number of measurements. In this review, initial selection of the geometric mean served to minimize the excessive weight on the mean of occasional extreme high or low individual values. Further into the article, when analyzing the range of values reported for each chemical in specific environments (Tables 5 to 7, and Figures 7 to 8), the rest of the statistical parameters mentioned above are introduced.

109

110 3. Results and Discussion

111

112 3.1. Indoors

113

114 Indoor environments comprised two broad categories: 1) Home and School, and 2) Commercial.

115 The first category included homes new and old, with and without air quality complaints, homes and

116 schools located in industrial, urban, suburban, residential, semi-rural and rural environments. The second

117 category included car cabins, restaurants (non-smoking, smoking, and both), stores, non-residential

118 spaces (offices and non-offices) and newspaper stands. It did NOT include the air inside a pig farm's

119 fattening house.

120

121 In the home/school environments, 152 volatiles were measured and reported (Figure 1, left side).

122 22 of them (14%) were present at concentrations ranging from approximately 10 to 200 $\mu\text{g}/\text{m}^3$. 44

123 compounds (29%) were present at concentrations ranging from about 3 to 10 $\mu\text{g}/\text{m}^3$. Another 44

124 substances (29%) were present at concentrations ranging from 0.55 to about 3 $\mu\text{g}/\text{m}^3$. The remaining 42

125 chemicals (28%) were present at concentrations ranging from 0.01 to about 0.55 $\mu\text{g}/\text{m}^3$.

126

Figure 1. Comparison of VOC concentrations (geometric means) measured in two types of indoor environments: Home/School and Commercial.

In the commercial environments, 96 volatiles were measured and reported (Figure 1, right side). 22 of them (23%) were present at concentrations ranging from approximately 8 to 1,000 $\mu\text{g}/\text{m}^3$. 44 compounds (46%) were present at concentrations ranging from about 2 to 7 $\mu\text{g}/\text{m}^3$. The remaining 29 substances (30%) were present at concentrations ranging from 0.30 to about 2 $\mu\text{g}/\text{m}^3$.

There were 74 measured compounds common to both indoor environments: home/school and commercial (Figure 2 and Table 1). Of those, 32 (43%) were higher in home/school, 40 (54%) were higher in commercial, and the remaining 2 were present at similar levels in both environments. From those chemicals higher in home/school environments, only 2 were higher by a factor (i.e., ratio) larger than 10: 1-butanol (factor of 25) and trichloroethene (factor of 12), and just one was higher by a factor between 5 and 10: nonanal (factor of 6.0). The other 29 chemicals were higher by smaller factors ranging from 1.1 to 4.6. In contrast, from those chemicals higher in commercial environments, 5 were higher by factors larger than 10: tetrachloroethylene (factor of 68), 1,2,4-trichlorobenzene (58), tetrahydrofuran (19), 1,3-dichlorobenzene (17), and 1,3,5-trimethylbenzene (13), and as many as 7 were higher by factors between 5 and 10: trichloroethylene (factor of 9.7), 3-ethenylpyridine (8.2), 1,2-dibromoethane (7.1), 1,1,1-trichloroethane (6.2), ethanol (5.2), acetone (5.1), and 1,2-dichlorobenzene (5.1). The remaining 28 chemicals were higher by smaller factors ranging from 1.2 to 4.8.

Figure 2. Comparison of concentrations (geometric means) for indoor VOCs found in common between Home/School and Commercial environments.

149 **Table 1.** Comparison of vapor concentration levels for indoor volatile compounds common to
150 Home/School and Commercial environments (ratios based on geometric means). Compounds are listed in
151 descending magnitude of ratio. **Bolded** chemicals were higher in their respective environment by a ratio
152 (i.e., factor) larger than 10.
153

Volatiles higher in Home/School environments	Ratio	Volatiles higher in Commercial environments	Ratio
1-Butanol	25	Tetrachloroethylene	68
Trichloroethene	12	1,2,4-Trichlorobenzene	58
Nonanal	6.0	Tetrahydrofuran	19
Methyl isobutyl ketone (MIBK)	4.6	1,3-Dichlorobenzene (m-Dichlorobenzene)	17
Methyl tert-butyl ether (MTBE)	3.9	1,3,5-Trimethylbenzene	13
Acetic acid	3.7	Trichloroethylene	9.7
Trichlorofluoromethane (Freon 11)	3.7	3-Ethenylpyridine (3-Vinylpyridine)	8.2
Formaldehyde	3.6	1,2-Dibromoethane	7.1
n-Decane	3.3	1,1,1-Trichloroethane	6.2
Xylene(s)	2.8	Ethanol	5.2
alpha-Pinene	2.8	Acetone	5.1
Limonene	2.7	1,2-Dichlorobenzene (o-Dichlorobenzene)	5.1
1,4-Dichlorobenzene (p-Dichlorobenzene)	2.4	1,3-Butadiene	4.8
Naphthalene	2.3	1,1,2,2-Tetrachloroethane	4.8
n-Butyl acetate	2.2	3-Ethyltoluene (m-Ethyltoluene)	4.4
1,1-Dichloroethene	2.2	Chloroform	4.1
n-Hexane	2.1	Bromomethane	3.9
Ammonia	2.0	Methyl ethyl ketone (MEK)	3.8
Methylcyclohexane	1.9	Toluene	3.0
n-Heptane	1.7	Isoprene	2.4
n-Undecane	1.7	Dodecane	2.3
Benzaldehyde	1.7	1,1-Dichloroethane	2.2
Propanal	1.5	o-Xylene	2.1
4-Ethyltoluene (p-Ethyltoluene)	1.5	2-Butanone	2.0
Carbon tetrachloride	1.5	Benzene	1.9
Acetaldehyde	1.4	1,2-Dichloroethane	1.9
Hexanal	1.3	Vinyl chloride	1.9
n-Octane	1.2	p-Xylene	1.8
Dichlorodifluoromethane	1.1	Hexachlorobutadiene	1.8
Cyclohexane	1.1	m/p-Xylene	1.7
Phenol	1.1	Ethylbenzene	1.6
1,2,3-Trimethylbenzene	1.1	Styrene	1.6
Hexanoic acid	1.0	Benzyl chloride	1.6
		1,1,2-Trichloroethane	1.4
		Ethylacetate	1.3
		1,2,4 Trimethylbenzene	1.3
		Methylchloride (Chloromethane)	1.3
		Chlorobenzene	1.2
		Methylene chloride	1.2
		1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	1.2
Total: 33		Total:40	

154

155

156   When analyzed in terms of chemical families, the commercial environments had, in general, higher
157 concentrations and numbers of halogenated aromatics, halogenated aliphatics, non-halogenated
158 aromatics, and ketones, whereas the home/school environments had higher concentrations and numbers
159 of carboxylic acids, aldehydes, lineal aliphatics, and cyclic aliphatics (Table 2).

160

160 Table 2. List of volatiles, sorted by chemical type, found at higher concentrations (geometric means) in
 161 each of the two Indoor environments selected. **Bolded** chemicals were higher in their respective
 162 environment by a factor (i.e., ratio) larger than 10.
 163

Volatiles higher in Home/School environment	Volatiles higher in Commercial environment
	Halogenated Aromatics
1,4-Dichlorobenzene (p-Dichlorobenzene)	Chlorobenzene
	Benzyl chloride
	1,2-Dichlorobenzene (o-Dichlorobenzene)
	1,2,4-Trichlorobenzene
	1,3-Dichlorobenzene (m-Dichlorobenzene)
	Halogenated Aliphatics
Trichlorofluoromethane (Freon 11)	1,1,1-Trichloroethane
Dichlorodifluoromethane	Hexachlorobutadiene
Trichloroethene	Methylchloride (Chloromethane)
1,1-Dichloroethene	Methylene chloride
Carbon tetrachloride	1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)
	Chloroform
	1,1,2-Trichloroethane
	1,1,2,2-Tetrachloroethane
	1,1-Dichloroethane
	Trichloroethylene
	1,2-Dichloroethane
	Bromomethane
	Tetrachloroethylene
	Vinyl chloride
	1,2-Dibromoethane
	Non-Halogenated Aromatics
Xylene(s)?	Toluene
Benzaldehyde	p-Xylene
4-Ethyltoluene (p-Ethyltoluene)	m/p-Xylene
Naphthalene	1,2,4 Trimethylbenzene
Phenol	Benzene
1,2,3-Trimethylbenzene	Ethylbenzene
	o-Xylene
	3-Ethyltoluene (m-Ethyltoluene)
	Styrene
	3-Ethenylpyridine (3-Vinylpyridine)
	1,3,5-Trimethylbenzene
	Carboxylic Acids
Acetic acid	
Hexanoic acid	
	Aldehydes
Formaldehyde	
Acetaldehyde	
Nonanal	
Propanal	
Hexanal	
(Benzaldehyde)	
	Ketones
Methyl isobutyl ketone (MIBK)	Acetone
	Methyl ethyl ketone (MEK)
	2-Butanone
	Alcohols
1-Butanol	Ethanol

Volatiles higher in Home/School environment	Volatiles higher in Commercial environment
n-Butyl acetate	Esters Ethylacetate
Methyl tert-butyl ether (MTBE)	Ethers Tetrahydrofuran
n-Decane	Lineal Aliphatics Dodecane
n-Heptane	Isoprene
n-Undecane	1,3-Butadiene
n-Hexane	
n-Octane	
Limonene	Cyclic Aliphatics (Tetrahydrofuran)
Alpha-Pinene	
Methylcyclohexane	
Cyclohexane	
	Inorganic
Ammonia	

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165

165

166 3.2. Outdoors

167

168 Outdoor environments comprised two broad categories: 1) Non-industrial and 2) Industrial. The
169 non-industrial environments included urban, residential, and semi-rural spaces. The industrial
170 environments did include the cases of the air in the vicinity of a pig farm and in the vicinity of an oil
171 refinery.

172

173 In the air of non-industrial environments, 54 volatiles were measured and reported (Figure 3, left
174 side). 30 of them (56%) were present at concentrations ranging from 0.80 to 12 $\mu\text{g}/\text{m}^3$. The remaining 24
175 compounds (44%) were present at concentrations ranging from 0.02 to 0.71 $\mu\text{g}/\text{m}^3$.

176

Outdoor Non-industrial

Outdoor Industrial

Figure 3. Comparison of VOC concentrations (geometric means) measured in two types of outdoor environments: Non-industrial and Industrial.

179

180   In industrial environments (including the vicinity of the pig house), 45 volatiles were measured and
181 reported (Figure 3, right side). 30 of them (67%) were present at concentrations ranging from 3.3 to 108
182 $\mu\text{g}/\text{m}^3$. The remaining 15 compounds (33%) were present at concentrations ranging from 0.10 to 3.1
183 $\mu\text{g}/\text{m}^3$.

184

185   There were 23 measured compounds common to both outdoor environments: non-industrial and
186 industrial (Figure 4 and Table 3). All of them but one (ethanol) were higher in the industrial environment.
187 Ethanol was higher in the non-industrial environment by a factor (i.e., ratio) of 2.5. The other 22 chemicals
188 were higher in the industrial environment by factors ranging from 1.3 to 403. From these, 2 substances
189 were higher by a factor larger than 100: trichloroethylene (factor of 403) and phenol (317); 4 substances
190 were higher by a factor larger than 10: hexanal (18), 1-butanol (17), n-hexane (12), and tridecane (11);
191 and 5 substances were higher by a factor between 5 and 10: n-heptane (7.3), benzene (6.3),
192 ethylbenzene (6.0), nonane (5.7), and n-octane (5.1). The remaining 11 substances were higher by
193 smaller factors ranging from 1.3 to 4.8.

194

195

196 Figure 4. Comparison of concentrations (geometric means) for outdoor VOCs found in common between Non-
197 industrial and Industrial environments.

198

199

199 Table 3. Comparison of vapor concentration levels for outdoor volatile compounds common to Non-
200 industrial and Industrial environments (ratios based on geometric means). Compounds are listed in
201 descending magnitude of ratio. **Bolded** chemicals were higher in their respective environment by a ratio
202 (i.e., factor) larger than 10.
203

Volatiles higher in Non-industrial environments	Ratio	Volatiles higher in Industrial environments	Ratio
Ethanol	2.5	Trichloroethylene	403
		Phenol	317
		Hexanal (Hexaldehyde)	18
		1-Butanol	17
		n-Hexane	12
		Tridecane	11
		n-Heptane	7.3
		Benzene	6.3
		Ethylbenzene	6.0
		Nonane	5.7
		n-Octane	5.1
		n-Decane	4.8
		m/p-Xylene	4.6
		n-Dodecane	4.4
		Toluene	4.0
		n-Undecane	3.5
		p-Ethyltoluene (4-Ethyltoluene)	3.2
		2-Ethyltoluene (o-Ethyltoluene)	3.2
		Styrene	2.5
		3-Ethyl-toluene (m-Ethyltoluene)	1.8
		o-Xylene	1.4
		Naphthalene	1.3

204

205

205

206 3.3 Indoor vs. Outdoor

207

208 All indoor environments were combined and compared with the combined outdoor environments.

209 There were a total of 175 compounds reported and measured indoors (Figure 5, left side). 32 of them

210 (18%) were present at concentrations ranging from 8 to 267 $\mu\text{g}/\text{m}^3$. Another 57 compounds (33%) ranged

211 from 2 to 8 $\mu\text{g}/\text{m}^3$. Next, 59 compounds (34%) ranged between 0.50 and 2 $\mu\text{g}/\text{m}^3$. Finally, 27 compounds

212 (15%) ranged between 0.01 and 0.5 $\mu\text{g}/\text{m}^3$.

213

INDOOR

OUTDOOR

INDOOR

OUTDOOR

Figure 5. Comparison of VOC concentrations (geometric means) measured Indoors and Outdoors.

There were a total of 76 compounds reported and measured outdoors (Figure 5, right side). 19 of them (25%) were present at concentrations ranging from 7 to 108 $\mu\text{g}/\text{m}^3$. Another 15 compounds (20%) ranged from 2 to 6 $\mu\text{g}/\text{m}^3$. Next, 24 compounds (32%) ranged from 0.50 to 2.0 $\mu\text{g}/\text{m}^3$. Finally, 18 compounds (24%) ranged from 0.02 to 0.50 $\mu\text{g}/\text{m}^3$.

There were 58 measured compounds in common to both indoor and outdoor environments (Figure 6 and Table 4). Of those, only 11 (19%) were higher outdoors whereas 44 (76%) were higher indoors and 3 (5%) were at about the same concentration outdoors and indoors. Those at the same concentration were: benzene (at 3.4 $\mu\text{g}/\text{m}^3$), carbon tetrachloride (at 0.5 $\mu\text{g}/\text{m}^3$), and methyl benzoate (at 0.3 $\mu\text{g}/\text{m}^3$). From the 11 compounds that were higher outdoors, two were higher by a factor (i.e., ratio) greater than ten: pentanal (factor of 30) and methylcyclopentane (21). Another two were higher outdoors by a factor between 5 and 10: 2-methyl-1-propanol (factor of 6.6) and the “xylenes” (no specification of isomer in the original sources) (factor of 6.2). The other 7 compounds were higher outdoors by smaller factors ranging from 1.1 to 2.1. Curiously, 5 of the 11 compounds that were higher outdoors than indoors were derivatives of pentane: n-pentane, isopentane, pentanal, methylcyclopentane, and 2-methylpentane. From the 44 compounds that were higher indoors, 14 were higher by a factor between 10 and 150: methyl isobutyl ketone (factor of 152), isopropanol (91), ethanol (45), isobutyl acetate (33), p-dichlorobenzene (29), limonene (25), dodecane (24), beta-pinene (21), 1-butanol (19), tridecane (18), styrene (17), naphthalene (15), alpha-pinene (14), and 1,2,4-Trimethylbenzene (13). 7 compounds were higher indoors by a factor between 5 and 10: chloroform (factor of 8.8), butyl acetate, (8.6), n-nonane (8.1), cyclohexanol (7.0), n-undecane (6.2), acetone (5.8), and ethyl acetate (5.3). The other 23 compounds were higher indoors by a factor ranging from 1.2 to 4.3.

239 Figure 6. Comparison of concentrations (geometric means) for VOCs found in common between Indoors and
240 Outdoors.
241
242

242 Table 4. Comparison of vapor concentrations for volatile compounds common to Indoor and Outdoor
 243 environments (ratios based on geometric means). Compounds are listed in descending magnitude of ratio.
 244 **Bolded** chemicals were higher in their respective environment by a ratio (i.e., factor) larger than 10.
 245

Volatiles higher in Indoor environments	Ratio	Volatiles higher in Outdoor environments	Ratio
Methyl isobutyl ketone	152	Pentanal (Valeraldehyde)	30
Isopropyl alcohol (Isopropanol)	91	Methylcyclopentane	21
Ethanol	45	2-Methyl-1-propanol	6.6
Isobutyl acetate	33	Xylenes	6.2
p-Dichlorobenzene	29	Hexaldehyde (Hexanal)	2.1
Limonene	25	Trichlorotrifluoroethane	1.7
Dodecane	24	Isopentane	1.5
beta-Pinene	21	p-Xylene	1.4
1-Butanol	19	n-Pentane	1.3
Tridecane	18	Phenol	1.2
Styrene	17	2-Methylpentane	1.1
Naphthalene	15		
alpha-Pinene	14		
1,2,4-Trimethylbenzene	13		
Chloroform	8.8		
Butyl acetate	8.6		
Nonane (n-Nonane)	8.1		
Cyclohexanol	7.0		
Undecane (n-Undecane)	6.2		
Acetone	5.8		
Ethylacetate	5.3		
3-Ethyl-toluene (m-Ethyltoluene)	4.3		
Methylene chloride	4.0		
2-Ethyltoluene (o-Ethyltoluene)	3.9		
2-Butanone	3.6		
n-Heptane	3.4		
Benzaldehyde	3.1		
4-Ethyltoluene (p-Ethyltoluene)	2.9		
Nonanal	2.6		
2-Ethyl-1-hexanol	2.6		
Toluene	2.5		
n-Octane	2.3		
m-Xylene	2.2		
Ethylbenzene	2.1		
Xylene (m/p)	1.9		
Cyclohexane	1.8		
Trichloroethylene	1.8		
Tetrachloroethylene	1.6		
3-Carene	1.4		
o-Xylene	1.4		
Hexane	1.3		
1,2,3-Trimethylbenzene	1.3		
Acetophenone	1.3		
Butanal	1.2		

246 Total: 44
 247 Total: 11

248 3.4. Concentration range of individual chemicals in Indoor Home/School environments

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250 A concentration range was calculated for those compounds for which there were at least 2 values
251 ($n \geq 2$) reported in the literature sources. Figure 7 (left side) shows such compounds for the indoor
252 *home/school* environment (n = number of values). They are plotted in the same order as in Figure 1 (left
253 side), that is, in decreasing order of geometric mean concentration, but Figure 7 shows, instead, a box plot
254 for each chemical that illustrates the spread of concentrations reported, as explained next: The height of
255 each box encloses 50% of the data, with the median value depicted as a line. Thus, the top (upper
256 quartile, UQ) and the bottom (lower quartile, LQ) of each box mark the limits of $\pm 25\%$ of the total data.
257 Then, the distance between the upper and lower quartiles ($UQ - LQ$) represents the interquartile distance
258 (IQD). The lines extending from the top and bottom of each box mark the maximum and minimum value,
259 respectively, within the data set, *excluding* outliers. Outliers are defined as concentrations whose value is
260 either greater than ($UQ + 1.5 * IQD$) or less than ($LQ - 1.5 * IQD$). The outliers are plotted as empty
261 circles. Also, the arithmetic mean of the distribution of all reported concentrations (*including* outliers) for
262 each chemical is plotted as a filled circle.

263

Indoor Home/School

Indoor Commercial

265
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Indoor Home/School

Indoor Commercial

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Figure 7. Illustrating the range of VOCs concentrations (n = number of values) reported in Indoor Home/School (left side) and Indoor Commercial (right side) environments. For each chemical the graphs show a box plot (see text for details), the median (line inside the box), the outlier(s) (if any) (empty circles), and the arithmetic mean of all values including outlier(s) (filled circles).

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Table 5 lists all compounds in Figure 7 (left side) in decreasing size of the ratio between the maximum and the minimum values reported for each chemical (i.e., the concentration range or spread), providing also numerical values for the minimum, maximum, mean, median, standard deviation, variance, and standard error. Out of the 74 compounds, two show a concentration spread (i.e., range) of three orders of magnitude: styrene (range=1,600, n=23) and alpha-pinene (range=1,345, n=21); nine compounds show a concentration spread of two orders of magnitude: beta-pinene (range=490, n=8), benzene (range=486, n=23), trichloroethylene (range=350, n=8), 1,4-dichlorobenzene (range=289, n=19), n-heptane (range=246, n=15), naphthalene (range=179, n=10), 1,2,3-trichlorobenzene (range=140, n=2), o-xylene (range=139, n=15), and toluene (range=107, n=30); and 27 compounds show a concentration spread of one order of magnitude (see Table 5). The remaining 36 compounds show a concentration spread lower than one order of magnitude (Table 5).

Table 5. Statistics of VOC concentrations ($\mu\text{g}/\text{m}^3$) measured in Indoor Home/School environments.

Variable (Indoor Home/School VOCs)	Minimum	Maximum	Range: Max/Min	Mean	Median	Std Deviation	Variance	Std Error
Styrene (n=23)	0.04	64.0	1,600	6.1	0.9	14.2	202.270	2.97
alpha-Pinene (n=21)	0.20	269.0	1,345	32.8	11.0	62.3	3883.600	13.60
beta-Pinene (n=8)	0.10	49.0	490	9.6	2.8	16.8	283.490	5.95
Benzene (n=23)	0.09	43.7	486	6.1	2.5	9.8	95.910	2.04
Trichloroethylene (n=8)	0.02	7.0	350	1.4	0.3	2.5	6.059	0.87
1,4-Dichlorobenzene (p-Dichlorobenzene) (n=19)	0.50	144.6	289	26.5	4.1	39.3	1545.600	9.02
n-Heptane (n=15)	1.20	295.4	246	34.0	11.0	75.5	5695.800	19.49
Naphthalene (n=10)	0.29	51.8	179	7.1	1.3	15.8	250.300	5.00
1,2,3-Trichlorobenzene (n=2)	0.01	1.4	140	0.7	0.7	1.0	0.966	0.70
o-Xylene (n=15)	0.24	33.5	139	4.6	1.8	8.3	68.986	2.14
Toluene (n=30)	1.60	170.7	107	21.2	14.8	30.2	909.890	5.51
Ethylbenzene (n=28)	0.24	20.0	83	4.0	3.0	4.5	20.593	0.86
1,3,5-Trimethylbenzene (n=2)	0.02	1.6	80	0.8	0.8	1.1	1.248	0.79
Methyl isobutyl ketone (MIBK) (n=4)	0.46	32.7	71	12.6	8.6	15.2	230.740	7.60
Tetrachloroethylene (n=6)	0.02	1.3	65	0.5	0.4	0.4	0.191	0.18
1,2,4-Trimethylbenzene (n=12)	0.14	7.6	54	4.3	4.2	2.2	4.867	0.64
n-Tridecane (n=8)	0.78	40.0	51	7.3	3.0	13.3	177.510	4.71
2-Butanone (n=5)	0.24	11.0	46	4.6	3.0	4.3	18.481	1.92
n-Octane (n=8)	1.30	52.7	41	9.8	2.9	17.5	306.610	6.19
1,3-Dichlorobenzene (m-Dichlorobenzene) (n=2)	0.02	0.7	33	0.3	0.3	0.4	0.198	0.32
Acetic Acid (n=6)	6.80	190.0	28	48.3	21.9	70.1	4920.000	28.64
Methylene chloride (n=6)	0.30	8.2	27	2.5	0.4	3.4	11.743	1.40
Limonene (n=24)	1.90	49.3	26	20.6	19.2	13.1	171.680	2.67
n-Hexane (n=9)	1.50	36.4	24	10.7	7.3	11.0	120.190	3.65
Chloroform (n=8)	0.09	2.1	23	0.9	0.7	0.7	0.553	0.26
n-Nonane (n=14)	1.50	33.5	22	14.3	13.2	8.8	78.294	2.36
1,2,4-Trichlorobenzene (n=2)	0.07	1.4	20	0.7	0.7	0.9	0.884	0.67
n-Decane (n=17)	2.20	41.8	19	19.1	16.0	11.4	129.040	2.76
n-Butyl acetate (n=8)	2.50	47.0	19	16.3	9.0	17.5	305.730	6.18
Dodecane (n=10)	2.22	38.0	17	15.8	7.5	15.0	224.810	4.74
m/p-Xylene (n=15)	1.20	19.0	16	7.5	6.5	5.5	30.796	1.43
Ethanol (n=3)	70.00	860.0	12	340.7	92.0	449.9	202400.000	259.74
Phenol (n=3)	0.61	7.1	12	3.1	1.7	3.5	12.078	2.01
p-Xylene (n=9)	2.60	30.0	12	11.4	7.6	10.8	116.550	3.60
Tetrahydrofuran (n=2)	0.16	1.7	11	0.9	0.9	1.1	1.186	0.77
Trichlorofluoromethane (Freon 11) (n=4)	4.73	50.0	11	25.6	23.8	23.3	544.290	11.67
Formaldehyde (n=16)	12.70	134.0	11	60.5	53.4	34.8	1208.400	8.69
Ethylacetate (n=11)	3.30	34.0	10	16.6	16.7	9.9	98.928	3.00
Acetone (n=8)	9.10	87.1	9.6	35.0	32.8	24.2	587.050	8.57
n-Undecane (n=9)	3.00	24.1	8.0	9.6	8.8	6.2	38.392	2.07
2-Butoxyethanol (n=3)	0.75	5.8	7.7	3.1	2.6	2.6	6.528	1.48
Isopentane (n=2)	1.40	9.5	6.8	5.5	5.5	5.7	32.805	4.05
Pentanal (Valeraldehyde) (n=7)	1.00	5.5	5.5	2.4	1.3	1.8	3.303	0.69
2-Methylpentane (n=3)	0.37	1.8	4.9	1.2	1.5	0.8	0.569	0.44
Crotonaldehyde (2-Butenal) (n=8)	1.60	7.6	4.8	4.8	4.9	1.8	3.385	0.65
1-Butanol (n=8)	35.00	147.6	4.2	66.0	51.4	37.4	1400.800	13.23
n-Pentane (n=2)	1.40	5.8	4.1	3.6	3.6	3.1	9.680	2.20
Tetrachloroethene (n=2)	0.70	2.9	4.1	1.8	1.8	1.6	2.420	1.10
Xylene (n=6)	5.00	18.2	3.6	7.8	5.8	5.1	26.327	2.09
Butanal (n=9)	2.20	8.0	3.6	5.1	4.2	2.2	4.993	0.74
Isobutylketone (diisobutylketone) (n=4)	8.00	27.0	3.4	15.0	12.5	8.3	68.667	4.14
Benzaldehyde (n=7)	2.00	6.2	3.1	3.4	3.0	1.4	1.922	0.52
Octanal (n=2)	4.30	13.0	3.0	8.7	8.7	6.2	37.845	4.35
Camphene (n=2)	1.90	5.2	2.7	3.6	3.6	2.3	5.445	1.65
Nonanal (n=3)	8.10	22.0	2.7	16.0	18.0	7.2	51.203	4.13
3-Carene (n=2)	8.50	23.0	2.7	15.8	15.8	10.3	105.130	7.25
Trichloroethene (n=2)	2.30	6.0	2.6	4.2	4.2	2.6	6.845	1.85
Hexanal (n=10)	5.00	13.0	2.6	7.9	7.5	2.8	7.683	0.88
Chlorobenzene (n=3)	0.68	1.7	2.5	1.3	1.6	0.6	0.316	0.32
4-Ethyltoluene (p-Ethyltoluene) (n=6)	2.26	5.4	2.4	3.3	2.8	1.1	1.302	0.47
3-Ethyltoluene (m-Ethyltoluene) (n=5)	0.97	2.3	2.4	1.5	1.2	0.6	0.347	0.26
Acrolein (n=2)	1.00	2.3	2.3	1.7	1.7	0.9	0.845	0.65
2-Ethyltoluene (o-Ethyltoluene) (n=5)	1.02	2.3	2.3	1.5	1.3	0.5	0.270	0.23
Acetaldehyde (n=9)	11.00	24.3	2.2	17.8	20.0	5.1	26.292	1.71
Methyl ethyl ketone (MEK) (n=2)	3.60	7.4	2.1	5.5	5.5	2.7	7.220	1.90
Cyclohexane (n=2)	2.90	5.2	1.8	4.1	4.1	1.6	2.645	1.15
Methyl tert-butyl ether (MTBE) (n=2)	12.00	19.3	1.6	15.7	15.7	5.2	26.645	3.65
Propanal (n=7)	6.90	10.9	1.6	8.2	8.0	1.3	1.665	0.49
Carbon tetrachloride (n=5)	0.50	0.7	1.4	0.6	0.6	0.1	0.006	0.03
n-Tetradecane (n=2)	1.30	1.7	1.3	1.5	1.5	0.3	0.080	0.20
Methylchloride (Chloromethane) (n=2)	1.49	1.8	1.2	1.6	1.6	0.2	0.048	0.16
n-Pentadecane (n=2)	1.10	1.2	1.1	1.2	1.2	0.1	0.005	0.05
n-Hexadecane (n=2)	1.10	1.1	1.0	1.1	1.1	0.0	0.000	0.00
Methylbenzaldehyde (Tolualdehyde) (n=4)	1.00	1.0	1.0	1.0	1.0	0.0	0.000	0.00

287 3.5. Concentration range of individual chemicals in Indoor Commercial environments

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289 A concentration range was calculated for those compounds for which there were at least 2 values
290 reported in the literature sources. Figure 7 (right side) shows the spread of concentrations for such
291 compounds found in the indoor *commercial* environment (n=number of values). They are plotted in the
292 same order as in Figure 1 (right side), that is, in decreasing order of geometric mean concentration, but
293 Figure 7 presents box plots illustrating the spread of concentrations reported, exactly as explained in the
294 previous section. Table 6 lists these chemicals in decreasing size of the ratio between the maximum and
295 the minimum values reported for each chemical (i.e., the range), providing also numerical values for the
296 minimum, maximum, mean, median, standard deviation, variance, and standard error. Out of 68
297 compounds, six show a concentration spread of two orders of magnitude: acetone (range=241, n=3),
298 alpha-pinene (range=234, n=6), isopropyl alcohol (range=183, n=2), styrene (range=165, n=10),
299 tetrachloroethylene (range=144, n=4), and toluene (range=119, n=13); and thirteen compounds show a
300 concentration spread of one order of magnitude (see Table 6). The remaining 49 compounds show a
301 concentration spread lower than one order of magnitude (Table 6).

302

302   **Table 6.** Statistics of VOC concentrations ($\mu\text{g}/\text{m}^3$) measured in Indoor Commercial environments.

Variable (Indoor Commercial VOCs)	Minimum	Maximum	Range: Max/Min	Mean	Median	Std Deviation	Variance	Std Error
Acetone (n=3)	22.9	5510.0	241	1852.2	23.7	3167.70	10035000.000	1828.90
alpha-Pinene (n=6)	0.7	163.9	234	28.8	2.1	66.18	4379.400	27.02
Isopropyl alcohol (Isopropanol) (n=2)	2.7	493.0	183	247.9	247.9	346.69	120200.000	245.15
Styrene (n=10)	0.2	32.9	165	4.8	1.4	9.98	99.638	3.16
Tetrachloroethylene (n=4)	3.0	432.0	144	115.2	13.0	211.33	44660.000	105.67
Toluene (n=13)	6.5	776.5	119	112.3	33.3	208.47	43461.000	57.82
Ethylacetate (n=2)	2.1	135.0	64	68.6	68.6	93.97	8831.200	66.45
1,3,5-Trimethylbenzene (n=3)	0.2	8.8	44	5.6	7.8	4.70	22.120	2.72
1,4-Dichlorobenzene (p-Dichlorobenzene) (n=5)	0.3	13.0	43	5.5	2.4	5.73	32.847	2.56
Ethylbenzene (n=10)	0.6	25.1	42	6.8	5.0	7.33	53.798	2.32
Chloroform (n=5)	0.4	13.5	31	5.6	1.1	6.71	45.023	3.00
4-Ethyltoluene (p-Ethyltoluene) (n=3)	0.3	6.0	20	3.8	5.1	3.06	9.390	1.77
Benzene (n=12)	1.2	23.6	20	8.0	4.9	7.58	57.435	2.19
Dichlorodifluoromethane (Freon 21) (n=3)	2.8	42.9	15	16.3	3.3	23.01	529.400	13.28
Naphthalene (n=3)	0.3	4.3	13	1.7	0.5	2.23	4.990	1.29
o-Xylene (n=9)	1.5	17.3	12	6.5	4.1	5.85	34.192	1.95
1,2,4-Trimethylbenzene (n=6)	1.1	12.2	11	6.3	5.7	5.05	25.550	2.06
Trichloroethylene (n=3)	0.8	8.8	11	5.1	5.6	4.03	16.213	2.32
m/p-Xylene (n=7)	3.9	41.6	11	14.7	6.2	15.05	226.510	5.69
Carbon tetrachloride (n=3)	0.1	0.9	9.0	0.6	0.7	0.41	0.168	0.24
n-Heptane (n=4)	1.8	14.3	7.9	8.0	8.0	5.30	28.087	2.65
Hexaldehyde (Hexanal) (n=3)	2.2	17.0	7.7	8.2	5.4	7.79	60.640	4.50
p-Xylene (n=3)	6.6	46.9	7.1	20.2	7.2	23.10	533.420	13.33
Nicotine (n=2)	5.4	38.3	7.1	21.9	21.9	23.26	541.200	16.45
d-Limonene (n=8)	2.5	17.5	7.0	6.8	5.6	4.64	21.554	1.64
Xylene (n=2)	2.6	14.3	5.5	8.5	8.5	8.27	68.445	5.85
Propanal (Propionaldehyde) (n=2)	2.5	11.9	4.8	7.2	7.2	6.65	44.180	4.70
Isoprene (n=2)	4.5	20.6	4.6	12.6	12.6	11.38	129.610	8.05
1,1-Dichloroethane (n=2)	0.4	1.8	4.5	1.1	1.1	0.99	0.980	0.70
MTBE (methyl tert-butyl ether) (n=3)	2.3	10.0	4.4	4.9	2.4	4.43	19.615	2.56
m-Xylene (n=3)	12.3	50.4	4.1	25.4	13.5	21.66	469.110	12.51
1,1,2,2-Tetrachloroethane (n=2)	1.0	4.0	4.0	2.5	2.5	2.12	4.500	1.50
1,3-Butadiene (n=2)	1.1	4.3	3.9	2.7	2.7	2.26	5.120	1.60
Methylchloride (chloromethane) (n=3)	0.9	3.5	3.9	2.5	3.0	1.38	1.903	0.80
Formaldehyde (n=7)	5.6	21.3	3.8	15.4	17.1	5.55	30.818	2.10
3-Ethenylpyridine (n=2)	1.2	4.4	3.7	2.8	2.8	2.26	5.120	1.60
Dichloromethane (n=2)	14.1	50.2	3.6	32.2	32.2	25.53	651.600	18.05
Trichlorofluoromethane (Freon 11) (n=3)	2.8	9.8	3.5	5.1	2.8	4.04	16.333	2.33
Pyridine (n=2)	0.8	2.6	3.4	1.7	1.7	1.29	1.674	0.92
Methylene chloride (n=3)	0.7	2.2	3.3	1.2	0.8	0.87	0.759	0.50
3-Picoline (n=2)	0.7	2.2	3.3	1.4	1.4	1.09	1.186	0.77
Acetaldehyde (n=6)	7.5	24.4	3.3	13.7	10.4	7.19	51.663	2.93
Dodecane (n=2)	12.0	38.5	3.2	25.3	25.3	18.74	351.120	13.25
1,1,2-Trichlorotrifluoroethane (n=3)	0.9	2.6	2.9	1.6	1.4	0.87	0.763	0.50
Furfuryl aldehyde (n=2)	1.6	4.4	2.8	3.0	3.0	1.98	3.920	1.40
Phenol (n=2)	1.1	2.8	2.5	2.0	2.0	1.20	1.445	0.85
n-Undecane (n=2)	3.0	7.5	2.5	5.3	5.3	3.18	10.125	2.25
3-Ethyltoluene (m-Ethyltoluene) (n=3)	4.5	9.1	2.0	6.4	5.6	2.40	5.770	1.39
1,2,4-Trichlorobenzene (n=2)	12.8	24.5	1.9	18.7	18.7	8.27	68.445	5.85
Methylcyclohexane (n=2)	2.0	3.8	1.9	2.9	2.9	1.27	1.620	0.90
Trichloroethene (n=2)	0.2	0.4	1.9	0.3	0.3	0.14	0.020	0.10
Benzaldehyde (n=2)	1.5	2.3	1.5	1.9	1.9	0.57	0.320	0.40
Perchloroethylene (n=2)	1.4	2.1	1.5	1.8	1.8	0.48	0.231	0.34
Bromomethane (n=2)	1.1	1.6	1.5	1.4	1.4	0.35	0.125	0.25
1,2-Dichlorobenzene (o-Dichlorobenzene) (n=2)	1.6	2.3	1.4	2.0	2.0	0.49	0.245	0.35
1,3-Dichlorobenzene (m-Dichlorobenzene) (n=2)	1.6	2.2	1.4	1.9	1.9	0.42	0.180	0.30
Ethylchloride (n=2)	0.3	0.4	1.3	0.4	0.4	0.07	0.005	0.05
1,1,1-Trichloroethane (n=2)	13.4	17.1	1.3	15.3	15.3	2.62	6.845	1.85
n-Octane (n=2)	3.1	3.9	1.3	3.5	3.5	0.57	0.320	0.40
1,2-Dibromoethane (n=2)	0.9	1.1	1.2	1.0	1.0	0.14	0.020	0.10
Chlorobenzene (n=2)	1.4	1.7	1.2	1.6	1.6	0.21	0.045	0.15
1,1-Dichloroethene (n=2)	0.5	0.6	1.2	0.6	0.6	0.07	0.005	0.05
1-Butanol (n=2)	2.2	2.6	1.2	2.4	2.4	0.28	0.080	0.20
1,2-Dichloroethane (n=2)	0.6	0.7	1.2	0.7	0.7	0.07	0.005	0.05
1,1,2-Trichloroethane (n=2)	0.6	0.7	1.2	0.7	0.7	0.07	0.005	0.05
n-Decane (n=2)	4.4	4.7	1.1	4.6	4.6	0.21	0.045	0.15
1,2-Dichlorotetrafluoroethane (n=2)	0.7	0.7	1.0	0.7	0.7	0.00	0.000	0.00
1,2-Dichloroethene (n=2)	0.4	0.4	1.0	0.4	0.4	0.00	0.000	0.00

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307 3.6. Concentration range of individual chemicals in Outdoor Non-industrial environments

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309 Figure 8 shows the spread of concentrations for compounds found in *outdoor non-industrial*
310 environments with $n \geq 2$ (n =number of values). They are plotted in the same order as in Figure 3, that is, in
311 decreasing order of geometric mean concentration, but Figure 8 presents box plots illustrating the spread
312 of concentrations reported, exactly as explained above. In turn, Table 7 lists these chemicals in
313 decreasing size of the maximum/minimum ratio (i.e., range) and providing additional statistics (minimum,
314 maximum, mean, etc.) as mentioned above. Out of 30 compounds, five show a concentration spread of
315 two orders of magnitude: benzene (range=664, $n=10$), toluene (range=284, $n=10$), 1,2,4 trimethylbenzene
316 (range=160, $n=3$), alpha-pinene (range=140, $n=3$), and o-xylene (range=112, $n=8$); and eight compounds
317 show a concentration spread of one order of magnitude: n-octane (range=77, $n=5$), tetrachloroethylene
318 (range=71, $n=3$), d-limonene (range=51, $n=4$), tridecane (range=33, $n=3$), trichloroethylene (range=30,
319 $n=3$), 3-ethyltoluene (m-ethyltoluene) (range=23, $n=4$), styrene (range=17, $n=4$), and n-heptane
320 (range=16, $n=4$). The remaining 17 compounds show a concentration spread lower than one order of
321 magnitude (Table 7).

322

Outdoor Non-Industrial

Figure 8. Illustrating the range of VOCs concentrations (n = number of values) reported in outdoor Non-Industrial environments. For each chemical the graphs show a box plot (see text for details), the median (line inside the box), the outlier(s) (if any) (empty circles), and the arithmetic mean of all values including outlier(s) (filled circles).

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Table 7. Statistics of VOC concentrations ($\mu\text{g}/\text{m}^3$) measured in Outdoor Non-industrial environments.

Variable	Minimum	Maximum	Range: Max/Min	Mean	Median	Std Deviation	Variance	Std Error
Benzene (n=10)	0.06	39.8	664	7.8	2.37	12.87	165.700	4.07
Toluene (n=10)	0.52	147.9	284	20.6	4.84	45.06	2030.000	14.25
1,2,4-Trimethylbenzene (n=3)	0.01	1.6	160	1.0	1.40	0.87	0.750	0.50
alpha-Pinene (n=3)	0.10	14.0	140	4.7	0.11	8.02	64.357	4.63
o-Xylene (n=8)	0.45	50.5	112	8.1	1.04	17.37	301.850	6.14
n-Octane (n=5)	0.32	24.7	77	5.7	0.69	10.67	113.740	4.77
Tetrachloroethylene (n=3)	0.20	14.1	71	4.9	0.30	8.00	63.943	4.62
d-Limonene (n=4)	0.10	5.1	51	1.5	0.35	2.42	5.864	1.21
Tridecane (n=3)	0.01	0.3	33	0.2	0.22	0.16	0.026	0.09
Trichloroethylene (n=3)	0.01	0.3	30	0.2	0.20	0.15	0.022	0.09
3-Ethyl-toluene (m-Ethyltoluene) (n=4)	0.14	3.2	23	1.1	0.43	1.45	2.092	0.72
Styrene (n=4)	0.01	0.2	17	0.1	0.09	0.07	0.004	0.03
n-Heptane (n=4)	0.71	11.7	16	3.8	1.30	5.31	28.236	2.66
Naphthalene (n=4)	0.05	0.4	8.4	0.2	0.08	0.18	0.031	0.09
p-Xylene (n=3)	5.50	39.0	7.1	17.8	8.87	18.44	340.030	10.65
Ethylbenzene (n=9)	0.43	3.0	7.0	1.2	1.15	0.82	0.677	0.27
n-Dodecane (n=4)	0.17	0.9	5.3	0.4	0.30	0.33	0.111	0.17
n-Hexane (n=4)	1.60	7.4	4.6	3.5	2.54	2.65	7.042	1.33
p-Ethyltoluene (4-Ethyltoluene) (n=3)	0.39	1.4	3.7	0.8	0.64	0.55	0.301	0.32
m/p-Xylene (n=6)	2.00	6.9	3.5	3.1	2.40	1.90	3.592	0.77
2-Ethyltoluene (o-Ethyltoluene) (n=3)	0.17	0.6	3.2	0.3	0.21	0.21	0.044	0.12
1,4-Dichlorobenzene (p-Dichlorobenzene) (n=3)	0.10	0.3	3.0	0.2	0.20	0.10	0.010	0.06
n-Undecane (n=4)	0.45	1.3	2.9	1.0	1.14	0.38	0.144	0.19
n-Decane (n=4)	0.81	2.0	2.5	1.3	1.24	0.50	0.254	0.25
Nonane (n=3)	0.70	1.2	1.7	0.9	0.83	0.25	0.062	0.14
Methylene chloride (n=2)	0.20	0.3	1.5	0.3	0.25	0.07	0.005	0.05
beta-Pinene (n=2)	0.10	0.1	1.0	0.1	0.10	0.00	0.000	0.00
Carbon tetrachloride (n=2)	0.50	0.5	1.0	0.5	0.50	0.00	0.000	0.00
Chloroform (n=2)	0.10	0.1	1.0	0.1	0.10	0.00	0.000	0.00

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335 3.7. Concentration range of individual chemicals in Outdoor Industrial environments

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337 There are many potential kinds of industrial environments since each industry will have its
338 “signature” environment. To try to summarize even some of them is beyond the scope of the present
339 paper. As mentioned under “Outdoors”, this review has included two examples of industrial environments:
340 the vicinity of a pig farm and the vicinity of an oil refinery. Only four of the 45 chemicals reported in these
341 environments (see Figure 3, right side) include two or more measurements ($n \geq 2$): toluene ($n=2$), benzene
342 ($n=2$), ethylbenzene ($n=2$) and 1-propanol ($n=2$). This is too small a sample to provide any further insight.

343

344 4. Concluding Comments

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346 The present article compiles and analyzes data from the literature on the chemical species,
347 concentrations, and variability of airborne volatiles found and measured in two broad indoor environments:
348 homes/schools and commercial spaces, and in two outdoor environments: non-industrial and industrial
349 (the latter exemplified by the vicinity of a pig farm and the vicinity of an oil refinery). Included in the review
350 are data on mean airborne VOC concentrations collected in two recent comprehensive and informative
351 compilations focused exclusively on indoor spaces: one dealing specifically with residencies (Logue et al.,
352 2011) and the other dealing with residencies and non-residencies (i.e., public buildings) (Sarigiannis et al.,
353 2011). The principal aim of this study is to summarize in illustrative graphs and tables information gathered
354 from the literature, so that investigators addressing the many aspects of human environmental chemical
355 exposures have a centralized source for the types, levels, relative concentrations, concentration spread,
356 and number of volatiles found in these environments. As suggested by one of the reviewers, national and
357 local agencies worldwide should bring together their own available data on public air quality monitoring to
358 guide toxicology and sensory scientists in the prioritization of key compounds and mixtures.

359

360   In a number of studies, toxicological limits for individual compounds have been set out (American
361   Conference of Governmental Industrial Hygienists, 2008; Bercu and Dolan, 2013). In the present work we
362   have collected information on the many chemical species found in a given environment. We are using this
363   data to devise a method of assessment of air quality due to mixtures and hope to report on our results in
364   the near future.

365

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Figure Legends

Figure 1. Comparison of VOC concentrations (geometric means) measured in two types of indoor environments: Home/School and Commercial.

Figure 2. Comparison of concentrations (geometric means) for indoor VOCs found in common between Home/School and Commercial environments.

Figure 3. Comparison of VOC concentrations (geometric means) measured in two types of outdoor environments: Non-industrial and Industrial.

Figure 4. Comparison of concentrations (geometric means) for outdoor VOCs found in common between Non-industrial and Industrial environments.

Figure 5. Comparison of VOC concentrations (geometric means) measured Indoors and Outdoors.

Figure 6. Comparison of concentrations (geometric means) for VOCs found in common between Indoors and Outdoors.

Figure 7. Illustrating the range of VOCs concentrations (n = number of values) reported in Indoor Home/School (left side) and Indoor Commercial (right side) environments. For each chemical the graphs show a box plot (see text for details), the median (line inside the box), the outlier(s) (if any) (empty circles), and the arithmetic mean of all values including outlier(s) (filled circles).

Figure 8. Illustrating the range of VOCs concentrations (n = number of values) reported in outdoor Non-Industrial environments. For each chemical the graphs show a box plot (see text for details), the median (line inside the box), the outlier(s) (if any) (empty circles), and the arithmetic mean of all values including outlier(s) (filled circles).

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