

Summary of Literature Reporting Exposure to α -Pinene

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NOTE: These tables provide information extracted from the published literature on α -pinene and monoterpene concentrations in different exposure scenarios. The tables provide an idea of relative exposure levels from different sources. A systematic literature search was conducted in 2022 and updated in 2023 for Tables 1, 2, and 4. No risk-of-bias analysis or data integration was performed.

Table 1. Evidence for Exposure to α -Pinene in Consumer Products from a Systematic Literature Search in 2023

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Sack et al. 1992	United States NR	8 household product classes (1159 products)	Air; prevalence in household products analyzed for alpha-pinene; other; 991; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR percent (%); other	0.5 percent (%)	List of product classes: 1) automotive products, 2) household cleaners/polishes, 3) paint-related products, 4) fabric and leather treatments, 5) cleaners for electronic equipment, 6) oils, greases, and lubricants, 7) adhesive-related products, 8) miscellaneous products.
			Air; prevalence in paint-related products; other; 463; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR percent (%); other	0.5 percent (%)	

Table 1. Evidence for Exposure to α -Pinene in Consumer Products

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; prevalence in fabric and leather treatments; other; 91; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR percent (%); other	2.3 percent (%)	
			Air; prevalence in miscellaneous products; other; 71; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR percent (%); other	1.6 percent (%)	
			Air; concentration in paint-related products; other; 463; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR weight % other	0.2 weight %	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; concentration in fabric and leather treatments; other; 91; 10-minute purge time (purge-and-trap GC/MS)	Alpha-pinene; NR weight % other	6.7 weight %	
Baumann et al. 1999	United States March–June 1997	Particleboard and medium- density fiberboard	Air; southern pine particleboard emission rate; other; 22; 48 hours	Alpha-pinene; 42 $\mu\text{g}/\text{m}^2/\text{hr}$ arithmetic mean	11–152 $\mu\text{g}/\text{m}^2/\text{hr}$	Alpha-pinene was not detected in any of the medium-density fiberboard samples.
			Air; pine particleboard emission rate; other; 8; 48 hours	Alpha-pinene; 42 $\mu\text{g}/\text{m}^2/\text{hr}$ arithmetic mean	6–209 $\mu\text{g}/\text{m}^2/\text{hr}$	
			Air; hardwood particleboard emission rate; other; 3; 48 hours	Alpha-pinene; 9 $\mu\text{g}/\text{m}^2/\text{hr}$ arithmetic mean	6–11 $\mu\text{g}/\text{m}^2/\text{hr}$	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Jensen et al. 2001	Denmark NR	Wood and wood-based materials used in furniture, interior furnishings, and building products	Air; Douglas-fir particleboard emission rate; other; 4; 48 hours	Alpha-pinene; 11 $\mu\text{g}/\text{m}^2/\text{hr}$ arithmetic mean	0–34 $\mu\text{g}/\text{m}^2/\text{hr}$	
			Air; other wood species particleboard emission rate; other; 2; 48 hours	Alpha-pinene; 51 $\mu\text{g}/\text{m}^2/\text{hr}$ arithmetic mean	NR	
			Air; pine heartwood from southern Sweden emission rate; other; NR; 4 days	Alpha-pinene; approx. 3,920 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine heartwood from southern Sweden emission rate; other; NR; 11 days	Alpha-pinene; approx. 2,360 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; pine heartwood from southern Sweden emission rate; other; NR; 27 days	Alpha-pinene; approx. 2,570 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine sapwood from southern Sweden emission rate; other; NR; 4 days	Alpha-pinene; approx. 3,430 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine sapwood from southern Sweden emission rate; other; NR; 11 days	Alpha-pinene; approx. 4,500 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine sapwood from southern Sweden emission rate; other; NR; 27 days	Alpha-pinene; approx. 1,840 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; pine heartwood from northern Finland emission rate; other; NR; 4 days	Alpha-pinene; approx. 9,640 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine heartwood from northern Finland emission rate; other; NR; 11 days	Alpha-pinene; approx. 8,460 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine heartwood from northern Finland emission rate; other; NR; 27 days	Alpha-pinene; approx. 4,710 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine sapwood from northern Finland emission rate; other; NR; 4 days	Alpha-pinene; approx. 1290 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; pine sapwood from northern Finland emission rate; other; NR; 11 days	Alpha-pinene; approx. 410 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
			Air; pine sapwood from northern Finland emission rate; other; NR; 27 days	Alpha-pinene; approx. 660 $\mu\text{g}/\text{m}^2/\text{hr}$ NR	NR	
Liu et al. 2004	United States NR	Electric plug- in air freshener	Air; other; NR; 120.23 hours	Alpha-pinene; NR ppm; NR	0.032 (max) ppm	
Kwon et al. 2007	Korea NR	59 household products sold in Korea	Air; prevalence in household products sold in Korea; other; 59; NR	Alpha-pinene; NR percent (%); other	19 percent (%)	
Lamorena and Lee 2008	Korea NR	Oil-based liquid car air freshener	Air; other; NR; 1 hour	Alpha-pinene; 0.046 ppm; NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Gminski et al. 2010	Germany NR	Pine wood panels and oriented strand boards (OSB)	Air; pine wood panel, day 1; other; NR; 1 day	Alpha-pinene; 12.79 ppm; NR	NR	
			Air; pine wood panel, day 3; other; NR; 3 days	Alpha-pinene; 2.58 ppm; NR	NR	
			Air; pine wood panel, day 7; other; NR; 7 days	Alpha-pinene; 1.36 ppm; NR	NR	
			Air; pine wood panel, day 14; other; NR; 14 days	Alpha-pinene; 1.42 ppm; NR	NR	
			Air; pine wood panel, day 21; other; NR; 21 days	Alpha-pinene; 0.732 ppm; NR	NR	
			Air; pine wood panel, day 28; other; NR; 28 days	Alpha-pinene; 1.03 ppm; NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; OSB panel, day 1; other; NR; 1 day	Alpha-pinene; 8.54 ppm; NR	NR	
			Air; OSB panel, day 3; other; NR; 3 days	Alpha-pinene; 2.64 ppm; NR	NR	
			Air; OSB panel, day 8; other; NR; 8 days	Alpha-pinene; 0.813 ppm; NR	NR	
			Air; OSB panel, day 11; other; NR; 11 days	Alpha-pinene; 0.738 ppm; NR	NR	
			Air; OSB panel, day 15; other; NR; 15 days	Alpha-pinene; 0.612 ppm; NR	NR	
			Air; OSB panel, day 24; other; NR; 24 days	Alpha-pinene; 0.438 ppm; NR	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Yrieix et al. 2010	France April 2008– January 2009	6 laboratories measuring VOC emissions from wood particleboard	Air; OSB panel, day 28; other; NR; 28 days	Alpha-pinene; 0.302 ppm; NR	NR	Study is an emission chamber test for emission concentrations and emission rates from 5 types of furniture products: 1) desk chair, 2) bedside table, 3) dining table, 4) sofa, 5) cabinet. Alpha-pinene emissions from cabinet reported as not detected.
			Air; other; 12; 3 days	Alpha-pinene; 0.009 ppm; arithmetic mean	NR	
			Air; other; 24; 28 days	Alpha-pinene; 0.0058 ppm; arithmetic mean	NR	
Ho et al. 2011	Korea August– December 2009	5 types of furniture products	Air; desk chair; other; 7; 2 weeks	Alpha-pinene; 0.00135 ppm; arithmetic mean	0.00127– 0.00144 ppm	
			Air; bedside table; other; 7; 2 weeks	Alpha-pinene; 0.00015 ppm; arithmetic mean	0.00013– 0.00017 ppm	
			Air; dining table; other; 7; 2 weeks	Alpha-pinene; 0.00058 ppm; arithmetic mean	0.0000036– 0.0015 ppm	
			Air; sofa; other; 7; 2 weeks	Alpha-pinene; 0.0339 ppm; arithmetic mean	0.0239– 0.0402 ppm	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; all products; other; 28; 2 weeks	Alpha-pinene; 0.00899 ppm; arithmetic mean	0.0000036– 0.0402 ppm	
			Air; desk chair emission rate; other; 7; 2 weeks	Alpha-pinene; 0.019 mg/unit/hr arithmetic mean	0.018–0.02 mg/unit/hr	
			Air; bedside table emission rate; other; 7; 2 weeks	Alpha-pinene; 0.0021 mg/unit/hr arithmetic mean	0.0018–0.0024 mg/unit/hr	
			Air; dining table emission rate; other; 7; 2 weeks	Alpha-pinene; 0.0081 mg/unit/hr arithmetic mean	0.000054–0.021 mg/unit/hr	
			Air; sofa emission rate; other; 7; 2 weeks	Alpha-pinene; 0.47 mg/unit/hr arithmetic mean	0.33–0.56 mg/unit/hr	
			Air; all products, emission rate; other; 28; 2 weeks	Alpha-pinene; 0.13 mg/unit/hr arithmetic mean	0.000054–0.56 mg/unit/hr	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Norgaard et al. 2014	France, Greece, Hungary, Italy, and the Netherlands July 2013– December 2014	5 office buildings before and after replacement of cleaning agent	Air; Greece; in office before cleaning agent replacement (morning); environmental; NR; 2 hours	Alpha-pinene; 0.000036 ppm; arithmetic mean	NR	The Netherlands was a reference building (i.e., no cleaning agent used).
			Air; Greece; in office before cleaning agent replacement (noon and afternoon); environmental; NR; 2 hours	Alpha-pinene; 0.000018 ppm; arithmetic mean	NR	
			Air; Greece; in office after cleaning agent replacement (morning); environmental; NR; 2 hours	Alpha-pinene; 0.00022 ppm; arithmetic mean	NR	
			Air; Greece; in office after cleaning agent replacement (noon); environmental; NR; 2 hours	Alpha-pinene; 0.00011 ppm; arithmetic mean	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; Greece; in office after cleaning agent replacement (afternoon); environmental; NR; 2 hours	Alpha-pinene; 0.00013 ppm; arithmetic mean	NR	
			Air; Hungary; in office before cleaning agent replacement (morning); environmental; NR; 2 hours	Alpha-pinene; 0.000018 ppm; arithmetic mean	NR	
			Air; Hungary; in office before cleaning agent replacement (noon); environmental; NR; 2 hours	Alpha-pinene; 0.000054 ppm; arithmetic mean	NR	
			Air; Hungary; in office before cleaning agent replacement (afternoon); environmental; NR; 2 hours	Alpha-pinene; 0.000036 ppm; arithmetic mean	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; Hungary; in office after cleaning agent replacement (morning, noon, and afternoon); environmental; NR; 2 hours	Alpha-pinene; below level of detection (LOD = 0.0000036– 0.000018 for Tenax tubes; = 0.000072 for DNPH cartridges) ppm; arithmetic mean	NR	
			Air; Italy; in office before cleaning agent replacement (morning, noon, and afternoon); environmental; NR; 2 hours	Alpha-pinene; below level of detection (LOD = 0.0000036– 0.000018 for Tenax tubes; = 0.000072 for DNPH cartridges) ppm; arithmetic mean	NR	
			Air; Italy; in office after cleaning agent replacement (morning and noon); environmental; NR; 2 hours	Alpha-pinene; 0.000036 ppm; arithmetic mean	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; Italy; in office after cleaning agent replacement (afternoon); environmental; NR; 2 hours	Alpha-pinene; below level of detection (LOD = 0.0000036–0.000018 for Tenax tubes; = 0.000072 for DNPH cartridges) ppm; arithmetic mean	NR	
de Gennaro et al. 2015	Italy NR	Estimated concentration for 30 m ³ room	Indoor air; application of solvent-based wood stain to floor; other; NR; NR	Alpha-pinene; 0.014 ppm; other	NR	Based on emission test chamber modeling data to simulate short-term emissions (after 3 days exposure of the product in test chamber) from solvent-based wood stain.
			Indoor air; application of solvent-based wood stain to 4 walls; other; NR; NR	Alpha-pinene; 0.035 ppm; other	NR	
Dimitroulopoulou et al. 2015	European countries NR	Modeling of acute and long-term exposure to VOCs emitted from use of selected household	Air; product A2 (liquid kitchen cleaning agent), acute exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	Acute exposure = max 30-minute rolling average concentration; long-term exposure = 24-hour mean concentration. Worst-case ventilation rate = 0.1 air exchanges per hour. Modeling results are reported for the highest

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		consumer products (at worst-case ventilation)	Air; product A2 (liquid kitchen cleaning agent), long-term exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	concentration for alpha-pinene in each product class at the worst-case ventilation rate.
			Air; product A3 (liquid floor cleaning agent), acute exposure; other; NR; NR	Alpha-pinene; 0.0034 ppm; other	NR	
			Air; product A3 (liquid floor cleaning agent), long-term exposure; other; NR; NR	Alpha-pinene; 0.0014 ppm; other	NR	
			Air; product A8 (candle 1), acute exposure; other; NR; NR	Alpha-pinene; 0.00072 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; product A8 (candle 1), long-term exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	
			Air; product A8 (candle 2), acute exposure; other; NR; NR	Alpha-pinene; 0.00054 ppm; other	NR	
			Air; product A8 (candle 2), long-term exposure; other; NR; NR	Alpha-pinene; 0.00018 ppm; other	NR	
			Air; product A10 (gel passive air freshener), acute exposure; other; NR; NR	Alpha-pinene; 0.0093 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; product A10 (gel passive air freshener), long-term exposure; other; NR; NR	Alpha-pinene; 0.0063 ppm; other	NR	
			Air; product A11 (electric air freshener, liquid 1), acute exposure; other; NR; NR	Alpha-pinene; 0.0018 ppm; other	NR	
			Air; product A11 (electric air freshener, liquid 1), long- term exposure; other; NR; NR	Alpha-pinene; 0.0011 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; product A11 (electric air freshener, liquid 2), acute exposure; other; NR; NR	Alpha-pinene; 0.0023 ppm; other	NR	
			Air; product A11 (electric air freshener, liquid 2), long- term exposure; other; NR; NR	Alpha-pinene; 0.0014 ppm; other	NR	
			Air; product A14 (spray deodorant), acute exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; product A14 (spray deodorant), long-term exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	
			Air; product A15 (perfume, spray pump 1), acute exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	
			Air; product A15 (perfume, spray pump 1), long- term exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	
			Air; product A15 (perfume, spray pump 2), acute exposure; other; NR; NR	Alpha-pinene; 0.0009 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; product A15 (perfume, spray pump 2), long- term exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	
Dimitroulopoulou et al. 2015	European countries NR	Modeling of acute and long-term exposure to VOCs emitted from use of selected household consumer products (at worst-case ventilation)	Air; housekeepers in western Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.0022 ppm; other	NR	Acute exposure = max 30-minute rolling average concentration; long-term exposure = 24-hour mean concentration. Worst-case ventilation rate = 0.1 air exchanges per hour.
			Air; housekeepers in western Europe, long-term aggregated exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	Modeling results are reported for the highest aggregated exposure (i.e., across home microenvironments as a result of multiple product use) for alpha-pinene at the worst-case ventilation rate.

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; housekeepers in southern Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.0018 ppm; other	NR	
			Air; housekeepers in southern Europe, long- term aggregated exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	
			Air; housekeepers in eastern Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.0032 ppm; other	NR	

Table 1. Evidence for Exposure to α -Pinene in Consumer Products

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; housekeepers in eastern Europe, long-term aggregated exposure; other; NR; NR	Alpha-pinene; 0.00018 ppm; other	NR	
			Air; retirees in western Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.0045 ppm; other	NR	
			Air; retirees in western Europe, long-term aggregated exposure; other; NR; NR	Alpha-pinene; 0.00018 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; retirees in southern Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.00072 ppm; other	NR	
			Air; retirees in southern Europe, long- term aggregated exposure; other; NR; NR	Alpha-pinene; <0.00018 ppm; other	NR	
			Air; retirees in eastern Europe, acute aggregated exposure; other; NR; NR	Alpha-pinene; 0.0048 ppm; other	NR	

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; retirees in eastern Europe, long-term aggregated exposure; other; NR; NR	Alpha-pinene; 0.00036 ppm; other	NR	
Steinemann 2015	United States NR	Air freshener	Air (F, G); other; 6; NR	Alpha-pinene; NR ppm; other	0–1.05 ppm	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
			Air (F, R); other; 3; NR	Alpha-pinene; NR ppm; other	1–7.77 ppm	
Steinemann 2015	United States NR	Cleaner	Air (F, G); other; 4; NR	Alpha-pinene; NR ppm; other	0–1.19 ppm	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
			Air (F, R); other; 3; NR	Alpha-pinene; NR ppm; other	0–0.24 ppm	
Steinemann 2015	United States NR	Laundry product	Air (F, R); other; 5; NR	Alpha-pinene; NR ppm; other	0–1.24 ppm	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Steinemann 2015	United States NR	Personal care product	Air (F, G); other; 5; NR Air (F, R); other; 5; NR	Alpha-pinene; NR ppm; other Alpha-pinene; NR ppm; other	0–1.95 ppm 0–0.87 ppm	F = fragrancd, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
Steinemann 2015	United States NR	Prevalence in consumer products	Air; fragrancd products; other; 31 products; NR Air; “green” products; other; 17 products; NR Air; “regular” products; other; 20 products; NR	Alpha-pinene; NR percent (%); other Alpha-pinene; NR percent (%); other Alpha-pinene; NR percent (%); other	74 percent (%) 65 percent (%); 60 percent (%)	Reporting threshold = headspace concentrations of greater than 100 $\mu\text{g}/\text{m}^3$ (0.018 ppm for alpha-pinene). “Green” products make a claim such as “green,” “organic,” “nontoxic,” “environmentally friendly,” “essential oils,” or “natural” on their product label or MSDS; also includes claims of “green certified” or “certified organic.” “Regular” products are those other than in the “green” category.
Steinemann 2015	United States NR	Percent of total VOCs emitted from air fresheners	Air; (F, G); other; 6; NR	Alpha-pinene; NR percent (%); other	0–7.19 percent (%)	F = fragrancd, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).

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Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Steinemann 2015	United States NR	Percent of total VOCs emitted from cleaners	Air; (F, R); other; 3; NR	Alpha-pinene; NR percent (%); other	0.3–17.9 percent (%)	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
			Air; (F, G); other; 4; NR	Alpha-pinene; NR percent (%); other	0–2.69 percent (%)	
			Air; (F, R); other; 3; NR	Alpha-pinene; NR percent (%); other	0–6.7 percent (%)	
Steinemann 2015	United States NR	Percent of total VOCs emitted from personal care products	Air; (F, G); other; 5; NR	Alpha-pinene; NR percent (%); other	0–43.85 percent (%)	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
			Air; (F, R); other; 5; NR	Alpha-pinene; NR percent (%); other	0–4.81 percent (%)	
Steinemann 2015	United States NR	Percent of total VOCs emitted from laundry products	Air; (F, R); other; 5; NR	Alpha-pinene; NR percent (%); other	0–3.55 percent (%)	F = fragranced, G = green, R = regular. Products were analyzed using headspace gas chromatography/mass spectrometry (EPA Method TO-15).
Derbez et al. 2018	France 2013–2014	Wood or wood-based products used in newly built and retrofitted energy-	Indoor air during heating season; other; 70; 7 days	Alpha-pinene; 0.010 ppm; arithmetic mean	NR	Sampled using radial diffusive samplers. Heating season defined as operating of the heating system from November 1 to late February; measured median outdoor temperature = 5 degrees Celsius. Non-heating season defined as no operation of the heating

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		efficient dwellings	Indoor air during non-heating season; other; 68; 7 days	Alpha-pinene; 0.011 ppm; arithmetic mean	NR	system from mid-May to mid-September; measured median outdoor temperature = 20 degrees Celsius.
Nematollahi et al. 2018	Australia NR	42 fragranced baby products	Air; prevalence in baby products; other; 42; NR	Alpha-pinene; NR percent (%); other	50 percent (%)	
Zarogianni et al. 2018	Greece June 2014	Office mopping and window cleaning	Air; mopping (GPC); environmental; NR; 15 min	Alpha-pinene; NR ppm; NR	0.04621 (max) ppm	GPC = general purpose cleaner; DB = domestic bleach; GC = glass cleaner (spray)
			Air; mopping (DB); environmental; NR; 15 min	Alpha-pinene; NR ppm; NR	0.04452 (max) ppm	
			Air; mopping (GPC) and cleaning windows (GC); environmental; NR; 15 min	Alpha-pinene; NR ppm; NR	0.04781 (max) ppm	

Table 1. Evidence for Exposure to α -Pinene in Consumer Products

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; mopping (DB) and cleaning windows (GC); environmental; NR; 15 min	Alpha-pinene; NR ppm; NR	0.04633 (max) ppm	
CPID 2021	United States 2015–2019	Air freshener or fragrance for home or automobile	Liquid, aerosol, or solid; not specified; NR; NR	Alpha-pinene; NR percent alpha- pinene content of products (%); other	0–1.0 percent alpha-pinene content of products (%)	Air fresheners for the home include liquid fragrance diffuser kits, professional use aerosols, and scented oil refills in various scents (e.g., “Fresh Seaside” scented oil refill, 0.1–1.0% alpha-pinene). Automobile air fresheners are liquid or solid vent clips. Detected (concentration not reported) in other scents.
CPID 2021	United States 2015	Cologne	Liquid; not specified; NR; NR	Alpha-pinene; NR percent alpha- pinene content of products (%); other	0.1–1.0 percent alpha-pinene content of products (%)	
CPID 2022	United States 2021	Hair remover	Cream; not specified; NR; NR	Alpha-pinene; NR percent alpha- pinene content of products (%); other	0.0005–0.005 percent alpha- pinene content of products (%)	

Table 1. Evidence for Exposure to α -Pinene in Consumer Products

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Al-Tawarah et al. 2023	Jordan April 2021	Peppermint and rosemary oils used to enhance memory functions in a scopolamine- induced amnesia rat model	Rosemary essential oil; other; NR; NR	Alpha-pinene; NR percent (%); other	8.03 percent (%)	
Kim et al. 2023	Korea November 2022	50 participants wearing passive samplers to assess exposure to terpenes in vehicles and studio apartments using an oil diffuser	Air, inside vehicle (morning, using diffuser); personal; 25; 0.58 hours	Alpha-pinene; 0.0034 ppm; arithmetic mean	0.00018– 0.0123 ppm	
			Air, inside vehicle (afternoon, using diffuser); personal; 25; 0.58 hours	Alpha-pinene; 0.0038 ppm; arithmetic mean	0.00018– 0.012 ppm	
			Air, inside studio apartment, using diffuser; personal; 25; 8.9 hour	Alpha-pinene; 0.00077 ppm; arithmetic mean	0.00018– 0.0024 ppm	

Table 1. Evidence for Exposure to α -Pinene in Consumer Products

Reference	Location, Collection Date	Product Description or Use	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Warburton et al. 2023	UK October 2021–March 2022	60 homes in Ashford, UK using plug-in fragrance diffusers	Air; environmental; 259; 3 days	Alpha-pinene; 0.0016 ppm; median	NR	
Wei et al. 2023	China NR	None (literature review)	Bitter almond essential oil; not specified; NR; NR	Alpha-pinene; NR mg/kg; other	0.19–0.24 mg/kg	

CPID = Consumer Product Information Database; DB = domestic bleach; DNPH = 2,4-dinitrophenylhydrazine; F = fragranced; G = "green" (product description); GC = glass cleaner (spray); GC/MS = gas chromatography/mass spectrometry; GPC = general purpose cleaner; LOD = limit of detection; MSDS = material safety data sheet; N = number of measurements; NR = not reported; OSB = oriented strand board; R = regular; VOC = volatile organic compound.

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured from a Systematic Literature Search in 2023

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Eriksson and Levin 1990	Sweden NR	Swedish sawmill	Air; personal; 3 (once per day); 8 hours	Alpha-pinene; Worker 1; 21 ppm; arithmetic mean	5.6–30.5 ppm	Urine metabolites (cis and trans-verbenol) also detected. One worker was in the mechanical workshop for most of 1 day resulting in lower exposure.
		Two saw shed workers	Air; personal; 3 (once per day); 8 hours	Alpha-pinene; Worker 2; 31.7 ppm; arithmetic mean	26.9–37.7 ppm	
Stromvall and Petersson 1991	Sweden July– September 1989	Logging operations	Air; pine harvesting; other; 8; NR	Alpha-pinene; 0.086 ppm; other	NR	
		Pine stand 35 km northwest of Goteborg; spruce stand 25 km east of Goteborg	Air; spruce harvesting; other; >20; NR	Alpha-pinene; 0.082 ppm other	NR	
Eriksson and Levin 1995	Sweden NR	4 sawmills	Air; personal; 18; 6–8 hours	Alpha-pinene; NR ppm NR	1.6–16.7 ppm	
Demers et al. 2000	British Columbia 1996	Softwood lumber mills	Air; personal; 222; 7–8 hours	Alpha-pinene; 0.018 ppm; geometric mean	< LOD– 0.92 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Edwards et al. 2001	Finland Fall 1996– Winter 1997	Reported as “workplace”	Air; workplace; other; NR; 48 hours	Alpha-pinene; 0.0006 ppm; geometric mean	0.014 (maximum) pp m	Personal exposures and microenvironment (i.e., participant’s residences and workplaces) VOC concentrations were measured simultaneously during a 48-hour sampling period. See Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements and Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements for this study.
Sunesson et al. 2001	Sweden September– November 1999	8 dairy farms in northern Sweden Dairy farmers’ chemical environment during milking	Air (personal and stationary samples); other; 46; 131– 157 minutes (stationary samples), 108– 142 minutes (personal samples)	Alpha-pinene; 0.009 ppm; arithmetic mean	0.0007– 0.04 ppm	All farms used sawdust on the floor (the main source of monoterpenes in the air).
Fransman et al. 2003	New Zealand NR	Plywood mill workers	Air; personal; 20; 8 hours	Alpha-pinene; 0.18 ppm; geometric mean	NR	
Lai et al. 2004	UK 1998–2000	Reported as “workplace indoor”	Air; workplace indoor; other; NR; NR	Alpha-pinene; 0.0033 ppm; geometric mean	NR	Study reported simultaneous personal exposures and microenvironmental measurements (home and work indoors). See Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements and Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements for this study.

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Pierucci et al. 2005	Italy NR	Aerobic biological processing of municipal solid waste (before biofilter)	Air; environmental; NR; after 16 hours	Alpha-pinene; 13.1 ppm; other	NR	A study of VOCs released during aerobic biological processing of municipal solid waste in a pilot-scale reactor with a biofilter.
			Air; environmental; NR; after 40 hours	Alpha-pinene; 1.5 ppm; other	NR	
			Air; environmental; NR; after 65 hours	Alpha-pinene; 0.39 ppm; other	NR	
			Air; environmental; NR; after 85 hours	Alpha-pinene; 0.13 ppm; other	NR	
			Air; environmental; NR; after 110 hours	Alpha-pinene; 0.17 ppm; other	NR	
			Air; environmental; NR; after 161 hours	Alpha-pinene; < 0.09 ppm; other	NR	
Dodson et al. 2007	United States NR	Workplace (office and school) concentrations for 55	Air; office concentration; environmental; NR; 16 hours	Alpha-pinene; 0.00045 ppm; arithmetic mean	NR	Data collected as part of Boston Exposure Assessment in Microenvironments (BEAM) study. Personal and residential samples collected over 48-hour sampling period and office and school samples collected over a 16-

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Lehtinen and Veijanen 2011	Finland 2005–2007	nonsmoking participants sampled in summer and winter	Air; school concentration; environmental; NR; 16 hours	Alpha-pinene; 0.00018 ppm; arithmetic mean	NR	hour sampling period. See Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements and Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements for this study.
		Wastewater treatment plant in central Finland	Air; bar screens; other; 5; NR	Alpha-pinene; 0.002 ppm; arithmetic mean	0.00095– 0.0033 ppm	
			Air; sand filter; other; 4; NR	Alpha-pinene; 0.0032 ppm; arithmetic mean	0.0015– 0.0051 ppm	
			Air; primary clarifier; other; 4; NR	Alpha-pinene; 0.00045 ppm arithmetic mean	0.00014– 0.00084 ppm	
			Air; sludge thickening; other; 4; NR	Alpha-pinene; 0.0071 ppm; arithmetic mean	0.00065– 0.02 ppm	
			Air; incoming waste gas to biofilter; other; 4; NR	Alpha-pinene; 0.0067 ppm; arithmetic mean	0.0038– 0.01 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; exhaust gas from biofilter; other; 4; NR	Alpha-pinene; 0.004 ppm; arithmetic mean	0.001– 0.007 ppm	
Tani and Nozoe 2012	Japan May–July 2006	Japanese rosemary- and lavender- growing greenhouse	Air; during pot moving task; other; 3; 5 minutes	Alpha-pinene; NR ppm; NR	0.0061– 0.0092 ppm	
			Air; during shoot cutting task; other; 3; 5 minutes	Alpha-pinene; NR ppm; NR	0.0028– 0.0052 ppm	
Lehtinen et al. 2013	Finland 2003–2004	2 solid waste management plants (optic sorting plant and waste transferring plant)	Air; process hall, optic sorting plant; other; 4; NR	Alpha-pinene; 0.0054 ppm; arithmetic mean	0.0036– 0.013 ppm	
			Air; control room, optic sorting plant; other; 2; NR	Alpha-pinene; 0.00072 ppm; arithmetic mean	0.00054– 0.0009 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; receiving hall, waste transferring plant; other; 4; NR	Alpha-pinene; NR ppm; NR	0.00054– 0.007 ppm	
Glas et al. 2015	Sweden and Finland 2004–2006	Office workers	Air; northern Sweden (Umea); personal; 108; 1 week	Alpha-pinene; 0.0007 ppm; median	0.00004– 0.022 ppm	
			Air; northern Finland (Vasa); personal; 50; 1 week	Alpha-pinene; 0.0008 ppm; median	0.0001– 0.031 ppm	
Straumfors et al. 2018	Norway 2013–2016	Sawmill workers	Air; personal; 409; NR	Alpha-pinene; 0.11 ppm; geometric mean	NR	
Su et al. 2018	United States NR	Healthcare workers from 14 occupations	Air; personal samples; personal; NR; NR	Alpha-pinene; NR ppm; other	0.00004– 0.00016 ppm	Values shown are for range of geometric mean
			Air; area samples; other; NR; NR	Alpha-pinene; NR ppm; other	0.00014– 0.00019 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Benson et al. 2019	NR NR	Hospital surgical technicians	Air; other; 6; NR	Alpha-pinene; 0.00039 ppm; geometric mean	NR	Pilot study to evaluate the usefulness of various sampling methods for characterization of full-shift personal exposures to surgical smoke generated by the use of electrocautery instruments.
Vaissiere and Escale 2020	France NR	Essential oil packaging company	Air; environmental; 3; NR	Alpha-pinene; 0.65 ppm; arithmetic mean	NR	
Urso et al. 2022	United States February 27– September 3, 2019	3 commercial indoor cannabis cultivation facilities in Denver, CO Metro North Front Range	Exhaust air, Facility A North Exhaust, prior to carbon filter controls, 5 AM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.0095 ppm	
			Exhaust air, Facility A North Exhaust, prior to carbon filter controls, 10 AM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.0354 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Exhaust air, Facility A North Exhaust, prior to carbon filter controls, 4 PM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.0255 ppm	
			Exhaust air, Facility A South Exhaust, prior to carbon filter controls, 5 AM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.005 ppm	
			Exhaust air, Facility A South Exhaust, prior to carbon filter controls, 10 AM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.016 ppm	
			Exhaust air, Facility A South Exhaust, prior to carbon filter controls, 4 PM; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.0266 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Exhaust air, Facility B July 15, 2019 sampling, (no installed filtration), 7 AM; environmental; NR; 5 minutes	Alpha-pinene; NR ppm; NR	0.0153 ppm	
			Exhaust air, Facility B July 15, 2019 sampling, (no installed filtration), 11 AM; environmental; NR; 5 minutes	Alpha-pinene; NR ppm; NR	1.5363 ppm	
			Exhaust air, Facility B July 15, 2019 sampling, (no installed filtration), 3 PM; environmental; NR; 5 minutes	Alpha-pinene; NR ppm; NR	0.8611 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Exhaust air, Facility B July 18, 2019 sampling, (no installed filtration), 7 AM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.1 ppm	
			Exhaust air, Facility B July 18, 2019 sampling, (no installed filtration), 11 AM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.2641 ppm	
			Exhaust air, Facility B July 18, 2019 sampling, (no installed filtration), 3 PM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.3001 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Exhaust air, Facility D Rear Exhaust (door open), 9 AM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.194 ppm	
			Exhaust air, Facility D Rear Exhaust (door closed), 2 PM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.0772 ppm	
			Exhaust air, Facility D Front Exhaust (door open), 10 AM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.2457 ppm	
			Exhaust air, Facility D Front Exhaust (door closed), 9 AM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.2049 ppm	

Table 2. Evidence for Occupational Exposure to α -Pinene – Measured

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N, Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Exhaust air, Facility D Front Exhaust (door open), 2 PM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.0537 ppm	
			Exhaust air, Facility D Front Exhaust (door closed), 2 PM; environmental; NR; 10 minutes	Alpha-pinene; NR ppm; NR	0.0612 ppm	

BEAM = Boston Exposure Assessment in Microenvironments; LOD = limit of detection; N = number of measurements; NR = not reported; VOC = volatile organic compound.

Table 3. Evidence for Occupational Exposure to α -Pinene – Calculated from a Systematic Literature Search in 2022

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Stromvall and Petersson 1992	Sweden NR	Thermo- mechanical pulp mill and sulphite pulp mill	Air; thermo- mechanical pulp refiner emissions; environmental; NR; NR	Alpha-pinene; NR ppm; NR	0.73 (max) ppm	Terpene emissions reported to be 58% alpha- pinene for both mills.
			Air; sulphite pulp mill chipping emissions; environmental; NR; NR	Alpha-pinene; NR ppm; NR	6.25 (max) ppm	
Stromvall and Petersson 1993	Sweden 1991	Timber and pulpwood barking	Air; pine timber barking; other; 4; 10–20 minutes	Alpha-pinene; NR ppm; other	0.0004– 0.0016 ppm	Ranges for alpha-pinene were calculated by multiplying total monoterpene emissions by the percentage composition values for alpha- pinene. Alpha-pinene percentage composition = 44% for Scots pine timber and Norway spruce pulpwood and 51% for Norway spruce timber.
			Air; spruce timber barking; other; 6; 10–20 minutes	Alpha-pinene; NR ppm; other	0.0005– 0.0018 ppm	
			Air; spruce pulpwood barking; other; 2; 10–20 minutes	Alpha-pinene; NR ppm; other	0.0039– 0.0079 ppm	

Table 3. Evidence for Occupational Exposure to α -Pinene – Calculated

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Dahlqvist et al. 1996	Sweden NR	Swedish sawmill workers	Air; workers wearing respirators with a filter; personal; 10; 5 hours	Alpha-pinene; 6.7 ppm; median	5.3–8.3 ppm	Values for alpha-pinene were calculated as 64% of total terpenes reported in the article.
			Air; workers wearing respirators without a filter; personal; 9; 5 hours	Alpha-pinene; 6 ppm; median	4.8–8.5 ppm	
Svedberg and Galle 2000	Sweden NR	Sawmill workers (pine sawing)	Air; other; NR; two work shifts (approx. 18 hours)	Alpha-pinene; 18.6 ppm; arithmetic mean	29.1 (max.) ppm	Alpha-pinene reported to be 62.3% of total terpenes for pine processing; no composition data reported for spruce processing.
Rosenberg et al. 2002	Finland 1997–1999	Sawmill workers; winter and summer	Air; pine processing; other; 216; NR	Alpha-pinene; 7.174 ppm; other	0.057– 23.56 ppm	Values for alpha-pinene were calculated as 68% of total monoterpenes (for pine) or 64% of total monoterpenes (for spruce) reported in the article. Urinary verbenol (sum of cis- and trans-isomers) also was measured.
			Air; spruce processing; other; 234; NR	Alpha-pinene; 0.689 ppm; other	0.042– 1.84 ppm	

N = number of measurements; NR = not reported.

Table 4. Evidence for Exposure to α -Pinene in Indoor Air from a Systematic Literature Search in 2023

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Hodgson et al. 2000	United States 1997–1998	7 site-built houses Hot humid or mixed humid areas	Indoor air; environmental; 7; NR	Alpha-pinene; 0.0281 ppm; geometric mean	0.0122– 0.060 ppm	Eastern and southeastern United States.
Hodgson et al. 2000	United States 1997–1998	4 manufactured houses Hot humid or mixed humid areas	Indoor air; environmental; 4; NR	Alpha-pinene; 0.0163 ppm; geometric mean	0.0054– 0.0353 ppm	Eastern and southeastern United States.
Edwards et al. 2001	Finland Fall 1996– Winter 1997	Reported as “residential indoor”	Indoor air; residential concentration; other; NR; 48 hours	Alpha-pinene; 0.0016 ppm; geometric mean	0.039 (maximum) ppm	Personal exposures and microenvironment (i.e., participant’s residences and workplaces) VOC concentrations were measured simultaneously during a 48-hour sampling period. See Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements and Table 2. Evidence for Occupational Exposure to α -Pinene – Measured for workplace measurements for this study.
Lai et al. 2004	UK 1998–2000	Reported as “residential indoor”	Air; residential indoor; other; NR; NR	Alpha-pinene; 0.0016 ppm; geometric mean	NR	Study reported simultaneous personal exposures and microenvironmental measurements (home and work indoors). See Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements and Table 2. Evidence for Occupational Exposure to α -Pinene – Measured alpha pinene table for workplace measurements for this study.

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Shendell et al. 2004	United States June 2000– June 2001	13 portable classrooms in 2 school districts (SD)	Indoor air; SD1, First sampling, weekly integrated average; environmental; 5; approx. 6,200 minutes	Alpha-pinene; 0.0022 ppm; arithmetic mean	0.0001– 0.0056 ppm	Weekly and daily integrated samples measured with passive samplers in the cooling and heating seasons between June 2000 and June 2001.
			Indoor air; SD1, Second sampling, weekly integrated average; environmental; 5; approx. 6,200 minutes	Alpha-pinene; 0.00047 ppm; arithmetic mean	0.0001– 0.00088 ppm	
			Indoor air; SD1, second sampling, daily integrated average; environmental; 5; approx. 8 hours	Alpha-pinene; 0.0012 ppm; arithmetic mean	0.0001– 0.006 ppm	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Indoor air; SD2, first sampling, weekly integrated average; environmental; 8; approx. 6,200 minutes	Alpha-pinene; 0.00025 ppm; arithmetic mean	0.00005– 0.00057 ppm	
			Indoor air; SD2, second sampling, Weekly integrated average; environmental; 6; approx. 6,200 minutes	Alpha-pinene; 0.00032 ppm; arithmetic mean	0.0001– 0.00066 ppm	
			Indoor air; SD2, second sampling, daily integrated average; environmental; 6; approx. 8 hours	Alpha-pinene; 0.00027 ppm; arithmetic mean	0.00007– 0.00056 ppm	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Dodson et al. 2007	United States NR	Residential indoor air monitoring for 55 nonsmoking participants sampled in summer and winter	Indoor air; residential concentration; environmental; NR; 48 hours	Alpha-pinene; 0.002 ppm; arithmetic mean	NR	Data collected as part of Boston Exposure Assessment in Microenvironments (BEAM) study. Personal and residential samples collected over 48-hour sampling period and office and school samples collected over a 16-hour sampling period. See Table 5. Evidence for Cumulative Exposure to α -Pinene for personal monitoring measurements and Table 2. Evidence for Occupational Exposure to α -Pinene – Measured for office and school measurements for this study.
Jia et al. 2008	United States Summer 2004–Winter 2005	159 residences monitored in two seasons	Indoor air; environmental; 252; NR	Alpha-pinene; 0.0016 ppm; arithmetic mean	max. = 0.025 ppm	Samplers deployed to collect 3–4 weekday integrated VOC samples at indoor and outdoor locations.
Cacho et al. 2013	United States 1994–1998	100 office and public commercial buildings	Indoor air; Not specified; NR; NR	Alpha-pinene; 0.0007 ppm; arithmetic mean	NR	EPA BASE – Building Assessment Survey and Evaluation Study.
Raysoni et al. 2017	United States March 1–June 4, 2010	4 elementary schools in El Paso, TX	Indoor air; School EP-A; environmental; 12; approx. 96 hours	Alpha-pinene; 0.000027 ppm; arithmetic mean	0.000007– 0.000050 ppm	VOC concentrations at each school (indoor and outdoor) were measured using passive badge samplers. Indoor samplers were placed in the computer laboratory at one school and in the library at the other 3 schools. Article notes “most VOC sample durations were approximately 96 h, but a few were only 72 h due to logistical constraints.”
			Indoor air; School EP-B; environmental; 12; approx. 96 hours	Alpha-pinene; 0.000063 ppm; arithmetic mean	0.000041– 0.00011 ppm	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Fortenberry et al. 2019	United States July 22 to August 4, 2016	Concentrations in single-family home measured over 3 different natural ventilation conditions	Indoor air; School EP-C; environmental; 12; approx. 96 hours	Alpha-pinene; 0.000061 ppm; arithmetic mean	0.000007– 0.000095 ppm	Air Composition and Reactivity from Outdoor and Indoor Mixing (ACRONIM) study.
			Indoor air; School EP-D; environmental; 12; approx. 96 hours	Alpha-pinene; 0.000075 ppm; arithmetic mean	0.000025– 0.00011 ppm	
			Indoor air; windows closed; environmental; NR; 4 hours	Alpha-pinene; 0.017 ppm; arithmetic mean	NR	
			Indoor air; 1 window opened; environmental; NR; 4 hours	Alpha-pinene; 0.00372 ppm; arithmetic mean	NR	
			Indoor air; 2 windows opened; environmental; NR; 4 hours	Alpha-pinene; 0.00215 ppm; arithmetic mean	NR	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Angulo-Milhem et al. 2021	NR NR	Emission of VOCs from tea tree oil using 3 different diffusers	Liquid; mass concentration; other; NR; NR Air; concentration; electric and nebulizing diffusers; other; NR; 0–2 hours (10- minute sampling every 30 minutes); 2– 6 hours (10- minute sampling every hour); 0–1 hour (continuous sampling every 15 minutes); 1– 5 hours (continuous sampling every hour); 8– 60 hours (1- hour sampling with intervals 6, 8, and 12 hours)	Alpha-pinene; 2.72 % w/w other Alpha-pinene; NR ppm; NR	NR 1.6 (max.) ppm	The 3 devices were: 1) nebulizing diffuser, 2) ceramic heat (electric) diffuser, and 3) capillarity diffuser.

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; mass emission rate; electric diffuser; other; NR; 0–2 hour (10- minute sampling every 30 minutes); 2– 6 hour (10- minute sampling every hour); 0–1 hour (continuous sampling every 15 minutes); 1– 5 hour (continuous sampling every hour); 8– 60 hour (1-hour sampling with intervals 6, 8, and 12 hours)	Alpha-pinene; NR mg/hr/ per gram of tea tree oil; NR	26.0 (max.) mg/hr/ per gram of tea tree oil	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; mass emission rate; nebulizing diffuser; other; NR; 0–2 hour (10- minute sampling every 30 minutes); 2– 6 hour (10- minute sampling every hour); 0–1 hour (continuous sampling every 15 minutes); 1– 5 hour (continuous sampling every hour); 8– 60 hour (1-hour sampling with intervals 6, 8, and 12 hours)	Alpha-pinene; NR mg/hr/ per gram of tea tree oil NR	25.0 (max.) mg/hr/ per gram of tea tree oil	
			Air; mass emission rate; capillarity diffuser; other; NR; 4 minutes every 15 minutes	Alpha-pinene; NR mg/hr/ per gram of tea tree oil NR	1.8 (max.) mg/hr/ per gram of tea tree oil	

Table 4. Evidence for Exposure to α -Pinene in Indoor Air

Reference	Location, Collection Date	Description of Indoor Air Setting	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Stringari et al. 2023	Spain March 26– May 8, 2020	12 seedlings of green beans cultivated in a building- integrated rooftop greenhouse (i-RTG)	Indoor air; environmental; NR; 15 minutes	Alpha-pinene; NR ppm; NR	0.00024– 0.0054 ppm	
Szabados et al. 2023	Hungary October 2019– September 2021	15 passive houses in the heating and non-heating seasons	Indoor air during non- heating season; environmental; 15; 168 hours	Alpha-pinene; 0.01 ppm; arithmetic mean	0.00039– 0.11 ppm	“Passive house” refers to a construction standard that assures a high level of indoor thermal comfort with minimum energy consumption throughout the year and without applying a conventional heat distribution system.
			Indoor air during heating season; environmental; 14; 168 hours	Alpha-pinene; 0.0088 ppm; arithmetic mean	0.00065– 0.067 ppm	

ACRONIM = Air Composition and Reactivity from Outdoor and Indoor Mixing; BASE = Building Assessment Survey and Evaluation Study; BEAM = Boston Exposure Assessment in Microenvironments; N = number of measurements; NR = not reported; VOC = volatile organic compound.

Table 5. Evidence for Cumulative Exposure to α -Pinene from a Systematic Literature Search in 2022

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Eriksson and Levin 1990	Sweden NR	Sawmill workers	Urine; biological; 2; samples collected 3 hours after work had been in progress	Trans-verbenol; NR $\mu\text{g/mL}$; NR	18.9–25.2 $\mu\text{g/mL}$	Biomonitoring; urinary metabolites of alpha-pinene (cis- and trans-verbenol) were measured.
			Urine; biological; 2; samples collected 3 hours after work had been in progress	Cis-verbenol; NR $\mu\text{g/mL}$; NR	2.6–3.4 $\mu\text{g/mL}$	
Eriksson et al. 1996	Sweden NR	Sawmill workers	Urine; biological; 48; post-shift	Verbenols (cis- and trans-verbenol); 7.72 micromoles per millimole creatinine; geometric mean	1.31–32.8 micromoles per millimole creatinine	Biomonitoring; cis- and trans-verbenol (metabolites of alpha-pinene) were measured.
Eriksson et al. 1997	Sweden NR	Joinery shops	Urine; biological; 38; post-shift	Verbenols (cis- and trans-verbenol); 9.12 micromoles per millimole creatinine; geometric mean	0.6–101 micromoles per millimole creatinine	Biomonitoring; cis- and trans-verbenol (urinary metabolites of alpha-pinene) were measured.

Table 5. Evidence for Cumulative Exposure to α -Pinene

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Edwards et al. 2001	Finland fall 1996– winter 1997	Continuous personal sampling at all times during 48-hour sampling period	Air; personal concentration; personal; NR; 48 hours	Alpha-pinene; 0.0012 ppm; geometric mean	0.023 (maximum) ppm	Personal monitoring; personal exposures and microenvironmental (i.e., participant's residences and workplaces) VOC concentrations were measured simultaneously during a 48-hour sampling period. See Table 2. Evidence for Occupational Exposure to α -Pinene – Measured for workplace measurements for this study and Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements.
Rosenberg et al. 2002	Finland 1997–1999	Sawmill workers	Urine; pine processing, summer and winter; biological; 94; post-shift	Verbenols (cis- and trans-verbenol) 10.5 mmol/mol creatinine; geometric mean	6.4–15 mmol/mol creatinine	Biomonitoring; cis- and trans-verbenol (urinary metabolites of alpha-pinene) were measured. Mean and range of geometric means shown.
			Urine; spruce processing, summer and winter; biological; 87; post-shift	Verbenols (cis- and trans-verbenol); 1.02 mmol/mol creatinine; geometric mean	0.49– 1.4 mmol/mol creatinine	
Liljelind et al. 2003	Sweden NR	Sawmill workers	Urine; worker 1; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 12.3 micromoles per millimole creatinine; geometric mean	NR	Biomonitoring; verbenol (a urinary metabolite of alpha-pinene) was measured.

Table 5. Evidence for Cumulative Exposure to α -Pinene

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Urine; worker 2; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 8.5 micromoles per millimole creatinine; geometric mean	NR	
			Urine; worker 3; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 4.2 micromoles per millimole creatinine; geometric mean	NR	
			Urine; worker 4; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 37.6 micromoles per millimole creatinine; geometric mean	NR	
			Urine; worker 5; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 18.6 micromoles per millimole creatinine; geometric mean	NR	
			Urine; worker 6; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 17.8 micromoles per millimole creatinine; geometric mean	NR	

Table 5. Evidence for Cumulative Exposure to α -Pinene

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Lai et al. 2004	UK 1998–2000	Personal exposure monitoring	Urine; worker 7; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 18.9 micromoles per millimole creatinine; geometric mean	NR	Personal monitoring; study reported simultaneous personal exposures and microenvironmental measurements (home and work indoors). See Table 2. Evidence for Occupational Exposure to α -Pinene – Measured for workplace measurements for this study and Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements.
			Urine; worker 8; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 21.4 micromoles per millimole creatinine; geometric mean	NR	
			Urine; worker 9; biological; 4; end-of-shift sampling	Verbenol (alpha- pinene urinary metabolite); 5.8 micromoles per millimole creatinine; geometric mean	NR	
			Air; personal concentration; personal; NR; 48 hours	Alpha-pinene; 0.0015 ppm; geometric mean	NR	

Table 5. Evidence for Cumulative Exposure to α -Pinene

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Dodson et al. 2007	United States NR	Personal exposure monitoring for 55 nonsmoking participants sampled in summer and winter	Air; personal concentration; personal; NR; 48 hours	Alpha-pinene; 0.0014 ppm; arithmetic mean	NR	Personal monitoring; data collected as part of Boston Exposure Assessment in Microenvironments (BEAM) study. Personal and residential samples collected over 48-hour sampling period and office and school samples collected over a 16-hour sampling period. See Table 2. Evidence for Occupational Exposure to α -Pinene – Measured for office and school measurements and Table 4. Evidence for Exposure to α -Pinene in Indoor Air for residential measurements for this study.
Schmidt et al. 2015	Germany NR	45 German daycare centers Children	Urine; biological; 222; full-day stay	Trans-verbenol; 18.5 $\mu\text{g/L}$; median	2.0–428 $\mu\text{g/L}$	Biomonitoring; alpha-pinene urinary metabolites; median alpha-pinene air concentration 3 $\mu\text{g/m}^3$.
			Urine; biological; 222; full-day stay	Cis-verbenol; 18.6 $\mu\text{g/L}$; median	1.1–328 $\mu\text{g/L}$	
			Urine; biological; 222; full-day stay	Myrtenol; 7.2 $\mu\text{g/L}$; median	1.1–197 $\mu\text{g/L}$	
Sumitomo et al. 2015	Japan July 2013	Forest walking	Serum; biological; 4; samples collected after walking in a conifer forest for 60 minutes	Alpha-pinene; 19.4 nM; arithmetic mean	NR	Biomonitoring; study reported serum measurements of subjects who walk in conifer forests; alpha-pinene serum concentration before walking was 2.6 nM.

Table 5. Evidence for Cumulative Exposure to α -Pinene

Reference	Location, Collection Date	Occupation or Other Exposure Scenario	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Leja et al. 2016	Latvia NR	17 adult patients undergoing H. pylori eradication therapy combined with a yeast probiotic	Exhaled breath (after eradication therapy); biological; NR; NR	Alpha-pinene; 45.09 ppb; median	NR	Biomonitoring; median alpha-pinene in exhaled breath before <i>Helicobacter pylori</i> eradication therapy = 35.93 ppb.
Silva et al. 2020	United States NR	Smokers and nonusers	Serum; biological; 40 smokers; NR	Alpha-pinene; 0.112 $\mu\text{g/L}$; arithmetic mean	NR	Biomonitoring; study measured terpene levels in serum from smokers and nonusers.
			Serum; biological; 10 nonusers; NR	Alpha-pinene; 0.084 $\mu\text{g/L}$; arithmetic mean	NR	
Bach et al. 2021	Spain July 2019	Forest walking	Whole blood; biological; 5; samples collected after walking in a Mediterranean holm oak forest for 2 hours	Alpha-pinene; 0.458 nM; arithmetic mean	NR	Biomonitoring; study reported whole blood measurements of subjects who walk in Mediterranean holm oak forests; mean alpha-pinene whole blood concentration before walking was 0.426 nM.

N = number of measurements; NR = not reported.

Table 6. Evidence for Occupational Exposure to Terpenes and Monoterpenes from a Systematic Literature Search in 2022

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Hedenstierna et al. 1983	Sweden NR	Sawmill workers	Air; personal; 48; NR	Terpenes (no further description); 45.6 ppm; arithmetic mean	17.95– 98.73 ppm	
Stromvall and Petersson 1990	Sweden May–June 1989	Stone groundwood pulp production	Air; environmental; NR; 20–80 minutes	Total monoterpenes; >0.11 ppm; other	NR	
Stromvall and Petersson 1992	Sweden 1990–1991	2 Swedish pulp mills	Air; environmental; NR; NR	Total monoterpenes; NR ppm; NR	18 (max.) ppm	
Eriksson and Levin 1995	Sweden NR	4 sawmills	Air; personal; 18; 6–8 hours	Total terpenes; NR ppm; NR	2.7–23.3 ppm	
			Air; Site A area samples; environmental; 6; NR	Total terpenes; 40.9 ppm; arithmetic mean	NR	
			Air; Site B area samples; environmental; 6; NR	Total terpenes; 19.7 ppm; arithmetic mean	NR	

Table 6. Evidence for Occupational Exposure to Terpenes and Monoterpenes

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
			Air; Site C area samples; environmental; 6; NR	Total terpenes; 4.3 ppm; arithmetic mean	NR	
			Air; Site D area samples; environmental; 6; NR	Total terpenes; 1.8 ppm; arithmetic mean	NR	
			Air; Area samples (all sites); environmental; 24; NR	Total terpenes; NR ppm; NR	43.1 (max.) ppm	
Eriksson et al. 1996	Sweden NR	Swedish sawmill workers	Air; personal; 48; 6–8 hours	Total monoterpenes; 10.77 ppm; geometric mean	1.97–28.36 ppm	Biomonitoring of urine (cis- and trans-verbenol) was also done. Total monoterpenes = sum of alpha- and beta-pinene and delta-3-carene.
Eriksson et al. 1997	Sweden NR	4 joinery shops	Air; personal; 38; 7–8 hours	Total monoterpenes; 7.72 ppm; geometric mean	1.62–38.42 ppm	Biomonitoring of urine (cis- and trans-verbenol) was also done. Total monoterpenes = sum of alpha- and beta-pinene and delta-3-carene.
Teschke et al. 1999	British Columbia, Canada Summer 1996	Lumber mill	Air; personal; 222; full work shift (7–8 hours)	Total monoterpenes; 0.199 ppm; geometric mean	0.054–5.42 ppm	Total monoterpenes = sum of alpha-pinene, beta-pinene, delta-3-carene, and unidentified wood volatiles.

Table 6. Evidence for Occupational Exposure to Terpenes and Monoterpenes

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Svedberg and Galle 2000	Sweden NR	Sawmill workers (saw shed, spruce sawing)	Air; other; NR; two work shifts (approx. 18 hours)	Total terpenes; NR ppm; NR	1.8–4.5 ppm	
Edman et al. 2003	Sweden NR	Industrial production of wood pellets and briquettes	Air; personal; 24; 8 hours	Total monoterpenes; 0.898 ppm; geometric mean	0.11–5.03 ppm	Total monoterpenes = sum of alpha- and beta-pinene and delta-3-carene.
			Air; static samples; other; 49; 8 hours	Total monoterpenes; 0.718 ppm; geometric mean	<0.151– 13.28 ppm	
Liljelind et al. 2003	Sweden NR	Sawmill workers	Air; personal; 4; NR	Total monoterpenes; Worker 1: 6.91 ppm; geometric mean	NR	Urinary verbenol was also measured. Total monoterpenes = sum of alpha- and beta-pinene and delta-3-carene.
			Air; personal; 4; NR	Total monoterpenes; Worker 2: 6.16 ppm; geometric mean	NR	
			Air; personal; 4; NR	Total monoterpenes; Worker 3: 4.33 ppm; geometric mean	NR	
			Air; personal; 4; NR	Total monoterpenes; Worker 4: 21.9 ppm; geometric mean	NR	

Table 6. Evidence for Occupational Exposure to Terpenes and Monoterpenes

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Eriksson and Wiklund 2004	Sweden August and September (year not reported)	Swedish sawmills and joinery shops	Air; personal; 4; NR	Total monoterpenes; Worker 5: 18.31 ppm; geometric mean	NR	Dermal exposure measured with an activated charcoal patch sampling technique. Total monoterpenes = sum of alpha- and beta-pinene and delta-3- carene.
			Air; personal; 4; NR	Total monoterpenes; Worker 6: 15.47 ppm; geometric mean	NR	
			Air; personal; 4; NR	Total monoterpenes; Worker 7: 16.46 ppm; geometric mean	NR	
			Air; personal; 4; NR	Total monoterpenes; Worker 8: 26.39 ppm; geometric mean	NR	
			Air; personal; 4; NR	Total monoterpenes; Worker 9: 3.72 ppm; geometric mean	NR	
			Total body exposure; pine sawing; other; 30; 120 minutes	Total monoterpenes; 238 mg/h; geometric mean	29.0–1,890 mg/h	
			Total hand exposure; pine sawing; other; 30; 120 minutes	Total monoterpenes; 9.24 mg/h; geometric mean	1.03–90.9 mg/h	

Table 6. Evidence for Occupational Exposure to Terpenes and Monoterpenes

Reference	Location, Collection Date	Occupation Description	Sampling Matrix; Approach; N; Duration	Agent; Exposure Level	Exposure Range	Comments/Additional Data
Hagstrom et al. 2012	Denmark 2003–2004	Pine furniture industry	Total body exposure; collecting of pine boards; other; 30; mean sampling time = 95 minutes (range = 55–120 minutes)	Total monoterpenes; 100 mg/h; geometric mean	12.2–959 mg/h	Sum of monoterpenes = alpha-pinene and delta-3-carene.
			Total hand exposure; collecting of pine boards; other; 30; mean sampling time = 95 minutes (range = 55–120 minutes)	Total monoterpenes; 3.25 mg/h; geometric mean	0.29–25.4 mg/h	
			Air; personal; 161; average of 7 hours (range = 4–8 hours)	Sum of monoterpenes; 1.42 ppm; geometric mean	0.47–13.8 ppm	

N = number of measurements; NR = not reported.