

Online Supplementary Material

Exposures to Volatile Organic Compounds among Healthcare Workers: Modeling the Effects of Cleaning Tasks and Product-Use

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Supplemental Table 1. Total VOCs and selected cleaning-related VOC exposures, tasks and chemical ingredients in products used by occupation.

Occupation (n)	A/P	VOC Concentrations in ppb (GM, GSD)								Average time on predominant Tasks and Product Ingredient/Composition per work shift in minutes
		Ethanol	Acetone	2-Propanol	Chloroform	α -Pinene	<i>d</i> -Limonene	TVOC11	TVOC14	
Clinical laboratory technician (8)	A	82.7, 20.0	32.5, 7.67	20.2, 43.6	0.04, 1.22	0.15, 1.00	1.22, 1.46	13.1, 6.12	480, 3.83	Composition: aldehyde=15.6; aromatic=15.6
	P	269, 4.32	70.6, 3.35	82.5, 1.93	0.09, 1.00	0.04, 1.00	0.38, 2.92	126, 10.8	873, 4.99	
Nursing assistant (8)	A	1037, 3.10	21.3, 1.74	671, 1.51	0.12, 2.26	0.14, 1.54	1.28, 2.97	4.52, 1.60	1973, 1.94	Tasks: bathe patient=30.6; Composition: alcohol=36.3; alkane=24.4; amide=8.75; ester=8.75; halogenated=24.4
	P	2594, 2.72	40.8, 1.65	1194, 1.71	0.34, 3.21	0.16, 5.27	1.57, 3.91	15.0, 2.30	4367, 1.89	
Dental assistant (4)	A	2.31, 254	17.9, 1.64	3667, 1.50	0.09, 1.89	0.15, 1.00	1.00, 1.53	16.6, 2.06	3809, 1.54	Tasks: cleaning=33.8; Composition: alcohol=36.3; glycolethers=35.0; quats=35.0
	P	1.54, 253	23.0, 1.74	1097, 9.36	0.09, 1.00	0.04, 1.00	0.16, 2.68	10.7, 2.28	1565, 5.52	
Dental laboratory technician (4)	A	148, 1.11	12.4, 1.26	558, 1.31	0.07, 1.97	0.15, 1.00	1.71, 1.15	7.62, 2.38	729, 1.27	Tasks: pour mix products=12.5; Composition: acrylate=7.50; alcohol=38.8
	P	105, 3.58	18.5, 2.07	53.7, 4.68	0.09, 1.00	0.04, 1.00	0.19, 3.30	3.92, 2.20	225, 2.86	
Endoscopy technician (11)	A	36.2, 53.8	12.7, 1.54	260, 62.4	0.12, 2.47	0.15, 1.00	0.51, 2.62	3.24, 1.63	783, 6.25	Tasks: sterile and disinfect=34.1; wash equipment=32.3; scope cleaning=19.1; cleaning=14.5; tear down equipment=11.8; prepare procedure room=10.0; Composition: acid=40.0; alcohol=73.2; aldehyde=5.0; amide=27.7; amine=72.7; base=14.1; carboxylic acid=18.6; enzyme=40.5; ether=27.7; oxidizers=18.6; phenolics=14.1; salt=14.1; surfactant=14.5
	P	113, 7.68	34.6, 2.42	241, 8.40	0.18, 3.94	0.05, 2.75	0.12, 4.44	8.66, 5.93	577, 5.60	
Floor stripper/waxer (13)	A	319, 4.18	27.7, 2.72	546, 4.01	0.17, 1.57	0.19, 2.50	2.15, 7.16	13.5, 3.01	991, 3.68	Tasks: buff floor=46.2; mop floor=33.1; floor strip=12.3; Composition: acid=9.62; acrylate=5.38; alcohol=15.0; alkane=10.4; amine=52.7; ammonia=11.2; aromatic=21.2; base=21.2; ester=11.2; ether=26.2; fragrance=8.85; glycolethers=76.2; surfactant=8.85
	P	636, 3.25	41.6, 1.54	707, 5.27	0.17, 1.77	0.06, 3.00	0.79, 14.1	23.0, 2.64	1589, 3.69	
Housekeeper (31)	A	700, 2.73	19.8, 1.58	647, 2.77	0.19, 1.75	0.14, 1.82	2.02, 3.14	6.06, 1.92	1519, 2.25	Tasks: cleaning=65.8; mop floor=56.6; clean bathroom=18.9; clean window=6.45; Composition: acid=11.5; alcohol=123; amide=15.6; amine=67.4; base=53.2; bleach=6.13; carboxylic acid=55.5; ether=79.2; fragrance=21.1; glycolethers=8.06; phenolics=8.87; quats=114; salt=77.9; surfactant=15.0; terpene=43.7
	P	783, 1.99	47.4, 1.52	529, 3.33	0.22, 2.29	0.06, 2.34	1.09, 4.34	16.1, 2.53	1605, 1.91	
Licensed practical nurse (5)	A	2241, 1.89	24.4, 1.54	777, 1.42	0.22, 2.16	0.15, 1.56	2.66, 2.57	6.36, 1.51	3171, 1.61	Tasks: bathe patient=6.00
	P	2199, 7.23	54.3, 3.65	695, 4.29	0.57, 4.03	0.09, 7.69	1.08, 6.26	30.2, 3.06	4319, 2.98	
Medical appliance technician (2)	A	179, 1.17	30.2, 2.77	217, 1.70	0.08, 1.44	0.14, 1.16	12.2, 1.53	16.0, 1.54	448, 1.50	Tasks: pour mix products=22.5
	P	144, 1.03	33.1, 1.17	177, 1.25	0.18, 2.81	0.04, 1.00	4.23, 1.13	53.7, 1.33	411, 1.06	
Medical equipment preparer (7)	A	9.25, 71.6	10.0, 1.22	662, 7.27	0.09, 2.25	0.15, 1.00	1.08, 2.38	4.00, 1.50	995, 4.36	Tasks: wash equipment=83.6; cleaning=57.9; Composition: alcohol=80.7; alkane=9.29; amine=37.9; carboxylic acid=8.57; enzyme=38.6; oxidizers=8.57; phenolics=22.9; quats=32.1; salt=22.9; surfactant=61.4
	P	6.70, 76.6	42.1, 4.89	1310, 13.6	0.21, 3.80	0.07, 3.65	2.41, 40.6	31.4, 4.99	2142, 9.01	
Pharmacist/pharmacy technician (6)	A	68.7, 62.4	24.4, 1.26	135, 304	0.16, 1.96	0.17, 1.93	2.05, 2.45	18.5, 2.09	1885, 3.23	Composition: alcohol=13.3
	P	97.7, 18.7	31.3, 2.71	194, 35.6	0.10, 1.44	0.04, 1.00	0.38, 4.17	9.73, 3.47	1955, 6.00	
Registered nurse (34)	A	396, 14.1	18.7, 2.28	201, 42.9	0.16, 2.37	0.15, 1.66	1.00, 2.41	4.82, 2.37	1323, 2.90	Tasks: prepare procedure room=6.03; tear down equipment=5.00; Composition: acrylate=10.4; alcohol=37.1; amide=7.94; carboxylic acid=5.00; ester=5.15; ether=5.29; quats=15.9; salt=23.7
	P	1063, 3.77	30.9, 1.51	288, 18.4	0.18, 2.37	0.04, 2.10	0.28, 6.27	6.30, 2.38	1950, 2.79	
Respiratory therapist (8)	A	403, 2.91	12.5, 1.48	49.1, 64.2	0.08, 1.75	0.19, 2.14	0.76, 1.27	6.57, 1.74	646, 2.41	Composition: alcohol=12.5; glycolethers=6.88; halogenated=35.0; salt=32.5
	P	522, 13.3	41.7, 5.54	20.1, 47.7	0.13, 3.11	0.05, 2.15	0.16, 3.20	15.7, 4.18	2120, 3.84	
Surgical technologist (2)	A	237, 1.53	14.7, 1.21	459, 4.54	0.08, 2.78	0.15, 1.00	0.37, 1.59	2.29, 1.01	767, 3.01	Tasks: hand wash=12.5; cleaning=5.00; tear down equipment=5.00; Composition: enzyme=5.00; phenolics=12.5
	P	547, 4.15	30.2, 1.06	438, 3.60	0.11, 1.34	0.04, 1.00	0.50, 1.14	32.3, 1.44	1087, 3.50	

A/P, mobile area/personal VOCs; VOC, volatile organic compound; TVOC14, total 14 volatile organic compounds; TVOC11, excludes 3 most dominant compounds (ethanol, acetone and 2-propanol); GM, geometric mean; GSD, geometric standard deviation.

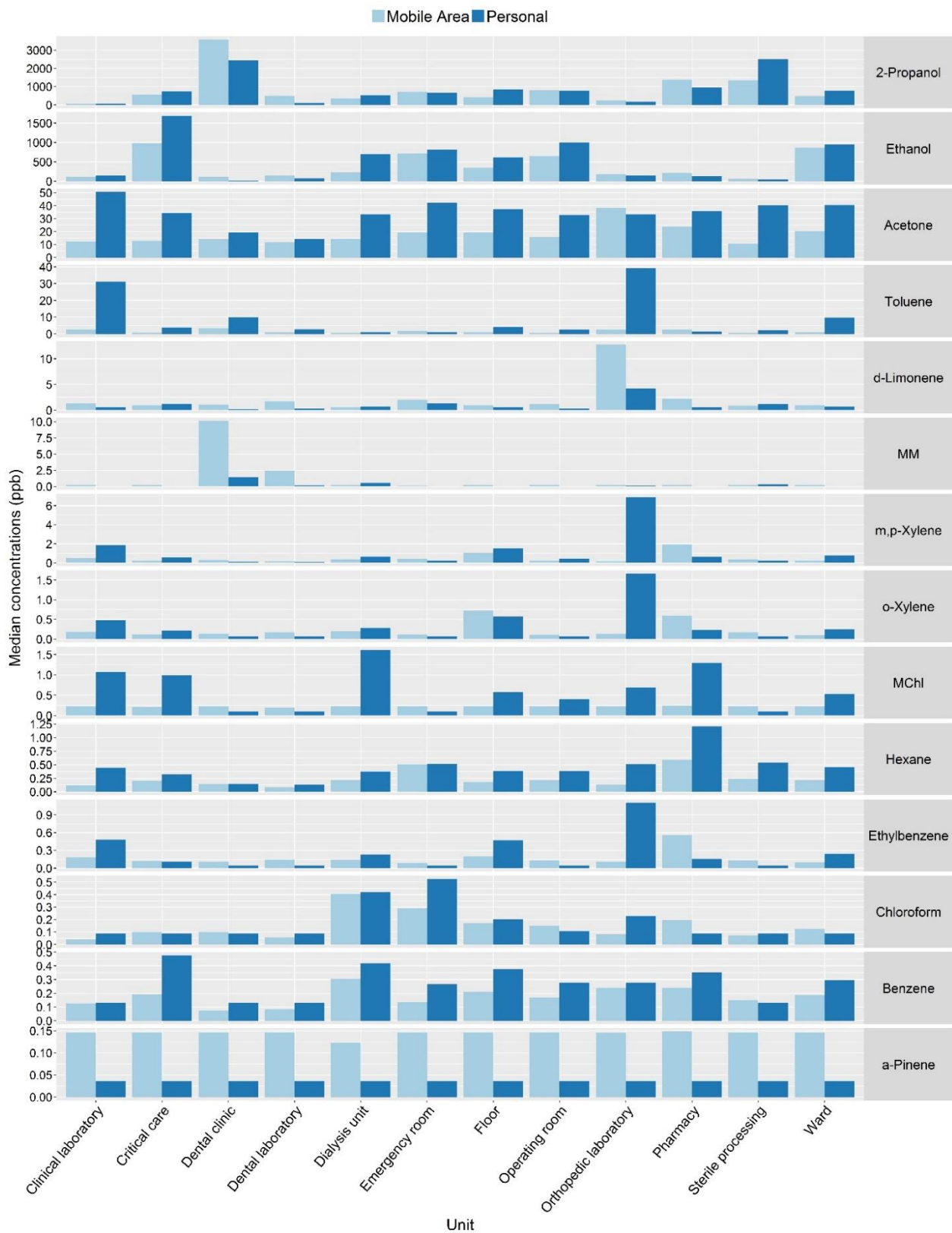
Supplemental Table 2. Results of simple linear mixed-effect models for selected and total VOCs and product-use groups.

Variable*	Count	Ethanol			Acetone			2-Propanol			Chloroform			α-Pinene			d-Limonene			TVOC14			TVOC11		
		β	SE	% Δ	β	SE	% Δ	β	SE	% Δ	β	SE	% Δ	β	SE	% Δ	β	SE	% Δ	β	SE	% Δ	β	SE	% Δ
Personal																									
Alcohol-based skin preparation	26	0.26	0.52	29.2	0.17	0.07	18.1	0.82	0.52	127	0.07	0.19	7.12	0.44	0.20	55.9	0.08	0.41	8.39	0.70	0.25	102	0.07	0.27	7.26
Alcohol-based surface cleaner	2	0.61	1.54	83.8	0.59	0.35	80.3	0.52	1.52	68.8	-0.19	0.54	-17.2	-0.18	0.57	-16.7	-0.25	1.24	-21.8	<i>1.25</i>	<i>0.64</i>	249	0.94	0.76	155
Chlorine-based surface cleaner	7	1.23	0.88	242	0.53	0.19	69.4	-0.48	0.90	-37.9	<i>0.55</i>	<i>0.33</i>	<i>74.1</i>	-0.32	0.34	-27.1	-0.43	0.70	-35.0	-0.03	0.43	-2.51	-0.40	0.46	-32.8
Chlorine-based skin preparation	9	-0.14	0.80	-13.1	-0.15	0.11	-13.7	1.07	0.80	191	0.30	0.29	34.8	0.42	0.30	52.2	-0.35	0.64	-29.8	0.78	0.37	117	0.09	0.42	9.44
Chlorine-based waste treatment	2	0.14	1.74	14.6	-1.12	0.49	-67.4	1.22	1.74	239	-0.48	0.66	-38.2	-0.43	0.69	-34.8	-0.60	1.37	-45.0	0.43	0.91	53.8	-1.37	0.91	-74.5
Detergent bathroom cleaner	4	-0.38	1.12	-31.7	<i>0.75</i>	<i>0.38</i>	<i>112</i>	-0.52	1.12	-40.8	0.40	0.40	49.4	0.37	0.42	44.9	1.19	0.89	228	-0.76	0.51	-53.0	-0.41	0.57	-33.7
Detergent instrument cleaner	4	-3.50	1.25	-97.0	<i>0.83</i>	<i>0.45</i>	<i>129</i>	0.98	1.28	167	-0.19	0.48	-17.2	0.54	0.51	71.3	3.06	0.99	2036	0.78	0.64	117	1.90	0.65	569
Detergent surface cleaner	4	0.25	1.24	27.9	.	.	.	-0.78	1.24	-54.3	0.99	0.47	170	0.22	0.49	24.1	-0.03	0.97	-2.66	-0.28	0.65	-24.0	-0.59	0.65	-44.5
Ethanolamine-based floor stripper	13	0.63	0.79	88.3	-0.04	0.18	-3.82	1.08	0.81	196	-0.19	0.31	-17.5	0.20	0.32	22.3	0.45	0.62	57.2	-0.02	0.43	-2.46	0.62	0.43	86.5
Ethanolamine-based glass cleaner	8	-1.22	0.88	-70.5	0.43	0.32	53.1	0.07	0.88	6.88	-0.12	0.33	-11.3	0.53	0.35	70.5	2.02	0.67	653	-0.12	0.44	-11.3	0.10	0.46	9.98
Ethanolamine-based surface cleaner	5	0.56	1.08	75.2	-0.46	0.79	-37.0	0.46	1.08	58.5	0.22	0.39	24.8	0.05	0.41	5.32	3.31	0.79	2635	0.34	0.50	40.3	0.65	0.55	91.0
Enzyme cleaner	11	-2.04	0.77	-87.1	0.18	0.09	19.9	1.01	0.79	174	0.22	0.30	25.1	-0.04	0.31	-3.75	0.55	0.62	74.1	-0.10	0.40	-9.49	0.18	0.42	19.6
High level instrument disinfectant	2	-1.04	1.54	-64.7	-0.34	0.42	-29.1	0.31	1.52	36.6	1.18	0.53	227	1.52	0.54	359	2.17	1.19	778.4	-0.31	0.68	-26.5	1.38	0.76	296
High level disinfectant-oxidizer	3	-5.34	1.52	-99.5	<i>0.86</i>	<i>0.43</i>	<i>136</i>	-0.18	1.59	-16.9	-0.69	0.62	-50.1	-0.43	0.65	-34.7	0.54	1.24	71.6	-0.40	0.86	-33.2	<i>1.45</i>	<i>0.83</i>	<i>328</i>
Iodine-based skin preparation	4	0.02	1.16	1.85	-0.27	0.23	-23.7	-0.87	1.15	-58.3	-0.60	0.42	-45.1	-0.29	0.44	-25.5	-0.18	0.92	-16.1	-0.54	0.55	-41.9	-0.14	0.60	-13.3
Phenolic-based surface cleaner	7	0.38	0.95	46.6	<i>-0.35</i>	<i>0.19</i>	<i>-29.7</i>	0.72	0.94	106	-0.25	0.35	-22.3	<i>-0.64</i>	<i>0.36</i>	<i>-47.4</i>	<i>-1.39</i>	<i>0.74</i>	<i>-75.0</i>	0.21	0.47	23.3	-0.52	0.49	-40.5
QAC-based bathroom cleaner	2	-0.39	2.09	-32.5	0.97	0.58	163	-0.44	2.12	-35.3	-0.78	0.83	-54.2	-0.49	0.86	-38.6	1.93	1.61	586	-1.40	1.17	-75.4	-0.39	1.13	-32.6
QAC-based floor cleaner	12	0.85	0.87	134	0.14	0.23	15.1	1.05	1.00	185	0.60	0.37	82.4	0.23	0.35	25.7	0.53	0.75	69.1	0.43	0.51	54.3	0.06	0.55	5.76
QAC-based skin preparation	2	0.96	1.63	160	-0.16	0.36	-14.7	0.10	1.62	10.5	-0.70	0.59	-50.5	-0.28	0.62	-24.8	-2.04	1.29	-87.0	0.37	0.77	44.6	0.63	0.83	87.1
QAC-based surface cleaner	27	-1.36	0.55	-74.3	0.14	0.16	14.8	0.31	0.58	36.5	0.12	0.22	12.7	0.07	0.23	7.08	1.71	0.42	452	0.10	0.31	10.9	0.07	0.31	7.10
Mobile Area																									
Alcohol-based skin preparation	26	0.36	0.40	43.0	-0.19	0.17	-17.5	0.56	0.63	75.8	-0.04	0.13	-4.27	0.04	0.12	3.56	0.01	0.24	1.05	<i>0.42</i>	<i>0.24</i>	52.5	-0.13	0.19	-11.9
Alcohol-based surface cleaner	2	-0.13	0.92	-12.5	0.18	0.53	19.6	0.76	1.95	113	-0.51	0.31	-39.8	-0.06	0.36	-5.39	-0.47	0.70	-37.3	0.05	0.71	4.72	1.33	0.49	279
Chlorine-based surface cleaner	7	0.34	0.67	40.7	-0.42	0.30	-34.6	0.16	1.10	16.9	0.44	0.21	56.0	-0.12	0.20	-11.3	0.22	0.41	24.5	-0.04	0.41	-3.78	0.07	0.32	7.46
Chlorine-based skin preparation	9	-0.47	0.58	-37.2	0.20	0.27	21.9	0.43	0.99	54.0	0.48	0.19	61.2	0.36	0.18	42.9	-0.59	0.36	-44.5	0.17	0.37	18.2	-0.07	0.29	-6.42
Chlorine-based waste treatment	2	0.55	1.98	72.9	0.04	0.57	3.88	1.37	2.07	292	0.20	0.51	22.0	0.00	0.37	-0.04	-0.08	0.80	-7.42	0.82	0.79	126	-0.55	0.67	-42.5
Detergent bathroom cleaner	4	-0.06	0.73	-5.68	-0.01	0.39	-1.18	-0.01	1.41	-0.91	<i>0.43</i>	<i>0.24</i>	53.0	-0.06	0.26	-5.45	0.52	0.51	68.9	-0.29	0.52	-25.4	0.19	0.39	21.1
Detergent instrument cleaner	4	0.16	1.08	17.1	-0.11	0.42	-10.5	1.18	1.53	227	0.08	0.33	8.62	<i>0.53</i>	<i>0.27</i>	<i>70.4</i>	1.44	0.57	323	0.55	0.59	73.6	1.16	0.47	217.7
Detergent surface cleaner	4	0.45	1.41	57.5	-0.07	0.41	-6.45	0.25	1.48	28.3	1.31	0.35	272	0.42	0.26	51.7	0.30	0.57	34.5	0.11	0.57	11.7	-0.24	0.48	-21.4
Ethanolamine-based floor stripper	13	0.03	0.83	2.55	<i>0.49</i>	<i>0.26</i>	<i>63.5</i>	0.82	0.95	127	-0.05	0.24	-5.23	0.43	0.16	53.8	0.35	0.36	41.3	-0.35	0.37	-29.4	0.74	0.30	109
Ethanolamine-based glass cleaner	8	0.67	0.74	94.7	0.18	0.29	19.7	0.10	1.06	10.4	0.28	0.22	31.7	-0.02	0.19	-2.14	<i>0.78</i>	<i>0.40</i>	<i>117</i>	-0.10	0.40	-9.28	0.09	0.33	9.03
Ethanolamine-based surface cleaner	5	0.31	0.73	35.9	0.14	0.37	14.8	-0.01	1.34	-0.81	0.62	0.23	85.3	0.75	0.23	112	2.72	0.40	1420	0.00	0.50	0.27	1.45	0.35	326
Enzyme cleaner	11	<i>-1.38</i>	<i>0.69</i>	<i>-74.9</i>	-0.34	0.26	-28.9	<i>1.81</i>	<i>0.94</i>	508	-0.01	0.21	-1.46	-0.05	0.17	-4.41	-0.47	0.36	-37.6	0.39	0.36	47.9	<i>-0.51</i>	<i>0.29</i>	<i>-39.8</i>
High level instrument disinfectant	2	-0.50	0.92	-39.4	0.06	0.53	6.15	4.50	1.81	8878	0.27	0.31	31.3	-0.06	0.36	-5.67	-0.47	0.70	-37.3	1.83	0.64	523	-0.26	0.52	-22.5
High level disinfectant-oxidizer	3	-1.73	1.93	-82.3	-0.54	0.51	-41.9	1.35	1.84	285	-0.83	<i>0.49</i>	<i>-56.5</i>	-0.04	0.32	-4.13	-0.94	0.72	-61.0	0.39	0.72	47.8	-0.14	0.63	-13.3
Iodine-based skin preparation	4	-0.33	0.84	-28.1	-0.53	0.39	-41.2	-3.84	1.35	-97.9	-0.39	0.26	-32.3	0.66	0.26	93.4	-0.32	0.53	-27.4	-1.82	0.49	-83.7	0.05	0.41	5.64
Phenolic-based surface cleaner	7	-0.54	0.77	-41.6	-0.20	0.31	-18.0	1.38	1.14	296	0.20	0.24	21.6	-0.10	0.20	-9.48	-0.03	0.43	-2.92	0.47	0.43	59.6	-0.25	0.35	-22.3
QAC-based bathroom cleaner	2	0.68	2.71	97.9	0.89	0.66	143	-0.23	2.41	-20.4	0.41	0.69	50.2	0.40	0.40	48.8	1.15	0.96	216	-1.30	0.95	-72.9	-0.16	0.85	-14.4
QAC-based floor cleaner	12	0.81	0.90	124	0.19	0.31	21.5	1.36	1.14	289	0.18	0.28	20.1	-0.24	0.17	-21.1	-0.16	0.42	-15.2	<i>0.83</i>	<i>0.45</i>	128	-0.33	0.34	-28.1
QAC-based skin preparation	2	1.08	1.18	195	0.69	0.55	99.8	-0.16	2.01	-14.6	-0.33	0.38	-28.2	0.00	0.37	0.00	-0.13	0.74	-12.3	0.28	0.75	32.7	0.69	0.58	99.4
QAC-based surface cleaner	27	0.26	0.68	29.2	-0.04	0.19	-3.54	0.52	0.67	68.1	0.29	0.18	33.2	0.05	0.12	4.73	0.69	0.26	100	0.06	0.26	6.30	0.06	0.22	6.65

VOC, volatile organic compound; TVOC14, sum of total 14 VOCs; TVOC11, sum of 11 VOCs (excluding three most dominant compounds: ethanol, acetone and 2-propanol); β, regression model estimate; SE, standard error; % Δ, percentage change was estimated by the following equation: (exp(β)-1)*100%; p-value <0.05 shown in bold, 0.05 < p-value <0.1 shown in italics.

*, the models used indicator variables (≥15 minutes; reference group: <15 minutes) to estimate VOC exposures.

The linear mixed-effect models had random effects of hospital and participants nested within hospitals, and also included bystander cleaning tasks and product-use.



Supplemental Figure 1. Median concentrations in parts per billion for personal and mobile-area VOCs by hospital unit.

VOC, volatile organic compound; MChI, methylene chloride; MM, methyl methacrylate. Note: Scale is different for each chemical, and chemicals arranged in a descending order of concentration range.