資料２

厚生労働省
シックハウス（室内空気汚染）問題に関する検討会
2013年5月28日

シックハウス症候群の原因解明のための全国規模の疫学研究

北海道大学　環境健康科学研究教育センター

岸　玲子

概要

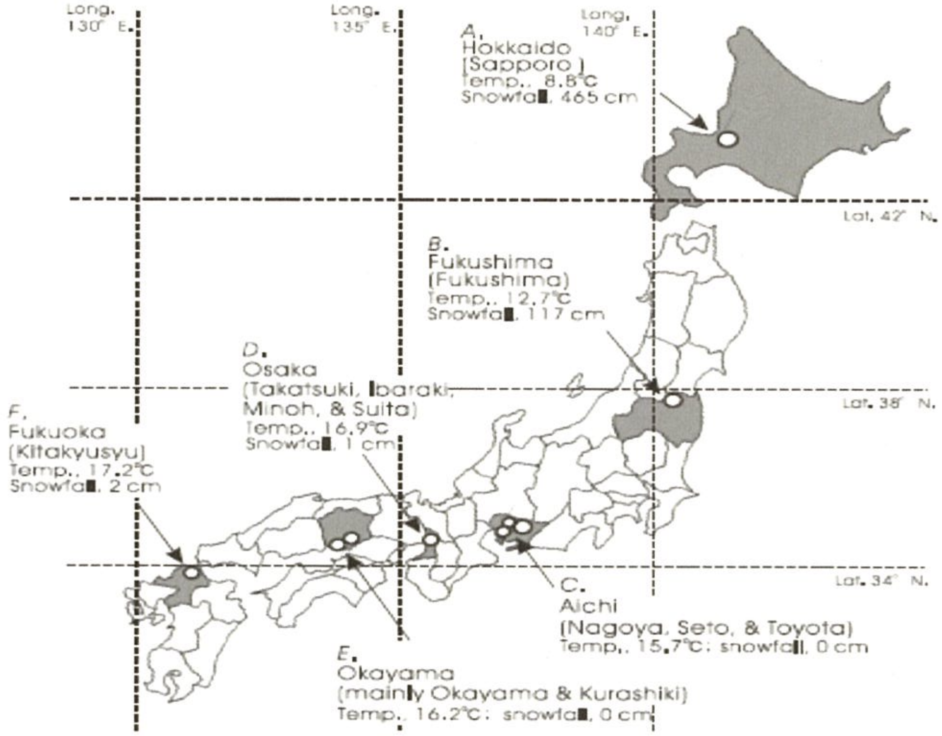
1．全国規模の疫学調査研究
- 1）　新築戸建て住宅の研究概要
- 2）　シックハウス症候群の有訴

2．室内環境中化学物質濃度とその影響
- 1)　アルデヒド・VOC類
- 2)　MVOC類
- 3)　SVOC類
  - ①　フタル酸エステル類
  - ②　リン酸トリエステル類

3．小学生を対象とした疫学調査研究

4．今後の課題

調査対象6地域



研究の流れ

2003　質問票

住宅確認申請から無作為に抽出した、6080 軒の戸建て住宅に調査票を郵送

491 軒
- **≧築6年以上**
- **宛先不明で返送**

2297 軒より回答（有効回答率41.1%）

1301 不同意
571 スケジュール調整不可

自宅環境調査

2004（ベースライン）　**425 軒（全居住者1479人）居間の曝露調査**

2005（追跡1回目）　**270 軒（全居住者935人）居間および寝室の曝露調査**

2006（追跡2回目）　**182 軒（全624人）居間の曝露調査**

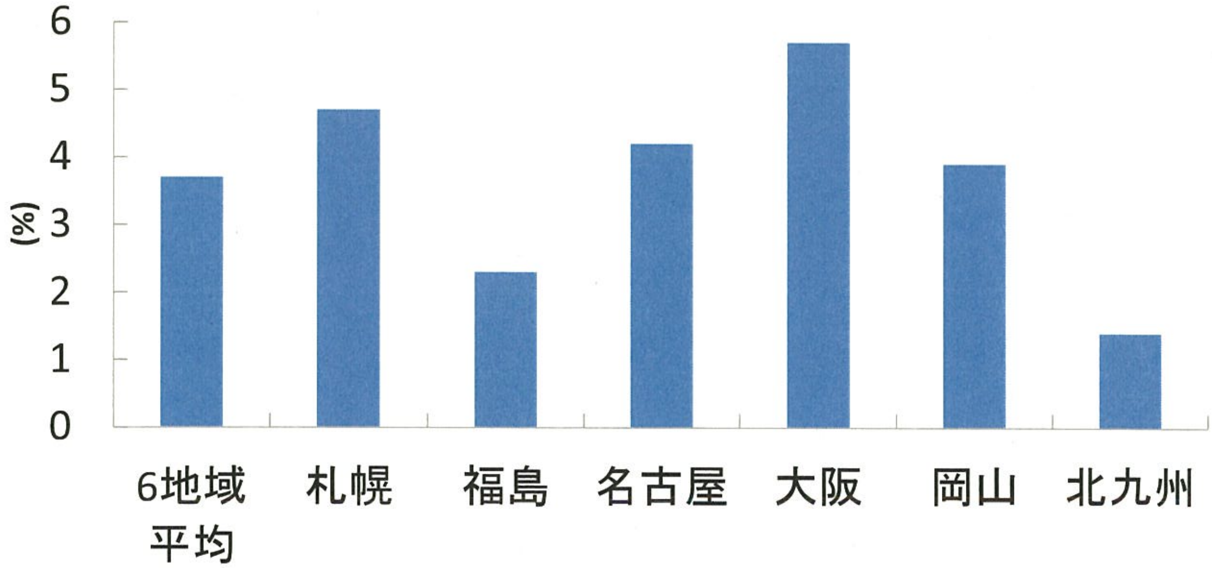
2007 殺虫剤調査（西日本のみ）　**58 軒（全203人）、居間の曝露調査**

対象住宅の特徴 (2003年)

		札幌	福島	名古屋	大阪	岡山	北九州
調査住宅数(n)		576	428	278	318	337	360
木造住宅(%)		98.3	81.5	71.7	69.4	68.1	63.2
築年(%)	<2	33.8	32.9	62.6	52.5	26.7	39.0
	2-3	35.6	38.0	28.4	42.8	43.6	33.7
	4-6	30.5	29.1	9.0	4.7	29.7	27.3
家族数(%)	1-2	20.7	25.2	28.1	16.7	20.5	23.1
	3-4	63.9	51.2	48.6	64.4	53.3	56.8
	≧5	15.3	23.6	23.4	18.9	26.2	20.1

Kishi et al., Indoor Air 2009

住宅あたりのSHS有訴率 (2003年)



SHS症状がいつも、または時々ある居住者がいる住宅は3.7%（1.7-5.4%）

Kishi et al., Indoor Air 2009

SHSのリスクとなる要因

		OR(95%CI)
家の空気が汚れていると感じる		2.11(1.08-4.13)
家の臭いが気になる		2.81(1.52-5.17)
家具の臭いが気になる		1.13(0.50-4.13)
室内でペットを飼っている		1.09(0.66-1.78)
機械換気がない		1.12(0.66-1.92)
ダンプネス指数	0	Reference
	1	1.37(0.71-2.65)
	2	1.43(0.72-2.85)
	3	2.39(1.14-5.00)
	4-5	2.09(0.68-6.43)
		P for trend =0.03

ダンプネスの訴えが多いとSHSの訴えが多い

Kishi et al., Indoor Air 2009

自宅環境調査 調査票（2004-2006年）

1．個人調査票：居住者全員に配布

- シックハウス症候群（SHS）に関する項目(MM040EA)
- 2年以内のアレルギーの既往
- 属性・ライフスタイルに関する項目
  - 性、年齢、職業（学年）、喫煙、飲酒習慣、家で過ごす時間、ストレス、睡眠の質、等

2．住宅調査票：1軒に1部を配付

- 構造、築年、幹線道路からの距離、機械換気の有無、改築の有無、室内での喫煙者の有無、床材、壁材、カーペット・防虫剤・芳香剤の使用
- ダンプネス（結露、目に見えるカビの生育、カビ臭、浴室の湿気、5年以内の水漏れ）

シックハウス症候群の定義

SHS ：MM040EA 日本語版 (Andersson 1998, Mizoue et al., 2001)

本研究におけるSHSの定義

① 症状が毎週のようによくある

　　　　毎週のようによく・あるいはときどきある

② かつ、その症状は家を離れるとよくなる

症状カテゴリー

下記のいずれか

① 一般症状：疲労、頭痛、頭重、吐き気やめまい、集中困難

② 眼症状：眼がかゆい、あつい、チクチクする

③ 鼻症状：鼻水、鼻づまり、ムズムズ

④ 喉症状：声のかすれ・喉の乾燥、咳

⑤ 皮膚症状：皮膚が赤くなる、掻痒、乾燥

（②〜④）眼、鼻、喉の症状をまとめて、粘膜への刺激症状

最近３か月間に、次の症状がありましたか。

何もなかった方も、すべての項目にお答えください。

	(1) はい、よくあった（毎週のように）	(2) はい ときどき	(3) いいえ まったく	「はい」の方は、その症状は自宅の環境によるものと思いますか。(1) はい	(2) いいえ
1. とても疲れる	☐	☐	☐	☐	☐
2. 頭が重い					
3. 頭が痛い	☐	☐	☐	☐	☐
4. はきけやめまいがする	☐	☐	☐	☐	☐
5. 物事に集中できない	☐	☐	☐	☐	☐
6. 目がかゆい・あつい・チクチクする	☐	☐	☐	☐	☐
7. 鼻水・鼻づまり、鼻がムズムズする	☐	☐	☐	☐	☐
8. 声がかすれる、のどが乾燥する	☐	☐	☐	☐	☐
9. せきがでる	☐	☐	☐	☐	☐
10. 顔が乾燥したり赤くなる	☐	☐	☐	☐	☐
11. 頭や耳がかさつく・かゆい	☐	☐	☐	☐	☐
12. 手が乾燥する・かゆい・赤くなる	☐	☐	☐	☐	☐

シックハウス症候群あり

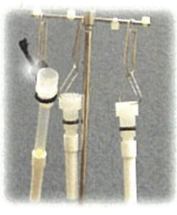
自宅環境調査 測定項目(2004-2006年）

1. 温度･湿度
2. 気中アルデヒド･VOC類
3. 気中真菌
4. 床ダスト中ダニアレルゲン
5. SVOC (Semi-volatile VOCs) (2006年のみ)
6. MVOC (Microbial VOCs) (2006年のみ)

アルデヒド類･VOC類

サンプリングと分析法

- アルデヒド類
  - Supelco DSD-DNPH 拡散サンプラーで24時間室内空気を捕集
  - HPLC 分析（13化合物）
- VOC類：Volatile Organic Compounds（揮発性有機化合物）
  - Supelco VOC-SD 拡散サンプラーで24時間室内空気を捕集
  - GC-MS 分析(29化合物）



指針値が定められている化合物の濃度
（その他の化合物は手元資料参照）

単位：μg/m^3

	95%値	最大値	検出率(%)
ホルムアルデヒド	86.6	202.8	95.8
アセトアルデヒド	63.8	208.9	96.5
アセトン	126.1	606.0	97.4
トルエン	42.2	144.2	96.0
エチルベンゼン	9.2	24.8	89.2
キシレン	23.3	101.1	90.8
スチレン	1.2	52.7	6.4
p-ジクロロベンゼン	241.6	1689.8	60.9
TVOC（29化合物）	517.5	1770.9	100.0

室内濃度指針値を超過していた住宅はホルムアルデヒド 3.5%、アセトアルデヒド 12%、p-ジクロロベンゼン 5.6%、TVOC(暫定指針値) 8.0%

Takigawa et al., Int Arch Occup Environ Health 2010

SHS症状と化学物質濃度
（詳細は手元資料参照）

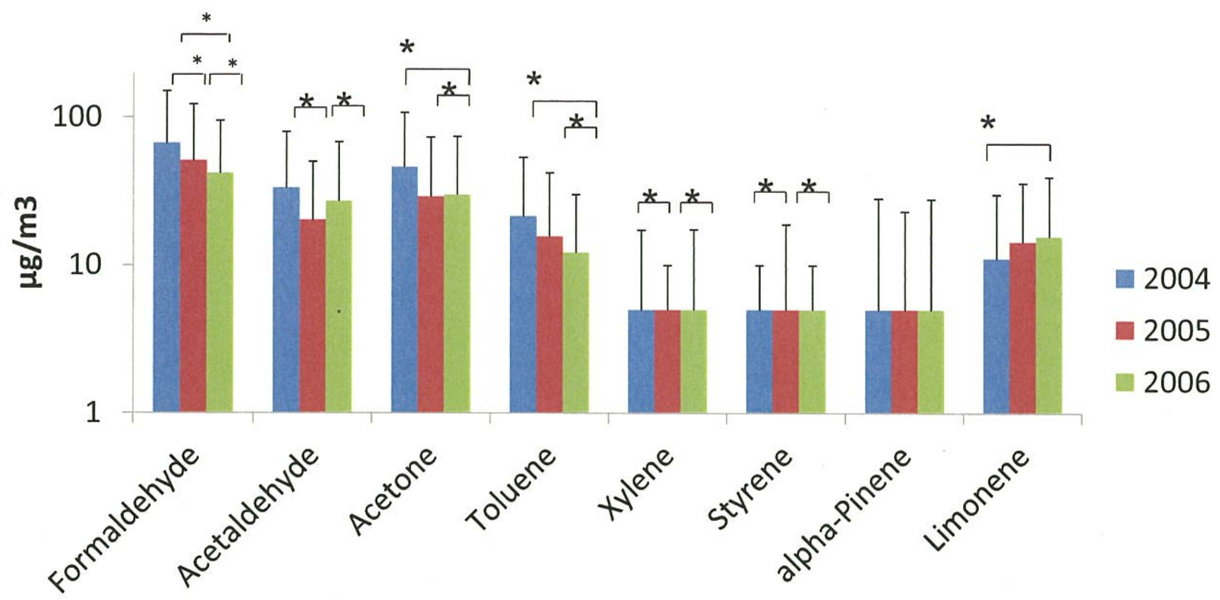
症状	化合物	濃度（4分位）別のOR(95%CI)			
		1st	2nd	3rd	4th
いずれか	ホルムアルデヒド	1	2.13(1.21-3.76)	2.28(1.22-4.25)	2.35(1.22-4.56)
一般	クロロジブロモメタン		1	—	10.3(2.38-44.7)
眼	ホルムアルデヒド	1	1.97(0.60-6.46)	4.24(1.21-14.9)	1.74(0.45-6.78)
	アセトン	1	0.93(0.25-3.37)	1.16(0.30-4.54)	4.46(1.17-17.1)
	n-ノナン		1	3.63(1.37-9.58)	9.48(2.53-35.6)
鼻	ホルムアルデヒド	1	2.89(1.39-6.00)	2.59(1.15-5.81)	1.74(0.74-4.10)
皮膚	プロピオンアルデヒド	1	1.07(0.38-3.04)	3.37(1.15-9.91)	1.76(0.43-7.24)

地域、性、年齢、喫煙、家で過ごす時間、飲酒、ストレス、結露、カビ発生、ペット、アレルギー、温湿度で調整
化学物質はbackward stepwise methodによりモデルに投入
濃度が10倍になったときのOR(95%CI)

ホルムアルデヒドは濃度が高いほど「SHSいずれか一つ以上の症状あり」のリスクが高くなる

Takigawa et al., Int Arch Occup Environ Health 2010

室内化学物質濃度推移(継続3年間)



Bars shows median+75% (n=41) P-values were calculated by Friedman test for 3-year variance (*p<0.05). When p<0.05, Wilcoxon test. * p<0.017 (Bonferroni)

室内濃度指針値超住宅数は、2004年、2005年、2006年それぞれホルムアルデヒド 7, 3, 0軒、TVOCは 0, 3, 3軒

荒木ら、日衛誌 2011

アルデヒド・VOCのまとめ

指針値が定められている13化合物のうち、

- 指針値を超える濃度を示したのは、ホルムアルデヒド、アセトアルデヒド、p-ジクロロベンゼン
- ホルムアルデヒドやトルエン濃度は3年間の観察で継時的に室内濃度が低くなった
- ホルムアルデヒドの濃度が高くなるとSHSのリスクが上昇する

13化合物以外にも、クロロジブロモメタン、アセトン、n-ノナンがSHS症状のリスクを上げる可能性が示唆された

MVOC (Microbial VOCs）

- 微生物によって産生される化学物質の総称
- 培養実験により、150種類以上もの化合物がMVOCとして知られている (Fiedler 2001; Korpi 1997; Pasanen 1997; Scholler 2002)
- 屋外よりも室内で高いことから、健康影響が懸念されるようになった (Wessen and Schoeps, 1996)
- MVOC 濃度はダンプネスのある建物でない建物よりも高い (Wieslander et al., 2007)
- ヒトへの実験的曝露で、1-Octen-3-olの眼や気道の粘膜刺激症状、頭痛や吐き気(Walinder et al., 2008)、3-methylfuranが眼、鼻、軌道への急性症状が報告(Walinder et al., 2005)

疫学研究で用いる分析法を確立し、世界でも初めて自宅室内MVOCを測定した

MVOCの測定

対象化合物

- 8化合物（後にVOCとMVOC13化合物の一斉分析法を確立し、51化合物の同時分析を可能にした）

サンプリング

- Supleco VOC-SD 拡散サンプラー
- 48時間室内空気を捕集

分析

- GC-MS (SIM)で分析

Araki et al., Indoor Air 2009

室内MVOC濃度

N=182, 単位：μg/m3

	GM	最大値	検出(%)
3-methyl-1-butanol	0.47	10.64	68.7
1-pentanol	0.60	12.15	78.6
2-pentanol	0.30	4.17	48.4
2-hexanone	0.32	2.56	70.9
2-heptanone	0.19	1.52	35.2
3-octanone	0.14	1.88	7.7
1-octen-3-ol	0.19	8.58	29.1
3-octanol	<LOD		0.0

ドイツの住宅と同程度、スウェーデンの学校より濃度は高い

Araki et al., Sci Total Environ 2010

SHS有訴とMVOC

N=620

	粘膜への刺激症状 OR (95%CI)
2-Pentanol	2.1 (0.9-4.9) †
1-Octen-3-ol	4.6 (1.7-12.9)**
Total Fungi	0.6 (0.3-1.4)
Mite allergen Der1	1.7 (1.0-2.7)*

症状はいつもあり
濃度が10倍になった時のOR(95%CI)を示す
変数は一度に投入し、性、年齢、喫煙で調整

1-octen-3-olが粘膜への刺激症状のリスクとなる可能性が示唆された

Araki et al., Sci Total Environ 2010

アレルギー有病とMVOC

N=608

	Atopic Dermatitis OR (95%CI)	Rhinitis OR (95%CI)	Conjunctivitis OR (95%CI)
1-pentanol	1.08 (0.42,2.79)	1.02 (0.46,2.28)	-
2-hexanone	1.72(0.36,8.27)	1.12(0.33,3.75)	-
2-heptanone	0.83(0.19,3.73)	-	-
Oct-1-en-3-ol	1.63(0.55,4.85)	4.10(1.71,9.80)**	3.54(1.17,10.7)**
Total fungi	0.07(0.02,0.70)**	0.54(0.38,1.08)	0.36(0.18,0.74)**

濃度が10倍になった時のOR(95%CI)を示す
変数は一度に投入し、性、年齢、喫煙、改築、カーペットの敷き詰め、ダンプネス指数、花粉症の有無で調整

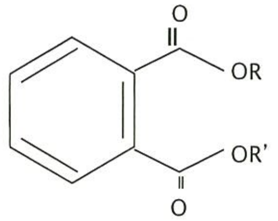
1-octen-3-olが鼻炎、結膜炎のリスクとなる可能性を示唆

Araki et al., Sci Total Environ 2012

MVOCのまとめ

- 1-octen-3-olがSHS粘膜への刺激症状、アレルギー性鼻炎、アレルギー性結膜炎のリスクとなる可能性を示した
- 1-octen-3-olはヒトへの曝露実験で粘膜症状が報告されているが、曝露濃度よりもかなり低い室内濃度でも症状を引き起こす可能性が示唆された

SVOC：フタル酸エステル

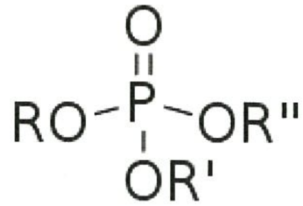


DMP (Dimethyl Phthalate):	R, R' = $-CH_3$
DEP (Diethyl Phthalate):	R, R' = $-C_2H_5$
DiBP (Di-iso-butyl Phthalate):	R, R' = $-C_4H_9$ (iso-butyl)
DnBP (Di-n-butyl Phthalate):	R, R' = $-C_4H_9$
BBzP (Butylbenzyl Phthalate):	R= $-C_4H_9$, R' = $-C_6H_5$
DEHP (Di-2-ethylhexyl Phthalate):	R, R' = $-C_8H_{17}$
DINP (Di-isononyl phthalate):	R, R' = $-C_9H_{19}$

- 沸点：240~400℃の半揮発性有機化合物
- 物質から徐々に揮発し、ガス状、浮遊微粒子状、ダストに吸着して存在
- 用途と曝露経路：食品容器、ビニール製の玩具、パーソナルケア製品、塗料、家具、建材などに広く汎用され、経口、皮膚接触により曝露
- 動物実験：アレルギーのアジュバント効果、免疫抑制効果*(Larsen et al., 2001, 2002)*
- 疫学研究：アレルギーとの関連が示唆されている *(Bornehag et al.,2004; 2005, Hsu et a., 2012; Kolarik et al.,2008)*
  - DEHPが喘息、喘鳴、鼻炎のリスク、BBzPが鼻炎 、皮膚炎のリスク、DBPが皮膚炎のリスク

SVOC：リン酸トリエステル

- 難燃剤、可塑剤として用いられ、2009年には約3.5万tが生産された(経済産業省 2010)
- 臭素系のうち蓄積性が高いPBDEは、日本では1990年代に関連業界の自主規制によりリン系難燃剤に移行した結果、リン系難燃剤は臭素系よりも濃度が高い(Saito et al., 2007)
- 揮発性が低く室内空気中に長時間とどまる可能性があるため、汚染が懸念されている
- 動物実験では神経毒性が報告されている(Carrington et al. 1990, Weiner et al. 1999)
- ヒトではMeeker ら(2010)によってTDCPPと血中遊離チロキシンの間に負の相関が報告されているが、疫学研究はほとんどない。



SVOCの測定

対象化合物

1. フタル酸エステル類7化合物、アジピン酸ジエステル
2. リン酸トリエステル類11化合物
3. アルキルフェノール類2化合物、塩素系共力剤1化合物、
4. 殺虫剤（ピレスロイド5種、塩素系共力剤1種、有機リン10種）

サンプリング

1. ダスト：Floor(床上35cm以下)およびMulti-surface(床上35cm以上の棚、鴨居等)のダスト捕集、共雑物を除去後分析
2. 空気：Empore™ Disks C18 filter を装着し、流速200ml/minでアクティブ法により48時間室内空気捕集

分析：GC, GC-FID 分析

気中フタル酸エステル類濃度(札幌)

N=41

	Med. (ng/m^3)	Range (ng/m^3)	検出率(%)
DMP	47.9	11.9-191	100
DEP	60.7	22.3-203	100
DiBP	75	13.2-321	100
DnBP	200	79.6-740	100
BBzP	<LOD	<LOD-26.6	25.6
DEHP	147	11.8-1660	100
DiNP	<LOD	<LOD-192	12.8

DEHP、DnBPの濃度が高い
分子量が小さいDMPは気中からは検出されたが、ダスト中からの検出は低い
先行研究(米)と比較して、DEP、DiBP,、DnBP、BBzP濃度は本研究では低い

Kanazawa et al., Indoor Air 2010

気中リン酸トリエステル類濃度(札幌)

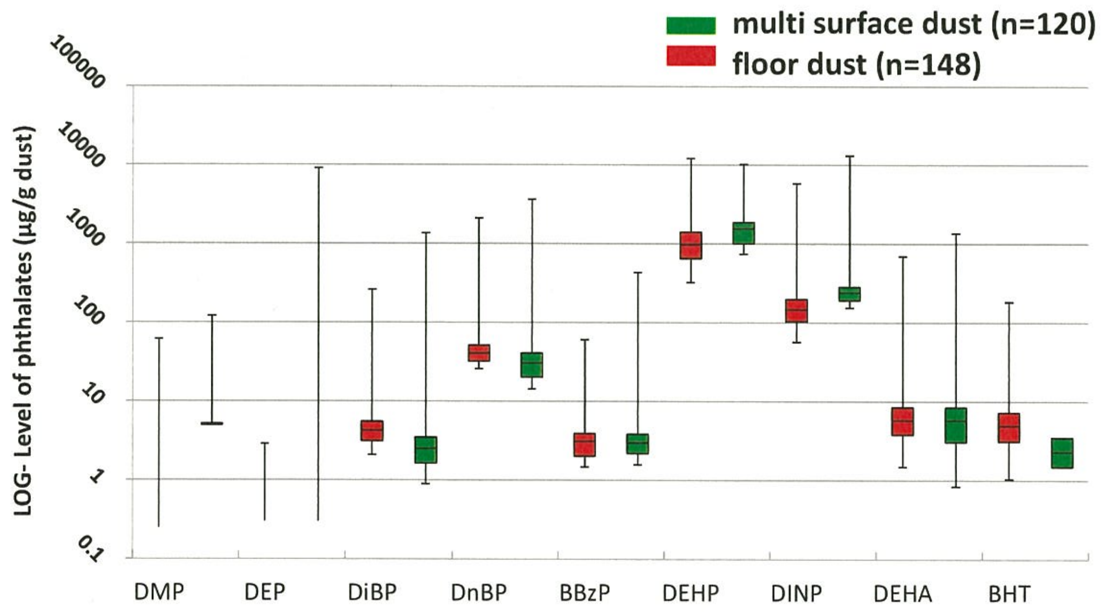
N=41

	Med (ng/m^3)	Range(ng/m^3)	検出率(%)
TEP	62.3	18.1-511	100
TBP	27.1	<LOD-121	97.5
TCiPP	89.2	15.5-2660	100
TCEP	15.5	<LOD-297	60
TBEP	23	<LOD-159	64.1
TDCPP	<LOD	<LOD-61.4	37.5

分子量が小さいTEPは気中からは検出されたが、ダスト中からの検出は低い

Kanazawa et al., Indoor Air 2010

ダスト中フタル酸エステル類濃度



DMP DEP DiBP DnBP BBzP DEHP DINP DEHA BHT

Correlation between floor and multi-surface

DiBP	DnBP	BBzP	DEHP	DINP	DEHA	BHT
0.537**	0.248**	0.382**	0.383**	0.419**	0.339**	0.119

Spearman's rank correlation coefficients, **p<0.01

Kishi et al., ICOH2012

床のダスト中フタル酸エステル類濃度とアレルギー有病、SHS有訴

	Asthma		Dermatitis		Rhinitis		Conjunctivitis		SBS	
	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)
DiBP	2.20	(0.85,5.72)	1.23	(0.59,2.53)	0.81	(0.42,1.56)	1.18	(0.49,2.80)	0.85	(0.37,1.96)
DnBP	1.41	(0.76,2.6)	1.09	(0.69,1.71)	0.73	(0.48,1.1)	1.14	(0.69,1.88)	0.74	(0.42,1.32)
BBzP	1.90	(0.77,4.67)	2.12	(1.14,3.97)*	1.41	(0.83,2.38)	1.46	(0.71,3.04)	1.31	(0.66,2.59)
DEHP	1.34	(0.45,4.03)	1.54	(0.72,3.29)	0.88	(0.45,1.72)	3.74	(1.56,8.94)**	1.47	(0.61,3.50)
DINP	0.94	(0.37,2.34)	0.88	(0.46,1.71)	0.93	(0.53,1.61)	0.64	(0.30,1.39)	1.24	(0.59,2.58)
DEHA	3.25	(1.46,7.23)**	2.23	(1.23,4.07)**	1.12	(0.66,1.92)	1.11	(0.53,2.34)	1.05	(0.52,2.13)
BHT	0.95	(0.32,2.82)	0.64	(0.30,1.39)	0.57	(0.29,1.13)	0.31	(0.11,0.82)	0.43	(0.18,1.06)

Each environmental variable was modeled separately using a logistic-regression model. Asthma and allergies models were adjusted for gender, age, smoking, wall-to-wall carpet, renovation, dampness index, and pollen allergy. (n=390)

*:p< 0.05, **:p< 0.01

Kishi et al., *ICOH2012*

棚のダスト中フタル酸エステル類濃度とアレルギー有病、SHS有訴

	Asthma		Dermatitis		Rhinitis		Conjunctivitis		SBS	
	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)
DiBP	1.41	(0.63,3.15)	1.47	(0.85,2.55)	0.91	(0.53,1.59)	0.67	(0.27,1.64)	0.76	(0.32,1.80)
DnBP	2.57	(1.09,6.10)*	1.30	(0.71,2.36)	0.90	(0.52,1.57)	0.52	(0.22,1.23)	0.75	(0.38,1.50)
BBzP	1.06	(0.47,2.42)	0.81	(0.43,1.51)	0.94	(0.54,1.61)	1.67	(0.80,3.50)	0.73	(0.37,1.45)
DEHP	2.53	(0.78,8.17)	1.66	(0.82,3.37)	1.50	(0.78,2.87)	1.42	(0.56,3.63)	0.79	(0.38,1.64)
DINP	0.84	(0.39,1.80)	1.01	(0.61,1.66)	0.80	(0.51,1.26)	0.54	(0.27,1.04)	1.10	(0.63,1.90)
DEHA	1.18	(0.57,2.43)	1.16	(0.69,1.94)	1.24	(0.79,1.96)	0.54	(0.22,1.30)	0.64	(0.32,1.29)
BHT	1.49	(0.42,5.30)	0.84	(0.37,1.91)	1.02	(0.49,2.13)	0.89	(0.31,2.58)	0.91	(0.38,2.15)

Each environmental variable was modeled separately using a logistic-regression model.

The odds ratios were calculated using log10-transformed variables.

SBS models were adjusted for gender, age, smoke exposure. (n=400)

Asthma and allergies models were adjusted for gender, age, smoking, wall-to-wall carpet, renovation, dampness index, and pollen allergy. (n=390)

*:p< 0.05, **:p< 0.01

Kishi et al., *ICOH2012*

まとめ:フタル酸エステル類

- 床から採取したダスト中のDEHP , BBzP、DEHA は喘息、アトピー性皮膚炎、アトピー性結膜炎のリスクであった。
- 棚から採取したダスト中のフタル酸エステル類ではDnBPが喘息のリスクであった。
- SHSとダスト中フタル酸エステル類濃度に有意な関連は見られなかった。
- DEHP濃度は、スウェーデンで行われた先行研究と同程度であったが (Bornhag et al.,)、BBzP濃度は本研究の方が低かった。スウェーデンのPVC床材にはBBzPが含有されるが、日本ではBBzPの輸入量は少なく、またPVC床材にはDEHPが含有されることがその理由と考えられる。
- BBzPは濃度が低いにもかかわらずアトピー性皮膚炎のリスクであり、更なる検討が必要であろう。

ダスト中リン酸トリエステル類濃度

	Floor (N=148)			Multi-surface (N=120)			Correlation (r)
	Med. (μg/g)	Range (μg/g)	>LOD (%)	Med. (μg/g)	Range (μg/g)	>LOD (%)	
TBP	1.03	<LOD-133	63.0	1.15	<LOD-42.8	73.3	-0.076
TCPP	8.69	<LOD-430	97.3	25.8	1.3-462	100	0.284**
TCEP	5.83	<LOD-338	93.9	8.26	<LOD-2320	90.8	0.551**
TEHP	2.07	<LOD-51	64.2	1.47	<LOD-73.1	56.7	0.391**
TBEP	508	<LOD-5890	100	111	5.29-14100	100	0.295**
TDCPP	2.80	<LOD-864	67.6	10.8	<LOD-593	95.0	0.623**
TPhP	4.51	<LOD-245	88.5	11.5	<LOD-889	94.2	0.205**

Only >LOD above 20% are shown, ***P*<0.01

Abbrecivations: Trimethylphosphate (TMP), Triethylphosphate (TEP), Tripropylphosphate (TPP), Tributylphosphate (TBP), Tris(2-chloro-iso-propyl)phosphate (TCPP), Tris(2-chloroethyyl)phosphate (TCEP), Tris(2-butoxyethyl)phosphate (TBEP), Tris(1,3-dichloro-2-propyl)phosphate (TDCPP), Triphenylphosphate (TPhP), Tricresylphosphate (TCP)

Araki et al., *Indoor Air submitted*

床のダスト中リン酸トリエステル類濃度とアレルギー有病、SHS有訴

	Asthma	Dermatitis	Rhinitis	Conjunctivitis	SHS
	OR(95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR(95%CI)
TNBP	2.85(1.23,6.59)*	1.56(0.83,2.95)	0.77(0.45,1.34)	0.88(0.40,1.94)	1.47(0.76,2.84)
TCIPP	0.87(0.33,2.35)	2.43(1.28,4.61)**	0.99(0.62,1.58)	0.78(0.38,1.64)	0.97(0.50,1.90)
TCEP	1.16(0.42,3.28)	1.66(0.82,3.35)	1.22(0.74,2.00)	1.01(0.47,2.19)	1.40(0.68,2.90)
TEHP	2.16(0.73,6.42)	1.83(0.82,4.07)	1.59(0.87,2.90)	0.51(0.19,1.38)	1.69(0.74,3.85)
TBOEP	1.15(0.51,2.62)	1.01(0.57,1.81)	1.27(0.83,1.93)	0.88(0.47,1.65)	1.19(0.65,2.18)
TDCIPP	1.85(0.96,3.58)	1.84(1.17,2.88)**	0.82(0.57,1.18)	1.45(0.86,2.45)	1.16(0.72,1.87)
TPHP	1.60(0.55,4.67)	1.86(0.92,3.75)	1.12(0.63,1.99)	1.27(0.52,3.07)	0.76(0.32,1.81)

濃度が10倍になった時のOR(95%CI)を示す
変数は一度に投入し、性、年齢、喫煙、改築、カーペットの敷き詰め、ダンプネス指数、花粉症の有無で調整

Araki et al., Indoor Air 2013

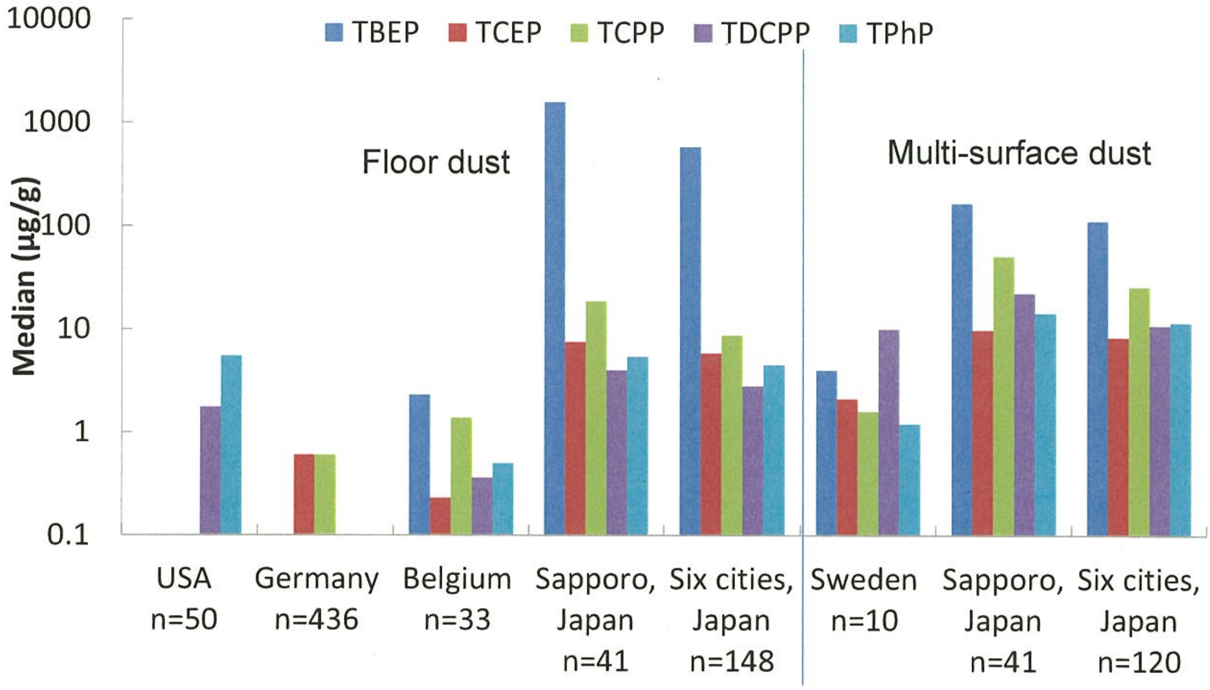
棚のダスト中リン酸トリエステル類濃度とアレルギー有病、SHS有訴

	Asthma	Dermatitis	Rhinitis	Conjunctivitis	SHS
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
TNBP	5.34(1.45,19.7)*	1.27(0.49,3.30)	2.55(1.29,45.01)**	1.68(0.59,4.77)	1.75(0.71,4.32)
TCIPP	1.26(0.55,2.87)	0.92(0.44,1.95)	1.43(0.82,2.53)	1.15(0.46,2.87)	1.41(0.69,2.88)
TCEP	1.58(0.36,6.92)	1.02(0.56,1.86)	1.27(0.83,1.95)	1.20(0.61,2.35)	1.69(0.97,2.94)
TEHP	1.68(0.68,4.78)	1.24(0.50,3.09)	0.90(0.40,1.90)	1.12(0.36,3.53)	1.58(0.64,3.86)
TBOEP	1.55(0.59,4.09)	0.96(0.49,1.87)	0.77(0.46,1.30)	1.31(0.59,2.88)	1.40(0.71,2.75)
TDCIPP	1.82(0.65,5.09)	1.01(0.51,1.99)	0.89(0.52,1.50)	1.47(0.65,3.35)	1.41(0.71,2.79)
TPHP	1.64(0.60,4.85)	0.85(0.42,1.68)	0.83(0.48,1.43)	0.72(0.31.1.66)	1.01(0.52,1.96)

濃度が10倍になった時のOR(95%CI)を示す
変数は一度に投入し、性、年齢、喫煙、改築、カーペットの敷き詰め、ダンプネス指数、花粉症の有無で調整

Araki et al., Indoor Air 2013

リン酸トリエステル類濃度の海外との比較



Germany: Ingerowski et al., 2001; USA: Meeker et al., 2010; Belgium: Van dern Eege et al., 2011; Sweden Berth et al, 2010; Sapporo, Japan: Kanazawa et al., 2010, Six cities, Japan: Araki et al., submitted

まとめ:リン酸トリエステル類

- TCIPPとTDCIPPがアトピー性皮膚炎のリスク、TBP曝露が喘息と鼻炎のリスクとなる可能性が示唆された。
- ダスト中のリン酸トリエステル類濃度とSHSには統計学的に有意な関連は見られなかった。
- ダスト中リン酸トリエステル類濃度は海外で測定された結果と比較して高濃度であり、臭素系難燃剤からリン系難燃剤への移行が日本よりも遅れて進んでいる米国等でも健康影響への注目が高まっている。
- 今後も引き続き調査研究が必要であると考えられる。

小学生を対象（その背景）

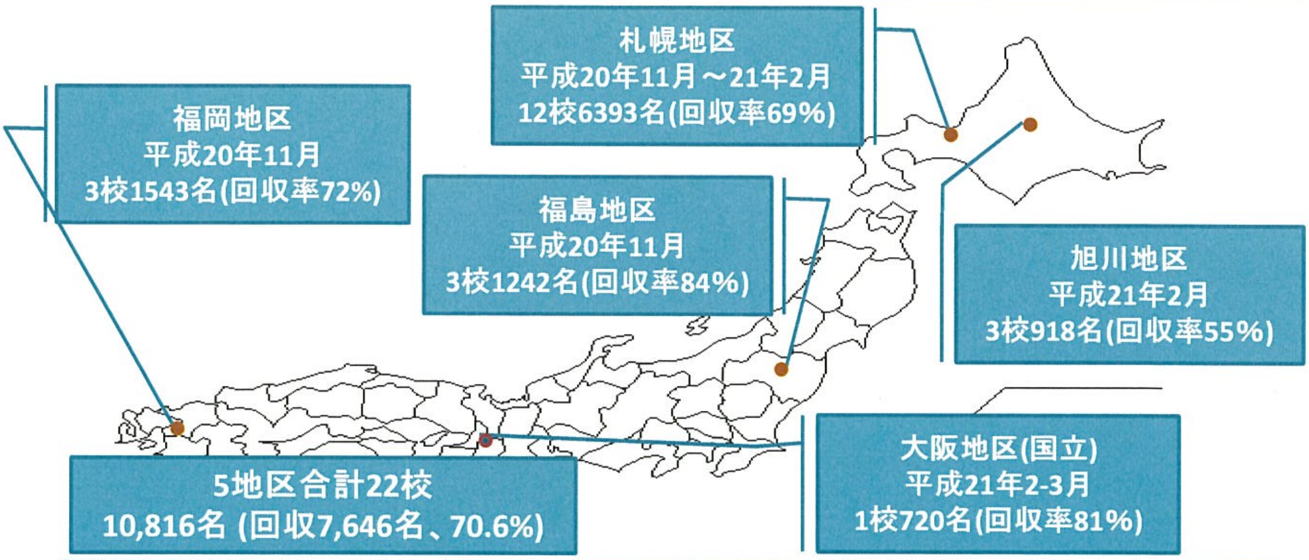
- これまでの全国6地域の調査で
- 戸建て住宅を対象にシックハウス症候群と室内環境を測定。

- 小学生の有訴率は12.2%
- 成人よりも約2倍多く、ハイリスク集団であった。
- 住宅として、戸建て住宅に加えて、集合住宅や築年の古い住宅を対象に調査を実施した。

研究の流れ

- 質問紙調査 (2008)
  - 5地区：旭川、札幌、福島、大阪、大宰府
  - 21公立、1国立小学校の1-6年生全児童10816人
  - MM080 School (Andersson 1998, Saijo et al., 2010)、ISAAC(International Study of Asthma and Allergy in Childhood)、ライフスタイル、ダンプネスを含む住環境
  - 学校のアルデヒド類、VOC類（旭川、札幌、福島）
- 児童の自宅環境調査(2009-2010)
  - 178 軒
  - 自宅環境測定：ホルムアルデヒド、アセトアルデヒド、アセトン、VOC類34化合物、MVOC13化合物、2E1H、SVOC(札幌)
  - エンドトキシン、βグルカン、ダニアレルゲン
  - ミニサンプラーを用いた児童の個人化学物質曝露24hモニター（2010札幌）

SHS有訴あり、アレルギー診断あり



		旭川	札幌	福島	大阪	福岡
SHS（いつも症状あり）有訴 (%)		5.9	8.5	8.0	3.6	4.4
診断 (%)	喘息	10.5	20.2	19.5	17.0	22.4
	季節性鼻炎・花粉症	34.9	19.5	33.4	24.7	26.0
	アトピー性皮膚炎	13.7	23.3	14.0	16.2	19.0

結論

- 結露やカビ臭といったダンプネスはSHSの独立したリスク要因である。
- 住宅で指針値を超過する化学物質は、ホルムアルデヒド、アセトアルデヒド、p-ジクロロベンゼン、総VOC（暫定値）に限定される。
- 指針値がない化学物質で室内濃度が比較的高いのは、リモネン、ピネン、C8-12アルカンであった。
- MVOCのうち1-octen-3-ol濃度が高いことが、SHSやアレルギー性鼻炎、結膜炎のリスクとして示唆された。
- SVOCのうちDEHPやBBzP（フタル酸エステル類）、TCIPPやTDCIPP（リン酸トリエステル類）がアレルギーのリスクを上げる可能性が示唆された。日本の生活様式では、床ダストとの接触が多いので、床のダスト中濃度が高いことがリスクとなった原因であると考えられる。

今後の課題

- C8-12アルカンによる、SHSのリスク上昇が示唆された。灯油や合成繊維が発生源である可能性があり、研究の蓄積が必要。
- リモネンやピネンは木材の他、衛生用品などに香料として多く含まれ、室内濃度が高い。リモネンやピネンの酸化によるリモネンオキサイド・ピネンオキサイドは粘膜への刺激作用が知られており、測定の工夫が必要。
- グリコールエーテルは、健康への影響が懸念されているものの、日本での知見はほとんどない。
- フタル酸エステル類曝露源は室内空気質以外に食事等からの摂食があるため、今後、尿中代謝物の分析など、生体内に取り込まれた量を用いる生物学的モニタリング法の確立とリスク評価が必要。
- リン酸トリエステルは海外よりも日本の住宅の濃度が高く、フタル酸エステル類と同様に、生物学的モニタリング法の確立とリスク評価が必要。

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<分担研究者>

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- 森本兼曩（大阪大学）
- 柴田英治（愛知医科大学）
- 河合俊夫（中央労働災害防止協会）
- 西條泰明（旭川医科大学）
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（別添）

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ORIGINAL ARTICLE

Relationship between indoor chemical concentrations and subjective symptoms associated with sick building syndrome in newly built houses in Japan

Tomoko Takigawa · Bing-Ling Wang · Yasuaki Saijo · Kanehisa Morimoto · Kunio Nakayama · Masatoshi Tanaka · Eiji Shibata · Takesumi Yoshimura · Hisao Chikara · Keiki Ogino · Reiko Kishi

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Abstract
Objectives This study explored possible associations between chemical substances and sick building syndrome (SBS)-type symptoms of residents living in new houses in Japan.
Methods We randomly sampled 5,709 newly built conventional homes. In the end, 1,479 residents in 425 households completed a questionnaire survey and agreed to environmental monitoring for indoor aldehydes and volatile organic compounds (VOCs) to be conducted in their homes. If the residents had complained about at least one SBS-related symptom, they were classified as suffering from SBS. Multiple logistic regression analysis was used to select predictive chemical factors of SBS symptoms.
Results About 14% of the subjects suffered from SBS. Many aldehydes and VOCs were associated factors of optical, nasal, and gular symptoms in univariate analysis. After adjustment for other possible risk factors, formaldehyde dose-dependently showed to be a significant risk factor for SBS. Several chemicals had tendency to be associated with SBS symptoms.
Conclusions Chemicals detected in Japanese newly built houses tend to increase the risk of subjective symptoms in residents suffering from SBS.

Keywords Sick building syndrome · Indoor air · Aldehydes · Volatile organic compounds · Subjective symptoms

Introduction

Health problems caused by indoor chemical and biological pollution, poor control of temperature and humidity, or other factors in office buildings have been recognized as sick building syndrome (SBS) in Western countries

T. Takigawa · B.-L. Wang · K. Ogino
Department of Public Health,
Okayama University Graduate School of Medicine,
Dentistry and Pharmaceutical Sciences,
2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan

Y. Saijo
Department of Health Science,
Asahikawa Medical College,
Midorigaoka E2-1-1-1, Asahikawa 078-8510, Japan

K. Morimoto · K. Nakayama
Department of Social and Environmental Medicine,
Osaka University Graduate School of Medicine,
2-2 Yamadaoka, Suita 565-0871, Japan

M. Tanaka
Fukushima College, 1-1 Chigoike Miyashiro,
Fukushima 960-8505, Japan

E. Shibata
Department of Health and Psychosocial Medicine,
Aichi Medical University School of Medicine,
Nagakute-cho, Aichi Prefecture 480-1195, Japan

T. Yoshimura · H. Chikara
Fukuoka Institute of Health and Environmental Sciences,
39 Mukouzano, Dazaifu 818-0135, Japan

R. Kishi (✉)
Department of Public Health,
Hokkaido University Graduate School of Medicine,
Kita 15, Nishi 7, Kita-ku, Sapporo 060-8638, Japan
e-mail: rkishi@med.hokudai.ac.jp

since the 1970s (Godish 1994; World Health Organization 1983). Originally, fewer office workers in Japan were considered to suffer health hazards from room air contaminants, because indoor environments in Japanese buildings had been controlled within the framework of the Building Standard Law, which was for large-scale buildings (Torii 2000). In the 1990s, however, some Japanese people living in newly built houses or renovated individual homes started to describe a variety of nonspecific subjective symptoms such as irritation of the eye, nose, and throat, headache, and general fatigue (Saijo et al. 2004). The constellation of these symptoms resembles SBS and is designated as "sick house syndrome" (Ando 2002; Seki et al. 2007; Torii 2001). Meanwhile, gray areas remain regarding the specific details of SBS and its definition is usually based on questionnaire in earlier population-based studies including our study. It is unlikely that there is a single cause or a clear diagnostic criterion for SBS at this time and the fact incites public's anxiety. Recently, indoor chemical substances emitted from building materials, including formaldehyde or volatile organic compounds (VOCs), have been acknowledged to be major sources of SBS in Japan because the incidence of SBS patients living in new or renovated houses had increased (Ministry of Health, Labour and Welfare of Japan 2002; Sakaguchi and Akabayashi 2003; Takigawa 2006; Torii 2001).

Numerous epidemiologic studies in foreign countries have reported many factors such as chemical, biological, physical, technical, and psychosocial factors as influential agents of SBS symptoms (Andersson 1998). Although the occurrence of SBS in Japan is also an important problem to solve, no field survey has yet been conducted thoroughly in Japan. In this survey, we measured indoor air chemical concentrations, air fungal colonies, and mite allergen concentrations in detached houses all over Japan and gathered information on residents' health complaints by questionnaire. To our knowledge, there has been no previous report where both environmental monitoring and a questionnaire survey have been performed for so many newly built houses in Japan as with our large sample. In the present paper, we focused on the associations between chemical substances and subjective symptoms. Analyses on other factors will be discussed in papers to be published in the future.

Materials and methods

Study population and selection of homes

We randomly sampled 5,709 households in dwellings aged 7 or less in six prefectures from northern to southern Japan, Hokkaido (1,240 households), Fukushima (910), Aichi (1,070), Osaka (885), Okayama (906), and Fukuoka (698). The household list was obtained from building plan approval applications, which are official data available for inspection. Preliminary questionnaires on indoor air quality were sent to the households between November, 2003 and January, 2004. The responses were returned by the residents of 2,297 households (response rate; 41.1%) after excluding those sent back due to incorrect addresses and those sent to dwellings aged more than 7 at the time that the questionnaire was returned (5,589 remained in total). Of the respondents, 1,522 residents of 444 households agreed to participate in this study conducted from September to November, 2004. We chose autumn for this study because the climate is moderate. In this season, fewer persons use air-conditioning equipments and it could minimize the effect of them to indoor environments. The study was conducted with all the subjects' informed consent and approved by the institutional ethical boards for epidemiological studies at Hokkaido University Graduate School of Medicine which was the principal investigator and at all the regional universities involved in this study.

Environmental monitoring

Indoor aldehydes and VOCs were measured in the living room of each dwelling visited. In this study, VOCs are defined as organic chemical compounds that have high enough vapor pressures under normal conditions, including a wide range of carbon-based molecules, such as aliphatic, aromatic, or halogenated hydrocarbons, and it means a chemical family. Air samples were collected onto diffusive air samplers (DSD-DNPH and VOC-SD for aldehydes and VOCs, respectively, both from Sigma–Aldrich, Japan) at approximately 1.5 m above the floor for 24 h on weekdays. At the same time, travel blank samples were obtained to determine sample contamination during travel to the laboratory. Room temperature and relative humidity were also measured in parallel every 15 min for 24 h with Thermo Recorder (TR-72U, T&D Corporation, Japan). Concentrations of 13 target aldehydes and 29 VOCs were quantified using high-performance liquid chromatograph with UV detection and gas chromatograph with mass spectrometry, respectively, as previously described (Takigawa et al. 2004). This list of chemicals covers the major component of indoor chemicals detected in Japanese residences (Tanaka-Kagawa et al. 2005). Total VOC concentration was defined as the sum of the concentrations of the target VOCs.

Questionnaire study

We distributed the self-administered questionnaires based on the "questionnaire for national investigation for SBS and its potential risk factors in Japan" (Wang et al. 2008) to the participants when we visited their homes for environmental monitoring. If the participants could not read or write, another family member answered the questionnaires for them. In particular, we asked parents to answer questions on behalf of their children. The questionnaire included questions on personal characteristics (e.g., sex, age, smoking habits, environmental tobacco smoking, time spent at home, alcohol habits, and mental stress level), indoor environmental characteristics (the occurrence of dew condensation, mold growth, and having pets in the dwellings), and on subjective symptoms (see the Appendix). The section on symptom groups consisted of part of the Japanese version of MM040EA, a validated questionnaire designed for epidemiologic assessment of SBS symptoms (Mizoue et al. 2001); optical symptoms (eye irritation), nasal symptoms (rhinitis, blocked nose, and sneezing), gular symptoms (hoarseness, dry throat, coughing, and wheezing), dermal symptoms (itching, dry, flushed, and erupted skin), and general symptoms (fatigue, feeling heavy headed, headache, nausea, dizziness, and having difficulty concentrating). We also applied this questionnaire on symptoms to children, because the same questions appeared in a validated questionnaire "MM 080," which is an indoor climate questionnaire for children designed to be answered by a parent. Participants were asked to refer to their health complaints during the last 3 months in choosing responses to each question; always, sometimes, or never. Continuous symptoms were defined as occurring at least three times a week, and sporadic symptoms were defined as occurring once or twice a week. They were also asked whether they attributed the symptom to their home environment. If subjects reported any continuous or sporadic symptom in an anatomic site related to the home environment, they were designated positive for the symptom group. If they had complained about at least one symptom group, they were classified as SBS.

Statistical analysis

The data below limit of quantitation for chemical concentrations (1 μg/m^3) were assigned half of the limit of quantitation (0.5 μg/m^3). Limit of quantitation is calculated from S/N ratio. We applied all the chemical sensitivity to the lowest one because we performed simultaneous analyses. Chemical concentrations were categorized into four groups at quartiles. After crude analyses for all chemicals, the most important ones with $P \leq 0.20$ were selected for calculation of multiple logistic regression models for each symptom group (SBS symptoms and individual physical symptoms including optical, nasal, gular, dermal, and general symptoms). Chi-square test or Fisher's exact test, Spearman rank test, and Mann–Whitney U test were used where appropriate. For multiple logistic regression analysis, the factors on personal and indoor environmental characteristics (sex, age, residential area, tobacco smoking, time at home, alcohol drinking, mental stress, condensation, fungi reported, pet, and passive smoking, allergic diseases, temperature, and relative humidity) were forced into the model as adjusted variables and the chemical factors were entered into the models in a backward stepwise fashion. We adopted this two-step process because only a backward fashion would not select associated values from many target variables. Two-sided values of $P < 0.05$ were considered statistically significant. All analyses were performed with SPSS 14.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Characteristics of the participants

Of the subjects, 1,479 participants in 425 households remained for analysis after eliminating data with missing values. The distribution of households among the six prefectures was as follows; Hokkaido (104 households), Fukushima (65), Aichi (57), Osaka (78), Okayama (71), and Fukuoka (50). The participation rate for environmental monitoring was 18.5% in respondents of the preliminary questionnaire survey. The average age of analyzed participants was 33 (range 0–90) years. There were significantly more females, persons exposed to environmental tobacco smoke, persons spending longer time in their houses, persons reporting much mold growth in their homes, and persons with allergic diseases in the SBS group (Table 1). About 14% of the subjects suffered from SBS, among which the most frequently reported symptoms were nasal and gular at 7.8 and 6.9%, respectively; next were dermal 4.1%, and then optical and general at 3.4 and 2.0%, respectively.

Chemical concentrations in living rooms

The average age of dwellings was 3.3 (range 1.08–7.0) years at the time of study. Indoor chemical concentrations in the living rooms are listed in Table 2. When compared in terms of the detection rates, aldehydes and acetone were more abundant than VOCs in indoor air. Formaldehyde and acetaldehyde were found in the studied houses at the concentrations exceeding the guideline values (100 and 48 μg/m^3, respectively) established by the Japanese ministry (Ministry of Health, Labour and Welfare of Japan 2002) at 3.5 and 12.2%, respectively. For VOCs, hydrocarbons such as toluene, xylenes, terpenes (α-pinene

Table 1 Prevalence of personal data and perception about humidity environment for subjects among SBS and non-SBS groups

Variables	SBS ($n = 210$) (%)	Non-SBS ($n = 1{,}269$) (%)	P
Female	60.5	50.6	0.008
Age (years)			
<20	34	38.6	0.002
20–39	26	33.3	
40–59	26.8	22.9	
>59	13.2	5.2	
Current smoker	10.0	12.6	0.289
Environmental tobacco smoking	31.4	29.8	0.004
Alcohol drink (≥1/week)	28.7	31.6	0.402
Time spent at home (≥20 h per day)	21.4	15.5	0.031
Mental stress level (high)	32.1	25.9	0.064
Having pets in the house	27.1	25.5	0.547
Dew condensation	63.8	64.4	0.873
Mold growth	84.8	70.8	<0.001
Allergic disease	25.7	9.5	<0.001

Chi-square test

Table 2 Concentrations of aldehydes and VOCs in the living rooms ($n = 425$)

Compounds	Detection rate (%)	Minimum	95%	Maximum
Formaldehyde	95.8	ND	86.6	202.8
Acetaldehyde	96.5	ND	63.5	208.9
Acetone	97.4	ND	126.1	606.0
Acrolein	0.2	ND	ND	6.1
Propionaldehyde	92.7	ND	22.4	127.1
Crotonaldehyde	58.1	ND	14.6	112.5
n-Butyraldehyde	76.2	ND	15.5	109.5
Benzaldehyde	76.9	ND	30.8	117.1
iso-Valeraldehyde	57.4	ND	22.7	104.6
Valeraldehyde	77.4	ND	23.5	223.7
Tolualdehyde	39.1	ND	11.8	222.9
Hexaldehyde	95.8	ND	44.2	198.5
2,5-Dimethylaldehyde	7.5	ND	1.3	19.7
n-Hexane	20.2	ND	5.8	178.1
2,4-Dimethylpentane	7.3	ND	1.4	3.8
n-Heptane	41.9	ND	10.4	129.6
n-Octane	39.1	ND	12.6	45.5
n-Nonane	48.9	ND	19.2	160.0
n-Decane	39.5	ND	17.7	84.7
n-Undecane	43.1	ND	25.8	101.3
Benzene	50.8	ND	5.9	21.7
Toluene	96.0	ND	42.2	144.2
Ethylbenzene	89.2	ND	9.2	24.8
Xylene	90.8	ND	23.3	101.1
Styrene	6.4	ND	1.2	52.7
Trimethylbenzene	66.1	ND	17.3	103.0
α-Pinene	85.4	ND	138.6	1052.7
Limonene	93.2	ND	72.6	601.6
Chloroform	17.2	ND	2.7	5.9
1,2-Dichloroethane	4.0	ND	ND	9.8
1,1,1-Trichloroethane	6.4	ND	1.2	15.6
Carbontetrachloride	2.4	ND	ND	1.4
1,2-Dichloropropane	0.2	ND	ND	2.8
Chlorodibromomethane	1.6	ND	ND	6.0
Trichloroethylene	1.4	ND	ND	3.8
Tetrachloroethylene	6.8	ND	1.6	167.0
p-Dichlorobenzene	60.9	ND	241.6	1689.8
Ethyl acetate	45.9	ND	28.9	313.2
Butyl acetate	74.8	ND	13.0	61.4
2-Butanone	29.4	ND	6.5	37.5
2-Pentanone	28.9	ND	4.7	32.0
n-Butanol	22.4	ND	2.7	11.6
Total VOC	100.0	16.0	517.5	1770.9

Concentrations are expressed in μg/m^3

VOC volatile organic compound; *ND* not detected

and limonene), trimethylbenzene, halogenated hydrocarbons such as *p*-dichlorobenzene, esters such as ethyl acetate and butyl acetate were ubiquitously detected compounds in indoor air. Maximum concentrations for α-pinene and *p*-dichlorobenzene were up to 1,053 and 1,690 μg/m^3, respectively, and no other VOCs were higher than these levels. As for VOCs with guideline values, 5.6% of the samples exceeded the guideline value for *p*-dichlorobenzene, 240 μg/m^3. Others were all within the limits. Total VOC, which was calculated by adding all the detected VOCs, was higher than the provisional guideline value (400 μg/m^3) in 8.0% of the houses. We analyzed the association between age of the house and indoor chemical concentrations (Table 3). Most of the chemicals varied little, however, α-pinene decreased drastically ($r_s = -3.50$).

Associations between chemical concentrations and SBS

Almost all individual aldehydes showed higher medians in the SBS group than in the non-SBS group (Table 4). For VOCs, unlike aldehydes, this trend was not seen because much lower levels of VOCs were detected than those of aldehydes. We also tested the associations between chemical concentrations and SBS occurrence among each symptom group (Table 5). For the participants that suffered from

Table 3 Association between age of the house and indoor chemical concentrations ($n = 425$)

Compounds	r_s^a	P
Formaldehyde	0.038	0.440
Acetaldehyde	−0.039	0.427
Acetone	−0.081	0.094
Acrolein	−0.018	0.708
Propionaldehyde	−0.016	0.741
Crotonaldehyde	0.006	0.904
n-Butyraldehyde	−0.070	0.150
Benzaldehyde	−0.004	0.942
iso-Valeraldehyde	−0.007	0.890
Valeraldehyde	−0.040	0.410
Tolualdehyde	0.008	0.862
Hexaldehyde	−0.052	0.287
2,5-Dimethylaldehyde	0.057	0.241
n-Hexane	0.115	0.017
2,4-Dimethylpentane	−0.032	0.506
n-Heptane	−0.007	0.884
n-Octane	0.119	0.014
n-Nonane	0.163	0.001
n-Decane	0.035	0.473
n-Undecane	0.038	0.433
Benzene	0.005	0.916
Toluene	−0.010	0.839
Ethylbenzene	0.051	0.296
Xylene	0.057	0.244
Styrene	−0.052	0.284
Trimethylbenzene	0.147	0.002
α-Pinene	−0.350	<0.001
Limonene	−0.015	0.759
Chloroform	0.043	0.374
1,2-Dichloroethane	−0.011	0.826
1,1,1-Trichloroethane	−0.031	0.521
Carbontetrachloride	−0.021	0.663
1,2-Dichloropropane	−0.062	0.202
Chlorodibromomethane	0.016	0.746
Trichloroethylene	0.021	0.667
Tetrachloroethylene	0.017	0.724
p-Dichlorobenzene	0.051	0.297
Ethyl acetate	0.061	0.207
Butyl acetate	−0.055	0.255
2-Butanone	−0.001	0.987
2-Pentanone	−0.132	0.006
n-Butanol	−0.028	0.566
Total VOC	−0.086	0.076

VOC volatile organic compound

[a] Spearman rank-correlation coefficient

optical or nasal symptoms, it was mainly aldehyde concentrations that were higher in their homes than in the homes of those without symptoms. For cases with gular symptoms, besides aldehydes, VOCs concentrations were also higher. For dermal and general symptoms, few chemicals showed higher concentrations in the homes of participants with symptoms. Additionally, linear regression analysis was used to determine the relationship between the number of SBS positive subjects per dwelling and chemical concentrations. In this analysis, the numbers of SBS positive subjects were dependent variables and the chemical concentrations and the numbers of family members were the independent variables. There were significant relationships among the number of SBS positive subjects and several chemical concentrations such as formaldehyde, iso-valeraldehyde, and *n*-undecane.

The health risks associated to each chemical substance

After adjusting for other possible risk factors (Table 6), only odds ratio (OR) of SBS increased with formaldehyde concentration dose-dependently with statistical significance. Formaldehyde also increased ORs of optical and nasal symptoms without significance. Chlorodibromomethane increased ORs of several symptom groups; however, this chemical was detected in few houses to conclude its effect on symptoms. Several chemicals tended to be associated with SBS symptoms.

Discussion and conclusion

Our results suggest associations between measured environmental factors such as aldehydes or VOCs and SBS symptoms of residents living in newly built houses in Japan. Even when adjusted for personal factors including perception about the present state of humidity environment in dwellings, and the data pertaining to indoor temperature and relative humidity (Fang et al. 1999; Mizoue et al. 2004; Wolkoff and Kjaergaard 2007), these associations were evident.

Indoor chemical concentrations have decreased recently in Japan (Takigawa 2006). Overall, the measured concentrations of indoor aldehydes and VOCs were also low in this study. The air pollutant concentrations were similar to those reported outside of Japan (Hodgson et al. 2000). The maximum levels of some chemicals such as formaldehyde, acetaldehyde, *p*-dichlorobenzene, and total VOC, however, exceeded their guideline values (100, 48, 240, and 400 μg/m^3, respectively) (Ministry of Health, Labour and Welfare of

Table 4 Differences in chemical concentrations in the living rooms and other factors between SBS and non-SBS groups

Compounds	SBS			Non-SBS			*P*
	25%	Median	75%	25%	Median	75%	
Formaldehyde	33.7	48.5	66.5	26.8	39.4	55.9	<0.001
Acetaldehyde	15.9	24.3	35.9	14.0	22.2	34.0	0.093
Acetone	29.7	42.6	63.1	23.1	33.4	54.4	<0.001
Acrolein	ND	ND	ND	ND	ND	ND	0.684
Propionaldehyde	5.6	10.9	14.8	4.4	7.4	14.2	0.002
Crotonaldehyde	ND	7.6	10.5	ND	3.8	9.1	<0.001
n-Butyraldehyde	1.4	4.1	7.8	ND	2.2	6.3	<0.001
Benzaldehyde	1.7	6.2	14.4	ND	3.6	9.9	<0.001
iso-Valeraldehyde	ND	4.8	12.2	ND	2.5	8.2	<0.001
Valeraldehyde	2.2	5.5	13.2	1.1	3.6	8.6	<0.001
Tolualdehyde	1.0	1.0	3.4	1.0	1.0	3.0	0.034
Hexaldehyde	6.3	10.5	22.4	4.6	9.6	18.1	0.002
2,5-Dimethylaldehyde	ND	ND	ND	ND	ND	ND	0.215
n-Hexane	ND	ND	ND	ND	ND	ND	0.746
2,4-Dimethylpentane	ND	ND	ND	ND	ND	ND	0.292
n-Heptane	ND	ND	3.7	ND	ND	2.6	0.732
n-Octane	ND	ND	3.4	ND	ND	2.4	0.026
n-Nonane	ND	1.8	7.6	ND	ND	4.4	0.002
n-Decane	ND	ND	3.3	ND	ND	3.2	0.808
n-Undecane	ND	ND	1.7	ND	ND	2.4	0.172
Benzene	ND	1.1	2.3	ND	1.1	2.4	0.825
Toluene	7.6	12.9	21.4	8.4	12.9	20.4	0.474
Ethylbenzene	1.7	3.2	4.9	1.6	2.8	4.5	0.108
Xylene	3.0	6.0	12.3	2.9	5.8	10.5	0.134
Styrene	ND	ND	ND	ND	ND	ND	0.498
Trimethylbenzene	1.5	2.9	6.4	1.5	2.7	5.2	0.271
α-Pinene	2.6	7.0	27.8	2.3	7.6	26.7	0.696
Limonene	4.2	9.0	24.0	3.8	9.0	18.8	0.518
Chloroform	ND	ND	ND	ND	ND	ND	0.892
1,2-Dichloroethane	ND	ND	ND	ND	ND	ND	0.027
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	0.858
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	0.308
1,2-Dichloropropane	ND	ND	ND	ND	ND	ND	0.009
Chlorodibromomethane	ND	ND	ND	ND	ND	ND	<0.001
Trichloroethylene	ND	ND	ND	ND	ND	ND	0.049
Tetrachloroethylene	ND	ND	ND	ND	ND	ND	0.395
p-Dichlorobenzene	ND	1.1	6.1	ND	2.0	17.3	<0.001
Ethyl acetate	ND	ND	5.9	ND	ND	6.4	0.837
Butyl acetate	ND	2.5	6.0	0.8	2.6	4.9	0.961
2-Butanone	ND	ND	ND	ND	ND	1.9	0.006
2-Pentanone	ND	ND	1.3	ND	ND	1.1	0.029
n-Butanol	ND	ND	ND	ND	ND	ND	0.786
Total VOC	64.3	116.5	206.2	68.5	108.2	201.8	0.385
Age[a]	9.75	33.50	41.00	12.00	36.00	48.00	0.003
Age of house[b]	1.17	2.50	3.67	1.00	2.00	3.27	0.123

Concentrations are expressed in μg/m^3. Mann–Whitney *U* test ($n = 1{,}479$)

SBS sick building syndrome; *ND* not detected; *VOC* volatile organic compound

[a] *t*-test for participants ($n = 1{,}479$)

[b] *t*-test for houses ($n = 425$)

Table 5 Significant differences in chemical concentrations in the living rooms between SBS and non-SBS among symptom groups

	Compounds	SBS Median	Non-SBS Median	*P*
Optical	Formaldehyde	48.8	39.7	0.018
	Acetone	60.2	34.4	<0.001
	Propionaldehyde	11.4	7.6	0.004
	Crotonaldehyde	8.5	4.2	0.002
	n-Butyraldehyde	4.7	2.2	0.006
	Benzaldehyde	9.7	3.7	<0.001
	iso-Valeraldehyde	8.3	2.7	<0.001
	Valeraldehyde	8.8	3.8	0.009
	Tolualdehyde	1.0	1.0	0.054
	n-Nonane	1.8	ND	0.164
	Benzene	1.8	1.1	0.037
	1,2-Dichloroethane	ND	ND	<0.001
	1,1,1-Trichloroethane	ND	ND	0.178
	2-Pentanone	ND	ND	0.033
	Total VOC	170.6	108.6	0.199
Nasal	Formaldehyde	45.7	39.7	0.018
	Acetone	42.3	34.2	0.012
	Propionaldehyde	11.0	7.6	0.01
	Crotonaldehyde	8.5	3.9	<0.001
	n-Butyraldehyde	4.8	2.2	<0.001
	Benzaldehyde	7.5	3.7	<0.001
	iso-Valeraldehyde	6.0	2.7	<0.001
	Valeraldehyde	5.6	3.8	0.003
	Hexaldehyde	10.3	9.7	0.115
	2,5-Dimethylaldehyde	ND	ND	0.031
	n-Nonane	1.8	ND	0.074
	1,2-Dichloroethane	ND	ND	0.006
	Chlorodibromomethane	ND	ND	<0.001
	Trichloroethylene	ND	ND	0.161
	p-Dichlorobenzene	1.2	1.9	0.08
	2-Butanone	ND	ND	0.016
	2-Pentanone	ND	ND	0.107
Gular	Formaldehyde	50.6	39.7	<0.001
	Acetaldehyde	24.2	22.2	0.146
	Acetone	42.6	34.4	0.015
	Valeraldehyde	4.5	3.8	0.157
	Hexaldehyde	10.5	9.6	0.034
	2,4-Dimethylpentane	ND	ND	0.018
	n-Heptane	1.0	ND	0.046
	n-Octane	1.1	ND	0.001
	n-Nonane	2.1	ND	0.001
	Benzene	1.3	1.0	0.011
	Toluene	14.9	12.9	0.075
	Ethylbenzene	3.8	2.7	0.004
	Xylene	8.1	5.8	0.003
	Trimethylbenzene	3.4	2.7	0.009

Table 5 continued

	Compounds	SBS Median	Non-SBS Median	*P*
	Limonene	11.1	8.9	0.044
	1,2-Dichloroethane	ND	ND	0.104
	1,2-Dichloropropane	ND	ND	<0.001
	Chlorodibromomethane	ND	ND	<0.001
	Trichloroethylene	ND	ND	0.188
	Tetrachloroethylene	ND	ND	0.183
	p-Dichlorobenzene	1.3	1.9	0.098
	Butyl acetate	3.5	2.5	0.043
	2-Pentanone	ND	ND	<0.001
	n-Butanol	ND	ND	0.005
	Total VOC	151.0	108.2	0.009
Dermal	Formaldehyde	49.8	39.7	0.018
	Tolualdehyde	1.0	1.0	0.135
	2,5-Dimethylaldehyde	ND	ND	0.032
	1,1,1-Trichloroethane	ND	ND	0.114
	Chlorodibromomethane	ND	ND	<0.001
	2-Butanone	ND	ND	0.137
General	Formaldehyde	45.5	40.2	0.144
	Acetaldehyde	31.6	22.2	0.086
	Propionaldehyde	12.3	7.7	0.014
	Crotonaldehyde	8.5	4.2	0.101
	iso-Valeraldehyde	6.3	2.8	0.141
	n-Nonane	2.8	ND	0.035
	Limonene	9.4	9.0	0.158
	Chlorodibromomethane	ND	ND	<0.001
	Tetrachloroethylene	ND	ND	0.137

Concentrations are expressed in μg/m^3. Mann–Whitney *U* test ($n = 1{,}479$)

SBS sick building syndrome; *VOC* volatile organic compound; *ND* not detected

Japan 2002), though the levels of total VOC depended on the number of VOCs measured in our study. Chemicals that were found in high frequencies were aldehydes, aliphatic and aromatic hydrocarbons, terpenes, and *p*-dichlorobenzene. These findings were the same as a previous review in which VOCs including alcohols, aromatics, aldehydes, and halocarbons were concluded to occur in indoor environments (Wang et al. 2007). According to the analysis of the association between age of the house and indoor chemical concentrations, most of the indoor chemicals were not associated with the age of the house. Only α-pinene declined greatly with age. α-Pinene is mainly emitted from wood, so this decrease is considered to be due to the aging of the houses. Cleaning agents are also important sources of indoor chemical concentrations. Acetone and butyl acetate detected in this study are used as these agents and are

Table 6 Adjusted ORs (95% CI) for type of symptoms adjusted for chemical substances and other factors (n = 1,479)

	Compounds	Quartiles of indoor concentration			
		1	2	3	4
SBS	Formaldehyde	1	2.13 (1.21–3.76)	2.28 (1.22–4.25)	2.35 (1.22–4.56)
	Acetaldehyde	1	0.92 (0.55–1.55)	0.53 (0.30–0.95)	0.58 (0.31–1.10)
	Propionaldehyde	1	0.55 (0.30–0.99)	1.03 (0.55–1.94)	0.62 (0.28–1.36)
	n-Butyraldehyde	1	2.10 (1.15–3.82)	1.80 (0.83–3.92)	1.41 (0.54–3.67)
	Benzaldehyde	1	0.86 (0.50–1.50)	0.95 (0.47–1.92)	2.18 (0.93–5.11)
	n-Octane		1	0.38 (0.20–0.75)	0.58 (0.31–1.11)
	n-Nonane		1	1.40 (0.84–2.32)	2.39 (1.23–4.67)
	1,2-Dichloropropane		1		15.01 (1.16–194.86)
	Chlorodibromomethane		1		5.71 (2.26–14.46)
Optical	Formaldehyde	1	1.97 (0.60–6.46)	4.24 (1.21–14.86)	1.74 (0.45–6.78)
	Acetone	1	0.93 (0.25–3.37)	1.16 (0.30–4.54)	4.46 (1.17–17.06)
	Propionaldehyde	1	0.20 (0.05–0.84)	0.68 (0.18–2.59)	0.28 (0.06–1.40)
	Hexaldehyde	1	0.20 (0.07–0.63)	0.19 (0.05–0.64)	0.33 (0.10–1.10)
	n-Octane		1	0.26 (0.08–0.91)	0.11 (0.03–0.38)
	n-Nonane		1	3.63 (1.37–9.58)	9.48 (2.53–35.58)
	n-Undecane		1	1.77 (0.67–4.63)	0.39 (0.13–1.16)
	Ethylbenzene	1	0.43 (0.15–1.19)	0.49 (0.17–1.43)	1.45 (0.49–4.31)
	2-Butanone		1		2.61 (0.76–8.96)
	2-Pentanone		1	0.68 (0.12–3.76)	3.38 (1.54–7.43)
Nasal	Formaldehyde	1	2.89 (1.39–6.00)	2.59 (1.15–5.81)	1.74 (0.74–4.10)
	Propionaldehyde	1	0.53 (0.24–1.18)	1.22 (0.53–2.80)	0.72 (0.27–1.92)
	Benzaldehyde	1	0.82 (0.40–1.69)	0.81 (0.35–1.88)	1.77 (0.70–4.44)
	Chlorodibromomethane		1		6.07 (2.07–17.85)
Gular	Crotonaldehyde	1	1.61 (0.38–6.83)	3.58 (0.90–14.19)	8.82 (1.92–40.51)
	n-Butyraldehyde	1	1.69 (0.84–3.42)	1.19 (0.47–2.97)	0.13 (0.04–0.46)
	Benzaldehyde	1	1.37 (0.66–2.83)	2.47 (0.95–6.37)	9.90 (1.82–53.72)
	iso-Valeraldehyde	1	0.15 (0.03–0.76)	0.06 (0.01–0.27)	0.05 (0.01–0.42)
	1,2-Dichloropropane		1		42.95 (3.20–575.81)
	Chlorodibromomethane		1		4.45 (1.55–12.75)
	2-Pentanone		1	1.70 (0.67–4.32)	2.16 (1.28–3.65)
Dermal	Acetone	1	0.27 (0.09–0.78)	0.51 (0.19–1.39)	0.39 (0.12–1.23)
	Propionaldehyde	1	1.07 (0.38–3.04)	3.37 (1.15–9.91)	1.76 (0.43–7.24)
	Benzaldehyde	1	0.71 (0.26–1.98)	0.43 (0.08–2.34)	11.68 (1.25–108.70)
	iso-Valeraldehyde	1	0.87 (0.20–3.71)	0.32 (0.07–1.52)	0.04 (0.01–0.36)
	n-Octane		1	0.11 (0.02–0.50)	0.45 (0.16–1.31)
	n-Nonane		1	0.87 (0.20–3.71)	0.32 (0.07–1.52)
	Chlorodibromomethane		1		9.05 (1.85–44.14)
	p-Dichlorobenzene	1	2.33 (0.90–6.03)	0.61 (0.25–1.49)	0.70 (0.28–1.76)
	2-Butanone		1	0.10 (0.01–0.96)	0.74 (0.24–2.31)
General	Benzaldehyde	1	0.36 (0.09–1.48)	1.75 (0.55–5.60)	1.11 (0.27–4.57)
	Chlorodibromomethane		1		10.31 (2.38–44.69)

Adjusted for area code, gender, age of participant, tobacco smoking, time spent at home, alcohol drinking, mental stress, condensation, fungi reported, pet, and passive smoking, allergic diseases, temperature, and relative humidity (for details, see Table 1). Chemicals were entered into the models using a backward stepwise method

OR odds ratio; *CI* confidence interval; *SBS* sick building syndrome. The chemical concentrations were divided into four groups by the quartiles. Blank columns mean that the quartiles have been removed from the multiple logistic regression model because of inhomogeneous concentration distributions significantly associated with SBS symptoms. We asked the participants whether they used benzine and nail polish during environmental measurement and nobody and 1.6% answered yes, respectively. Though almost the same percentage of the people using nail polish might have used nail polish remover including acetone or butyl acetate, there were too few to analyze. The use of cleaning agents will result in a temporal increase of the indoor VOC level. This increase can enhance the probability of increased exposure and possibly have an impact on the perceived indoor air quality. The increase can also result in increased reporting the SBS symptoms (Wolkoff et al. 1998).

There is no standardized definition of SBS at this time. When defining the SBS groups, we used the criterion to include subjects that reported any "continuous or sporadic" symptom because this broad definition could be useful to find more potential risk factors (Wang et al. 2008). The subjective symptoms observed in the present study could be partially attributed to the indoor chemicals. Most of these chemical substances were detected relatively at low concentrations, and it is unknown whether there may be any long term biological adverse effects to humans. Therefore, we can only suggest that there may be associations with these low level chemicals and SBS; it is difficult to determine the associations until further toxicological studies are completed in lower concentration ranges. In contrast, formaldehyde could be concluded to induce SBS symptoms because it has been detected at high frequencies and in concentrations high enough to influence subjective symptoms (Dally et al. 1981; Garrett et al. 1999; Krzyzanowski et al. 1990; Main and Hogan 1983; Ritchie and Lehnen 1987). Nasal symptoms in SBS are frequently caused by formaldehyde, but were not in this study. Further study will be needed to determine whether it was just by chance or not. Total VOC concentration was reported to be significantly related to throat and respiratory symptoms in a study in Japan (Saijo et al. 2004); however, no such relationship was found in the present study. It could be attributed to the possibility that the constituents of total VOC might differ between the two studies because of response by industry to regulations for several specific chemicals including guideline values and compulsory environmental monitoring by the Japanese ministry in recent years.

There are some limitations in this study. First, the participation rate was relatively low, so the generalizability of our findings to the population as a whole should carry some caution. We have posted to some nonparticipants in our study and found most reason was they were satisfied with their house. In addition, to some extent, our participants were self-selected which might have introduced a volunteer bias to the extent that nonparticipants differed from participants. Nonparticipants might have considered home visits for environmental monitoring a heavy burden because they were too busy to spare the time to meet us or they hesitated to invite strangers into their houses. We had no information on the nonparticipants. The actual prevalence of SBS would be lower than our results suggest if the nonparticipants had failed to participate due to lack of interest because they had no problems in their houses. We did not consider the members of subjects as cluster but as independent from each other. We analyzed data using the single level logistic regression analysis, not the multi-level analysis. Therefore, the results were not corrected for the intraclass correlations in our study. In this study design, we had no other choice to prevent from decreasing the number of the samples. Also we collected subjects' personal information by a questionnaire, and it resulted in the recall bias. At least as for the association between chemical concentrations and symptoms, the bias was not predicted because subjects could not know their chemical exposure level even if they had symptoms. Secondly, we did not sample, analyze, and identify all of the compounds in the air. Other unmeasured chemicals such as reactive chemicals, particulate matter, bioaerosols, and organic acids might also have influenced the subjective symptoms (Kostiainen 1995; Wolkoff et al. 2006). We are planning to measure substances including these chemicals in a future study. As for measured chemicals, limonene was a major component of several cleaning agents, but we did not ask the participants whether they had used such agents. We could not adjust seasonal changes but we considered room temperature and relative humidity represented seasonality to some extent. In addition, the measured concentrations in the present study were lower than those in newer houses built within 1 year in which chemicals would be emitted into indoor air at higher concentrations and more likely to cause SBS (Park and Ikeda 2004; Sakaguchi and Akabayashi 2003). We investigated only the living rooms of the dwellings. It might be argued that we should have investigated all of the rooms. However, most Japanese houses are relatively smaller than Western houses and have a similar chemical distribution. And as most Japanese residents seem to stay in the living room for many hours except for sleeping (Sakaguchi and Akabayashi 2003), we considered that exposure levels in the living rooms represented exposure levels in the dwellings.

In conclusion, indoor chemicals in newly built houses can be associated to SBS symptoms. According to our experience, we further emphasize the importance of early involvement of residents in environmental monitoring to recognize the status of indoor pollution. To more thoroughly address the potential impacts of indoor chemicals on human health, future work should target other chemical substances to measure and more newly built dwellings where indoor chemical levels are high. Moreover, we only covered detached houses. The residents in single-family houses reported much lower levels of complaints and symptoms than those living in multi-family buildings (Andersson 1998). If these buildings were included as objects of study, the symptom prevalence might be higher. We have to involve collective housing in a future study.

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Conflict of interest The authors declare that they have no conflict of interest.

Appendix

The questionnaire used in this study conducted in 2004 is as follows.

Questions about indoor climate to be answered by one member of the household

Have you ever seen dew condensation in your house?	1. Yes	2. No
Have you ever seen mold growing in your house?	1. Yes	2. No
Do you have any pets in your house?	1. No	2. Yes
Do any members of your household smoke indoors?	1. Yes	2. No

Questions about personal characteristics and health complaints to be answered by every member of the household

Please answer the following questions. If any member of the household can not read or write, we ask that another family member complete these questions on their behalf.

How old are you?

What is your sex?

Do you smoke cigarettes? 1. No 2. Used to 3. Yes

Are there anyone who smoke cigarettes in your house? 1. Yes 2. No

How many hours do you spend per day in your house on average?

1. Less than 8 hours 2. 8 to 12 hours 3. 12 to 16 hours
4. 16 to 20 hours 5. At least 20 hours

Approximately how often (days) do you drink alcohol?

1. Everyday 2. 2 to 4/week 3. 1/week
4. 1/month 5. Rarely

How high would you rate your mental stress level in daily life?

1. High 2. Medium 3. Low

Do you have any pet in your house? 1. No 2. Yes

Has condensation ever occurred in your house? 1. Yes 2. No

Has mold ever grown in your house? 1. Yes 2. No

Have suffered from any of the following health complaints during the last 3 months? (Respond "yes, always," "yes, sometimes," or "no, never": "Always" = at least three times a week, and "sometimes" = once or twice a week. If you answer "yes," please indicate whether you attribute the symptom to your home environment.

1. Itching, burning, or irritation of the eyes
2. Irritated, stuffy, or runny nose
3. Hoarse, dry throat
4. Coughing, wheezing
5. Dry or flushed facial skin
6. Scaling/itching scalp or ears
7. Dry, itching, red skin of hands
8. Fatigue
9. Feeling heavy headed
10. Headache
11. Nausea/dizziness
12. Difficulties concentrating

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厚生労働科学研究費補助金 健康安全・危機管理対策総合研究事業
シックハウス症候群の原因解明のための全国規模の疫学研究
−化学物質及び真菌・ダニ等による健康影響の評価と対策−
（研究代表者　岸　玲子）

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表7：SHS有訴と室内環境測定項目との関連

	指針値超軒数 (SHSあり/SHSなし)	SHS有訴あり (n=55)					SHS有訴なし (n=73)					
		min	25%	50%	75%	max	min	25%	50%	75%	max	p-value
化学物質(μg/m³)												
Formaldehyde	0	8.5	17.46	29.48	43.06	71.73	8.2	21.4	26.37	40.75	80.69	0.998
Acetaldehyde	12(6/6)	<LOD	13.12	21.5	30.42	106.4	5.9	14.61	23.14	32.75	114.96	0.543
Acetone	—	<LOD	10.18	14.49	22.06	452.08	6.73	12.2	17.37	25.56	374.07	0.067
Methylethylketone	—	<LOD	1.09	1.71	2.83	1801.41	<LOD	0.69	1.38	2.68	22.84	0.273
Ethylacetate	—	<LOD	1.16	3.9	6.59	1779.07	<LOD	0.71	2.63	6.34	439	0.093
n-Hexane	—	<LOD	0.83	1.15	2.04	21.5	<LOD	0.67	0.95	1.95	16.11	0.18
Chloroform	—	<LOD	0.55	2.17	2.75	4.84	<LOD	<LOD	0.9	2.36	4.78	0.04
1,2-Dichloroethane	—	<LOD	<LOD	<LOD	<LOD	2.35	<LOD	<LOD	<LOD	<LOD	5.11	0.624
2,4-Dimethylpentane	—	<LOD	<LOD	<LOD	<LOD	1.47	<LOD	<LOD	<LOD	<LOD	0.89	0.748
1,1,1-Trichloroethane	—	<LOD	<LOD	<LOD	<LOD	2.73	<LOD	<LOD	<LOD	<LOD	2.05	0.728
1-Butanol	—	<LOD	<LOD	1.64	5.28	26.59	<LOD	<LOD	0.92	2.7	26.96	0.21
Benzene	—	0.74	1.3	1.97	5.39	21.39	<LOD	1.27	3.09	4.26	18.4	0.565
Carbon Tetrachloride	—	<LOD	<LOD	<LOD	0.54	0.73	<LOD	<LOD	<LOD	0.54	0.65	0.354
2,2,4-Trimethylpentane	—	<LOD	<LOD	<LOD	<LOD	2.02	<LOD	<LOD	<LOD	<LOD	2.07	0.744
n-Heptane	—	<LOD	<LOD	<LOD	1.16	14.25	<LOD	<LOD	<LOD	0.62	121.09	0.915
Methylisobutylketone	—	<LOD	<LOD	<LOD	0.61	5.68	<LOD	<LOD	<LOD	0.58	5.23	0.858
Toluene	0	1.22	4.6	8.34	17.37	69.73	1.47	4.94	7.65	17.08	207.45	0.559
Chlorodibromomethane	—	<LOD	<LOD	<LOD	<LOD	1.25	<LOD	<LOD	<LOD	<LOD	0.93	0.505
Butylacetate	—	<LOD	1.29	1.87	3.32	57.95	<LOD	1.11	2.01	3.59	57.25	0.885
n-Octane	—	<LOD	1.17	2.81	7.54	62.44	<LOD	<LOD	1.11	3.09	14.84	0.005
Tetrachloroethylene	—	<LOD	<LOD	<LOD	<LOD	18.95	<LOD	<LOD	<LOD	<LOD	17.87	0.552
Ethyl Benzene	0	0.7	1.69	3.14	6.19	54.64	0.67	1.82	3.41	5.75	981.89	0.956
Styrene	0	<LOD	<LOD	<LOD	0.66	6.09	<LOD	<LOD	<LOD	0.64	3.47	0.734
Total Xylene	0	<LOD	3.27	8.14	18.8	200.44	<LOD	3.22	7.09	14.54	479.31	0.431
n-Nonane	—	<LOD	1.95	6.09	19.04	266.13	<LOD	0.71	2.39	7.09	37.29	0.001
α-Pinene	—	<LOD	0.87	1.36	7.29	179.24	<LOD	1.11	2.65	9.85	440.91	0.1
n-Decane	—	<LOD	5.97	10.27	26.06	356.58	<LOD	<LOD	6.77	11.97	125.03	0.008
p-Dichlorobenzene	4(4/0)	<LOD	<LOD	<LOD	4.51	1541.22	<LOD	<LOD	0.61	4.16	126.49	0.985
Trimethylbenzene	—	1	3.12	8.13	23.33	296.62	<LOD	3.09	7.41	13.79	95.33	0.416
Limonene	—	<LOD	7.22	12.51	25.53	476.35	1.06	5.58	10.47	25.78	244.99	0.564
Nonanal	—	<LOD	0.95	1.58	2.57	26.84	<LOD	0.75	1.32	1.93	5.4	0.115
n-Undecane	—	<LOD	3.65	8.38	37.84	430.12	<LOD	2.35	4.66	11.05	103.16	0.013
Decanal	—	<LOD	<LOD	<LOD	<LOD	7.77	<LOD	<LOD	<LOD	<LOD	2.19	0.011
n-Dodecane	—	<LOD	0.95	2.59	5.8	71.15	<LOD	<LOD	1.64	2.88	15.95	0.008
n-Tridecane	—	<LOD	0.53	1.43	2.55	161.52	<LOD	<LOD	1.12	2.47	19.14	0.254
TVOC	19(13/6)	34.29	89.65	146.19	373.66	4161.7	20.2	75.59	124.81	214.81	1758.03	0.08
2-Methylfuran		<LOD	<LOD	<LOD	<LOD	2.71	<LOD	<LOD	<LOD	<LOD	2.07	0.156
3-Methylfuran		<LOD	<LOD	<LOD	<LOD	0.51	<LOD	<LOD	<LOD	<LOD	0.59	0.849
2-Pentanol		<LOD	<LOD	<LOD	<LOD	3.44	<LOD	<LOD	<LOD	<LOD	3.24	0.692
3-Methyl-1-butanol		<LOD	<LOD	<LOD	1.16	19.03	<LOD	<LOD	<LOD	1.25	17.74	0.668
2-Methyl-1-butanol		<LOD	<LOD	<LOD	<LOD	4.05	<LOD	<LOD	<LOD	<LOD	4.26	0.602
Dimethyl Disulfide		<LOD	<LOD	<LOD	<LOD	0.68	<LOD	<LOD	<LOD	<LOD	0.74	0.467
1-Pentanol		<LOD	<LOD	<LOD	<LOD	2.37	<LOD	<LOD	<LOD	0.64	10.5	0.28
2-Hexanone		<LOD	<LOD	<LOD	<LOD	0.7	<LOD	<LOD	<LOD	<LOD	0.75	0.095
2-Heptanone		<LOD	<LOD	<LOD	<LOD	1.96	<LOD	<LOD	<LOD	<LOD	1.53	0.631
1-Octen-3-ol		<LOD	<LOD	<LOD	1.15	16	<LOD	<LOD	<LOD	0.71	4.48	0.029
3-Octanone		<LOD	<LOD	0.66	2.79	58.31	<LOD	<LOD	<LOD	1.05	29.62	0.032
3-Octanol		<LOD	<LOD	<LOD	<LOD	3.13	<LOD	<LOD	<LOD	<LOD	0.77	0.417
2-Pentylfuran		<LOD	<LOD	<LOD	<LOD	1.84	<LOD	<LOD	<LOD	<LOD	2.53	0.641
2-Ethyl-1-hexanol		<LOD	1.32	1.83	3.11	43.6	<LOD	1.23	1.73	2.86	7.17	0.339
dust)												
Derf1		<LOD	0.21	0.63	3.51	19.77	<LOD	0.3	1.01	1.78	34.21	0.86
Derp1		<LOD	<LOD	<LOD	0.52	22.96	<LOD	<LOD	<LOD	0.39	17.15	0.712
Der1		<LOD	0.38	1.80	4.92	23.01	<LOD	0.73	1.61	3.81	34.28	0.944
Endotoxin (EU/g dust)		714	1958	3407	4869	13048	608	2491	3696	7128	34949	0.133
β-glucan (ng/g dust)		28	183	337	488	1618	47	238	328	578	1517	0.325

【List of Publications】

◇ 報告書 ◇

厚生労働科学研究費補助金　健康安全・危機管理対策総合研究事業　平成 20-22 年度　総合研究報告書「シックハウス症候群の原因解明のための全国規模の疫学研究-化学物質及び真菌・ダニ等による健康影響の評価と対策」　研究代表者：岸 玲子

厚生労働科学研究費補助金　地域健康危機管理研究事業　平成 18-19 年度　総合研究報告書「シックハウス症候群の実態解明及び具体的対応方策に関する研究」　研究代表者：岸 玲子

厚生労働科学研究費補助金　健康科学総合研究事業　平成 15-17 年度　総合研究報告書「全国規模の疫学研究によるシックハウス症候群の実態と原因の解明」　研究代表者：岸 玲子

◇ 著書 ◇

厚生労働科学研究「シックハウス症候群の実態解明および具体的対応方策に関する研究」班：「シックハウス症候群に関する相談と対策マニュアル」　日本公衆衛生協会、115、2009.

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