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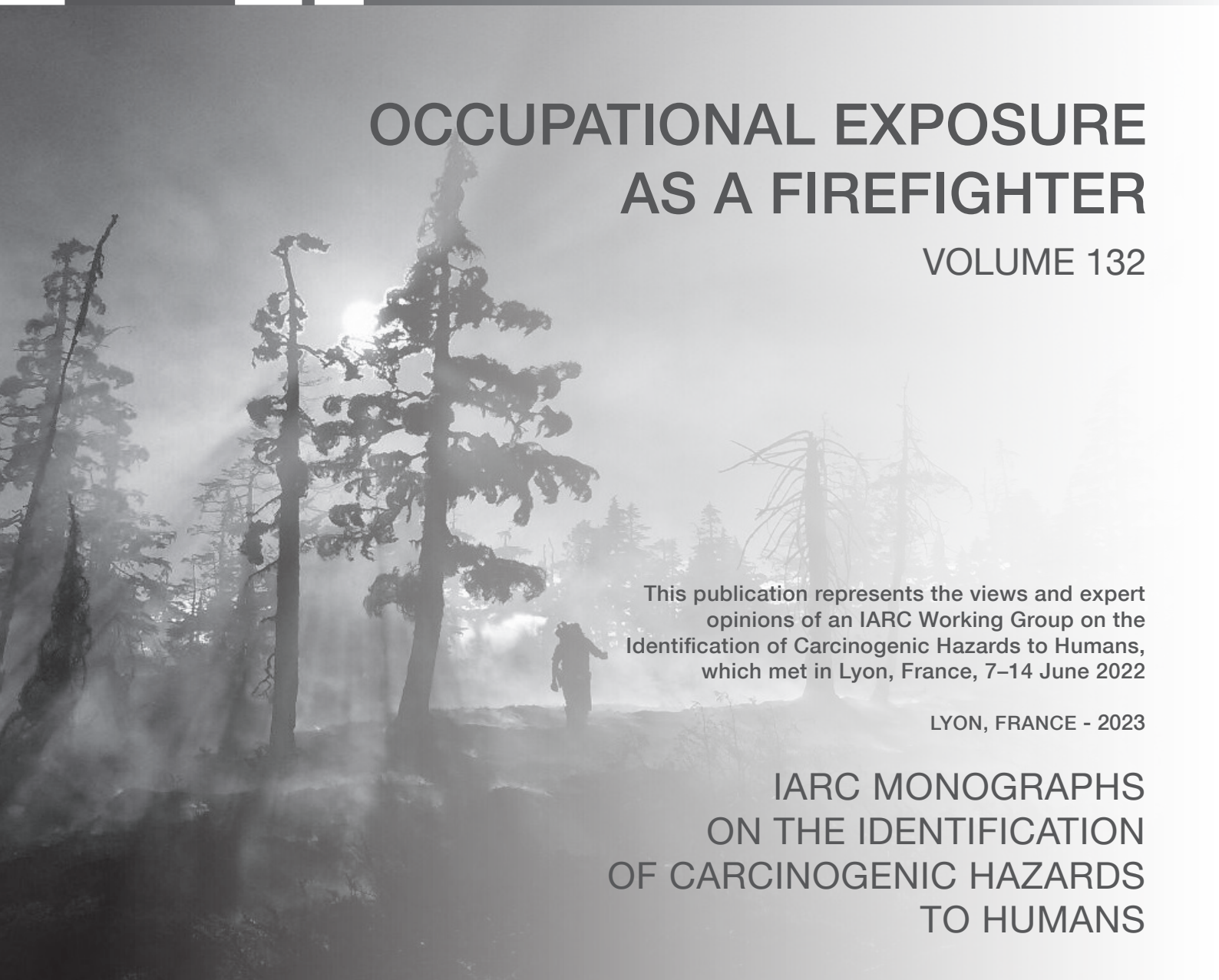

OCCUPATIONAL EXPOSURE AS A FIREFIGHTER

VOLUME 132

This publication represents the views and expert opinions of an IARC Working Group on the Identification of Carcinogenic Hazards to Humans, which met in Lyon, France, 7–14 June 2022

LYON, FRANCE - 2023

IARC MONOGRAPHS ON THE IDENTIFICATION OF CARCINOGENIC HAZARDS TO HUMANS

International Agency for Research on Cancer

World Health Organization

Table S1.12 Levels of carbon monoxide, polycyclic aromatic hydrocarbons, particulate matter, and volatile and semi-volatile organic compounds measured at structure fires

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Carbon monoxide (CO)							
Personal air	Structure fires – industrial or residential fires	NR	26 events (during 60 days)	mg/m^3	Residential fires 135.7 (7.89–291.9) Industrial fires 200.9 (16.43–384.2)	Riyadh, Saudi Arabia	Alharbi et al. (2021)[c]
Ambient air	Structure fires	August 2016 to February 2017	2 events	mg/m^3	2.3; 11.5	South Florida, USA	Caban-Martinez et al. (2018)[c]
Personal air	Structure fires – municipal fires (*n* = 45)	April to November 2008	4 days (full-shift)	mg/m^3	1.20; 2.07[a] (< 1.15–33.0)	British Columbia, Canada	Kirkham et al. (2011)[c,g]
Ambient air	Structure fires – experimental residential fires	NR	6 events (30 min)	mg/m^3	166.7	USA	Anthony et al. (2007)[c]
Personal air	Structure fires – residential and commercial buildings (*n* = 17)	NR	16 fire events (> 25 min)	mg/m^3	31.6; 26.2[a]	Phoenix, Arizona, USA	Burgess et al. (2002)[c]
Ambient air	Structure fires – municipal experiments	NR	15 events	mg/m^3	(27.6–534.7)	Canada	Austin et al. (2001a)[c]
Ambient air	Structure fires – municipal fires	NR	9 events	mg/m^3	184; 32[a]	Canada	Austin et al. (2001b)[c]
Ambient air	Structure fires – residential and commercial buildings (*n* = 51)	May to October 1999	16 events (> 25 min)	mg/m^3	14.0; 12.1[a] 39.2; 39.9[a]	Phoenix, Arizona, USA	Burgess et al. (2001)[c]
Personal air	Structure fires	NR	5 events	mg/m^3	(ND–720)	Poland	Pośniak (2000)
Ambient air	Structure fires (*n* = 440)	NR	NR	mg/m^3	(282.9–1667) 31 050[d]	Tucson, Arizona, USA	Burgess & Crutchfield (1995)[c]

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air	Structure fires – 6 training and 15 residential fires and 1 automobile fire	NR	22 events (30 min)	mg/m³	Knockdown: (BG–2177)] Overhaul: [(BG–94)	Lewistown, Pittsburgh, Pennsylvania, USA; New York City, New York; Phoenix, Arizona; Boston, Massachusetts; Cincinnati, Ohio, USA	Jankovic et al. (1991)[c]
Air inside mask	Structure fires – 6 training and 15 residential fires and 1 automobile fire	NR	22	mg/m³	(< 1.15–120.3)	Lewistown, Pittsburgh, Pennsylvania, USA; New York City, New York; Phoenix, Arizona; Boston, Massachusetts; Cincinnati, Ohio, USA	Jankovic et al. (1991)[c]
Personal air	Structure fires (*n* = 37)	NR	14 events (30 min)	mg/m³	(12.6–191)	Buffalo, New York, USA	Brandt-Rauf et al. (1989)[c]
Personal air	Structure fires (*n* = 51)	January 1986	26 events (30 min)	mg/m³	(13.1–1250)	Buffalo, New York, USA	Brandt-Rauf et al. (1988)[c]
Ambient air	Structure fires	NR	100 events	mg/m³	1661 (ND–17 184)	Dallas, Texas, USA	Lowry et al. (1985)[c]
Ambient air	Structure fires	NR	25 events	mg/m³	(ND–3440)	Los Angeles, USA	Barnard & Weber (1979)[c]
Personal air	Structure fires (*n* = 45)	NR	(7–9 min)	mg/m³	126.0 GM; 3.44 GSD	Boston, Massachusetts, USA	Gold et al. (1978)[c]

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Polycyclic aromatic hydrocarbons (PAHs)							
Personal air	Structure fires – emergency responses (*n* = 28)	January to October 2015	18 events (10–420 min)	µg/m^3	Acenaphthylene: 14.57; 1.58[b] (0.09–2839.90) Acenaphthene: 1.84; 1.49[b] (0.07–186.85) Anthracene: 1.46; 1.63[b] (0.03–746.85) Benz[*a*]anthracene: 0.91; 1.48[b] (0.02–236.05) Benzo[*a*]pyrene: 1.54; 1.44[b](0.03–133.76) Benzo[*b*]fluoranthene: 1.52; 1.55[b] (0.02–218.59) Benzo[*g,h,i*]perylene: 0.75; 1.54[b] (0.02–98.65) Benzo[*k*]fluoranthene: 0.69; 1.46[b] (0.03–79.12) Chrysene: 1.31; 1.63[b] (0.03–1062.72) Dibenz[*a,h*]anthracene: 0.27; 1.29[b] (0.02–5.58) Fluoranthene: 5.95; 1.53[b] (0.11–1441.33) Fluorene: 4.02; 1.51[b] (0.16–747.16) Indeno[1,2,3-*c,d*]pyrene: 1.07; 1.47[b] (0.04–146.36) Naphthalene: 182.59; 1.48[b] (3.95–15 916.0) Phenanthrene: 9.07; 1.64[b] (0.16–4543.59) Pyrene: 1.97; 1.79[b] (0.02–1294.32)	Ottawa, Canada	Keir et al. (2020)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air	Structure fires – live firefighting (*n* = 56)	November 2018 to March 2019	3024 shifts	pmol/tag[c]	Acenaphthene: 14.4; 64.7[a] (ND–596) Acenaphthylene: (ND–173) Anthracene: 14.9; 21.0[a] (ND–120) Benz[*a*]anthracene: 3.14; 8.84[a] (ND–72.5) Benzo[*b*]fluoranthene: 7.47; 7.14[a] (ND–42.2) Benzo[*k*]fluoranthene: 5.17; 6.17[a] (ND–26.1) Benzo[*j*]fluoranthene: (ND–24.1) Benzo[*b*]fluorene: (ND–35.7) Benzo[*c*]fluorene: (ND–18.4) Benzo[*g*,*h*,*i*]perylene: 0.378 (ND–10.8) Benzo[*e*]pyrene: 3.72; 5.14[a] (ND–33.0) Chrysene: 2.36; 7.21[a] (ND–62.0) Cyclopenta[*c*,*d*]pyrene: (ND–96.3) Dibenzothiophene: 19.7; 11.4[a] (ND–67.6) Fluoranthene: 60.9; 51.9[a] (ND–428) Fluorene: 76.5; 57.4[a] (ND–513) Indeno[1,2,3-*c*,*d*]pyrene: (ND–21.8) Naphthalene: 184; 156[a] (ND–1260) Naphtho[1,2-*b*]fluoranthene: 1.15 (ND–8.81)	Kansas City, Missouri, USA	Poutasse et al. (2020)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air (cont.)					Phenanthrene: 260; 131[a] (37.5–773) Pyrene: 44.4; 33.1[a] (ND–292) Retene: 24.2; 25.8[a] (ND–223) Triphenylene: 2.41; 5.11[a] (ND–26.5) 2-Methylanthracene: 43.3; 28.0[a] (ND–148) 2,3-Dimethylanthracene: (ND–33.3) 1-Methylnaphthalene: 165; 113[a] (ND–568) 2-Methylnaphthalene: 297; 194[a] (ND–907) 1,2-Dimethylnaphthalene: 56.7 ± 48.6 (ND–350) 2-Ethylnaphthalene: 78.5; 63.6[a] (ND–386) 1,4-Dimethylnaphthalene: 33.0; 24.0[a] (ND–141) 1,5-Dimethylnaphthalene: 21.4; 22.8[a] (ND–149) 2,6-Dimethylnaphthalene: 199; 169[a] (ND–1310) 2-Methylphenanthrene: 72.2; 41.3[a] (ND–22) 3,6-Dimethylphenanthrene: 8.42; 10.2[a] (ND–60.6) 1-Methylpyrene: 8.12; 6.73[a] (ND–43.2)		Poutasse et al. (2020) (cont.)
Ambient air – wristbands	Structure fires (*n* = 15)	June 2019	4 events	ppb	1-Methylnaphthalene: (1.70–43.8) 2-Methylnaphthalene: (2.60–91.9) Acenaphthylene: (2.00–11.3)	Dominican Republic	Caban-Martinez et al. (2020)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air – wristbands (cont.)					Acenaphthene: (1.50–4.80) Anthracene: (1.90–8.50) Benz[*a*]anthracene: (1.30–4.30) Benzo[*b*]fluoranthene: (0.65–5.70) Benzo[*k*]fluoranthene: (0.53–1.50) Benzo[*a*]pyrene: (1.50–1.60) Benzo[*g,h,i*]perylene: (0.53–2.00) Chrysene: (1.60–8.40) Dibenz[*a,h*]anthracene: 0.65 Fluoranthene: (10.00–29.00) Fluorene: (4.20–13.30) Indeno[1,2,3-*c,d*]pyrene: (0.53–1.50) Naphthalene: (0.64–137.0) Phenanthrene: (21.60–63.6) Pyrene: (11.80–45.90)		Caban-Martinez et al. (2020) (cont.)
Personal air	Structure fires – residential training exercises (*n* = 34)	NR	3 events (< 45 min)	µg/m^3	Total PAHs: (2780–34 000)	Illinois, USA	Fent et al. (2019)
Personal air	Structure fires – training exercises (*n* = 7)	May 2014	7 events (74–196 min)	ng/m^3	Benz[*a*]anthracene: 2.56; 2.23[a] (1.03–10.1) Benzo[*b*]fluoranthene: 10.8; 2.05[a] (4.48–38.9) Benzo[*k*]fluoranthene: 5.31; 2.34[a] (1.51–16.3) Benzo[*a*]pyrene: 8.67; 3.06[a] (1.46–51.4) Chrysene: 4.57; 1.90[a] (2.32–14.4) Dibenz[*a,h*]anthracene: 2.03; 2.92[a] (0.423–11.6)	Stockholm, Sweden	Sjöström et al. (2019)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air (cont.)					Indeno[1,2,3-*c*,*d*]pyrene: 15.8; 2.66[a] (3.06–74.4) Naphthalene: 1810; 1.58[a] 1010–3680) Total PAHs: 3600; 1.97[a] (1740–16 000)		Sjöström et al. (2019) (cont.)
Ambient air	Structure fires – residential buildings (*n* = 72)	NR	12 events (4–60 min)	µg/m³	Total PAHs: 14 200[e] (5600–35 900)	Illinois, USA	Fent et al. (2018)
Personal air				µg/m³	Total PAHs: (< 30–23 800) (7460–78200)	Illinois, USA	Fent et al. (2018)
Ambient air	Structure fires – live fires (*n* = 28)	NR	29 events	µg/m³	Total PAHs: (5.23–28 604)	Ottawa, Canada	Akhtar et al. (2016)
Personal air	Structure fires – training exercises at burn houses (*n* = 28)	NR	5 events (30 min)	µg/m³	Acenaphthylene: (5.9–33) Acenaphthene: (ND–2.7) Benz[*a*]anthracene: (0.7–17.5) Benzo[*a*]fluoranthene: (0.1–5.8) Benzo[*a*]pyrene: (0.3–14.3) Benzo[*b*]fluoranthene: (0.3–9.7) Benzo[*e*]pyrene: (0.3–8.9) Benzo[*j*]fluoranthene: (0.2–7.0) Benzo[*k*]fluoranthene: (0.3–10.5) Benzo[*g*,*h*,*i*]fluoranthene: (0.5–12.8) Benzo[*c*]phenanthrene: (0.2–10.6) Chrysene: (1.1–21.9) Cyclopenta[*c*,*d*]pyrene: (0.2–10.6) Biphenyl: (4.1–14.6) Fluorene: (2.0–18.7)	Ontario, Canada	Fernando et al. (2016)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air (cont.)					Fluoranthene: (3.6–47) Naphthalene: (38–119) 1-Methylnaphthalene: (4.5–19.6) 2-Methylnaphthalene: (5.2–37.6) Perylene: (0.1–5.0) Phenanthrene: (11.8–76) Pyrene: (4.2–45) Total PAHs: (85–548)		Fernando et al. (2016) (cont.)
Ambient air	Structure fires – live fire training	NR	5 events (20–44 min)	µg/m³	Acenaphthylene: (83–390) Acenaphthene: (7.9–37) Anthracene: (24–110) Benz[*a*]anthracene: (4.1–46) Benzo[*b*+*k*]fluoranthene: (4.3–60) Benzo[*g*,*h*,*i*]perylene: (1–23) Benzo[*a*]pyrene: (1.8–47) Chrysene: (3.4–42) Dibenz[*a*,*h*]anthracene: (0.2–2) Fluoranthene: (33–180) Fluorene: (27–120) Indeno[1,2,3-*c*,*d*]pyrene: (0.9–18) Naphthalene: (73–1300) Phenanthrene: (120–490) Pyrene: (29–180)	Queensland, Australia	Kirk & Logan (2015)
Air inside PPE	Structure fires – live fire training	NR	5 events (20–44 min)	µg/m³	Acenaphthylene: (2.4–18) Acenaphthene: (0.34–2.6) Anthracene: (0.36–8.2) Benz[*a*]anthracene: (0.56–11) Benzo[*b*+*k*]fluoranthene: (0.9–15)	Queensland, Australia	Kirk & Logan (2015)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Air inside PPE (cont.)					Benzo[*g*,*h*,*i*]perylene: (0.29–2.8) Benzo[*a*]pyrene: (0.4–13) Chrysene: (0.74–10) Dibenz[*a*,*h*]anthracene: (0.2–0.6) Fluoranthene: (1.7–28) Fluorene: (0.56–5.4) Indeno[1,2,3-*c*,*d*]pyrene: (0.28–2.6) Naphthalene: (13–210) Phenanthrene: (2.2–37) Pyrene: (1.9–33)		Kirk & Logan (2015) (cont.)
Personal air	Structure fires – firehouses (*n* = 10)	NR	5 events (15–30 min)	µg/m^3	Acenaphthylene: (1.32–8.04) Naphthalene: (2.44–89.91) Benzo[*b*,*j*,*k*]fluoranthene: (7.3–23.30)	Cincinnati (OH), USA	Baxter et al. (2014)
Ambient air	Structure fires – experimental residential fires	NR	6 events (30 min)	ppm	Acenaphthene: (< 0.0023 to > 0.0065) Acenaphthylene: (0.012 to > 0.0074) Fluorene: (0.0023–0.0044) Naphthalene: (0.01–0.078) Phenanthrene: (0.0003–0.00048)	USA	Anthony et al. (2007)
Ambient air	Structure fires – municipal experiments	NR	15 events	ppm	Naphthalene: 3.0	Canada	Austin et al. (2001a)
Ambient air	Structure fires – municipal fires	NR	9 events	ppm	Naphthalene: (0.01–2.14)	Canada	Austin et al. (2001b)
Personal air	Structure fires (*n* = 20)	June to September 1998	25 events (> 20 min)	µg/m^3	Acenaphthene: 77.7; 15.8[a] (66.5–88.8) Acenaphthylene: 415.0; 536[a] (88–2440) Anthracene: 22.2	Phoenix, USA	Bolstad-Johnson et al. (2000)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air (cont.)					Benz[*a*]anthracene: 24.9; 4.9[a] (19–28) Benzo[*b*]fluoranthene: 22.3; 10.6[a] (10–34) Benzo[*k*]fluoranthene: 23.8; 1.7[a] (23–25) Benzo[*a*]pyrene: 33.2; 13.6[a] (19–50) Benzo[*g,h,i*]perylene: 29.0; 23.3[a] (12.5–45.4) Chrysene: 12.9 Dibenz[*a,h*]anthracene: 45.5; 31.6[a] (23–68) Fluoranthene: 120; 39.9[a] (79.1–169) Indeno[1,2,3-*c,d*]pyrene: 19.5; 8.4[a] (14–29) Naphthalene: 223.0; 101[a] (73–540) Phenanthrene: 24.3; 9.19[a] (10.8–40.5) Pyrene: 93.1; 83.8[a] (13.8–211)		Bolstad-Johnson et al. (2000) (cont.)
Ambient air	Structure fires – training exercises at houses	February, June 1997	5 events (38–182 min)	µg/m^3	Acenaphthene: (ND–65) Acenaphthylene: (44–100) Anthracene: (ND–1.6) Benz[*a*]anthracene: (ND–0.29) Benzo[*b*]fluoranthene: (ND–0.21) Benzo[*k*]fluoranthene: (ND–0.12) Benzo[*a*]pyrene: (ND–0.39) Benzo[*g,h,i*]perylene: (ND–0.25)	Virginia, USA	NIOSH (1998)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air (cont.)					Fluorene: (2.4–18) Fluoranthrene: (ND–1.1) Naphthalene: (30–200) Phenanthrene: (3.5–8.0) Pyrene: (ND–0.74)		NIOSH (1998) (cont.)
Personal air	Structure fires – training activities (*n* = 10)	NR	4 events (30–90 min)	µg/m^3	Benzo[*a*]pyrene: (300–700) Pyrene: (850–2610) Total PAHs: (8480–14 750)	Netherlands	Feunekes et al. (1997)
Ambient air	Structure fires – training and residential fires	NR	22 events (30 min)	µg/m^3	Acenaphthene: 63; 100[d] Anthracene: 15; 30[d] Benz[*a*]anthracene: 15; 1; 30[d] Benzo[*b*]fluoranthene: 6; 12[d] Benzo[*k*]fluoranthene: 3; 6[d] Benzo[*a*]pyrene: 10; 20[d] Benzo[*e*]pyrene: 22; 1; 40[d] Benzo[*g,h,i*]perylene: 5; 10[d] Chrysene: 10; 1; 20[d] Dibenz[*a,h*]anthracene: 3; 5[d] Fluoranthene: 32; 2; 60[d] Indeno[1,2,3-*c,d*]pyrene: 10; 20[d] Phenanthrene: 54; 100[d] Pyrene: 36; 2; 70[d]	Pennsylvania, Pittsburgh, New York, Phoenix, Boston, Cincinnati, USA	Jankovic et al. (1991)
Particulate matter (PM)							
Ambient air	Structure fires – firehouses (*n* = 10)	NR	5 events (15–30 min)	mg/m^3 number/cm^3	$PM_{2.5}$ (0.253–17.53) Total PM (95684–139406)	Cincinnati, Ohio, USA	Baxter et al. (2014)
Personal air	Structure fires – emergency firefighting (*n* = 8)	October 2014 to July 2015	8 events (20–240 min)	mg/m^3	0.137; 0.0018[a] (0.047–0.268)	Stockholm, Sweden	Sjöström et al. (2019)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air	Structure fires – residential buildings (n = 72)	NR	12 events (4–60 min)	mg/m^3 number/cm^3	Respirable PM 484[e] (63.05–715.0) Thoracic PM 490[e] (64.1–721) 1 580 000[e] (102 700–2 970 000)	Illinois, USA	Fent et al. (2018)
Ambient air	Structure fires – residential experimental fires	NR	6 events	number/cm^3	(5.36×10^3–2.11×10^6)	Ohio, USA	Baxter et al. (2010)
Ambient air	Structure fires – experimental residential fires	NR	6 events (30 min)	mg/m^3	Respirable PM 17.2; 30.1[d]	USA	Anthony et al. (2007)
Personal air	Structure fires – residential and commercial buildings (n = 17)	NR	16 fire events (> 25 min)	mg/m^3	Respirable dust 5.26; 6.34[a]	Phoenix, USA	Burgess et al. (2002)
Ambient air	Structure fires – residential and commercial buildings (n = 51)	May to October, 1999	16 events (> 25 min)	mg/m^3	Respirable dust 6.18; 7.80[a]	Phoenix, USA	Burgess et al. (2001)
Ambient air	Structure fires – training exercises at houses	February, June 1997	5 events (38–182 min)	mg/m^3	Total dust (0.20–5.3) Respirable dust (< 0.10–1.2)	Virginia, USA	NIOSH (1998)
Ambient air	Structure fires (n = 440)	NR	NR	mg/m^3	Total PM 232; 15000[d]	Tucson, Arizona, USA	Burgess & Crutchfield (1995)
Ambient air	Structure fires – training and residential fires	NR	22 events (30 min)	mg/m^3	Total PM (NR–560)	Pennsylvania, Pittsburgh, New York, Phoenix, Boston, Cincinnati, USA	Jankovic et al. (1991)
Personal air	Structure fires (n = 51)	January 1986	26 events (30 min)	mg/m^3	Total PM (10.1–344.4)	Buffalo, New York, USA	Brandt-Rauf et al. (1988)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air	Structure fires (*n* = 39)	NR	179 events	mg/m^3	Suspended PM Light exposure: 6.9 Moderate exposure: 34.7 Heavy exposure: 56.1	Boston, Massachusetts, USA	Musk et al. (1979)
Personal air	Structure fires (*n* = 45)	NR	(7–9 min)	mg/m^3	Total PM 21.5; 4.7[a]	Boston, Massachusetts, USA	Gold et al. (1978)
Volatile and semi-volatile organic compounds (VOCs and sVOCs)							
Personal air	Structure fires – industrial and residential fires	NR	26 events	ppm	*Residential fires* Total VOCs: 0.363; 0.438[a] (0.065–1.817) BTEX: 0.0449 (0.00007–0.985) Non BTEX: 0.0149 (0.00018–0.510) *Industrial fires* Total VOCs: 0.145; 0.077[a] (0.058–0.247) BTEX: 0.0174 (0.00060–0.1081) Non BTEX: 0.0113 (0.00029–0.1053)	Riyadh, Saudi Arabia	Alharbi et al. (2021)
Personal air	Structure fires – residential	NR	3 events (< 45 min)	mg/m^3	Benzene: (9.57–101.1)	Illinois, USA	Fent et al. (2019)
Ambient air	Training fires (*n* = 34)			mg/m^3	Acetaldehyde: (< 0.154–291) Acrolein: (< 0.497–60.6) Formaldehyde: (< 0.133–35.2)		Fent et al. (2019)
Personal air	Structure fires – emergency firefighting (*n* = 8)	October 2014 to July 2015	8 events (20–240 min)	mg/m^3 µg/m^3	Benzene: 0.018; 0.0021[a] (0.00537–0.079) 1,3–Butadiene: 2.69; 2.32[a] (0.454–9.58)	Stockholm, Sweden	Sjöström et al. (2019)
Ambient air	Structure fires – training exercises	NR	3 events (12–18 min)	mg/m^3	Acetaldehyde: (3.0–5.1) Acetone: (0.82–1.4) Benzaldehyde: (0.97–1.2) Benzene: (4.5 to > 7.8) Crotonaldehyde: (0.06–0.16)	Queensland, Australia	Kirk & Logan (2019)

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air (cont.)					Butyraldehyde: (0.15–0.23) Ethylbenzene: (0.21–0.34) Formaldehyde: (1.3–2.2) Hexaldehyde: (ND–0.06) Methyl ethyl ketone: (ND–4) *n*-Decane: (ND–0.08) Propionaldehyde: (0.22–0.39) Styrene: (0.94–1.50) Toluene: (2.2–2.9) Trimethyl benzenes: (0.09–2) Xylenes: (0.28–0.36)		Kirk & Logan (2019) (cont.)
Air inside PPE	Structure fires – training exercises	NR	3 events (12–18 min)	mg/m^3	Acetaldehyde: (0.05–1.2) Acetone: (ND–0.58) Benzene: (0.16–4.9) Benzaldehyde: (ND–0.20) Butyraldehyde: (ND–0.13) Ethylbenzene: (0.05–0.09) Formaldehyde: (ND–0.20) Methyl ethyl ketone: (ND–8) Styrene: (ND–0.33) Toluene: (ND–0.91) Xylenes: (NR–0.15)		Kirk & Logan (2019)
Ambient air	Structure fires	August 2016 to February 2017	2 events	ppm	Total VOCs: (ND–5)	South Florida, USA	Caban-Martinez et al. (2018)
Ambient air	Structure fires – residential buildings (n = 72)	NR	12 events (4–60 min)	mg/m^3	Benzene: 0.044[e] (0.205–66.67) Ethylbenzene: 0.0044[e] (< 0.0013–0.032) Toluene: 0.240[e] (0.0047–0.746) Xylenes: 0.0041[e] (< 0.002–0.112)	Illinois, USA	Fent et al. (2018)[c]

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Personal air	Structure fires – residential buildings (*n* = 72)	NR	12 events (4–60 min)	mg/m^3	Benzene: (< 0.032–128.56) 1027[d]		Fent et al. (2018)[c]
Personal air	Structure fires – training exercises at burn houses (*n* = 28)	NR	5 events (30 min)	µg/m^3	Guaiacol: (29–479) Methylguaiacol: (20–408) Ethylguaiacol: (11.3–332) Syringol: (11.9–568) Eugenol: (2.8–96) Isoeugenol: (3.9–335) Propylguaiacol: (2.2–93) Acetovanillone: (2.7–172) Methylsyringol: (8.4–164) Ethylsyringol: (3.6–237) Propylsyringol: (1.9–52) Guaiacylacetone: (9.2–416) Acetosyringone: (9.7–222) Butylsyringone: (ND–38) Propylsyringone: (ND–35) Synapelaldehyde: (ND–15) Total methoxyphenols: (120–7)	Ontario, Canada	Fernando et al. (2016)
Ambient air	Structure fires – experimental residential fires	NR	6 events (30 min)	mg/m^3	Acetaldehyde: (0.288–1.062) Acrolein: (< 0.005–0.366) Benzene: (0.274–0.989) Ethylbenzene: (0.0226–0.317) Formaldehyde: (0.271–1.476) *m,p*-Xylene: (0.054–0.281) *o*-Xylene: (0.012–0.087) Styrene: (0.034–1.87) Toluene: (0.173–0.942)	USA	Anthony et al. (2007)[c]
				ppm	Benzaldehyde: (0.0018–0.012) 1,3,5-Trimethylbenzene: (0.0014–0.023)		

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air (cont.)					1,2,4-Trimethylbenzene: (0.0016–0.015) Acetone: (< 0.031–0.17) Butyraldehyde: (0.012–0.033) Butyl benzene: (0.00041–0.0041) Crotonaldehyde: (0.0023–0.019) Cumene: (0.00094–0.0036) Dichlorodifluoromethane: (0.00068–0.0062) Methylbromide: (0.00055–0.0085) Methylchloride: (0.0016–0.022) Methylenechloride: (0.0029–0.021) Methylisothiocyanate: (< 0.081–2.1) *p*-Isopropyltoluene: (0.00095–0.0099) Propionaldehyde: (0.028–0.2) Propylbenzene: (0.00063–0.012) Valeraldehyde: (< 0.0052–0.02)		Anthony et al. (2007)[c] (cont.)
Personal air	Structure fires – residential and commercial buildings (*n* = 17)	NR	16 events (> 25 min)	mg/m^3	Acetaldehyde: 0.738; 0.972[a] Benzene: 1.69; 0.83[a] Formaldehyde: 0.307; 0.320[a]	Phoenix, USA	Burgess et al. (2002)[c]
Personal air	Structure fires – residential and commercial buildings (*n* = 51)	May to October 1999	16 events (> 25 min)	mg/m^3	Acetaldehyde: 0.284; 0.067[a] 0.689; 0.889[a] Acrolein: 0.037 Benzene: 1.777; 1.483[a] Formaldehyde: 0.134; 0.224[a] 0.316; 0.306[a] Gluteraldehyde: 0.08	Phoenix, USA	Burgess et al. (2001)[c]

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air	Structure fires – municipal experiments	NR	15 events	ppm mg/m^3	Total VOCs: (0.10–107) 1,3-Butadiene: 0.1 Benzene: (1.91–207.3) Styrene: 1.70	Canada	Austin et al. (2001a)[c]
Ambient air	Structure fires – municipal fires	NR	9 events	ppm mg/m^3	Total VOCs: 22.8; 25.5[a] 1,3-Butadiene: (0.03–4.84) Benzene: (0.383–2.42) Toluene: (0.188–20.8) Styrene: (0.013–8.56)	Canada	Austin et al. (2001b)[c]
Personal air	Structure fires	NR	5 events	mg/m^3	Benzene: (ND–89.4) Ethylbenzene: (ND–125.0) Formaldehyde: (0.52–5.3) *n*-Octane: (ND–407.9) Toluene: (3.2–640.0) Trimethylbenzene: (ND–91.4) Diethylbenzene: (ND–58.0) Tetramethylbenzene: (ND–185.4) *m,p*-Xylene: (ND–80.5)	Poland	Pośniak (2000)
Personal air	Structure fires ($n = 20$)	June to September 1998	25 events (> 20 min)	mg/m^3 ppm	Acetaldehyde: 0.612; 0.738[a] (0.074–3.15) Acrolein: 0.282; 0.305[a] (0.030–0.687) Benzene: 1.222; 1.356[a] (0.07–6.348) Formaldehyde: 0.307; 0.310[a] (0.020–1.45) Glutaraldehyde: 0.046; 0.04[a] (0.005–0.15) Benzaldehyde: 0.057; 0.03[a] (0.223–0.13) Isovaleraldehyde: 0.07; 0.038[a] (0.02–0.16)	Phoenix, USA	Bolstad-Johnson et al. (2000)[c]

Table S1.12 (continued)

Sample type	Type of fire (*n*, no. of firefighters)	Sampling period	No. of fires (sampling duration)	Units	Mean concentration; SD[a] or SEM[b] unless otherwise indicated (range)	Location	Reference
Ambient air	Structure fires – training exercises at houses	February, June 1997	5 events (38–182 min)	mg/m^3	Acetaldehyde: (ND–0.234) Acrolein: (ND–0.046) Formaldehyde: (0.074–0.221)	Virginia, USA	NIOSH (1998)[c]
Ambient air	Structure fires (n = 440)	NR	NR	mg/m^3	Acrolein: 4.35; 224[d] Benzene: (14.99–178.6) 797[d]	Tucson, Arizona, USA	Burgess & Crutchfield (1995)[c]
Ambient air	Structure fires – training and residential fires	NR	22 events (30 min)	mg/m^3	Acetaldehyde: (NR–14.58) Acrolein: (NR–7.33) Benzene: (NR–70.18) Formaldehyde: (NR–9.84) Methane: (NR–189.6)	Pennsylvania, Pittsburgh, New York, Phoenix, Boston,	Jankovic et al. (1991)[c]
Air inside mask					Acetaldehyde: (NR–1.62) Acrolein: (NR–2.06) Benzene: (NR–67.0) Formaldehyde: (NR–0.369) Methane: (NR–21.6)	Cincinnati, USA	Jankovic et al. (1991)[c]
Personal air	Structure fires (n = 51)	January 1986	26 events (30 min)	mg/m^3	Benzene: (26.5–797) Formaldehyde: (0.123–4.06)	Buffalo, New York, USA	Brandt-Rauf et al. (1988)[c]
Ambient air	Structure fires	NR	100 events	ppm	Acetaldehyde + formaldehyde: 5 (1–15) Total hydrocarbons: 800 (500–1200)	Dallas, Texas, USA	Lowry et al. (1985)

BG, background; BTEX, benzene, toluene, ethylbenzene, and xylene; CO, carbon monoxide; GM, geometric mean; GSD, geometric standard deviation; min, minute; ND, not detected; NR, not reported; PAH, polycyclic aromatic hydrocarbon; PM, particulate matter; PPE, personal protective equipment; ppm, parts per million; SD, standard deviation; SEM, standard error of mean; sVOC, semi-volatile organic compound; VOC, volatile organic compound.

[a] Standard deviation (SD) of the mean.

[b] Standard error of the mean (SEM).

[c] Data was converted from ppm to mg/m^3.

[d] Maximum peak value.

[e] Value expressed as median.

[f] pmol of substance per silicon dog tag (sampling medium).

[g] The study does not specify the type and number of firefighting activities performed during the full shift.

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