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INDOOR AIR PROJECT

Persistent Organic Pollutants and Metals

A report to the
Air Quality Section, Environment Standards Branch,
Department of the Environment, Water, Heritage and the Arts
COMMONWEALTH OF AUSTRALIA

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Contents

Glossary

BBI53	brominated fire retardant, 2,2’4,4’,5,5’-hexabromobiphenyl
BBzP	phthalate ester, butyl benzyl phthalate
Cd	cadmium
DEHP	phthalate ester, diethylhexyl phthalate
DnBP	phthalate ester, di-n-butyl phthalate
DEP	phthalate ester, diethyl phthalate
Endosulfan	organochlorine insecticide
GC-HRMS	gas chromatography with high resolution mass spectrometry
Hg	mercury
ICPMS	inductively coupled plasma with mass spectrometry
MDL	minimum detection limit
Ni	nickel
NMI	National Measurement Institute
PBDE	polybrominated diphenyl ether
ΣPBDEs	sum of the measured concentrations of all of the polybrominated diphenyl ethers.
PBFR	polybrominated fire retardants
PCBs	polychlorinated biphenyls
PFAS	perfluoroalkyl sulfonate
PFOA	perfluoroctanoic acid
PFOS	perfluorooctane sulfonate
Pb	lead
PVC	polyvinyl chloride
SCCPs	short chain chlorinated paraffins
TSP	total suspended particulate

1. INTRODUCTION

CSIRO Marine and Atmospheric Research has been commissioned by the Department of the Environment, Water, Heritage and the Arts (DEWHA) to carry out a study of the concentrations of metals and persistent organic pollutants (POPs) in air and dust samples collected indoors and outdoors of 10 dwellings in Melbourne.

The chemical species measured in this study include:

- ◊ Metals
  - Lead in the particle phase
  - Cadmium in the particle phase
  - Nickel in the particle phase
  - Mercury in the gas phase
- ◊ POPs
  - Polybrominated diphenyl ethers (PBDEs) in air
  - Polybrominated diphenyl ethers in indoor dust
  - Phthalates (only indoors)
  - Endosulfan (only outdoors)
  - Short chain chlorinated paraffins (SCCPs)
  - Perfluorooctane sulfonate (PFOS)
  - Perfluoroalkyl sulfonate (PFAS)
  - Perfluorooctanoic acid (PFOA)
  - Polychlorinated biphenyls (PCBs)

The chemical species listed above were measured in air indoors and outdoors with the exception of phthalates and PBDEs which were only measured indoors, and endosulfan which was only measured outdoors. PBDEs were also measured in dust collected in each dwelling.

2. BACKGROUND

This section presents a summary of background information relevant to this study. The indoor and outdoor sources of each metal or POP are listed in Table 1. The consumer products found within the domestic environment that contain the metals or POPs are also listed in Table 1.

Table 1. Sources of metals and persistent organic pollutants investigated in this study

Species	Domestic Indoor sources	Outdoor sources	Domestic products containing species of interest
Mercury (vapour) REF 1&2	Combustion of home heating oil Broken thermometers and broken mercury lights Paint (pre 1960's)	Vehicles running on petrol Fossil fuel power plants Industrial point sources (metal smelters and cement-production facilities) Bushfire smoke	Batteries, thermometers, barometers, thermostats and mercury lights
Cadmium (particles) REF 3&4	Infiltration of outdoor sources Cigarette smoke Electric kettles	Manures and pesticides Vehicles (petrol, oils, tyres, automobile radiators) Fossil fuel power plants Industrial point sources (metal smelters, production of batteries and electrical apparatus) Waste incineration Phosphate fertilisers	PVC products, photocells, some textile dyes and colours, electronic components, heating elements in electric kettles and hot water systems, batteries, and ceramic glazes
Nickel (particles) REF 5&6	Infiltration of outdoor sources Cigarette smoke	Vehicles running on petrol and diesel fuel Fossil fuel power plants (particularly coal combustion) Industrial point sources (mining and refining operations, steel production, nickel alloy production, electroplating, and municipal waste incineration) Windblown dust Natural sources from soils and volcanoes	Coins, jewellery, nickel-cadmium batteries, some paints and ceramics, magnetic tapes, computer components, goods containing stainless steel (sinks, cooking utensils, cutlery)

Table 1. continued

Species	Domestic Indoor sources	Outdoor sources	Domestic products containing species of interest
Lead (particles) REF 7&8	Infiltration of outdoor sources Paint (pre 1970) Lead solder	Windblown dust Resuspended road dust Industrial point sources (lead smelting, and municipal waste incineration)	
PBDE REF 9&10	It is believed that PBDE are released from products containing them (see column 3) during their life span	Released during manufacture of products containing PBDE (see column 3). However not manufactured in Australia Released during incineration of waste (when waste includes products containing PBDE)	Used as a flame retardant e.g. pentaBDE polyurethane foam products such as furniture and upholstery in domestic furnishing, and in the automotive and aviation industries and octaBDE plastic products, such as housings for computers, automobile trim, telephone handsets and kitchen appliance casings.
PCB REF 11	Capacitors in old fluorescent lighting fixtures and old appliances such as television sets and refrigerators, which may leak small amounts of PCBs into the air when they get hot during operation	Leaks from electrical transformers containing PCBs. Electrical equipment in which PCBs have been replaced may still contain traces of them. PCBs may be released into the environment from either hazardous waste sites that contain PCBs or from illegal and improper dumping of PCB wastes. Bushfire smoke	Capacitors in old appliances (see column 1)
SCCP REF 12,13&14	Emitted from products containing fire retardants and plasticisers during their use (see column 3).	Believed to undergo long range transport Used as extreme pressure additives in metal working fluids so may be released to atmosphere near metal working industries, particularly if metal working fluids are aerosolised.	Secondary plasticizers in polymers, especially PVC. Found in mats, for floor and wall cover, and PVC covered wall papers, fillers and sealants (replaced PCB when they were phased out). Used as flame retardants

Table 1. continued

Species	Domestic Indoor sources	Outdoor sources	Domestic products containing species of interest
Phthalates REF 15&16	It is believed that phthalates are released from products containing them (see column 3) during their life span.	Released during the manufacture (although not manufactured in Australia) of products that use them such as chemicals, plastic parts and carpet backing. Released from the manufacture of machinery, during millwork and the disposal of paints and varnish. DEHP is distributed widely in the environment because of its diffuse use, volatility and persistence.	Di-n-butyl phthalate (DnBP) in colognes and perfumes, cosmetics, paints undercoats and primers, plastic products, floor polish, window cleaning products, caulks and sealants, latex-type adhesives, resin and rubber adhesives, safety glass, vinyl floors, hairspray and nail polish, elastomers, lacquers, explosives, printing inks, resin solvents, perfume oil solvents, paper coatings, adhesives, and nail polish, solid rocket propellant. Di-2-ethyl hexyl phthalate (DEHP) in polyvinyl chloride (PVC) plastic products like toys, vinyl upholstery, shower curtains, adhesives, and coatings, some food packaging, in medical product containers (including those for blood) and equipment, some inks, pesticides, cosmetics and vacuum pump oil. It has also reportedly been used as a replacement for polychlorinated biphenyls (PCBs) in dielectric fluids for electric capacitors and in vacuum pumps

Table 1. continued

Species	Domestic Indoor sources	Outdoor sources	Domestic products containing species of interest
Endosulfan REF 17	Infiltration of outdoor source	Pesticide use in agricultural and horticultural areas on crops, including cotton, cereal, oilseeds, fruit, vegetables and other crops.	Endosulfan products are not registered for home garden use.
Perfluorinated Compounds REF 18	Overheating of Teflon during cooking		PFOA is in Teflon products. PFOS is a breakdown product of chemicals formerly used to make Scotchguard products Cleaning and personal-care products like shampoo, dental floss, and denture cleaners. Water proof clothing e.g., Gore-Tex clothing

1. NPI Mercury Fact sheet, available at http://www.npi.gov.au/database/substance-info/profiles/53.html
2. EA 2001, Air Toxics State of Knowledge Report, Part C Mercury Fact Sheet available at http://www.environment.gov.au/atmosphere/airquality/publications/sok/mercury.html
3. NPI Cadmium Fact sheet, available at http://www.npi.gov.au/database/substance-info/profiles/17.html
4. EA 2001, Air Toxics State of Knowledge Report, Part C Cadmium Fact Sheet available at http://www.environment.gov.au/atmosphere/airquality/publications/sok/cadmium.html
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6. EA 2001, Air Toxics State of Knowledge Report, Part C Nickel Fact Sheet available at http://www.environment.gov.au/atmosphere/airquality/publications/sok/nickel.html
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9. NICNAS 2001, Priority existing chemical assessment report No. 20, Polybrominated fire retardants, available at http://www.nicnas.gov.au/Publications/CAR/PEC/PEC20.asp
10. NICNAS 2007 Interim Public Health Risk Assessment of Certain PBDE congeners available at http://www.nicnas.gov.au/Publications/CAR/Other/Final%20Interim%20Report%20-%20March.pdf
11. EA 2001, Air Toxics State of Knowledge Report, Part C PCB Fact Sheet available at http://www.environment.gov.au/atmosphere/airquality/publications/sok/pcbs.html
12. NICNAS 2001, Priority existing chemical assessment report No. 16, Short chain chlorinated paraffins, available at http://www.nicnas.gov.au/Publications/CAR/PEC/PEC16.aspNICNAS Safety Info Sheet No. 16,
13. NICNAS Safety Information Sheet http://www.nicnas.gov.au/Publications/Information_Sheets/Safety_Information_Sheets/SIS_16_Short_Chain_Chlorinated_Paraffins_PDF.pdf
14. NICNAS, 2004 Environmental Exposure Assessment of Short Chain Chlorinated Paraffins (SCCPs) in Australia, July 2004.

15. EA 2001, Air Toxics State of Knowledge Report, Part C Phthalates Fact Sheet available at http://www.environment.gov.au/atmosphere/airquality/publications/sok/phthalates.html
16. NICNAS 2008, Phthalate Hazard Compendium, available at http://www.nicnas.gov.au/Publications/CAR/Other/Phthalates.asp
17. AVPMA 1998 Interim Report on Endosulfan Review, Environmental assessment, available at http://www.apvma.gov.au/chemrev/endosulfan.shtml
18. OECD 2002 Hazard assessment if perfluorooctane sulfonate (PFOS) and its salts, ENV/JM/RD(2002)17/FINAL.

2.1. Metals

2.1.1. Mercury

High atmospheric concentrations of mercury do not usually arise from natural emissions; rather they are the result of large emission associated with some human activities. The main indoor sources of mercury are fluorescent light tubes and mercury thermometers that have been broken inside the dwelling. Typically compact fluorescent lamps contain approximately 4 mg of vaporised mercury, larger industrial type tubes approximately 20 mg of vaporised mercury and older type thermometers typically contain 500 mg of liquid elemental mercury (http://www.p2pays.org/ref/43/42992.pdf. In addition until the 1960's paints in Australia contained mercury as a pigment in the form of mercuric sulphide commonly referred to as vermillion or cinnabar (van Alpen, 1998).

Outdoor sources of mercury include power stations burning fossil fuel, smelting of metal ores and cement production. Mercury can be emitted from diffuse sources such as burning biomass in bushfires or from home heating using biomass or fossil fuels, and in disposal of mercury containing wastes such as batteries or thermometers (Table 1).

2.1.2. Cadmium

The main indoor sources of cadmium are from infiltration of outdoor dust into the dwelling and cigarette smoke. Within a dwelling, cadmium is also emitted from paints, polyvinyl chloride (PVC) products, photocells, some textile dyes and colours, electronic components, heating elements in electric kettles and hot water systems, batteries, and ceramic glazes (Table 1).

Outdoor sources of cadmium include industrial emissions from processes such as metal production particularly the treatment of zinc, copper, lead, and iron ores, the production of batteries and electrical apparatus and waste incineration and fuel combustion from stationary sources such as coal and oil burning power stations. Cadmium is also emitted from phosphate fertilisers and during the combustion of petrol in cars, trucks, and planes, and is found in particles resulting from the wearing of vehicle tyres (Table 1).

2.1.3. Nickel

The main indoor sources of nickel are from infiltration of outdoor dust into the dwelling and cigarette smoke. Outdoor sources are natural (soils and volcanoes) and anthropogenic (smelting of nickel ores, industrial operations such as metal refining, oil and coal power plants, and trash incinerators Table 1). Studies of nickel concentrations in the background atmosphere suggest that nickel is subject to long range atmospheric transportation (Juntto et al., 1997; Lindroos et al., 1996; Rühling et al., 1996; Pacyna and Ottar 1985; Mukherje, 1998).

2.1.4. Lead

The main source of lead in the indoor environment is the penetration indoors of particles from outside point sources such as mining and smelting. In Australia, these large point sources are mainly limited to Port Pirie in South Australia and Mt Isa Mines in Mt Isa, Queensland. Most research into indoor lead in Australia has focused on these locations with point sources e.g. Port Pirie in South Australia, where lead concentrations in indoor dust ranged between 2000 – 7500 µg per g of dust (Brinkman et al. 1999); and at North Lake Macquarie (near a zinc smelter) where monthly concentrations reached as high as 4000 µg per g of dust (Gulson et al. 2004).

The deterioration of lead-based paints that used white lead ($Pb(OH)_2 \cdot PbCO_3$) or red lead (Pb_3O_4) as pigments is another source of indoor lead. These paints were used in Australia up until the 1970's (van Alpen, 1998). Renovation activities in older dwellings, particularly the sanding of leaded paint, can generate significant amounts of lead dust. It is estimated that the wall coatings of a dwelling built in 1900 could contain as much as 288 kg of lead resulting from paint with a lead loading of 103 mg lead cm^{-2} (van Alpen, 1998).

Lead solder used in electrical and plumbing joints and some recreational activities such as stained glass making and pottery can also contribute to lead indoors.

Lead on particles associated with vehicle exhaust penetrating the indoor environment was a significant source in all Australian cities until 1 January 2002, when leaded petrol was completely phased out.

2.2. Polybrominated Diphenyl Ethers

Polybrominated diphenyl ethers (PBDEs) are fire retardants that consist of 209 different PBDE congeners. While each PBDE has the same basic structure consisting of two benzene rings connected by an oxygen atom, they differ in the number and position of bromine atoms around the two aromatic rings. Individual congeners are known both by their congener number and by their IUPAC name. Table 2 lists the congener numbers and IUPAC names of the 35 PBDEs measured during this study.

PBDEs are emitted from household furnishings and carpets. Outdoors, PBDEs may be released during manufacture of products containing PBDE (Table 1) and during disposal of products containing PBDE e.g. at electronic waste recycling plants. PBDEs are not manufactured in Australia.

In an Australian study of five homes and three offices PBDEs were found to be present in all locations and highest concentrations were associated with the presence of carpets, air-conditioning, and other products containing PBDEs (Toms et al. 2009). Home indoor concentrations of 0.5 pg m^{-3} – 179 pg m^{-3} were observed for ∑PDBE. PBDEs were detected in dust of all of samples collected, at concentrations of 87 ng g^{-1} – 3070 ng g^{-1} of dust. PBDEs were detected on nine out of 10 surfaces sampled in two homes.

The amount of PBDE used in Australia is 100 times lower per capita than in the United States (NICNAS, 2001). This suggests that significantly lower amounts of PBDE are available to contribute to dwelling dust in Australia.

Table 2. Chemical names, congener numbers and molecular weights of the PBDEs measured in dust from 10 dwellings

IUPAC name of Congener	PBDE Congener	Molecular weight
2,2, 4'-Tribromodiphenyl ether	BDE-17	407
2,4,4'-Tribromodiphenyl ether + 2',3,4-Tribromodiphenyl ether	BDE-28 + 33	407
2,4,6-Tribromodiphenyl ether	BDE-30	407
2,2',4,4'-Tetrabromodiphenyl ether	BDE-47	486
2,2,4,',5'-Tetrabromodiphenyl ether	BDE-49	486
2,3',4,4'-Tetrabromodiphenyl ether	BDE-66	486
2,3',4',6-Tetrabromodiphenyl ether	BDE-71	486
3,3',4,4'-Tetrabromodiphenyl ether	BDE-77	486
2,2',3,4,4'-Pentabromodiphenyl ether	BDE-85	565
2,2',4,4',5-Pentabromodiphenyl ether	BDE-99	565
2,2',4,4',6-Pentabromodiphenyl ether	BDE-100	565
2,3',4,4',6-Pentabromodiphenyl ether	BDE-119	565
3,3',4,4',5-Pentabromodiphenyl ether	BDE-126	565
2,2',3,4,4',5'-Hexabromodiphenyl ether + 2,3,4,4',5,6-Hexabromodiphenyl ether	BDE-138 + 166	643
2,2',3,4,4',6-Hexabromodiphenyl ether	BDE-139	643
2,2',3,4,4',6'-Hexabromodiphenyl ether	BDE-140	643
2,2',4,4',5,5'-Hexabromodiphenyl ether	BDE-153	643
2,2',4,4',5,6'-Hexabromodiphenyl ether	BDE-154	643
2,3,3',4,4',5-Hexabromodiphenyl ether + 3,3',4,4',5,5'-Hexabromodiphenyl ether	BDE-156 + 169	643
2,2',4,4',5,5'-Hexabromobiphenyl ether	BB-153	643
2,2',3,3',4,4',6-Heptabromodiphenyl ether	BDE-171	722
2,2',3,4,4',5,5'-Heptabromodiphenyl ether	BDE-180	722
2,2',3,4,4',5',6-Heptabromodiphenyl ether	BDE-183	722
2,2',3,4,4',6,6'-Heptabromodiphenyl ether	BDE-184	722
2,3,3',4,4',5',6-Heptabromodiphenyl ether	BDE-191	722
2,2',3,3',4,4',5,6'-Octabromodiphenyl ether	BDE-196	801
2,2',3,3',4,4',6,6'-Octabromodiphenyl ether	BDE-197	801
2,2',3,3',4,5',6,6'-Octabromodiphenyl ether	BDE-201	801
2,2',3,4,4',5,5',6-Octabromodiphenyl ether	BDE-203	801
2,2',3,4,4',5,6,6'-Octabromodiphenyl ether	BDE-204	801
2,3,3',4,4',5,5',6-Octabromodiphenyl ether	BDE-205	801
2,2',3,3',4,4',5,5',6-Nonabromodiphenyl ether	BDE-206	880
2,2',3,3',4,4',5,6,6'-Nonabromodiphenyl ether	BDE-207	880
2,2',3,3',4,5,5',6,6'-Nonabromodiphenyl ether	BDE-208	880
2,2',3,3',4,4',5,5',6,6'-Decabromodiphenyl ether	BDE-209	959

2.3. Phthalates

Phthalates are the esters of phthalic acid, a dicarboxylic acid with an o-xylene type structure.

Table 3 gives the chemical names and the abbreviated names of the 27 phthalates measured during this study. Figure 1 shows the chemical structure of a phthalate ester, diethyl phthalate (DEP). Lower molecular weight phthalates are used as solvents in personal care products, while higher molecular weight phthalates are used as plasticisers. One of the main sources for phthalate esters indoors are plasticized polyvinyl chloride (PVC) materials (Bornehag et al. 2005) used in floor and wall covering materials, shower curtains, adhesives, synthetic leather, toys, cosmetics, and many other consumer products. Phthalates are constantly emitted to the air and indoor dust from these materials since the phthalates are not chemically bound to the PVC structure of the materials that contain them (Wormuth et al. 2006; Heudorf et al. 2007). Humans are exposed to phthalate esters mainly by inhalation, ingestion and dermal exposure (Heudorf et al. 2007).

There is no published information on the concentrations of phthalates in dwelling dust or air in Australian residences.

The presence of phthalates in indoor dust and in indoor air is well documented internationally (Kolarik et al., 2007) with the predominant phthalates in dust being bis(2-ethylhexyl) phthalate (DEHP) and butyl benzyl phthalate (BBzP). The dominant phthalate esters in indoor air are diethyl phthalate (DEP) and di-n-butyl phthalate (DNBP) (Fromme et al., 2004; Sheldon et al., 1993).

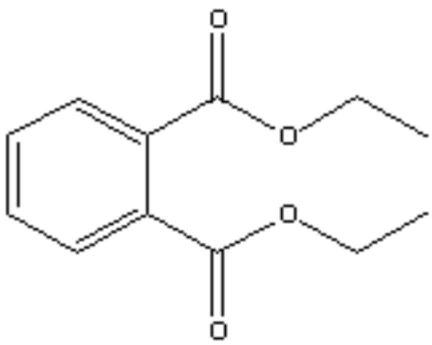

Figure 1. The chemical structure of Diethyl phthalate (DEP)

Table 3. Chemical names and abbreviated names of the range of phthalate esters measured in air indoors of 10 dwellings during this study

Chemical name	Abbreviation
Dimethyl phthalate	DMP
Diethyl phthalate	DEP
Diisobutyl phthalate	DIBP
Di-n-butyl phthalate	DNBP
Benzyl butyl phthalate	BBP
Dicyclohexyl phthalate	DCHP
Bis(2-Ethylhexyl)phthalate	DEHP
Di-n-octyl phthalate	DNOP
Bis(2-Methoxyethyl)phthalate	BMEP
Bis(2-Ethoxyethyl)phthalate	BEEP
Dipentyl phthalate	DPP
Bis(4-Methyl-2-pentyl)phthalate	BMPP
Di-n-hexyl phthalate	DNHP
Bis(2-n-Butoxyethyl)phthalate	BBEP
Dinonyl phthalate	DNP
Diallyl phthalate	DAP
Di-n-propyl phthalate	DNPP
Diisohexyl phthalate	DIHexP
Diisoheptyl phthalate	DIHepP
Diisooctyl phthalate	DIOP
Diisononyl phthalate	DINP
Diisodecyl phthalate	DIDP
Diisoundecyl phthalate	DISDP
Diundecyl phthalate	DUDP
Diisotridecyl phthalate	DIsoTDP
Ditridecyl phthalate	DTDP

2.4. Endosulfan

Endosulfan, (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,3,4-benzo(e)dioxathiepin-3-oxide) is an organochlorine insecticide that is used extensively to control insects in a variety of crops such as cereals, fruits, vegetables and cotton (Schmidt et al. 1997). Its dominant chemical structure is shown in Figure 2, and the break down product endosulfan sulfate is shown in Figure 3.

Endosulfan has asymmetric carbon atoms and exists in two entiometric forms, usually referred to as α-Endosulfan and β-Endosulfan. The commercial product is applied as a racemic mixture of the two forms, in the ratio of 7:3 (α-endosulfan : β-endosulfan) (Schmidt et al. 1997). The atmospheric fate of the two forms varies, α-endosulfan is found in predominately in air, and β-endosulfan predominately in rain (Schmidt et al. 1997).

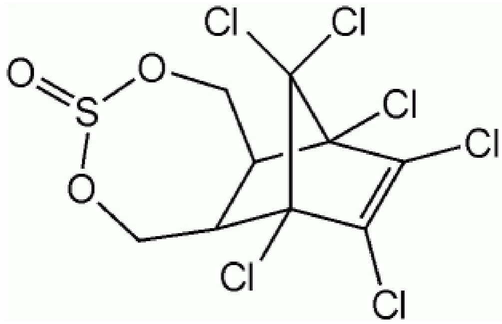

Figure 2. The chemical structure of endosulfan, an organochlorine insecticide

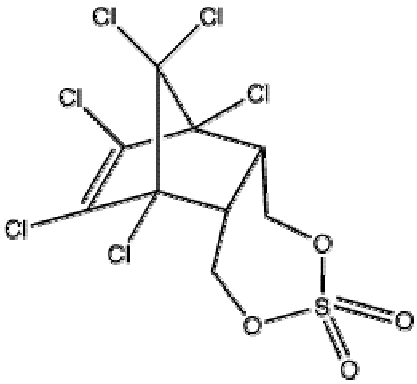

Figure 3. The chemical structure of endosulfan sulfate, a breakdown product of endosulfan

2.5. Short Chain Chlorinated Paraffins

Short chain chlorinated paraffins (SCCPs) are chlorinated linear alkanes of 10 to 13 carbon atoms in length (Figure 4). They are usually chlorinated to at least 50% of their mass, and no secondary carbon atom carries more than one chlorine atom.

Total SCCPs, denoted by ΣSCCP, represents the sum of penta- to nona-chlorinated decanes and undecanes, hexa- to nona-chlorinated dodecanes and hepta to nona-chlorinated tridecanes (i.e. 17 homolog groups: $Cl_{5-9}C_{10-11} + Cl_{6-9}C_{12} + Cl_{7-9}C_{13}$). There are a total of 4200 possible positional isomers within this group (Tomy et al. 1998).

SCCPs are used as extreme pressure lubricants in the metal processing industry, in fillers, adhesives, coating materials, and in leather and rubber treatments. SCCPs occur in the gas phase and aqueous phases (UNEP, 2006) and have environmental lifetimes of about seven days in air, and longer in aqueous solution and sludge. These environmental lifetimes are long enough to allow SCCPs to be transported over long distances (UNEP, 2006; Bayen et al. 2006). This results in the accumulation of these compounds in reservoirs such as human milk fat (Thomas et al. 2006) and riverine sediments and sludge (Tomy et al. 1999; Pribylova´ et al. 2006; Stejnarova´ et al. 2005).

To the best of our knowledge, it appears that the measurements of SCCPs in air made in this study are the first to be made in Australia and the first to be made in an urban environment.

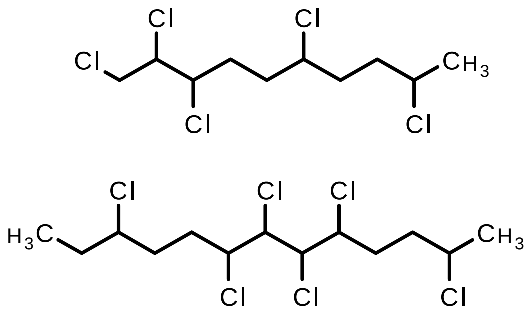

Figure 4. Structure of a short chain chlorinated paraffins 1,2,3,6,9-pentachlorodecane and 3,6,7,8,9,12-hexachlorotridecane

2.6. Perfluorinated Compounds (PFOS, PFAS and PFOA)

Perfluorooctane sulfonate (PFOS), Perfluoroalkyl sulfonate (PFAS), Perfluorooctanoic acid (PFOA) are a range of organic carboxylic acid or sulfonic acid structures consisting of eight or more carbons that are fluorinated to lesser or greater extents. Figure 5 and Figure 6 show typical examples of the structures of PFOS and PFOA respectively, in these cases the compounds are fully fluorinated.

The majority of PFOS-related chemicals are high molecular weight polymers used in a variety of products that can be divided into three main categories of use. The first is surface treatment applications that provide soil, oil, and water resistance to personal apparel and home furnishings. Specific applications in this use category include protection of apparel and leather, fabric/upholstery, and carpet. The second is paper protection by providing grease, oil, and water resistance to paper and paperboard including food containers. The final category is in performance chemicals including fire fighting foams, mining and oil well surfactants, acid mist suppressants for metal plating and electronic etching baths, photolithography, electronic chemicals, hydraulic fluid additives, alkaline cleaners, floor polishes, photographic film, denture cleaners, shampoos, chemical intermediates, coating additives, carpet spot cleaners, and as an insecticide in bait stations (OECD, 2002).

Table 4 lists the names of the four perfluorinated compounds measured in this study. These compounds are very stable in the environment, mainly due to the high bond enthalpy of the C-F bond of 489 kjoules mol^{-1}. They are almost indestructible and are resistant to various forms of chemical degradation such as reactions with acids and bases and oxidation or reduction reactions (Kissa, 2001). To the best of our knowledge, it appears that the measurements of PFOS, PFOA or PFAS in air made in this study are the first to be made in Australia.

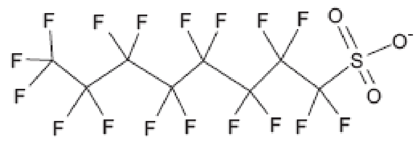

Figure 5. The chemical structure of a PFOS compound. The compound shown is heptadecafluorooctane sulfonate

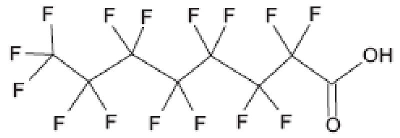

Figure 6. The chemical structure of perfluoroctanoic acid. The compound shown is pentadecafluorooctanoic acid, PFOA

Table 4. Chemical names of the polyfluorinated compounds measured in air indoors and outdoors of 10 dwellings

Chemical name	
Perfluoroctane sulfonate	PFOS
Perfluorooctanoic acid	PFOA
Perfluorohexane sulfonate	PFHS
Perfluorononanoic acid	PFNA

2.7. Polychlorinated Biphenyls

Polychlorinated biphenyl compounds (PCBs) are a synthetic class of chemical that were first produced in 1929 by Monsanto. There are a possible 209 congeners, and Figure 7 shows the typical structure of a PCB. The dioxin-like PCBs are those which have chlorines in the two para positions and at least two chlorines in the meta position. Examples of these, measured in this study are 3,3',4,4'-tetrachlorobiphenyl, 3,4,4',5-tetrachlorobiphenyl and 3,3',4,4',5-pentachlorobiphenyl.

PCBs were produced for a number of industries, mainly as dielectric fluids and as insulators for transformers and capacitors, but also in hydraulic fluids, casting wax, compressors, heat transfer systems, plasticisers, pigments, adhesives, and liquid cooled electric motors.

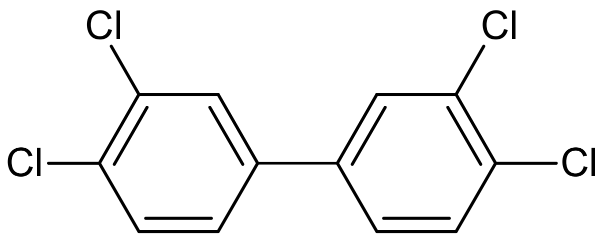

Figure 7. The chemical structure PCB 77, 3,3',4,4' tetrachlorobiphenyl

PCBs were synthesised because of their chemical and physical properties, such as high thermal and chemical resistance that make them useful in many industrial applications. Hence they do not easily breakdown when exposed to heat or chemical reactions (Cartwright, 2002). While this is a useful trait for lubricants and insulators it has resulted in the increase in concentration of PCBs in a number of environmental reservoirs.

The National Dioxins Program included the measurement of 12 PCBs at 10 sites around Australia between September 2002 and September 2003. Annual average concentrations in air ranged from 13.3 pg m^{-3} at a light industrial site in South Australia to 0.5 pg m^{-3} at Cape Grim where samples were collected from air masses that represented pristine remote background air (Gras and Mueller, 2004). At all sites the most concentrated congener was PCB 118 and the lowest was PCB 169. Concentrations have also been measured in air at two outdoor sites in Brisbane (Mueller et al., 2003).

PCBs can be released to the atmosphere as a result of biomass burning. Gras and Mueller (2004) observed a significant seasonal cycle in ambient PCB concentrations at a number of sites included in the National Dioxins Program, with maximum concentrations associated with woodsmoke produced from domestic heating appliances. Also as part of the National Dioxin Program Meyer et al. (2004) measured emission factors for dioxins, furans and PCBs from prescribed and wild fires, and reported that PCBs comprised approximately 10% of these compounds. Significantly, Meyer et al (2004) determined lower emission factors for these compounds than had previously been estimated.

Table 5 shows the chemical names, congener numbers and limits of detection of the PCBs, measured in this study.

Table 5. Chemical names, congener numbers and limits of detection of the PCBs measured in air indoors and outdoors of 10 dwellings

Compound	Congener	Limit of detection pg m^{-3}
3,3',4,4'-Tetrachlorobiphenyl	PCB 77	0.007
3,4,4',5-Tetrachlorobiphenyl	PCB 81	0.007
3,3',4,4',5-Pentachlorobiphenyl	PCB 126	0.001
3,3',4,4',5,5'-Hexachlorobiphenyl	PCB 169	0.001
2,3,3',4,4'-Pentachlorobiphenyl	PCB 105	0.10
2,3,4,4',5-Pentachlorobiphenyl	PCB 114	0.005
2,3',4,4',5-Pentachlorobiphenyl	PCB 118	0.24
2',3,4,4',5-Pentachlorobiphenyl	PCB 123	0.003
2,3,3',4,4',5-Hexachlorobiphenyl	PCB 156	0.048
2,3,3',4,4',5'-Hexachlorobiphenyl	PCB 157	0.005
2,3',4,4',5,5'-Hexachlorobiphenyl	PCB 167	0.014
2,3,3',4,4',5,5'-Heptachlorobiphenyl	PCB 189	0.002

3. SELECTION OF DWELLINGS

The dwellings measured in this study were selected to be representative of typical Australian dwellings and to provide a geographical spread of sample locations over the south-eastern suburbs of Melbourne. As the equipment required to collect sufficient sample volumes to enable analytical detection of the chemical specified was invasive (i.e. noisy), the sampling equipment could only be used in dwellings where the occupants were temporarily away, or where the residents were willing to tolerate the noise emitted by the sampling equipment. Samples were collected between December 2008 and February 2009.

3.1. Location of Dwellings

In this study measurements were carried out indoors and outdoors of 10 dwellings in the south-eastern suburban area of Melbourne; the latitude and longitudes of the dwellings are shown in Table 6, and their positions in Figure 8. Characteristics of the dwellings such as dwelling type, age and construction material are listed in Table 7.

Table 6. Locations of the dwellings used for the POPs, metals and mercury sampling program

Sample No.	Latitude (degrees)	Longitude (degrees)
POP-1	37.783	145.330
POP-2	37.897	145.076
POP-3	37.896	145.049
POP-4	38.167	145.191
POP-5	37.874	145.126
POP-6	37.889	145.005
POP-7	37.904	145.010
POP-8	38.024	145.109
POP-9	37.916	145.002
POP-10	37.902	145.011

Table 7. Age and other characteristics of the dwellings

Sample No.	Type of Dwelling	Age of Dwelling (years)	Material
POP-1	House	49	Brick veneer
POP-2	House	69	Double brick
POP-3	House	15	Double brick
POP-4	House	4	Weather board
POP-5	Townhouse	7	Brick veneer
POP-6	House	75	Double brick
POP-7	House	76	Double brick
POP-8	House	31	Brick veneer
POP-9	House	75	Double brick
POP-10	Townhouse	12	Brick veneer

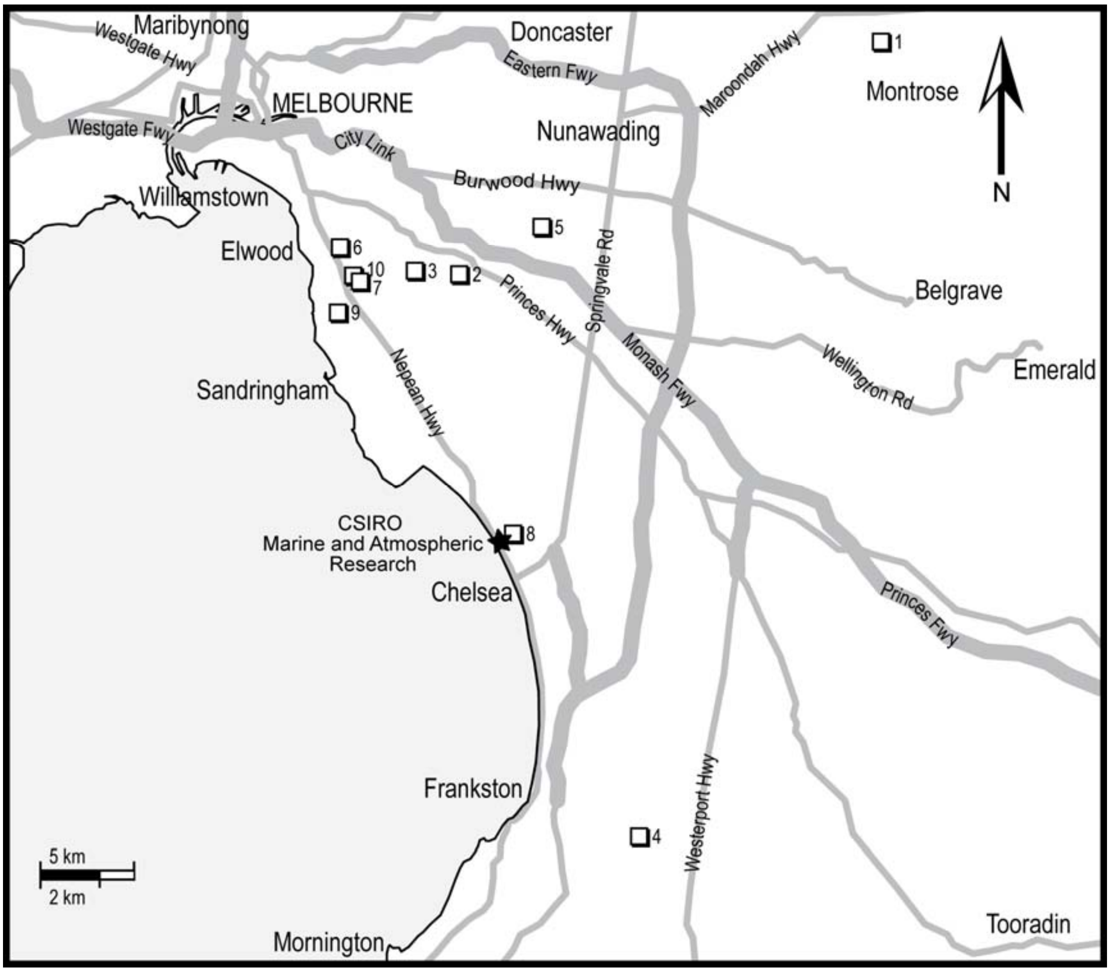

Figure 8. Location of dwellings used in this study

3.2. Measurement Techniques

The sampling and analytical techniques employed in this study are detailed in Appendix A. Appendix B lists the limits of reporting for the analytical methods used in this study. The methods and the institutions where the analyses were carried out are listed in Table 8.

Table 8. Analytical techniques used in this study and institutions performing the analysis

Species	Method	Institution
Ni, Cd, Pb	ICPMS	National Measurement Institute
Hg	Iodated carbon trap	Columbia Analytical Services
Endosulfan	GC-HRMS	National Measurement Institute
PBDEs	GC-HRMS	National Measurement Institute
PFAS	GC-HRMS	National Measurement Institute
PFOA	GC-HRMS	National Measurement Institute
PFOS	GC-HRMS	National Measurement Institute
Phthalates	GC-HRMS	National Measurement Institute
PCBs	GC-HRMS	National Measurement Institute
SCCPs	GC-HRMS	National Measurement Institute

3.3. Household Surveys

Data about the households was initially collected for the purpose of selecting participants. Further data on the household occupants and the household characteristics was collected by a survey and interview conducted at the time of equipment installation. The survey on dwelling characteristics was designed to collect information on components of the home that may contribute to the presence of POP compounds. For example the presence of old refrigerators in a dwelling may contribute to PBDE concentrations and transformers may contribute to PCB concentrations (Table 1).

A summary of the results of the household surveys is included in Appendix D and some key features are discussed here. Half of the dwellings were older than 50 years, and half less than 50 years, eight were free-standing dwellings and two were semi-attached town dwellings, six were constructed of brick and four were brick veneer. Three dwellings had attached garages and one dwelling was within 10 m of a major road. One dwelling was located within 50 m of a petrol station and two dwellings were located within 50 m of construction activities. Four dwellings were occupied during the sampling program, the remaining six were unoccupied. All 10 dwellings had gas hot water and nine had gas stove top cooking with the other electric. Seven dwellings had electric ovens and three had gas ovens. Nine dwellings had gas heating as the main source of heating and one dwelling used a woodheater. In five dwellings the gas heating was ducted to all rooms and four dwellings had secondary heating, three were electric and one was a wood heater. Eight dwellings had at least one air conditioner, seven of these being less than 10 years old.

In addition to the household survey, surveys of the chemicals present in the homes were carried out. However, because of the intrusive nature of the surveys, the veracity of the chemical surveys was irregular. The summary presented in Appendix D is based on the results of the chemicals surveys carried out in five homes that were assessed to be the most comprehensive and accurate. The chemicals were grouped into types of compounds based on their purpose (e.g. surface cleaners, detergents, personal products) and their form (i.e. liquid, aerosol spray or solid).

All dwellings contained greater amounts of liquid chemicals than solid and aerosol forms. Liquid personal products, detergents, solvents and surface cleaners were present in all five homes as were solid detergents.

The greatest average quantity of liquid chemicals was the personal products group, the greatest average quantity of aerosol chemicals were pesticides and degreasers, and the greatest quantity of solid chemicals were detergents.

4. RESULTS AND DISCUSSION

The concentrations of the chemicals measured indoors and outdoors in this study are discussed in the following sections. Each section includes a discussion of the summary statistics (average, median, minimum and maximum concentrations and ratios of indoor to outdoor concentrations (I/O ratios) where applicable, followed by a comparison of the concentrations measured in this study with those measured in indoor, urban outdoor, rural outdoor and remote outdoor locations elsewhere.

Note that beyond a qualitative assessment of the relationship between elevated concentrations of particular species and dwelling features (such as age, furnishings etc) no statistical analysis has been undertaken to explain elevated concentrations, since the low number of samples and wide variations in concentrations preclude such analyses. Instead, the reader is referred to Table 1 for a summary of the indoor and outdoor sources of the substances measured in this study, as well as products in the home that may contain them.

The data on chemicals measured indoors and outdoors in this study are presented in Appendix E of this report. The concentrations of mercury, cadmium, nickel and lead measured in particles and the concentrations of total suspended particles measured indoors and outdoors of 10 dwellings in Melbourne are presented in Table E 1 to Table E 3 in Appendix E. The concentrations of PBDE measured in dust from 10 dwellings in Melbourne are presented in Table E 4 of Appendix E. The concentration of PBDE, SCCP, PFOS and PCBs measured in air from indoors and outdoors of 10 dwellings in Melbourne are presented in Table E 5, Table E 8, Table E 9 and Table E 10 respectively in Appendix E. The concentrations of Phthalates measured in air indoors of 10 dwellings in Melbourne are presented in Table E 6 of Appendix E and the concentrations of endosulfan measured in air outdoors of 10 dwellings in Melbourne are presented in Table E 7 of Appendix E.

4.1. Mercury

Summary statistics of the concentrations of mercury and the I/O ratios are presented in Table 9. All dwellings had concentrations greater than the limit of reporting. I/O ratios indicate the indoor concentrations were on average greater than outdoor concentrations suggesting an indoor source for mercury. The variation in outdoor mercury concentrations is lower than the indoor mercury concentrations as suggested by the larger standard deviation in the indoor concentrations compared with that of the outdoor concentrations.

The indoor and outdoor concentrations of mercury as a function of dwelling age are shown in Figure 9. Dwellings less than 40 years of age generally had lower mercury concentrations (median of 1.9 ng m^{-3}) than dwellings in the 40 to 80 years age range (median concentration of 6.0 ng m^{-3}). This implies that some of the older dwellings have larger sources of mercury emissions than the dwellings less than 40 years of age.

Table 9. Average concentrations of TSP, cadmium, lead, nickel and gaseous mercury in indoor and outdoor samples. The median, standard deviation, maximum, minimum, number of samples and the number of samples above the limit of reporting (N<LOR) are also given. Note that the averages, medians and standard deviations were not calculated for cadmium, nickel and lead since their concentrations were below the limit of reporting

Concentration	TSP $\mu g\ m^{-3}$	Mercury $ng\ m^{-3}$	Cadmium $ng\ m^{-3}$	Lead $ng\ m^{-3}$	Nickel $ng\ m^{-3}$
Indoor					
Average	11.8	4.7	–	–	–
Median	11.9	3.2	–	–	–
SD	4.5	4.3	–	–	–
Max	18.3	13.4	<1.7	7.0	8.0
Min	4.8	1.2	<1.7	<1.7	<1.7
number	10	10	10	10	10
N<LOR	0	0	10	6	7
Outdoor					
Average	33.9	0.9	–	–	–
Median	32.1	0.8	–	–	–
SD	11.3	0.3	–	–	–
Max	55.4	1.6	<1.7	5.6	5.3
Min	18.6	0.6	<1.7	<1.7	<1.7
number	10	9	10	10	10
N<LOR	0	0	10	2	6
I/O					
Average	0.4	5.9	–	–	–
Median	0.3	3.9	–	–	–
Max	0.6	17.9	–	1.9	8.0
Min	0.2	1.7	–	–	–

The concentrations of mercury measured in this study are compared with other studies in Table 10. There have been few studies focused on the concentration of mercury gas in indoor air, and none performed in Australian dwellings. The concentrations of mercury measured indoors of the 10 dwellings in Melbourne are considerably lower than those measured in 12 free standing and apartment dwellings in New York (Capri et al., 2001). The highest concentration measured in the New York dwellings was in a home where the resident had broken a mercury thermometer within six months prior to sampling. At another dwelling high concentration could be traced to a localised area of the apartment even though the residents had no recollection of breaking a thermometer in the previous three years. Capri et al. (2001) suggest that mercury released from household devices can contaminate indoor residential environments for decades following the first release of the metal unless cleaned properly. The highest indoor concentration measured in the Melbourne dwellings is similar to the lowest concentration in the New York study. The lower concentrations measured in the Melbourne dwellings do not indicate broken mercury thermometers as the source of indoor mercury in the older homes, but instead more diffuse sources such as old paint. Until regulation in the 1960's paints could contain the pigment mercuric sulphide. The qualitative relationship between dwelling age and mercury concentration implied in Figure 9 may support this suggestion.

The outdoor concentrations measured at the Melbourne dwellings are lower than measured outdoors in Tokyo (Nakagawa and Hiromoto, 1997) and in rural areas of Japan and North America (Nakagawa and Hiromoto, 1997, Gabriel et al., 2005) but are similar to the concentrations measured in the remote atmosphere of the Arctic (Berg et al., 2001, Golubeva et al., 2003).

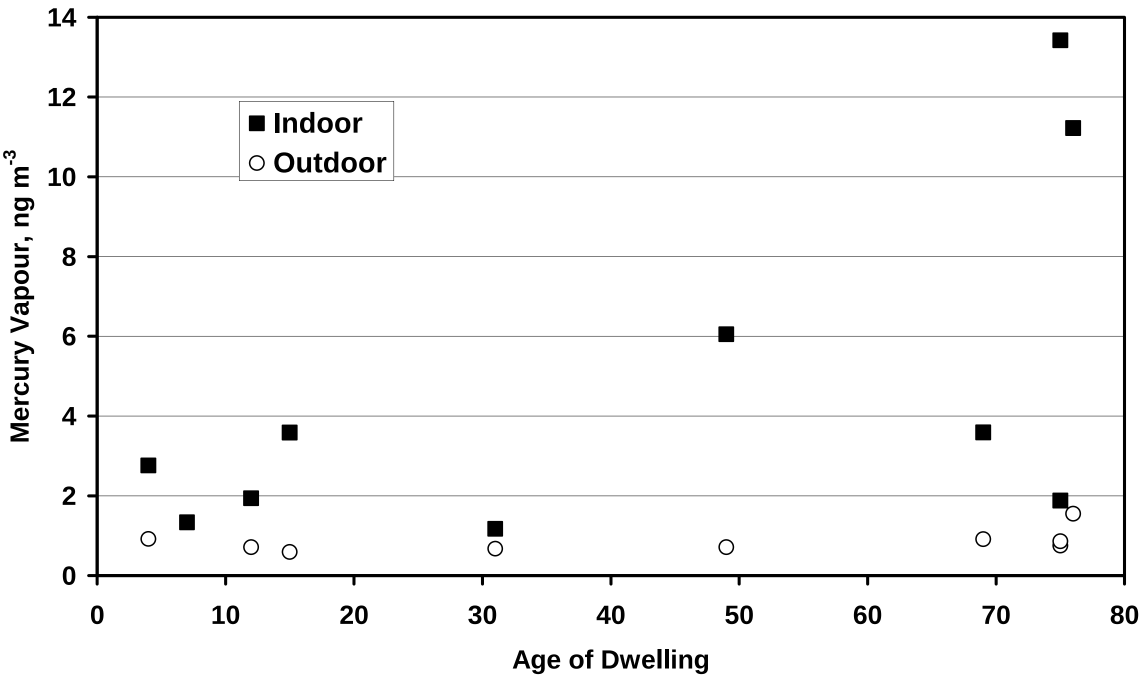

Figure 9. Mercury concentrations measured in air indoors and outdoors of dwellings plotted against the age of the dwelling. Only nine mercury vapour measurements were made outdoors

Table 10. Comparison of the range of mercury concentrations measured in air in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors 10 dwellings in Melbourne	1.2 – 13.4 ng m^{-3}	This study
Outdoors 10 dwellings in Melbourne	0.6 – 1.6 ng m^{-3}	This study
Indoors 12 dwellings in New York (range of dwellings and apartments)	6.5 – 523 ng m^{-3}	Capri et al. (2001)
Outdoors urban Tokyo, Japan	6.7 ng m^{-3} – 29 ng m^{-3}	Nakagawa and Hiromoto (1997)
Outdoors rural Cove Mountain, Tennessee	1.8 – 5.3 ng m^{-3} 3.2 ng m^{-3} (average)	Gabriel et al. (2005)
Outdoors rural Farmland, Japan	1.9 – 5.2 ng m^{-3}	Nakagawa and Hiromoto (1997)
Outdoors remote European Arctic Russian Arctic	0.7 – 2.2 ng m^{-3} 0.2 – 5 g m^{-3}	Berg et al. (2001); Golubeva et al. (2003)

4.2. Metals

Summary statistics of the concentrations of cadmium, lead and nickel as well as total suspended particles (TSP) for indoor and outdoor samples are listed in Table 9. Also listed are the summary statistics for I/O ratios. The concentration of cadmium, lead and nickel were very low. Cadmium was below the limit of reporting of 1.7 ng m^{-3} for all of the indoor and outdoor samples. Only one indoor/outdoor pair of samples was above the limit of reporting for nickel and four pairs in the case of lead. Hence the I/O ratios for were not considered for these metals because the number of indoor/outdoor pairs was too low.

The concentrations of cadmium measured in this study are compared with other studies in Table 11. Indoor concentrations of soluble cadmium in three rest homes in Vienna were lower than the limit of reporting of the analytical method used to analyse our samples (Komarnicki, 2005) as was the cadmium concentration measured in PM2.5 samples collected indoors of a dwelling in Minneapolis (Adgate et al., 2007). The highest concentrations listed in Table 11 were measured outdoors in urban areas of Korea and Italy (Park et al., 2008; Valerio et al., 1995) and are higher than observed indoors and outdoors of the Melbourne dwellings although again some of the lower concentrations measured in Korea and Italy were lower than the limit of reporting of the analytical method used to analyse our samples. The outdoor cadmium concentrations measured in the rural and remote atmospheres (Goforth et al., 2005; Shevchenko et al., 2003) are also lower than the limit of reporting of our analytical method.

Table 11. Comparison of cadmium concentrations measured in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	< 1.7 ng m^{-3}	This study
Outdoors urban 10 dwellings in Melbourne	< 1.7 ng m^{-3}	This study
Indoors urban 3 rest homes in Vienna during the day	0.6±0.30 ng m^{-3}(n=12)	Komarnicki (2005)
Indoors urban PM2.5 Minneapolis-St. Paul	mean 0.30 ng m^{-3}(n=235) 10^{th} percentile = 0.04 ng m^{-3} 90^{th} percentile = 0.33 ng m^{-3}	Adgate et al. (2007)
Outdoors urban 3 rest homes in Vienna during the day	0.7±0.4 ng m^{-3}(n=12)	Komarnicki (2005)
Outdoors urban 10 locations in Italy (5 in Genoa and 5 in La Spezia)	range of means at 10 sites 1.5 ng m^{-3} – 2.8 ng m^{-3} (n=393) range of individual measurements <0.1 ng m^{-3} – 36.2 ng m^{-3}	Valerio et al. (1995)
Outdoors urban Seoul, Korea	monthly averages 2.0 – 7.6 ng m^{-3} (n=6) Annual average 4.1 ng m^{-3}	Park et al. (2008)
Outdoors urban PM2.5 Minneapolis-St. Paul	mean 0.08 ng m^{-3}(n=140) 10^{th} percentile = -0.01 ng m^{-3} 90^{th} percentile = 0.18 ng m^{-3}	Adgate et al. (2007
Outdoors rural Lake Hartwell, South Carolina	mean 0.8 ng m^{-3}	Goforth et al. (2005)
Outdoors remote Franz Josef Land (Russian Arctic) Spring10 year average	0.08 ng m^{-3} (10 year average)	Shevchenko et al.(2003)

The concentrations of nickel measured in this study are compared with other studies in Table 12, noting that for seven of 10 indoor and six of 10 outdoor samples nickel concentrations were below the limit of reporting of the analytical method. Despite this, the concentrations of nickel measured indoors of the Melbourne dwellings are lower than measured in PM2.5 samples collected indoors in Minneapolis (Adgate et al., 2007), and are similar to concentrations of PM2.5 nickel measured indoors of 28 dwellings in Sweden (Molnar et al., 2007). The outdoor Melbourne concentrations are lower than those measured outdoors in urban Japan (Okuda et al., 2007) and rural South Carolina (Goforth et al., 2005) and greater than measured in the remote Arctic (Shevchenko et al., 2003) and Finnish atmosphere (Mukherjee 1998).

Table 12. Comparison of nickel concentrations measured in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	<1.7 – 8.0 ng m^{-3}	This study
Outdoors urban 10 dwellings in Melbourne	<1.7 – 5.3 ng m^{-3}	This study
Indoors urban PM2.5 Minneapolis-St. Paul metropolitan area	mean 12 ng m^{-3}(n=235) 10^{th} percentile = -1.2 ng m^{-3} 90^{th} percentile = 6.3 ng m^{-3}	Adgate et al. (2007)
Indoors Urban PM2.5 28 homes in Stockholm, Sweden	mean 1.1 ng m^{-3}(n=28) 0.3 – 3.5 ng m^{-3}	Molnar et al. (2007)
Outdoors urban Tokyo, Japan	mean 17±16 ng m^{-3} (n=89) <1 – 74 ng m^{-3}	Okuda et al. (2007)
Indoors Urban PM2.5 Stockholm, Sweden	mean 1.4 ng m^{-3}(n=35) 0.4 – 2.7 ng m^{-3}	Molnar et al. (2007)
Outdoors rural Lake Hartwell, South Carolina	average 25.3 ng m^{-3}	Goforth et al. (2005)
Outdoors remote Southwest Finland Finish Lapland	2 – 8 ng m^{-3} 0.5 ng m-^{3}	Mukherjee (1998)
Outdoors remote Franz Josef Land (Russian Arctic)	10 year average 0.85 ng m^{-3}	Shevchenko et al.(2003)

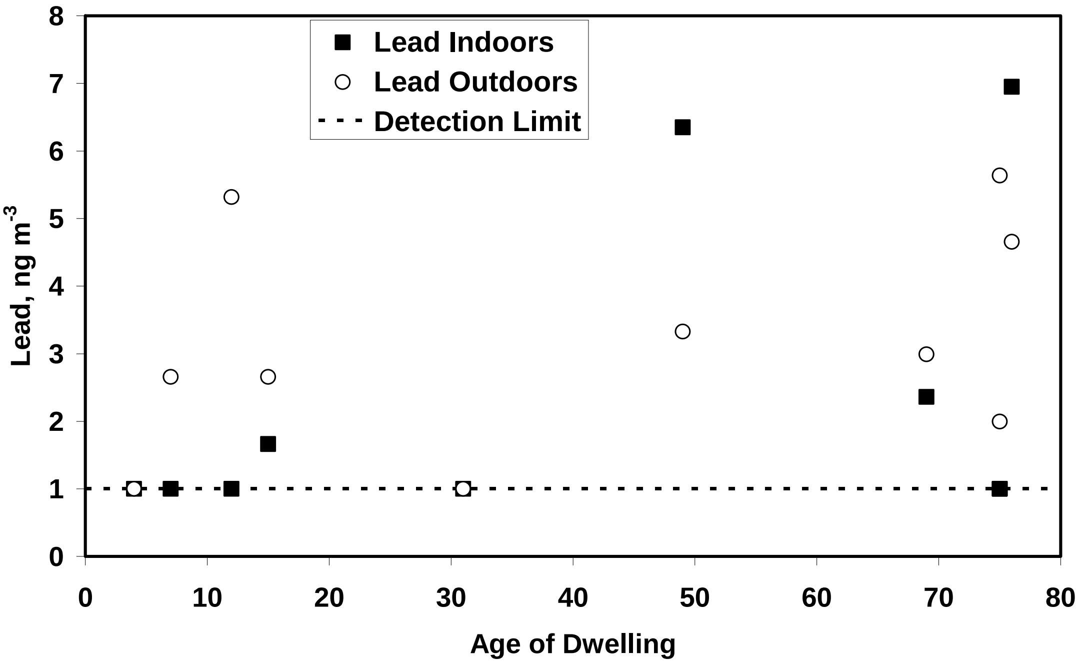

Figure 10 Lead concentrations measured in air indoors and outdoors of dwellings as a function of dwelling age. Note that concentrations of 1 ng m^{-3} are less than the limit of reporting, and that two dwellings are 75 years old, and have the same indoor concentration

The concentrations of lead measured in this study are compared with other studies in Table 13. The median concentration of lead indoors of the 10 dwellings in Melbourne is lower than measured in three rest homes in Vienna (Komarnicki 2005) and similar to the concentrations measured in PM2.5 collected in a home in Minneapolis (Adgate et al., 2007) and PM2.5 collected in 28 homes in Sweden (Molnar et al., 2007). The median outdoor concentration of the 10 Melbourne dwelling is an order of magnitude lower than observed in urban Vienna (Komarnicki 2005), lower than measured in rural South Carolina (Goforth et al., 2005) and similar to the remote Arctic atmosphere (Shevchenko et al., 2003).

Table 13. Comparison of lead concentrations measured at above detection levels in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	2.3 ng m^{-3} <1.7 – 7.0 ng m^{-3} 6 of 10 samples were <1.7 ng m^{-3}	This study
Outdoors urban 10 dwellings in Melbourne	3.1 ng m^{-3} <1.7 – 5.6 ng m^{-3} 2 of 10 samples were <1.7 ng m^{-3}	This study
Indoors Urban 3 rest homes in Vienna during the day	21 ± 21 ng m^{-3} (n=12)	Komarnicki (2005)
Indoors Urban PM2.5 Minneapolis-St. Paul metropolitan area	mean 3.4 ng m^{-3}(n=234) 10^{th} percentile = 0.7 ng m^{-3} 90^{th} percentile = 6.8 ng m^{-3}	Adgate et al. (2007)
Indoors Urban PM2.5 28 homes in Stockholm, Sweden	mean 3.4 ng m^{-3}(n=28) 0.04 – 8.0 ng m^{-3}	Molnar et al. (2007)
Outdoors urban 3 rest homes in Vienna during the day	32 ± 36 ng m^{-3}(n=12)	Komarnicki (2005)
Outdoors Urban PM2.5 Minneapolis-St. Paul metropolitan area	mean 2.0 ng m^{-3}(n=140) 10^{th} percentile = -0.2 ng m^{-3} 90^{th} percentile = 4.4 ng m^{-3}	Adgate et al. (2007)
Outdoors rural Lake Hartwell, South Carolina	mean 15.0 ng m^{-3}	Goforth et al. (2005)
Indoors Urban PM2.5 Stockholm, Sweden	mean 4.5 ng m^{-3}(n=28) 1.2 – 11 ng m^{-3}	Molnar et al. (2007)
Outdoors remote Franz Josef Land (Russian Arctic) Spring	10 year average 3.3 ng m^{-3}	Shevchenko et al.(2003)

Figure 11 shows the relationship between TSP measured indoors and outdoors at each dwelling. The outdoor TSP concentrations are higher than the indoor concentrations and 36% of the variation seen in the indoor concentrations can be explained by the outdoor concentrations of TSP. Lower TSP concentrations indoors than outdoor suggests that TSP is effectively removed within the dwellings, i.e. the infiltration of outdoor TSP combined with the indoor sources of coarse particles (here measured as TSP) are insufficient to overcome removal and maintain indoor concentrations comparable with those outdoors. However, it should be noted that a number of the dwellings were unoccupied during the sampling period so that activities that may have resulted in production of

TSP (such as sweeping, dusting, moving in the dwelling) would not have occurred in these dwellings.

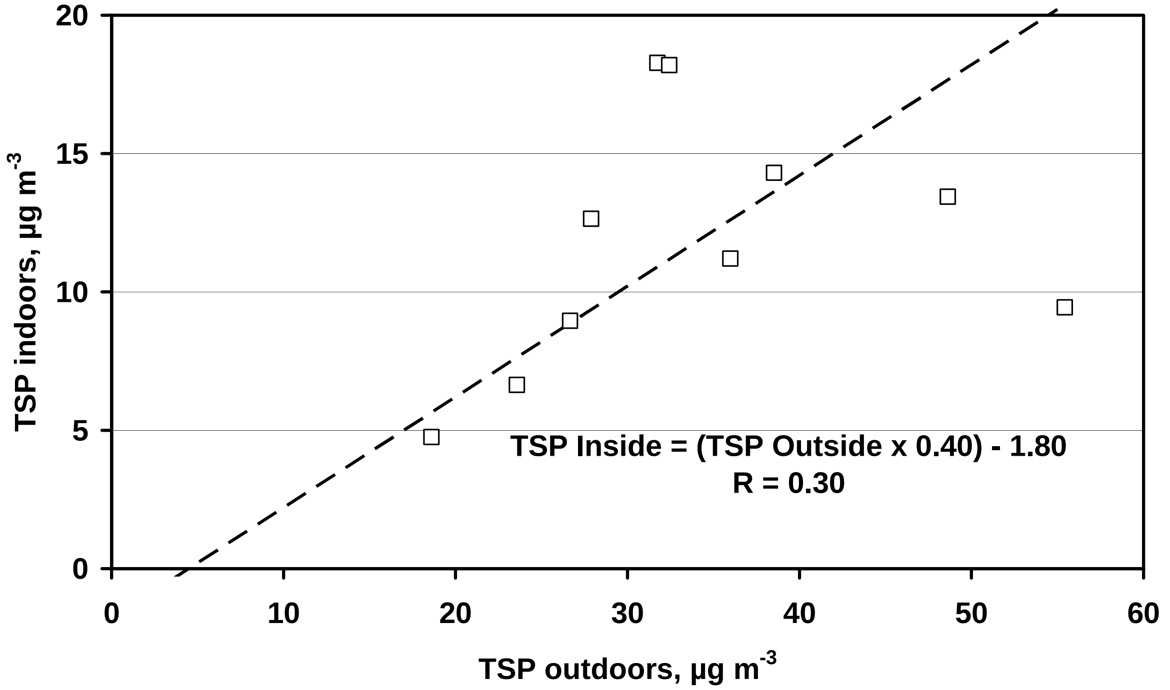

Figure 11. Indoor TSP concentrations plotted against outdoor concentrations

4.3. Polybrominated Diphenyl Ethers

4.3.1. Polybrominated Diphenyl Ethers in Dust

Table 14 shows some summary statistics for the mass concentrations of individual PBDEs measured in dust samples taken from the 10 dwellings sampled in this study. The median ΣPBDE mass concentration is 771 ng g^{-1} (300 ng g^{-1} to 2300 ng g^{-1}). The dominant PBDE congener is 209, ranging from 44 % to 87 % of the total of the 35 congeners, with an average of 64 %. In most dwellings BDE-99 was the second most concentrated congener with up to 25 % of ΣPBDE, followed by BDE-47 and BDE-206.

Table 14. Summary statistics for PBDEs measured in dust from 10 dwellings

BDE	Mean ng g^{-1}	Median ng g^{-1}	Max ng g^{-1}	Min ng g^{-1}	Mean fraction of ΣPBDE %	Max fraction of ΣPBDE %	Min fraction of ΣPBDE %
BDE-17	0.24	0.23	0.48	0.08	0.03	0.06	0.00
BDE-28 + 33	0.96	1.01	1.90	0.34	0.13	0.22	0.01
BDE-30			<0.01	<0.005			
BDE-47	64.5	60.0	190	18.0	8.03	14.7	0.78
BDE-49	1.53	1.55	2.60	0.59	0.20	0.36	0.03
BDE-66	1.45	1.30	2.70	0.53	0.18	0.33	0.02
BDE-71			<0.007	<0.0004			
BDE-77	0.02	0.02	0.10	0.00	0.00	0.01	0.00
BDE-85	4.33	2.70	16.0	1.50	0.52	1.29	0.10
BDE-99	88.3	65.0	340	29.0	10.2	24.7	1.52
BDE-100	14.7	12.5	38.0	5.70	1.81	3.55	0.25
BDE-119	0.10	0.10	0.21	0.05	0.01	0.02	0.00
BDE-126	0.01	0.01	0.01	<0.003	0.00	0.00	0.00
BDE-138 + 166	1.46	0.83	5.70	0.59	0.16	0.41	0.07
BDE-139	1.63	1.10	5.10	0.63	0.20	0.46	0.06
BDE-140	0.47	0.34	1.10	0.18	0.06	0.13	0.02
BDE-153	12.2	7.55	43.0	5.70	1.40	3.12	0.56
BDE-154	6.27	4.60	17.0	2.20	0.75	1.50	0.18
BDE-156 + 169			<0.05	<0.009			
BB-153	6.84	0.25	62.0	0.09	1.34	12.3	0.01
BDE-171	1.05	0.86	3.40	0.19	0.13	0.50	0.03
BDE-180	1.41	1.25	3.60	0.40	0.18	0.60	0.05
BDE-183	18.8	14.5	49.0	3.80	2.62	10.1	0.51
BDE-184	0.31	0.24	0.78	0.11	0.04	0.11	0.01
BDE-191	0.19	0.16	0.50	0.06	0.02	0.08	0.01
BDE-196	4.37	4.25	11.0	1.10	0.56	1.88	0.15
BDE-197	8.15	6.65	22.0	1.60	1.09	4.03	0.21
BDE-201	0.99	0.76	2.20	0.36	0.12	0.25	0.05
BDE-203	3.32	3.45	7.20	0.92	0.43	1.24	0.14
BDE-204			<0.1	<0.02			
BDE-205	0.06	0.05	0.10	<0.01	0.01	0.01	0.00
BDE-206	26.8	22.5	61.0	7.90	2.62	3.39	1.96
BDE-207	19.4	16.0	41.0	7.10	2.20	4.03	1.02
BDE-208	8.83	7.15	17.0	3.20	0.95	1.30	0.59
BDE-209	732	515	2000	130	64.0	86.9	43.7
ΣPDBE		771	2300	300			

Table 15. Comparison of PBDE concentrations measured in dust samples in this study with those measured in other studies

Study Information	Concentrations	Reference
10 dwellings in Melbourne	ΣPBDE 300 – 2,300 ng g^{-1} of dust, 771 ng g^{-1} (median) congener 209 was 64% of ΣPBDE	This study
5 dwellings and 2 offices in Brisbane	ΣPBDE 87 – 3,070 ng g^{-1} of dust congener 209 was 60 % to 80 % of the ΣPBDE	Toms et al. (2009)
10 dwellings in Brisbane	ΣPBDE 5,000 – 13,000 ng g^{-1} of dust congener 209 was 61 % of the total 1,200 ng g^{-1} (median)	Sjodin el al. (2008)
10 dwellings in Great Britain	ΣPBDE 950 – 54,000 ng g^{-1} of dust 10,000 ng g^{-1} (median) congener 209 was 100 % of the ΣPBDE	Sjodin el al. (2008)
10 dwellings in USA	ΣPBDE 520 – 29,000 ng g^{-1} of dust 4,200 ng g^{-1} (median)	Sjodin el al. (2008)
10 dwellings in Germany	ΣPBDE 17 – 550 ng g^{-1} of dust 74.4 ng g^{-1} (median)	Sjodin el al. (2008)
17 dwellings in Kuwait	ΣPBDE geometric mean of 76 ng g^{-1} ΣPBDE range 1 – 393 ng g^{-1} of dust	Gevao et al. (2006)
100 dwellings in Great Britain	ΣPBDE 10,449 ng g^{-1} of dust (average)	Santillo et al. (2003)
17 dwellings in USA	ΣPBDE 5,755 ng g^{-1} of dust (average)	Stapleton et al. (2005)

Table 15 compares the concentration of ΣPBDEs measured in dust samples in the 10 Melbourne dwellings with concentrations measured in other studies in Australia and internationally. The ΣPBDE concentrations of dust measured in five residences and three office buildings in Brisbane (Toms et al., 2009) are similar to the results from this study (although the range in the Brisbane study is greater than this study). The highest concentrations measured in the Brisbane study were found in the office buildings, while the mass concentrations measured in the Brisbane dwellings were lower than the highest values measured in this study. Like this study, congener 209 was 60 % to 80 % of the total PBDE mass in the Brisbane study. ΣPBDE in dust from 10 dwellings in

Brisbane were greater than those observed in this study with a median of 1200 ng g^{-1} (Sjodin el al. 2008) and again congener 209 comprised 61 % of ΣPBDE in Australia.

The Sjodin et al. (2008) study measured PBDE in dwellings of several other countries including Great Britain, USA and Germany. The highest concentrations were measured in 10 dust samples from Great Britain where the median ∑PBDE concentration was 10,000 ng g^{-1} with a range of 950 ng g^{-1} to 54,000 ng g^{-1}, an order of magnitude greater than measured in this study. Congener 209 made up 100 % of ∑PBDE. The ∑PBDE concentrations were also very high in the USA where the median of 10 dust samples 4,200 ng g^{-1} with a range of 520 ng g^{-1} to 29,000 ng g^{-1}. In contrast, the 10 houses in Germany had much lower ∑PBDE concentrations: a median of 7.4 ng $g^{-1}$and a range of 17 ng g^{-1} to 550 ng g^{-1}.

In a recent study dust samples collected from 17 dwellings in Kuwait were analysed for nine PBDE congeners (BDE-28, BDE-47, BDE-100, BDE-99, BDE-85, BDE-154, BDE-153, BDE-183, BDE-209) (Gevao et al., 2006). The concentrations of ∑PBDE of Kuwaiti dwellings were significantly lower than observed in this study. Gevao et al. (2006) also provides a summary of the nine PBDEs listed above measured in several countries including Kuwait, up to about 2005. They show that countries such as Finland, Denmark, Austria and Sweden have concentrations in the ranges that are similar to this study. Higher concentrations were observed in the Netherlands, Germany and Italy even though it is accepted that the mass concentrations of ∑PBDE are usually lower in continental Europe than they are in the USA and in Great Britain, (Sjodin et al., 2008). In all cases congener 209 was the most concentrated of the ΣPBDE, and usually above 60% of the total, most likely due to the process used to manufacture PBDEs.

Within the dust samples from North America BDE-209 was the most concentrated PBDE cogener. This reflects the global distribution of the PBDE manufacture and use, which in 1999 was 8500 metric tons manufactured, of which North America used 8290 metric tons while Europe used 210 metric tons. Although these data may have changed during the last 10 years it largely explains the reasons for the high concentration of ΣPBDE in North America compared with those in Europe.

Although there are 209 possible PBDE congeners, the commercial mixtures consist mainly of pentaBDEs, octaBDEs and decaBDEs, as well as minor fractions of other BDEs (de Wit, 2002). The manufacture of decaBDEs produces virtually 100 % of congener 209.

4.3.2. Polybrominated Diphenyl Ethers in Air

Table E 5 of Appendix E lists the concentrations of a range of PBDE measured in air inside and outside of 10 dwellings in Melbourne. These data are summarised as arithmetic mean, median, maximum and minimum and the fractions of each PBDE in Table 16 and Table 17. Table 18 lists the I/O ratios for each PBDE. The average concentration of ΣPBDE indoors is about 139 pg m^{-3}, significantly higher than outdoors average concentration of 28 pg m^{-3}. Both the maximum and minimum ΣPBDE concentrations are also significantly higher indoors than those observed outdoors. The higher indoor ΣPBDE concentrations are reflected in the I/O ratios being greater than one. However, the median I/O values, given in Table 18, show a ratio of less than one for a number of congeners, including 0.7 for the most concentrated congener BDE-209. The outdoor source of BDE-209 is not clear, but it may be due to its use as a fire retardant in motor vehicles or from the incineration of waste products that contain BDE-209.

Of the PBDEs measured indoors, BDE-47 had the highest average concentration, followed by BDE-209, making up about 46% and 21% respectively of the ΣPBDE indoors (Table 16). Outdoors BDE-209 shows the highest average concentration followed by BDE-47 which is about 45 % and 23 % of the ΣPBDE respectively.

The concentration of ∑PBDE measured in air samples in this study are compared with concentrations measured in other studies in Australia and overseas in Table 19. The indoor ∑PBDE concentrations measured in this study have a greater median value than measured in the only other Australian study (Toms et al., 2009) where the ∑PBDE in air sampled from five dwellings in Brisbane was measured. The Toms study also measured ∑PBDE in three offices in Brisbane and the range of concentrations measured in the indoor samples from our Melbourne study are similar to the Brisbane office values. Toms et al. (2009) found the indoors congener profile was dominated by BDE-209, BDE-47, BDE-183 and BDE-153 (in that order) although they did find one office where the congener profile was dominated by BDE-47. This contrasts our Melbourne study where congener BDE-47 was the most concentrated PBDE indoors. The indoor concentrations measured in this Melbourne study are two orders of magnitude lower than observed in a study of 12 dwellings in Michigan, USA (Batterman et al. 2009), but greater than the concentrations measured in two dwellings in a Japanese city (Takigami et al., 2009).

The outdoor ΣPBDE concentrations measured during this study are greater than those measured outside one of the dwellings in Brisbane (Toms et al., 2009) and are significantly lower than measured outdoors of 12 dwellings in Michigan (Batterman et al. 2009). They are similar to concentrations measured in the urban atmosphere in Turkey (Cetin et al., 2008), the remote atmosphere of the Arctic and North Pacific Ocean (Wang et al., 2005) and in the rural atmosphere in the UK (Lee et al., 2004).

Table 16. Summary statistics of ambient concentrations of PBDEs measured in air inside of 10 dwellings

BDE	Mean pg m^{-3}	Median pg m^{-3}	Max pg m^{-3}	Min pg m^{-3}	Mean fraction of ΣPBDE %	Max fraction of ΣPBDE %	Min fraction of ΣPBDE %
BDE-17	3.28	2.13	1.81	1.92	2.36	0.45	10.54
BDE-28 + 33	6.00	8.98	<2.85	<2.85	4.32		
BDE-30	0.03	0.26	<0.05	<0.05	0.02		
BDE-47	64.32	27.79	26.81	13.12	46.36	6.59	71.98
BDE-49	3.04	1.68	1.77	1.00	2.19	0.44	5.46
BDE-66	1.34	0.74	0.79	0.35	0.96	0.19	1.91
BDE-71	0.21	0.17	<0.01	0.11	0.15		0.58
BDE-77	0.02	0.02	<0.01	<0.01	0.01		
BDE-85	0.23	0.24	0.25	<0.07	0.17	0.06	
BDE-99	12.42	9.77	9.77	<1.83	8.95	2.40	
BDE-100	4.20	2.52	2.97	0.75	3.03	0.73	4.14
BDE-119	0.02	0.05	<0.01	<0.01	0.02		
BDE-126	0.05	0.01	<0.01	<0.01	0.04		
BDE-138 + 166	0.05	0.06	0.06	<0.07	0.03	0.01	
BDE-139	0.03	0.02	<0.02	<0.02	0.02		
BDE-140	0.02	0.02	<0.03	<0.03	0.01		
BDE-153	0.33	0.35	0.62	0.18	0.24	0.15	1.01
BDE-154	0.40	0.45	0.57	<0.08	0.29	0.14	
BDE-156 + 169	0.04	0.04	<0.08	<0.08	0.03		
BB-153	1.18	0.25	0.34	0.32	0.85	0.08	1.75
BDE-171	0.01	0.03	<0.01	<0.01	0.01		
BDE-180	0.03	0.03	0.16	<0.01	0.02	0.04	
BDE-183	0.43	0.29	0.47	0.24	0.31	0.12	1.32
BDE-184	0.01	0.01	<0.01	<0.01	0.00		
BDE-191	0.01	0.01	<0.01	<0.01	0.00		
BDE-196	0.37	0.10	2.86	<0.02	0.27	0.70	
BDE-197	0.20	0.09	1.18	0.07	0.15	0.29	0.39
BDE-201	0.02	0.04	1.34	<0.02	0.01	0.33	
BDE-203	0.43	0.13	3.57	<0.04	0.31	0.88	
BDE-204	0.01	0.01	<0.02	<0.02	0.01		
BDE-205	0.02	0.02	<0.04	<0.04	0.01		
BDE-206	4.93	0.41	45.94	<0.05	3.55	11.30	
BDE-207	3.39	0.24	32.07	0.13	2.44	7.89	0.69
BDE-208	2.11	0.11	20.10	0.04	1.52	4.94	0.23
BDE-209	29.60	6.14	253.20	<0.61	21.33	62.27	
ΣPBDE	138.54	81.72	406.63	18.22	100	100	100

Table 17. Summary statistics of ambient concentrations of PBDEs measured in air outside 10 dwellings

BDE	Mean pg m^{-3}	Median pg m^{-3}	Max pg m^{-3}	Min Pg m^{-3}	Mean fraction of ΣPBDE %	Max fraction of ΣPBDE %	Min fraction of ΣPBDE %
BDE-17	0.20	0.20	0.33	0.11	0.71	0.44	1.09
BDE-28 + 33	1.46	1.99	1.99	1.99	5.12	2.66	19.07
BDE-30	0.03				0.09		
BDE-47	6.63	7.69	14.51	1.89	23.29	19.37	18.14
BDE-49	0.37	0.41	0.65	0.25	1.31	0.87	2.42
BDE-66	0.24	0.23	0.41	0.06	0.83	0.55	0.57
BDE-71	0.02	0.03	0.06	0.01	0.08	0.08	0.05
BDE-77	0.01	0.02	0.02	0.02	0.03	0.02	0.16
BDE-85	0.06	0.13	0.17	0.05	0.21	0.22	0.50
BDE-99	3.34	5.71	6.57	1.80	11.73	8.76	17.23
BDE-100	0.97	1.52	1.91	0.57	3.40	2.55	5.44
BDE-119	0.01				0.02		
BDE-126	0.01				0.02		
BDE-138 + 166	0.01				0.02		
BDE-139	0.01	0.02	0.03	0.00	0.05	0.04	0.02
BDE-140	0.02				0.05	0.00	
BDE-153	0.09	0.17	0.22	0.12	0.33	0.29	1.13
BDE-154	0.22	0.22	0.31	0.12	0.76	0.42	1.18
BDE-156 + 169	0.04				0.14		0.00
BB-53	0.33	0.14	2.31	0.05	1.15	3.09	0.47
BDE-171	0.01				0.02		
BDE-180	0.01				0.02		
BDE-183	0.15	0.14	0.31	0.09	0.53	0.41	0.90
BDE-184	0.01				0.02		
BDE-191	0.01				0.02		
BDE-196	0.05	0.08	0.13	0.03	0.19	0.18	0.31
BDE-197	0.05	0.07	0.14	0.02	0.17	0.19	0.15
BDE-201	0.02	0.04	0.05	0.01	0.07	0.07	0.08
BDE-203	0.06	0.09	0.12	0.06	0.22	0.16	0.62
BDE-204	0.01				0.04		
BDE-205	0.02				0.07		
BDE-206	0.66	0.65	1.78	0.21	2.30	2.37	2.04
BDE-207	0.39	0.34	0.98	0.18	1.36	1.31	1.72
BDE-208	0.20	0.16	0.54	0.09	0.69	0.72	0.86
BDE-209	12.80	8.83	41.40	2.70	44.95	55.24	25.85
ΣPBDE	25.65	25.68	61.11	11.03	100.00	100.00	100.00

Table 18. Mean, median, minimum and maximum concentrations and I/O ratios air of PBDEs measured in this study

	I/O			
BDE	**Mean**	**Median**	**Max**	**Min**
BDE-17	16.26	10.5	24.45	10.5
BDE-28 + 33	4.11	4.5	10.23	0.9
BDE-30	1.04			
BDE-47	9.70	3.6	15.56	6.0
BDE-49	8.14	4.1	12.17	3.9
BDE-66	5.65	3.2	10.08	5.9
BDE-71	9.45	5.6	8.76	13.6
BDE-77	2.14	1.3	2.58	0.3
BDE-85	3.93	1.9	5.62	1.3
BDE-99	3.72	1.7	7.97	1.7
BDE-100	4.34	1.7	8.83	1.3
BDE-119	4.85			
BDE-126	10.00			
BDE-138 + 166	9.37			
BDE-139	1.74	0.6	4.51	6.0
BDE-140	1.00			
BDE-153	3.57	2.1	3.63	1.5
BDE-154	1.85	2.1	4.54	1.7
BDE-156 + 169	1.00			
BB-53	3.59	1.8	4.33	1.1
BDE-171	1.43			
BDE-180	5.03			
BDE-183	2.85	2.0	4.61	1.4
BDE-184	1.10			
BDE-191	1.00			
BDE-196	6.84	1.2	21.73	1.3
BDE-197	4.18	1.2	8.48	3.2
BDE-201	0.94	0.8	24.62	1.5
BDE-203	6.83	1.4	29.89	0.9
BDE-204	1.00			
BDE-205	1.00			
BDE-206	7.52	0.6	25.86	0.4
BDE-207	8.74	0.7	32.77	0.4
BDE-208	10.69	0.7	37.05	0.5
BDE-209	2.31	0.7	6.12	0.4
ΣPBDE	167	54	314	66

Table 19. Comparison of PBDE concentrations measured in air samples in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	ΣPBDE 18 – 407 pg m^{-3} 82 pg m^{-3} (median) congener 47 and 209 were 46% and 21% of the ΣPBDE respectively	This study
Outdoors urban 10 dwellings in Melbourne	ΣPBDE 10 – 61 pg m^{-3} 26 pg m^{-3} (median) congener 47 and 209 were 23% and 45% of the ΣPBDE respectively	This study
Indoors urban 5 dwellings in Brisbane	ΣPBDE 0.5 – 179 pg m^{-3} 50 pg m^{-3} (average) n=6 19 pg m^{-3} (median) congener 209 > cogener 47	Toms et al. (2009)
Indoors urban 3 offices in Brisbane	ΣPBDE 15 – 486 pg m^{-3} n=3 congener 209 was 60 % to 80 % of the ΣPBDE	Toms et al. (2009)
Indoors urban 12 dwellings in Michigan	ΣPBDE 5700 pg m^{-3} (average) 18,900 pg m^{-3}(maximum) 12 dwellings over two seasons	Batterman et al. (2009)
Indoors urban 2 dwellings in Hokkaido, Japan	ΣPBDE 17 – 55 pg m^{-3} n=2	Takigami et al. (2009)
Outdoors urban 1 dwelling in Brisbane	ΣPBDE 1.7 pg m^{-3} n=1	Toms et al. (2009)
Outdoors urban 4 sites in Izmir, Turkey	ΣPBDE 21 – 117 pg m^{-3} mean 52 pg m^{-3} n=8	Cetin et al. (2008)
Outdoors rural Hazelrigg, UK Chilton, UK	ΣPBDE 2.8 – 37 pg m^{-3} mean 12 pg m^{-3} n~35 ΣPBDE 3.4 – 33 pg m^{-3} mean 11 pg m^{-3} n~35	Lee et al. (2004)
Outdoors remote Mace Head, Ireland	ΣPBDE 0.2 – 5 pg m^{-3} mean 2.6 pg m^{-3} n~35	Lee et al. (2004)
Outdoors remote Arctic North Pacific Far East Asia	ΣPBDE congeners 28, 47, 66, 85, 99, 100, 138, 153, 154, 183, 209 <2.6 – 60.9 pg m^{-3} n=28 mean 17.3 pg m^{-3} <1.4 – 36.9 pg m^{-3} n= 20 mean 12.8 pg m^{-3} 2.3 – 198.9 pg m^{-3} n=28 mean 58.3 pg m^{-3}	Wang et al. (2005)

4.4. Phthalates

The median, mean, maximum and minimum phthalate concentrations measured during this study are presented in Table 20.

Table 21 compares the results of this study to phthalate concentrations measured indoors elsewhere. The phthalate measured in the 10 Melbourne dwellings with the highest median concentration was Di-n-butyl phthalate (DNBP), followed by Diethyl phthalate (DEP) and Diisobutyl phthalate (DIBP). This is generally the order of concentrations reported in other studies (for example those listed in Table 21).

In general the phthalate concentrations measured in the 10 Melbourne dwellings are lower than measured in other studies. For example, the median DNBP concentration is an order of magnitude lower than measured in 59 apartments in Berlin (Fromme et al., 2004) and is at the lower end of the range reported for seven residences in the USA (Rudel et al., 2001). It is also lower than concentrations reported in apartments in California (Sheldon et al., 1993) and residences in Massachusetts (Rudel et al., 2003).

The median DEP concentration measured indoors of the 10 dwellings in Melbourne is almost an order of magnitude lower than measured in the USA and German studies listed in Table 21. The median DIBP concentration is lower than that measured in the German apartments (Fromme et al., 2004) but is similar to that measured in the Massachusetts residences (Rudel et al., 2003).

Table 20. Summary statistics of phthalates measured in the indoor air of 10 dwellings (ng m^{-3})

	Median	**Mean**	**Maximum**	**Minimum**
DNBP	106.8	137.5	354.7	66.5
DEP	78.3	87.7	173.7	<0.01
DIBP	61.7	139.5	686.3	59.6
DEHP	16.5	39.6	142.0	8.5
DMP	7.4	8.8	21.9	2.0
BBP	4.9	6.8	15.2	0.5

Table 21. Concentration of phthalates measured in air indoors in this and other studies

Study Information	Concentrations	Reference
Indoors 10 dwellings in Melbourne	DNBP 67 – 355 ng m^{-3} DEP <0.01 – 174 g m^{-3} DIBP 60 – 686 ng m^{-3} DEHP 8 – 142 ng m^{-3} BBP 0.5 – 15.2 ng m^{-3} DMP 0.2 – 21.9 ng m^{-3}	This study
Indoors 7 residences in USA	DNBP 101 – 431 ng m^{-3} DEP 236 – 1290 ng m^{-3} DEHP 20 – 114 ng m^{-3} BBP 10 – 172 ng m^{-3}	Rudel et al. (2001)
Indoors 59 Apartments in Berlin	DNBP 1083 ng m^{-3} DEP 643 ng m^{-3} DIBP 563 ng m^{-3} DMP 436 ng m^{-3} DEHP 156 ng m^{-3} BBP 18 ng m^{-3}	Fromme et al. (2004)
Indoors 125 Apartments in California	DNBP 630 ng m^{-3} DEHP 140 ng m^{-3} BBP 62 ng m^{-3}	Sheldon et al. (1994)
Indoors 125 homes Cape Cod, Massachusetts	DNBP 220 ng m^{-3} DEP 590 ng m^{-3} DIBP 61 ng m^{-3} DEHP 77 ng m^{-3} BBP 480 ng m^{-3} (max)	Rudel et al. (2003)

4.5. Endosulfan

The summary statistics for endosulfan (α-endosulfan and β-endosulfan) and endosulfan sulfate, (an oxidation product of endosulfan) measured outdoors of 10 dwellings in Melbourne are shown in Table 22. The concentrations of α-endosulfan were always higher than the concentrations of β-endosulfan, and this is consistent with the concentrations ratio of 7:3 in the commercial product. There is also published evidence to suggest that α-endosulfan is slowly converted to β-endosulfan due to an intermediate structural form of the isomers (Schmidt et al. 1997; Schmidt et al. 2001).

Table 22. Summary statistics of α-endosulfan, β-endosulfan and endosulfan sulfate measured in air outside of 10 dwellings

	Average pg m^{-3}	Median pg m^{-3}	Maximum pg m^{-3}	Minimum pg m^{-3}
α-endosulfan	7.5	7.4	13.8	2.7
β-endosulfan	0.5	0.02	1.5	<0.02
endosulfan sulfate	0.1	0.02	0.6	<0.02

A comparison of the endosulfan concentrations measured in this study with those measured elsewhere is presented in Table 23. Endosulfan concentrations measured in this study are up to an order of magnitude lower than measured in other urban areas such as Seoul, Korea and Izmir, Turkey (Yeo et al. 2004).

Annually averaged concentrations of endosulfan measured in a network across North America using passive samples showed a wide range of concentrations. Shen et al. (2005) suggest that total endosulfan concentration is below 160 pg m^{-3} in areas away from agriculture across North America. Elevated concentrations are associated with areas of agricultural activity. For example, the highest annual concentrations of approximately 800 pg m^{-3} were observed at Summerland, a rural location in Canada where fruit growing dominates agricultural activity. High concentrations at Prince Edward Island were attributed to the use of endosulfan containing pesticides in tobacco farming. These agricultural-related endosulfan concentrations are almost three times greater than measured in urban locations such as Seoul, and considerably greater than observed in Melbourne.

Endosulfan concentrations have been measured in several sites in the Arctic atmosphere. Annual average concentrations measured in the Arctic atmosphere are similar to the weekly concentrations measured in Melbourne. Halsall et al. (1998) report annual average endosulfan concentrations of 4.2 pg m^{-3}, 7.0 pg m^{-3} and 2.99 pg m^{-3} in the arctic atmosphere at Alert, Tagish and Dunai respectively. The samples were collected over weekly periods and total endosulfan concentration ranged between 0.02 pg m^{-3} and 88 pg m^{-3}. The higher endosulfan concentrations are probably the result of long range transport from source regions. Halsall et al. (1998) suggest that 4.7 pg m^{-3} can be considered as the baseline concentration in the remote atmosphere due to long range transport.

Since the human toxicity of the three forms of endosulfan is considered to be similar, the total of the three forms will be considered here. The arithmetic average concentrations of the total of the three endosulfan compounds measured at the 10 outdoor sites in Melbourne are about 8.1 pg m^{-3}, which is not significantly higher than the assumed baseline concentration in the remote atmosphere of 4.7 pg m^{-3}.

A recent study has used passive samplers to measure a range of POPs including endosulfan, PCBs and PBDEs (Pozo et al., 2006; Pozo et al., 2009). This study measured very high concentrations of Σendosulfans averaged over four separate consecutive three month periods in agricultural regions, particularly at a site in South America, one in central America, several sites in Europe and a site at the Global Atmosphere Watch Station at Bukit Koto Tabang, Sumatra. Although Pozo et al. (2006) used passive samplers for these measurements, there appears to be no published data that compares the results from co-located active and passive samplers.

The endosulfan concentrations measured at the 10 sites in Melbourne appear to be very low compared to rural areas where it is used, and much closer to what could be considered background concentrations. They are much lower than the concentrations observed in the agricultural areas of North America.

Table 23. Comparison of endosulfan concentrations measured in outdoor air in this study with those measured in other studies

Study Information	Concentrations	Reference
Outdoors urban 10 dwellings in Melbourne	α-endosulfan 2.7 – 13.8 pg m^{-3} β-endosulfan <0.02 – 1.5 pg m^{-3}	This study
Outdoors urban Seoul, South Korea	mean α plus β-endosulfan 329 ±383 pg m^{-3} mean α-endosulfan 250 pg m^{-3} n=19 mean β-endosulfan 79 pg m^{-3} n=19 range of α plus β-endosulfan 8.9 – 1086 pg m^{-3}	Yeo et al. (2004)
Outdoors urban Izmir, Turkey	α-endosulfan* average 171±60 pg m^{-3} range 96 – 342 pg m^{-3} n=19 β-endosulfan average 20±7 pg m^{-3} range 3 – 30 pg m^{-3} n=13	Sofuoglu et al. (2004)
Outdoors rural Summerland, Canada Lake Ontario, Canada Lake Huron, Canada Lake Superior, Canada Prince Edward Island, Canada	 annual average ~800 pg m^{-3} n=1 annual average 93 pg m^{-3} n=1 annual average 18 pg m^{-3} n=1 annual average 12 pg m^{-3} n=1 annual average ~250 pg m^{-3} n=1	Shen et al. (2005)
Outdoors rural Ansung, Korea	mean α plus β-endosulfan 1351±2672 pg m^{-3} mean α-endosulfan 1062 pg m^{-3} n=19 mean β-endosulfan 289 pg m^{-3} n=19 range of α plus β-endosulfan 10 – 10262 pg m^{-3}	Yeo et al. (2004)
Outdoors remote Arctic, Alert	α-endosulfan annual mean 7.8 pg m^{-3} n=1	Shen et al. (2005)
Arctic Alert Tagish Duna	annual average and range of α-endosulfan plus β-endosulfan 3.6 pg m^{-3}, 0.02 – 9.4 pg m^{-3} n~52 5.8 pg m^{-3}, 0.08 – 15.3 pg m^{-3} n~52 3.0 pg m^{-3}, 0.05 – 7.2 pg m^{-3} n~52	Halsall et al. (1998)

* This is the total of α-endosulfan and α-chlordane

4.6. Short Chain Chlorinated Paraffins

The summary statistics for SCCPs measured indoors and outdoors of the 10 dwellings in Melbourne are presented in Table 24. The indoor concentrations were generally lower than outdoor concentrations resulting in average and median I/O ratio of less than one. Because some reports use ng $m^{-3}$and some pg m^{-3}, all concentrations have been converted to pg m^{-3} for this discussion.

Table 24. Summary statistics of SCCP measured in indoor and outdoor air at 10 dwellings in Melbourne

	Average pg m^{-3}	**Median pg m^{-3}**	**Maximum pg m^{-3}**	**Minimum pg m^{-3}**
SCCPs Indoors	59,900	51,850	121,200	34,500
SCCPs outdoors	98,600	80,950	164,000	56,500
I/O	0.66	0.63	1.14	0.33

There have been few measurements of SCCPs in ambient air, and none in Australia (Table 25). Concentrations at a semi-rural site in Lancaster, England during 1997 ranged from 5.4 pg m^{-3} to 1085 pg m^{-3} (Peters et al. 2000). In that study, two significantly different populations of SCCP concentrations were observed (150 ±110 pg m^{-3} and 800 ± 170 pg m^{-3}) with the elevated population associated with incidences of advective transport of contaminated air masses and/or releases to the environment from regional primary point sources rather than by temperature-dependent transport processes. In a second study carried out at the Lancaster site in 2003, Barber et al. (2005) reported higher concentrations of SCCP (averaged 1100 pg m^{-3}, ranging from <180 pg m^{-3} to 3400 pg m^{-3}). The highest concentrations reported in the literature are those from Bear Island, Norway where concentrations were up to 10,600 pg m^{-3} (Borgen et al., 2002).

The concentrations observed in this study are considerably higher than those observed in previous studies, and the reasons for this are unclear. One reason may be that other studies have been carried out in remote or rural areas, in contrast to the present study that has been carried out in an urban area. The results from Peters et al., (2000) lend support to this suggestion since in that study elevated concentrations of SCCP at the semi-rural site were associated with air masses advected from polluted areas. Of the 10 dwellings studied in this work nine had outdoor concentrations higher than inside concentrations, and the I/O varied from 0.33 to 1.14. Three of the dwellings in this study had garages that were attached to them and the three highest ratios were measured at these dwellings, indicating that SCCPs in the garage may have contributed to the indoor concentrations. Further tests are being undertaken to verify these results.

Table 25. Comparison of SCCP concentrations measured in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	34,500 – 121,200 pg m^{-3}	This study
Outdoors urban 10 dwellings in Melbourne	56,500 – 164,000 pg m^{-3}	This study
Outdoors semi-rural Lancaster, England U.K.	5.4 – 1085 pg m^{-3} <180 – 3400 pg m^{-3} 1100 pg m^{-3} (mean)	Peters et al. (2000) Barber et al. (2005)
Outdoors remote Bear Island, Norway Alert Svalbard	 10,600 pg m^{-3} (maximum) 20 pg m^{-3} (mean) 9.0 pg m^{-3} – 57 pg m^{-3}	 Borgen et al. (2002) Peters et al. 2000 Borgen et al. (2000)

4.7. Perfluorinated Compounds

Summary statistics of the concentrations of perfluorinated compounds (PFOS, PFOA, PFHS and PFNA) are presented in Table 26. PFOS was the most concentrated perfluorinated compound both indoors and outdoors, followed by PFOA. The median I/O ratio is greater than one for all species, indicating predominately indoor sources. As discussed above these sources can include surface treatments applications that provide oil and water resistance to personal apparel and home furnishings.

Table 26. Maximum, minimum and arithmetic average concentrations of perfluorinated compounds measured indoors and outdoors of 10 dwellings. Also listed are average and maximum I/O ratios

	PFOS pg m^{-3}	**PFOA pg m^{-3}**	**PFHS pg m^{-3}**	**PFNA pg m^{-3}**	**Total pg m^{-3}**
Max Indoors	349.5	109.9	17.9	18.3	481.9
Min Indoors	4.8	6.9	0.8	0.4	18.1
Average Indoors	47.6	33.5	2.6	5.8	89.0
Median Indoors	12.8	21.6	1.6	4.0	44.7
Max Outdoors	5.64	4.45	<1.0	<1.2	9.57
Min Outdoors	1.24	<1.8	<1.0	<1.2	1.24
Average Outdoors	3.25	2.72	<1.0	<1.2	5.24
Median Outdoors	3.06	2.77	<1.0	<1.2	5.56
I/O Median	4	8	1.6		8
I/O Max	62	25	18		50

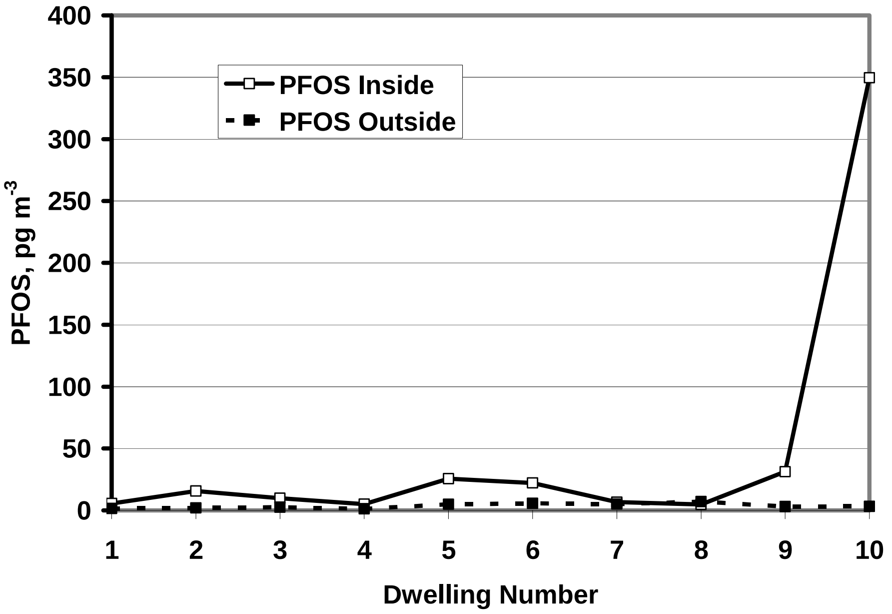

Figure 12. Concentrations of PFOS in air indoors and outdoors of 10 dwellings

The maximum, minimum and arithmetic average and median concentrations of PFHS and PFNA are also given in Table 26. The concentrations of PFHS are low, and usually <1.0 pg m^{-3}, except for POP-10 where the indoor concentration was 17.9 pg m^{-3}. The outdoor concentrations of PFNA are also low, and mostly <1.2 pg m^{-3}; the outdoor concentrations are lower than indoors where minimum and maximum concentrations of 0.4 pg m^{-3} and 18.3 pg m^{-3} were recorded.

The highest concentrations of the four perfluorinated compounds were measured inside the one dwelling, POP-10 (Figure 12). The average concentration of PFOS at the other nine dwellings was 14.7 pg m^{-3}, compared with 349.5 pg m^{-3} at POP-10. At this stage there is no obvious explanation for these high results. One possibility is the use of a particular brand of cleaner that the occupants have regularly employed to clean carpets. It is unlikely that this product contains perfluorinated compounds, but the manufacturer has not been able to divulge the chemical composition of the cleaner.

A comparison of the PFOS concentrations measured in this study with those measured elsewhere is presented in Table 27. The only published study reporting concentrations of the same perfluorinated compounds measured indoors of the Melbourne dwellings (PFOS, PFOA, PFHS and PFNA) was carried out in four homes in Norway. Concentrations of PFOA reported in that study were four times lower than the median PFOA concentration measured in the Melbourne dwellings. The concentration of PFNA was similar (Barber et al., 2007).

The concentrations of perfluorinated compounds in other outdoor urban locations are greater than observed in the Melbourne study. In particular, the annual mean PFOA concentration measured at an urban site in Kyoto Japan is 100 times greater than the median concentration measured outdoors in the Melbourne study (Harada et al., 2005), while the median concentration of PFOA measured in outdoor air in Albany New York is four times greater than measured in Melbourne (Kim and Kannan, 2007). The very high Japanese PFOA concentrations were attributed to the emissions from vehicle traffic and resuspended dust, since the sampling site was located alongside a major trucking route (Harada et al., 2005). The concentration of PFOS was also higher in both the New York and Japanese urban locations than outdoors of the Melbourne dwellings.

The concentrations of PFOS and PFOA measured outdoors of the Melbourne dwellings are slightly larger but of the same magnitude as measured at a rural location in Japan (Harada et al., 2005) and in the remote Canadian Arctic (Stock et al., 2007).

Table 27. Comparison of PFOS concentrations in air measured in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban 10 dwellings in Melbourne	PFOA 21.6 pg m^{-3} (medians) PFOS 12.8 pg m^{-3} PFHS 1.6 pg m^{-3} PFNA 4 pg m^{-3}	This study
Outdoors urban 10 dwellings in Melbourne	PFOA 2.77 pg m^{-3} (medians) PFOS 3.06 pg m^{-3} PFHS <1.0 pg m^{-3} PFNA <1.2 pg m^{-3}	This study
Indoors urban Tromso, Norway (4 samples 2005)	PFOA 4.4 pg m^{-3} (averages) PFNA 2.7 pg m^{-3}	Barber et al. (2007)
Outdoors urban Albany New York	PFOA 14.4 pg m^{-3} (medians) PFOS 2.08 pg m^{-3} PFHS 0.34 pg m^{-3} PFNA 0.2 pg m^{-3}	Kim and Kannan (2007)
Outdoors urban Near major trucking route in Kyoto, Japan	PFOA 262 pg m^{-3} (Annual means) PFOS 5.2 pg m^{-3}	Harada et al. (2005)
Outdoors rural Iwate, Japan	PFOA 2 pg m^{-3} (Annual means) PFOS 0.7 pg m^{-3}	Harada et al. (2005)
Outdoors remote Canadian Arctic (10 samples 2006 summer)	PFOA 1.4 pg m^{-3} (particulate only) PFOS 5.9 pg m^{-3} (particulate only) Summer means	Stock et al. (2007)

4.8. Polychlorinated Biphenyls

Concentrations of polychlorinated biphenyls measured indoors and outdoors of 10 dwellings are presented in Table E 10 of Appendix E. The concentrations of individual PCB species measured outdoors showed minimal variation between sites, compared with the indoor concentrations, where individual congener concentrations were more variable, for example, Figure 13 shows the indoor and outdoor concentrations of PCB 77 at each dwelling and Figure 14 shows PCB 118. In addition, indoor concentrations are greater than outdoor, suggesting that indoor concentrations may not be influenced by the outdoor concentrations. From this we infer that most of the PCBs measured indoors have an indoor source. Furthermore Figures 13 and 14 the variation in concentrations of PCB 77 and PCB118 from dwelling to dwelling are highly correlated indicating a common source.

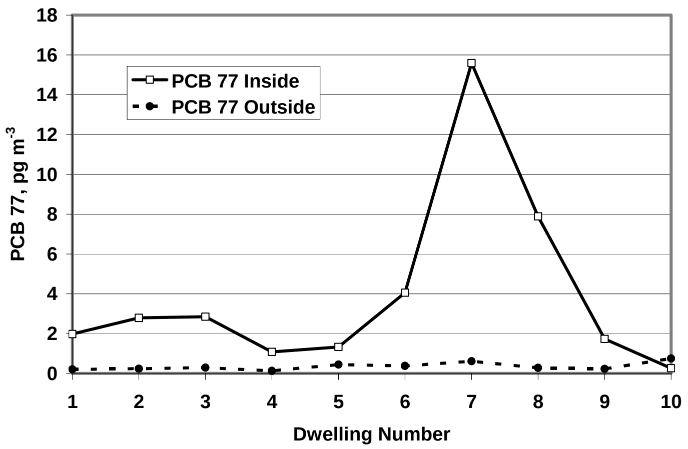

Figure 13. Concentrations of PCB 77 in air indoors and outdoors of 10 dwellings

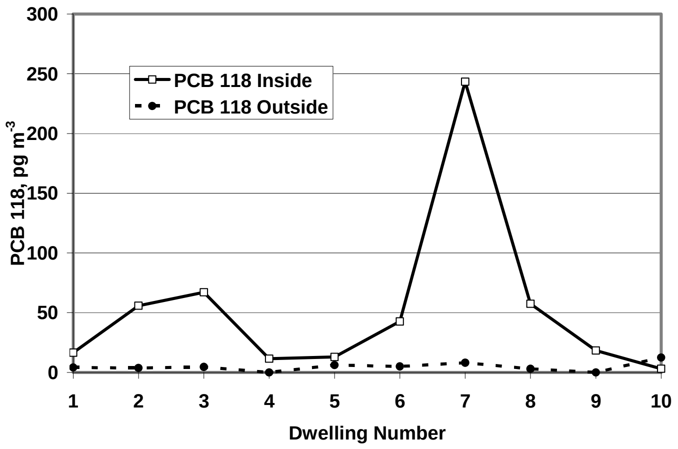

Figure 14. Concentrations of PCB 118 in air indoors and outdoors of 10 dwellings

Summary statistics for PCB concentrations measured indoors and outdoors are presented in Table 28. All PCBs had higher indoor median concentrations than outdoors. The dominant PCB measured was PCB 118 both indoors and outdoors, followed by PCB 105.

Table 28. Maximum, minimum and average concentration of PCBs measured in air indoors and outdoors of 10 dwellings (pg m^{-3}) and I/O ratios

PCB	Median in	Max in	Min in	Average in	Median out	Max out	Min out	Average out	Median I/O
PCB 77	2.38	15.59	0.26	3.6	0.29	0.75	0.13	0.32	8.3
PCB 81	0.12	0.97	<0.002	0.24	0.01	0.04	0.01	0.01	8.7
PCB 126	0.02	0.16	<0.008	0.04	0.01	0.03	<0.008	0.01	1.8
PCB 169	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
PCB 105	8.89	65.2	3.07	14.2	1.32	2.65	<0.3	1.36	6.7
PCB 114	0.83	5.11	0.34	1.18	0.09	0.21	<0.02	0.1	9.5
PCB 118	30.46	243.4	11.52	48.93	3.96	8.11	<0.40	4.21	7.7
PCB 123	0.53	3.13	0.17	0.73	0.06	0.12	<0.007	0.06	8.5
PCB 156	0.55	5.64	0.4	1.32	0.07	0.33	<0.07	0.17	7.9
PCB 157	0.12	1.05	0.07	0.24	0.03	0.08	<0.005	0.04	3.4
PCB 167	0.28	2.51	0.15	0.58	0.09	0.16	<0.02	0.1	3.2
PCB 189	0.01	0.07	<0.002	0.03	0.01	0.01	<0.002	0.01	
Total	44.18	343	17	71	5.94	12	0.8	5.5	7.4

A comparison of the PCB concentrations measured in this study with those measured elsewhere is presented in Table 29. PCBs have been measured indoors in a number of locations. The median concentration of the sum of seven congeners measured indoors at an urban location in Mexico City, a semi-rural site in the UK and an urban location in Sweden are all higher than the median concentrations measured indoors of the Melbourne dwellings (Bohlin et al., 2008), with the UK concentrations almost 200 times greater. The concentrations measured indoors at a semi-rural location in Mexico are similar to the median concentration measured indoors of the Melbourne dwellings. Note that the Bohlin et al. (2008) study employed passive samplers so the concentrations reported may be skewed towards gas phase concentrations rather than gas and particle phase concentrations measured in this work. The concentrations of PCBs measured in two dwellings in Hokkaido, Japan were also considerably greater than measured in the Melbourne dwellings (Takigami et al., 2009).

Annual average outdoor PCB concentrations (total of 12 congeners) measured at two major urban locations (Alphington in Melbourne and Westmead in Sydney) during the National Dioxins Program were similar to the median concentration measured in this study (Gras and Mueller, 2004). PCB concentrations measured outdoors at an urban/industrial site in Brisbane, (total of 12 congeners) was more than two orders of magnitude greater than measured outdoors of the Melbourne dwellings (Mueller et al., 2003), while another sample taken outdoors of rural/urban site in Brisbane, the concentration was 50 times greater than measured outdoors of the Melbourne dwellings. Annual average concentration at a light industrial site in South Australia during the National Dioxin Program was twice that measured in this study outdoors of the Melbourne dwellings (Gras and Mueller, 2004). The annual median concentration of PCBs measured in Sweden at 11 locations was 10 times greater than observed in the Melbourne study (Backe et al., 2000).

Table 29. Comparison of PCB concentrations measured in air in this study with those measured in other studies

Study Information	Concentrations	Reference
Indoors urban (Σ12 PCBs) 10 dwellings in Melbourne	44.18 pg m^{-3} (median) n=10	This study
Outdoors urban (Σ12 PCBs) 10 dwellings in Melbourne	5.6 pg m^{-3} (median) n=10	This study
Indoors (Σ7 PCBs) passive samplers Mexico urban Mexico semi-rural Gothenberg Lancaster	 140 pg m^{-3} (median) 46 pg m^{-3} (median) 160 pg m^{-3} (median) 330 pg m^{-3} (median)	Bohlin et al. (2008)
Indoors urban 2 dwellings in Hokkaido, Japan, 2 samples at each dwelling	730 – 1500 pg m^{-3} n=4	Takigami et al. (2009)
Outdoor urban(Σ12 PCBs) Alphington, Vic	5.9 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoor urban(Σ12 PCBs) Westmead, NSW	5.2 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoor industrial(Σ12 PCBs) Netley, SA	13.3 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoor urban/industrial(Σ12 PCBs) Brisbane	3586 pg m^{-3} n=1	Mueller et al. (2003)
Outdoor urban/rural (Σ12 PCBs) Brisbane	368 pg m^{-3} n=1	Mueller et al. (2003)
Outdoor rural (Σ12 PCBs) Mutdapilly, Qld	2.0 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoor rural (Σ12 PCBs) Boorolite, Vic	1.7 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoors urban and background (Σ12 PCBs) 11 sampling sites, Skania, southern Sweden.	87 pg m^{-3} (annual median) n=260	Backe et al. (2000)
Outdoors remote (Σ12 PCBs) Cape Grim (air sourced over the Southern Ocean)	0.5 pg m^{-3} (annual average) n=12	Gras and Mueller (2004)
Outdoors remote (Σ33PCBs) Arctic Norway 2000 – 2003	13 pg m^{-3} (annual average)	Kallenborn et al. (2007)

The median ΣPCB concentration measured outdoors of the Melbourne dwellings is 2–3 times greater than measured at two locations during the National Dioxin Program (Boorolite in Victoria and Mutdapilly in Queensland) (Gras and Mueller, 2004).

The median ΣPCB concentration measured outdoors of the Melbourne dwellings is greater than the annual average measured at Cape Grim during the National Dioxin Program (note that air was selectively sampled to represent pristine remote air masses), and is lower but of the same order of magnitude as the annual mean concentration measured at Bear Island in the Nordic Arctic (Gras and Mueller, 2004; Kallenborn et al. 2007).

Overall the outdoor concentrations of ΣPCB measured in this study are similar to those measured in Australia during the National Dioxin Program, but lower than measured elsewhere in the world. The indoor concentrations are lower than measured elsewhere.

5. CONCLUSIONS

Ambient air at 10 dwellings in the south-eastern suburbs of Melbourne have been sampled indoors and outdoors for metals, mercury and persistent organic pollutants. These dwellings were also sampled for PBDEs dust. The following conclusions have been reached.

- Volatile mercury concentrations were measured both indoors and outdoors of the 10 Melbourne dwellings. Significantly higher mercury vapour concentrations are measured indoors compared with outdoor concentrations. The higher concentrations are found in some dwellings in the 40 – 80 year age range. The mercury concentrations measured in these dwellings are lower than measured in 12 dwellings in New York and the outdoor concentrations are similar to those measured in the remote atmosphere.

- Particulate cadmium concentrations were measured both indoors and outdoors of the 10 Melbourne dwellings. Cadmium was not detected by the measurements both indoors and outdoors. Although the higher limit of reporting of the method used to measure cadmium concentration in this study limits comparison with other studies, the concentrations measured outdoor of the 10 dwellings in Melbourne are lower than measured at some outdoor urban locations elsewhere.

- Particulate nickel concentrations were measured both indoors and outdoors of the 10 Melbourne dwellings. Nickel was not detected by the measurements both indoors and outdoors. Nickel concentrations above the analytical limit of reporting were measured indoors and outdoors of only two dwellings. Indoor concentrations measured in this study are within the range of concentrations recorded in other studies.

- Particulate lead concentrations were measured both indoors and outdoors of the 10 Melbourne dwellings. Lead concentrations were above the limit of reporting in air outdoors of seven dwellings and indoors of three dwellings (average concentrations 3 ng m^{-3} and 2.2 ng m^{-3} respectively). Lead concentrations above the limit of reporting occurred indoors of dwellings older than 40 years in age. I/O ratios greater than one for the dwellings with the two highest lead concentrations suggest an indoor source of this lead, most likely from old lead paint. Indoor concentrations measured in this study are similar to those recorded in other studies. Outdoor concentrations of lead are lower than those in other urban environments and similar to those measured in the remote atmosphere.

- The concentrations of 12 PBDE congeners were measured in dust collected from the 10 Melbourne dwellings. The median (minimum, maximum) ΣPBDE concentrations measured in dust in 10 dwellings were 771 ng g^{-1} (300 – 2300 ng g^{-1}) with the dominant congener being BDE-209. The manufacturing process for PBDEs favours the formation of congener 209. The ΣPBDEs mass concentrations measured in this study are comparable with those measured in other Australian studies, and lower than those measured in North America and Europe.

- The concentration of 12 PBDE congeners were measured in air (particulate and gas phase) indoors of the 10 Melbourne dwellings. The median (minimum, maximum) ΣPBDE concentrations of air measured indoors of 10 dwellings were 82 pg m^{-3} (18 – 407 pg m^{-3}). The dominant congener was BDE-47 followed by BDE-209, making up about 46% and 21% of ΣPBDE respectively. Concentrations were higher in the Melbourne dwellings than measured in domestic dwellings in Brisbane and Kyoto, but several orders of magnitude lower than measured in domestic dwellings in the USA.

- The concentrations of 12 PBDE congeners were measured in air (particulate and gas phase) outdoors of the 10 Melbourne dwellings. The median (minimum, maximum) ΣPBDE concentrations of air measured outdoors of 10 dwellings were 26 pg m^{-3} (10 pg m^{-3} – 21 pg m^{-3}). The dominant congener was BDE-209 followed by BDE-47, making up about 45% and 23% of ΣPBDE respectively. The Melbourne median outdoor concentrations of ΣPBDE are greater than measured outdoors in Brisbane, but several orders of magnitude lower than measured outdoors in the USA. The median outdoor PBDE concentrations outdoors in Melbourne was 26 pg m^{-3}, which is similar to the range measured in large cities such as Izmir, Turkey. The concentrations observed outdoors in Melbourne are about double those measured in rural locations such as Lancaster, England and about an order of magnitude greater than remote locations such as Mace Head, Ireland.

- The concentrations of six phthalates were measured in air (particulate and gas phase) both indoors and outdoors of the 10 Melbourne dwellings. The phthalate with the highest median concentration was DNPB (106 ng m^{-3}) followed by DEP (78 ng m^{-3}) and DIBP (62 ng m^{-3}). In general the phthalate concentrations measured in the 10 Melbourne dwellings were lower than measured in dwellings in other countries, in some cases by an order of magnitude (e.g. Berlin).

- The concentration of endosulfan was measured in air (particulate and gas phase) outdoors of the 10 Melbourne dwellings. The median (minimum, maximum) α-endosulfan concentrations measured outdoors of air from 10 dwellings were 7 pg m^{-3} (3 pg m^{-3} –14 pg m^{-3}), greater than the median (minimum, maximum) concentrations of β-endosulfan of <0.02 pg m^{-3} (<0.02 pg m^{-3} – 1.5 pg m^{-3}). These concentrations are much lower than the concentrations observed in the agricultural areas of North America and closer to concentrations observed in the remote background atmosphere (e.g. Alert in the Canadian arctic).

- The concentration of SCCP was measured in air (particulate and gas phase) both indoors and outdoors of the 10 Melbourne dwellings. The median (minimum, maximum) concentrations of SCCPs measured indoors of the 10 dwellings were 51,850 pg m^{-3} (34,500 pg m^{-3} – 121,000 pg m^{-3}), which are lower than the concentrations measured outdoors of 81,950 pg m^{-3} (56,500 pg m^{-3} – 164,000 pg m^{-3}). These concentrations are considerably higher than concentrations measured elsewhere, and while the reasons for this are unclear, the higher concentrations in Melbourne may arise because these are the first reported measurements of SCCP in an urban environment.

- The concentrations of four perfluorinated compounds were measured in air (particulate and gas phase) both indoors and outdoors of the 10 Melbourne dwellings. The median (minimum, maximum) concentrations of total perfluorinated compounds measured indoors of the 10 dwellings were 45 ng m^{-3} (18– 482 ng m^{-3}) and outdoors were 6 ng m^{-3} (1.3 – 9 ng m^{-3}). The most concentrated perfluorinated compound measured both indoors and outdoors was PFOS followed by PFOA. The median I/O ratio was greater than one for all species, indicating predominately indoor sources. Median PFOA concentrations measured indoors of the Melbourne dwellings were higher than indoor PFOA concentrations measured in Norwegian dwellings. The Melbourne outdoor concentrations of PFOA were lower than urban locations elsewhere (in some cases 100 times lower such as Japan), and were higher than concentrations measured in rural and remote areas

- The concentrations of 12 PCB congeners were measured in air (particulate and gas phase) both indoors and outdoors of the 10 Melbourne dwellings. The dominant PCB was PCB 118 both indoors and outdoors, followed by PCB 105. All PCBs had higher indoor median concentrations than outdoors. Overall the outdoor concentrations of ΣPCB measured in the Melbourne study were similar to those measured in Australia during the National Dioxin Program, but lower than measured elsewhere in the world. The indoor concentrations are lower than those measured elsewhere.

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APPENDIX A. SAMPLING METHODS

Sampling for Metals Analysis

Total suspended particulate (TSP) samples were collected inside and outside of 10 dwellings for analysis for lead, cadmium and nickel with a Micro-Vol 1000 low volume aerosol sampler (Ecotech, Melbourne) with a TSP size selective inlet and flow rate of 3 l min^{-1}. Samples were collected on 47 mm stretched Teflon filters (Pall Teflo 47 mm 2 µm filters), that were weighed before and after sampling to determine the gravimetric mass of TSP. Samples were collected over seven days (Table A 1).

Table A 1. Details of filter samples collected for metals analysis at 10 dwellings. Corrected volume is the volume corrected to standard temperature and pressure.

Sample	Date/time On	Date/time Off	Sampling period (days)	Volume sampled (litres)	Corrected Volume (litres)
Metal1-In	31/12/2008 12:45	07/01/2009 10:51	6.92	29921	27189
Metal1-Out	31/12/2008 12:25	07/01/2009 11:20	6.95	30058	27444
Metal2-In	02/01/2009 13:57	09/01/2009 10:39	6.86	29654	27284
Metal2-Out	02/01/2009 11:20	09/01/2009 10:29	6.96	30081	27796
Metal3-In	08/01/2009 11:15	15/01/2009 10:09	6.95	30089	27531
Metal3-Out	08/01/2009 10:56	15/01/2009 10:24	6.98	30098	27527
Metal4-In	12/01/2009 10:33	19/01/2009 10:20	6.99	30175	27714
Metal4-Out	12/01/2009 10:58	19/01/2009 10:09	6.97	30093	27731
Metal5-In	20/01/2009 11:30	27/01/2009 11:10	6.99	30176	27100
Metal5-Out	20/01/2009 11:44	27/01/2009 11:00	6.97	30104	27036
Metal6-In	21/01/2009 10:54	28/01/2009 11:37	7.03	30370	27621
Metal6-Out	21/01/2009 11:10	28/01/2009 11:02	6.99	30152	27366
Metal7-In	29/01/2009 10:20	05/02/2009 10:16	7.00	30227	27136
Metal7-Out	29/01/2009 11:00	05/02/2009 10:05	6.96	30074	26962
Metal8-In	30/01/2009 10:26	06/02/2009 09:19	6.95	30046	27215
Metal8-Out	30/01/2009 10:25	06/02/2009 09:08	6.95	29328	27536
Metal9-In	09/02/2009 11:40	16/02/2009 10:21	6.95	30001	27716
Metal9-Out	09/02/2009 10:54	16/02/2009 09:56	6.96	30066	27059
Metal10-In	10/02/2009 11:00	17/02/2009 10:10	6.97	30089	27677
Metal10-Out	10/02/2009 10:30	17/02/2009 10:01	6.98	30089	27677

Sampling for Persistent Organic Pollutants

Samples for the analysis of POPs were collected using a Lear Siegler LSA flow set polyurethane foam (PUF) sampling system (Figure A 1). Particle phase POPs were collected on 102 mm diameter tissue quartz fibre filters, (Pallflex, 2500QAT-UP). The filters were prepared by heating for 30 hours at 600°C in a muffle furnace to completely remove any traces of organic compounds. The gas phase POPs were collected on pre-cleaned polyurethane foam plugs, held in glass containers, which contained a layer of XAD-2 resin, to increase the collection efficiency of the organic compounds.

Figure A 1. Lear Siegler high volume sampler for collection of POPs on quartz and polyurethane foam.

Samples were collected at a flow rate of 225 l min^{-1} over a period of approximately seven days, resulting in sample volumes of about 2200 m^3. Table A 2 shows the details of sampling dates, sample volumes and the average temperature and pressure during the sampling period. The samplers were located in convenient locations inside and outside of the dwellings, and sampling was carried out simultaneously. At the completion of sampling the quartz fibre filters and PUF's in the glass containers were wrapped in aluminium foil that had been baked at 150°C for 30 hours, sealed in a metal tin and stored at -10°C before being despatched to NMI for chemical analysis.

Table A 2. Details of POPs sampling indoors and outdoors of 10 dwellings.

Sample	Date/time On	Date/time Off	Volume m^3 (0^oC, 1 atm)	Sampling period (days)	Temp (^oC)	Pressure (hPa)
POP1-In	31/12/08 12:45	07/01/09 12:45	2103.1	6.89	20.7	999.3
POP1-Out	31/12/08 12:25	07/01/09 11:23	1950.6	6.36	19.9	996.8
POP2-In	02/01/09 12:40	09/01/09 10:45	2088.7	6.91	19.1	1015.4
POP2-Out	02/01/09 23:58	09/01/09 09:58	2111.9	6.91	17.6	1009.0
POP3-In	08/01/09 11:18	15/01/09 10:43	2088.9	6.97	23.3	1008.9
POP3-Out	08/01/09 10:58	15/01/09 10:09	2111.4	6.96	19.6	1009.4
POP4-In	12/01/09 11:48	19/01/09 10:28	2098.4	6.93	21.2	1006.4
POP4-Out	12/01/09 11:09	19/01/09 10:01	2129.9	6.95	17.3	1006.7
POP5-In	20/01/09 12:01	27/01/09 11:30	2097.6	6.96	25.3	996.6
POP5-Out	20/01/09 11:24	27/01/09 10:34	2125.6	6.96	21.5	996.2
POP6-In	21/01/09 14:36	28/01/09 11:48	2054.5	6.88	24.4	1008.5
POP6-Out	21/01/09 14:46	28/01/09 11:02	2063.5	6.83	20.8	1009.1
POP7-In	29/01/09 11:54	05/02/09 10:55	2049.0	6.96	28.6	1008.8
POP7-Out	29/01/09 11:10	05/02/09 10:20	2073.9	6.96	24.6	1009.7
POP8-In	30/01/09 11:36	06/02/09 09:40	1996.8	6.71	26.8	1004.7
POP8-Out	30/01/09 10:24	06/02/09 09:21	1916.9	6.35	21.4	1007.9
POP9-In	09/02/09 11:53	16/02/09 10:53	2065.6	6.94	22.8	1017.7
POP9-Out	09/02/09 10:57	16/02/09 10:09	2104.0	6.96	18.2	1018.0
POP10-In	10/02/09 11:30	17/02/09 10:31	2059.1	6.95	24.4	1017.4
POP10-Out	10/02/09 11:04	17/02/09 10:08	2086.0	6.95	20.7	1017.1

Sampling for Dust

Dust samples were collected from the dwellings using a newly purchased vacuum cleaner and vacuum bags made from paper. Table A 3 lists details of the sampling dates and the mass of dust collected from the dwelling. After dust samples were collected they were sieved through a pre-cleaned stainless steel mesh to remove large dust fragments, such as fluff and animal fur. The remainder of the sieved dust was then stored in aluminium foil that was previously cleaned by heating at 150^oC for 30 hours in a muffle furnace, to remove any traces of organic material.

Table A 3. Dust samples collected from the 10 dwellings.

Sample	Dust (gm)
POP1-In	11.81
POP2-In	81.63
POP3-In	10.56
POP4-In	78.12
POP5-In	77.28
POP6-In	10.41
POP7-In	15.77
POP8-In	121.85
POP9-In	40.35
POP10-In	21.72

Sampling for Mercury

Air samples for mercury analysis were collected inside and outside of 10 dwellings concurrently with POPs sampling over periods of approximately seven days. Table A 4 shows the sampling periods, the flow rates and total volumes collected during each sampling period.

Table A 4. Details of samples collected for mercury gas analysis

Sample	Sample numbe r	Date/time On	Date/time Off	Total flow (m^3)	flow rate (ml min^{-1})
Hg1-In	A19	31/12/2008 12:40	07/01/2009 10:15	6.8993	557
Hg1-Out	A24	31/12/2008 12:45	07/01/2009 11:05	6.9306	478
Hg2-In	A20	02/01/2009 12:22	09/01/2009 10:42	6.9306	608
Hg2-Out	A30	02/01/2009 11:30	09/01/2009 10:19	6.9507	374
Hg3-In	A28	08/01/2009 11:36	15/01/2009 10:32	6.9556	523
Hg3-Out	A26	08/01/2009 11:46	15/01/2009 10:15	6.9368	586
Hg4-In	A21	12/01/2009 11:45	19/01/2009 10:15	6.9375	385
Hg4-Out	A25	12/01/2009 11:26	19/01/2009 10:21	6.9549	569
Hg5-In	A16	20/01/2009 11:43	27/01/2009 11:21	6.9847	346
Hg5-Out	A23	20/01/2009 11:32	27/01/2009 10:30	6.9569	1283
Hg6-In	A17	21/01/2009 11:37	28/01/2009 10:42	6.9618	589
Hg6-Out	A18	21/01/2009 11:35	28/01/2009 10:38	6.9604	511
Hg7-In	A27	29/01/2009 10:45	05/02/2009 10:52	7.0049	281
Hg7-Out	A03	29/01/2009 11:14	05/02/2009 10:06	6.9528	585
Hg8-In	A05	30/01/2009 11:18	06/02/2009 09:47	6.9368	458
Hg8-Out	A04	30/01/2009 10:24	06/02/2009 09:07	6.9465	438
Hg9-In	A10	09/02/2009 11:47	16/02/2009 10:28	6.9451	500
Hg9-Out	A14	09/02/2009 11:15	16/02/2009 10:00	6.9479	677
Hg10-In	A11	10/02/2009 11:47	17/02/2009 10:27	7.9444	333
Hg10-Out	A12	10/02/2009 10:50	17/02/2009 10:02	6.9667	557

APPENDIX B. ANALYTICAL METHODS

Cadmium, Nickel and Lead

The concentrations of cadmium, nickel and lead collected on filters were analysed at NMI using ICP-MS and/or ICP-AES (depending on the concentration) according to the reference methods Digestion Method: in-house method and USEPA Method IO-3.1 (Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air) and Metal Determination: USEPA 6010 for ICP-AES, USEPA 6020 for ICP-MS. A whole filter was digested with HNO_3 / HCl and after appropriate dilution the metal concentrations are determined using ICP-MS and/or ICP-AES depending on concentration. For every batch of 20 samples or less, at least one blank, one blank spike, one sample spike and one laboratory control sample (such as a spiked filter sample) were analysed.

Mercury

The mercury vapour was collected onto two traps, “A” and “B” separated by glass wool. The iodated carbon was removed separately from the “A” and “B” sections of the tube and placed in teflon digestion vials. The samples were digested in a 10 ml mixture of 7:3 nitric and sulfuric acid on a hot plate at 125^{o}C for 2 hours. Once cooled, the digestive mixture was diluted to a standard volume with 5% BrCl solution. A small volume of $SnCl_2$ was added to the solution, and the mercury was purged from the digestion by bubbling N_2 gas through the solution where it was trapped onto a gold/sand trap. The mercury mass in the sample was determined by placing the gold/sand trap into an argon gas train where it was heated to 450^{o}C. The mercury volatilised from the gold trap was measured by a cold vapour atomic fluorescence spectrometer. The mean values for blanks was 0.4 ±0.16 ng, resulting in a limit of reporting of 0.07 ng m^{-3} for a 1 week with a sample flow rate of 1.0 l min^{-1}.

Polybrominated Diphenyl Ethers in Dust

The PBDE concentrations in dust samples were measured at NMI by High Resolution Mass Spectrometry according to the reference method USEPA 1614. Fifteen ^{13}C isotopically labelled PBDEs are spiked into each dust sample to act as surrogate standards. The dust sample was then ground and extracted in a manual or automated Soxhlet extraction device or Pressurised Solvent Extraction, using toluene. After extraction, concentration and splitting, the samples underwent cleanup process that included back-extraction with acid and/or base, gel permeation chromatography (GPC) to remove sulphur contamination, followed by alumina, silica gel, and activated carbon column clean-up. Four other isotopically-labelled PBDE internal standards were then added to sample extracts immediately before analysis, to allow the quantification of surrogate standard recovery. Qualitative/quantitative analysis for PBDEs was performed with a high-resolution gas chromatograph/high-resolution mass spectrometer/computerised data system. Two characteristic ions were selectively monitored for each PBDE congener group. Analyte identification was confirmed when target ions are detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of the labelled surrogates.

Polybrominated Diphenyl Ethers in Air (Gas and Particle Phase) Samples

The PBDE concentrations in the air samples (captured on the PUF, XAD-2 Resin and quartz filter) were measured at NMI by High Resolution Mass Spectrometry according to the reference method USEPA 1614. Fifteen ^{13}C isotopically labelled PBDEs are spiked into each PUF to act as surrogate standards. The PUF and filters were then extracted by toluene soxhlet extraction. After extraction the samples were cleaned up and analysed using the procedure outlined above for the dust samples.

Phthalates

The phthalate concentrations in the air samples (captured on the PUF, XAD-2 Resin and quartz filter) were measured at NMI by Low Resolution Mass Spectrometry according to the reference method USEPA 3640A. PUF and filters were extracted by a two stage solvent extraction using ethyl acetate: methanol (1:1, stage 1), followed by toluene (stage 2). Isotopically labelled phthalates were then spiked into each sample to act as surrogate standards. After extraction, concentration, splitting and spiking, the samples underwent a cleanup process that included silica gel and Waters GPC cleanup. An isotopically labelled standard was then added to sample extracts immediately before analysis, to allow the quantification of surrogate standard recovery. Qualitative/quantitative analysis for phthalates was performed with a high-resolution gas chromatograph/low-resolution mass spectrometer/computerised data system. Simultaneous selective ion monitoring and full scan (40-450amu) ion monitoring were performed for phthalate analysis. Analyte identification was confirmed when target ions are detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of the labelled surrogates.

Endosulfan

The endosulfan concentrations in the air samples (captured on the PUF foam, XAD-2 Resin and quartz filter) were measured at NMI by Low Resolution Mass Spectrometry according to the reference method USEPA 3640A. PUF and filters were extracted by a two stage solvent extraction using ethyl acetate: methanol (1:1, stage 1), followed by toluene (stage 2). Deuterated endosulfans were spiked into the extracted sample to act as surrogate standards. After extraction, concentration and splitting, the samples underwent a cleanup process that included silica gel and Waters GPC cleanup. An isotopically labelled standard was then added to sample extracts immediately before analysis, to allow the quantification of surrogate standard recovery. Qualitative/quantitative analysis for endosulfans was performed with a high-resolution gas chromatograph/low-resolution mass spectrometer/computerised data system. Simultaneous selective ion monitoring and full scan (40-450amu) ion monitoring were performed for endosulfan analysis. Analyte identification was confirmed when target ions are detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of the labelled surrogates.

Short Chain Chlorinated Paraffins

The SCCP concentrations in the air samples (captured on the PUF foam, XAD-2 Resin and quartz filter) were measured at NMI by Low Resolution Mass Spectrometry according to the reference method USEPA 3640A. PUF and filters were extracted by a two stage solvent extraction using ethyl acetate: methanol (1:1, stage 1), followed by toluene (stage 2). After extraction, concentration and splitting, the samples underwent a cleanup process that included silica gel and Waters GPC cleanup. Two isotopically labelled standards were then added to sample extracts immediately before analysis, to serve as internal standards for quantification. Qualitative/quantitative analysis for SCCPs was performed with a high-resolution gas chromatograph/low-resolution mass spectrometer/computerised data system. Simultaneous selective ion monitoring (two characteristic ions) and full scan (50-500 amu) ion monitoring were performed for SCCP analysis. Analyte identification was confirmed when target ions were detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of external standards.

Perfluorinated Compounds

The PFC concentration in air samples (captured on the PUF foam, XAD-2 Resin and quartz filter) were measured at NMI by High Performance Liquid Chromatography tandem Mass Spectrometry. PUF and filters were extracted through solvent extraction, using ethyl acetate: methanol (1:1). After extraction, concentration and splitting, the samples underwent a cleanup process. Isotopically labelled standards (four in total) were added to the sample to serve as internal standards for the quantification. The sample was then filtered through Micro-Spin, 0.2 µm centrifuge tubes (10 000 rpm, 5 min). Qualitative/quantitative analysis for PFCs was performed with a high performance liquid chromatograph/triple quadrupole mass spectrometer/computerised data system. Multiple reaction monitoring, or MRM, (two characteristic ions) was performed for PFC analysis. Analyte identification was confirmed when target ions were detected in both the monitored SIM windows in the correct abundance ratio, within established retention time windows. Quantification was based on the use of the labelled surrogates.

Polychlorinated Biphenyl

The PCB concentrations in the air samples (captured on the PUF foam, XAD-2 Resin and quartz filter) were measured at NMI by High Performance Liquid Chromatography tandem Mass Spectrometry. Fifteen ^{13}C isotopically labelled PCBs are spiked into each PUF to act as surrogate standards. PUF and filters were extracted by toluene soxhlet extraction. After extraction, concentration and splitting, the samples underwent a cleanup process that included back-extraction with acid and/or base, gel permeation chromatography (GPC) to remove sulphur contamination, followed by alumina, silica gel, and activated carbon column clean-up. Isotopically labelled standards (four in total) were added to the sample to serve as internal standards for the quantification. The sample was then filtered through Micro-Spin, 0.2 µm centrifuge tubes (10 000 rpm, 5 min). Qualitative/quantitative analysis for PCBs was performed with a high performance liquid chromatograph/high resolution mass spectrometer/computerised data system. Two characteristic ions were selectively monitored for each PCB congener group. Analyte identification is confirmed when target ions were detected in the correct abundance ratio within established retention time windows. Quantification was based on the use of the labelled surrogates.

APPENDIX C. LIMITS OF REPORTING (LOR) FOR MEASURED SPECIES

In this study a number of blank quartz filters and PUFs were analysed for the range of POPs and metals discussed previously. The results from these analyses were used to determine the limits of reporting (LOR) of the analyte and to correct for blank concentrations.

The LOR is the minimum concentration of an analyte that can be reported with confidence. The LOR for each analytical method was supplied by the analytical laboratories engaged in the study. If the method blank has no detectable response for an analyte the LOR is equal to the minimum detection limit (MDL) where MDL for an analyte is the concentration of the analyte resulting in a response three times greater than the background noise. In the case where the analyte has a quantifiable value in the method blank, the LOR value is three times the blank value. Hence the LOR includes the analytical detection limits and any small concentrations of the analyte present on the quartz filters of PUFs before sampling commenced. Since the quartz filters and the PUFs were cleaned prior to use, and the POPs are not ubiquitous, the blank levels were similar to the MDLs. The LOR for the POPs measured in this study are shown in the Tables C 1 to C 6 below. The LOR for metals and mercury are presented in Table C 6.

Table C 1. Limit of reporting for polybrominated diphenyl ethers (PBDE)

Compound	LOR pg	LOR (ng g^{-1})
BDE-17	50	5
BDE-28 + 33	250	25
BDE-30	50	5
BDE-47	500	50
BDE-49	50	5
BDE-66	50	5
BDE-71	50	5
BDE-77	50	5
BDE-85	50	5
BDE-99	500	50
BDE-100	250	25
BDE-119	50	5
BDE-126	50	5
BDE-138 + 166	50	5
BDE-139	50	5
BDE-140	50	5
BDE-153	250	25
BDE-154	100	10
BDE-156 + 169	50	5
BDE-171	50	5
BDE-180	50	5
BDE-183	100	10
BDE-184	100	10
BDE-191	100	10
BDE-196	100	10
BDE-197	100	10
BDE-201	250	25
BDE-203	250	25
BDE-204	250	25
BDE-205	250	25
BDE-206	250	25
BDE-207	250	25
BDE-208	250	25
BDE-209	1000	100
BB-153	100	10

Table C 2. Limits of reporting for perfluorocarboxylic acids (PFAS)

Compound	LOR pg
Perfluoro-n-butanoic acid	250
Perfluoro-n-pentanoic acid	250
Perfluoro-n-hexanoic acid	250
Perfluoro-n-heptanoic acid	250
Perfluoro-n-octanoic acid	250
Perfluoro-n-nonanoic acid	250
Perfluoro-n-decanoic acid	250
Perfluoro-n-undecanoic acid	500
Perfluoro-n-dodecanoic acid	500
Perfluoro-n-tridecanoic acid	500
Perfluoro-n-tetradecanoic acid	500

Table C 3. Limits of reporting for perfluoroalkane sulfonates (PFOS).

Compound	LOR pg
Perfluoro-1-butane sulfonate	250
Perfluoro-1-hexane sulfonate	250
Perfluoro-1-heptane sulfonate	250
Perfluoro-1-octane sulfonate	250
Perfluoro-1-decane sulfonate	500

Table C 4. Limits of reporting for phthalate esters.

Compound	LOR pg
diethyl phthalate	250
di-n-propyl phthalate	250
di-n-butyl phthalate	100
diisobutyl phthalate	100
benzyl butyl phthalate	250
dicyclohexyl phthalate	100
bis(2-ethylhexyl) adipate	100
bis(2-ethylhexyl) phthalate	250
di-n-octyl phthalate	100
diisooctyl phthalate	250

Table C 5. Limits of reporting for polychlorinated biphenyls.

Compound	LOR pg
Non-Ortho PCBs	
PCB 77	50
PCB 81	20
PCB 126	20
PCB 169	20
Mono-Ortho PCBs	
PCB 105	400
PCB 114	20
PCB 118	200
PCB 123	20
PCB 156	100
PCB 157	50
PCB 167	<50
PCB 189	<50

Table C 6. Limits of reporting for endosulfan, SCCPs and metals and mercury

Compound	LOR ng/ sample
α-endosulfan	0.1
β-endosulfan	0.1
endosulfan sulfate	0.1
SCCPs	50
lead	0.05
cadmium	0.05
nickel	0.05
mercury	0.5 – 1.0

APPENDIX D. RESULTS OF DWELLING AND CHEMICAL SURVEYS

Household Survey

Proximity to roads

Table D 1. Distance of dwelling from road and main road.

Distance From Road (m)	Frequency	Distance from main road (m)	Frequency
Distance ≤ 10	5	Distance ≤ 10	1
10 < Distance ≤ 500	5	10 < Distance ≤ 500	4
500 < Distance ≤ 1000	0	500 < Distance ≤ 1000	2
Distance > 1000	0	Distance > 1000	3
Total	10		10

Table D 2. Distance to construction, transformers and petrol stations.

Proximity To Other Sources - Distance in metres			
Dwelling	Construction	Transformers	Petrol Stations
POP1	N/A	N/A	N/A
POP2	N/A	N/A	100m
POP3	90m	2 in antique projectors in the house	N/A
POP4	N/A	N/A	N/A
POP5	N/A	30m	N/A
POP6	N/A	500m	N/A
POP7	50m	290m	N/A
POP8	N/A	150m	N/A
POP9	N/A	500m	N/A
POP10	N/A	N/A	>100m

Table D 3. Cooking and combustion.

Cooking and Combustion	No. Dwellings (%)	
	Gas	Electricity
Hot Water Unit	10 (100%)	0 (0%)
Stove Top	9 (90%)	1 (10%)
Oven	3 (30%)	7 (70%)
Other Combustion Activities	No. Dwellings (%)	
Smoking Indoors	0 (0%)	
Smoking Outdoors	1 (10%)	
Burning candles	0 (0%)	

Table D 4. Heating types in dwellings.

Main Heating		
Gas	9 (90%)	5 of which are ducted to all rooms
Wood	1 (10%)	
Electric	0 (0%)	
Total	10 (100%)	All houses had at least one source of heating
	Secondary Heating	
Gas	0 (0%)	
Wood	1 (10%)	
Electric	3 (30%)	
Total	4 (40%)	40% of houses had secondary heating

Table D 5. Numbers and age of air conditioners in dwellings.

Air conditioners per dwelling (number)	Number of dwellings	Age of air conditioners (years)	Number air conditioners
0	1	age < 1	1
1	7	1 ≤ age < 2	2
2	2	2 ≤ age < 5	1
> 2	0	5 ≤ age < 10	2
Total number of dwellings	10	age ≥ 10	3
		Unknown	2
		total number	11

Table D 6. Number and age of refrigerators in dwellings

Fridges in the dwellings (number)	Number of dwellings	Age of fridges (years)	Number of fridges
1	6	age < 1	0
2	3	1 ≤ age < 5	2
> 2	1	5 ≤ age < 10	4
Total number of dwellings	10	10 ≤ age < 20	7
Total number of fridges	16	age ≥ 20	3
		total number	16

Table D 7. Furnishings in 7 homes (note that the surveys of furnishings in 3 homes was not accurately carried out)

Plastic furniture (number)	Frequency
0	2
1 -5	3
6 -10	1
>10	1

Fabric furniture (number)	Frequency
0	1
1 -5	2
6 -10	1
11- 20	2
> 20	1

Vinyl furniture (number)	Frequency
0	3
1 - 5	3
6 -10	0
> 10	1

Electrical appliances (number)	Frequency
0-5	0
6-10	1
11-20	1
21-30	4
> 30	1

Plastic toys (number)	Frequency
0	3
1-50	1
51-100	1
>100	2

TVs (number)	Frequency
0	0
1	3
2	3
3	1
> 3	0

Computers (number)	Frequency
0	4
1	2
2	1
> 2	0

Table D 8. Energy efficient light globes (source of mercury**)**

Low energy light globes (number)	Frequency
0	2
2	0
4	2
6	3
8	1
10	0
12	2
> 12	0

Table D 9. Volume of petrol stored on five properties

volume of petrol stored on property (L)	Frequency
0	0
2	1
5	3
10	1
> 10	0

Table D 10. Kettles and hot water sevices

all dwellings have one electric kettle
all hot water servers are gas powered

Table D 11. Garages

3 dwellings had attached garages
Of these only two had cars stored in garages

Table D 12. Chemical durvey from five dwellings. Note volumes are based on container sizes.

	Number of dwellings	Average (ml)	Minimum (ml)	Maximum (ml)	Median (ml)
Liquids					
carpet cleaner	3	817	250	1700	500
detergent	5	2390	450	5750	1750
floor/toilet cleaner	5	1810	500	4750	1000
glues	1	1000	1000	1000	1000
nails	3	279	137	500	200
paint	2	5000	4000	6000	5000
personal products	5	3000	1500	5500	3000
petrol	2	1500	1000	2000	1500
pesticides etc	3	1542	500	3175	950
polish	3	317	200	500	250
stain remover	4	855	400	1170	925
surface cleaner	5	2280	1000	4150	2000
solvents	5	1210	500	2000	1050
aerosols					
degreaser	3	1075	225	2500	500
personal products	3	700	300	1000	800
pesticides etc	2	1075	700	1450	1075
polish	2	290	250	330	290
scotchguard	2	325	300	350	325
stain remover	3	467	250	775	375
solids		**average (g)**	**min (g)**	**max (g)**	**median (g)**
detergents	5	2700	1000	7500	1500
fertilisers	1	1000	1000	1000	1000
oven cleaner	3	342	125	500	400
surface cleaner	1	2000	2000	2000	2000

APPENDIX E. RESULTS

Metals, Mercury and Total Suspended Particulate

Table E 1 presents the mass of total suspended particles (TSP) in μg m^{-3} in air (measured on the stretched Teflon filters) collected indoors and outdoors of each of the dwellings.

Table E 1. Sampling periods for TSP filters, and TSP mass concentrations

Sample No.	Date/time On	Date/time Off	TSP μg m^{-3}
Metal1-In	31/12/2008 12:45	07/01/2009 10:51	4.8
Metal1-Out	31/12/2008 12:25	07/01/2009 11:20	18.6
Metal2-In	02/01/2009 13:57	09/01/2009 10:39	6.6
Metal2-Out	02/01/2009 11:20	09/01/2009 10:29	23.6
Metal3-In	08/01/2009 11:15	15/01/2009 10:09	12.6
Metal3-Out	08/01/2009 10:56	15/01/2009 10:24	27.9
Metal4-In	12/01/2009 10:33	19/01/2009 10:20	9.0
Metal4-Out	12/01/2009 10:58	19/01/2009 10:09	26.7
Metal5-In	20/01/2009 11:30	27/01/2009 11:10	13.4
Metal5-Out	20/01/2009 11:44	27/01/2009 11:00	48.6
Metal6-In	21/01/2009 10:54	28/01/2009 11:37	9.4
Metal6-Out	21/01/2009 11:10	28/01/2009 11:02	55.4
Metal7-In	29/01/2009 10:20	05/02/2009 10:16	14.3
Metal7-Out	29/01/2009 11:00	05/02/2009 10:05	38.5
Metal8-In	30/01/2009 10:26	06/02/2009 09:19	18.3
Metal8-Out	30/01/2009 10:25	06/02/2009 09:08	31.7
Metal9-In	09/02/2009 11:40	16/02/2009 10:21	18.2
Metal9-Out	09/02/2009 10:54	16/02/2009 09:56	32.4
Metal10-In	10/02/2009 11:00	17/02/2009 10:10	11.2
Metal10-Out	10/02/2009 10:30	17/02/2009 10:01	36.0

Table E 2 presents the concentrations of gaseous mercury in ng m^{-3} measured indoors and outdoors of each dwelling. Mercury was not measured outside at dwelling 5 because a malfunction in the sampler resulted in an uncertain flow rate.

Table E 2 Mercury gas concentrations measured indoors and outdoors of 10 dwellings.

Sample No.	Date/Time On	Date/Time Off	Mercury gas ng m^{-3}
Hg1-In	31/12/2008 12:40	07/01/2009 10:15	6.05
Hg1-Out	31/12/2008 12:45	07/01/2009 11:05	0.71
Hg2-In	02/01/2009 12:22	09/01/2009 10:42	3.59
Hg2-Out	02/01/2009 11:30	09/01/2009 10:19	0.92
Hg3-In	08/01/2009 11:36	15/01/2009 10:32	3.58
Hg3-Out	08/01/2009 11:46	15/01/2009 10:15	0.60
Hg4-In	12/01/2009 11:45	19/01/2009 10:15	2.76
Hg4-Out	12/01/2009 11:26	19/01/2009 10:21	0.92
Hg5-In	20/01/2009 11:43	27/01/2009 11:21	1.33
Hg6-In	21/01/2009 11:37	28/01/2009 10:42	13.42
Hg6-Out	21/01/2009 11:35	28/01/2009 10:38	0.75
Hg7-In	29/01/2009 10:45	05/02/2009 10:52	11.22
Hg7-Out	29/01/2009 11:14	05/02/2009 10:06	1.55
Hg8-In	30/01/2009 11:18	06/02/2009 09:47	1.17
Hg8-Out	30/01/2009 10:24	06/02/2009 09:07	0.67
Hg9-In	09/02/2009 11:47	16/02/2009 10:28	1.88
Hg9-Out	09/02/2009 11:15	16/02/2009 10:00	0.86
Hg10-In	10/02/2009 11:47	17/02/2009 10:27	1.94
Hg10-Out	10/02/2009 10:50	17/02/2009 10:02	0.72

Table E 3 lists the concentrations in ng m^{-3} of cadmium, lead and nickel measured in air indoors and outdoors of the dwellings. During the study six stretched Teflon filters were analysed as blanks, and the analytical results for them are also given in the Table.

Table E 3. Particulate metal concentrations measured indoors and outdoors of dwellings.

Sample No.	Date/Time On	Date/Time Off	Cd ng m^{-3}	Pb ng m^{-3}	Ni ng m^{-3}
Metal1-In	31/12/2008 12:45	07/01/2009 10:51	<1.7	6.4	2.0
Metal1-Out	31/12/2008 12:25	07/01/2009 11:20	<1.7	3.3	<1.7
Metal2-In	02/01/2009 13:57	09/01/2009 10:39	<1.7	2.4	<1.7
Metal2-Out	02/01/2009 11:20	09/01/2009 10:29	<1.7	3.0	5.3
Metal3-In	08/01/2009 11:15	15/01/2009 10:09	<1.7	1.7	8.0
Metal3-Out	08/01/2009 10:56	15/01/2009 10:24	<1.7	2.7	<1.7
Metal4-In	12/01/2009 10:33	19/01/2009 10:20	<1.7	<1.7	<1.7
Metal4-Out	12/01/2009 10:58	19/01/2009 10:09	<1.7	<1.7	<1.7
Metal5-In	20/01/2009 11:30	27/01/2009 11:10	<1.7	<1.7	<1.7
Metal5-Out	20/01/2009 11:44	27/01/2009 11:00	<1.7	2.7	2.0
Metal6-In	21/01/2009 10:54	28/01/2009 11:37	<1.7	<1.7	<1.7
Metal6-Out	21/01/2009 11:10	28/01/2009 11:02	<1.7	5.6	4.0
Metal7-In	29/01/2009 10:20	05/02/2009 10:16	<1.7	6.9	2.0
Metal7-Out	29/01/2009 11:00	05/02/2009 10:05	<1.7	4.7	2.3
Metal8-In	30/01/2009 10:26	06/02/2009 09:19	<1.7	<1.7	<1.7
Metal8-Out	30/01/2009 10:25	06/02/2009 09:08	<1.7	<1.7	<1.7
Metal9-In	09/02/2009 11:40	16/02/2009 10:21	<1.7	<1.7	<1.7
Metal9-Out	09/02/2009 10:54	16/02/2009 09:56	<1.7	2.0	<1.7
Metal10-In	10/02/2009 11:00	17/02/2009 10:10	<1.7	<1.7	<1.7
Metal10-Out	10/02/2009 10:30	17/02/2009 10:01	<1.7	5.3	<1.7
Blank 1			<1.7	<1.7	<1.7
Blank 2			<1.7	<1.7	<1.7
Blank 3			<1.7	<1.7	<1.7
Blank 4			<1.7	<1.7	<1.7
Blank 5			<1.7	<1.7	<1.7
Blank 6			<1.7	<1.7	<1.7

Polybrominated Diphenyl Ethers

Table E 4 presents the mass concentrations of 35 congeners measured in the dust collected from the 10 dwellings employed in this study.

Table E 5 presents the mass concentration of 35 congeners measured in the air samples collected indoors and outdoors of the 10 dwellings sampled in this study.

Table E 4 Mass concentrations of PBDE congeners measured in dust from 10 dwellings (ng g^{-1}).

PBDE Congener	POP-1	POP-2	POP-3	POP-4	POP-5	POP-6	POP-7	POP-8	POP-9	POP-10
BDE-17	0.25	0.11	0.2	0.18	0.084	0.13	0.35	0.29	0.33	0.48
BDE-28 + 33	1.1	0.41	0.91	0.8	0.34	0.47	1.1	1.1	1.5	1.9
BDE-30	<0.005	<0.01	<0.02	<0.003	<0.002	<0.002	<0.007	<0.01	<0.008	<0.008
BDE-47	77	30	40	58	18	22	190	62	77	71
BDE-49	2	0.72	1.1	1.3	0.59	0.64	2.3	1.8	2.6	2.2
BDE-66	2.3	0.64	1.1	1.3	0.53	0.62	2.7	1.3	2.1	1.9
BDE-71	<0.003	<0.007	<0.003	<0.0004	<0.004	<0.002	<0.002	<0.004	<0.007	<0.0004
BDE-77	0.096	0.0035	0.015	0.0085	0.017	0.028	0.028	0.0065	0.019	0.027
BDE-85	6.1	1.7	2.3	5.1	2.4	1.5	16	2.7	2.8	2.7
BDE-99	120	35	48	78	35	29	340	62	68	68
BDE-100	25	7.5	9.9	14	5.8	5.7	38	11	15	15
BDE-119	0.21	0.05	0.087	0.097	0.055	0.048	<0.6	0.097	0.15	0.15
BDE-126	0.011	<0.003	0.0074	0.0066	<0.003	0.0017	0.0094	<0.008	0.0051	0.0076
BDE-138 + 166	1.6	0.59	0.66	1.1	1.9	0.67	5.7	0.85	0.8	0.73
BDE-139	2.6	0.82	0.91	1.8	1.3	0.63	5.1	1	0.96	1.2
BDE-140	0.79	0.28	0.32	0.53	0.57	0.18	1.1	0.27	0.29	0.36
BDE-153	17	7.2	5.7	8	13	6.9	43	6.9	7.1	7.9
BDE-154	11	3.2	4	5.9	4.1	2.2	17	4.4	4.8	6.1
BDE-156 + 169	<0.04	<0.02	<0.01	<0.009	<0.05	<0.02	<0.05	<0.02	<0.02	<0.03
BB -153	0.12	0.27	0.22	0.43	0.13	4.6	0.35	62	0.089	0.16
BDE-171	1.3	1.5	0.32	0.25	3.4	1.5	0.35	0.19	0.96	0.75
BDE-180	2	1.8	0.61	0.4	3.6	2	0.65	0.53	1.2	1.3
BDE-183	23	30	6.1	3.8	49	29	7	11	14	15
BDE-184	0.5	0.32	0.17	0.11	0.78	0.21	0.18	0.13	0.26	0.39
BDE-191	0.29	0.23	0.094	0.059	0.5	0.13	0.11	0.069	0.18	0.28
BDE-196	6.3	5.6	1.8	1.1	11	5.2	2.1	2.1	4.4	4.1
BDE-197	11	12	2.9	1.6	22	11	2.9	4.8	7	6.3
BDE-201	1.4	0.75	0.62	0.36	2.2	0.77	0.64	0.58	0.94	1.6

Table E4. Continued

PBDE Congener	POP-1	POP-2	POP-3	POP-4	POP-5	POP-6	POP-7	POP-8	POP-9	POP-10
BDE-203	4.6	3.7	1.6	0.92	7.2	3.8	1.9	2.2	3.2	4.1
BDE-204	<0.1	<0.09	<0.03	<0.02	<0.2	<0.1	<0.04	<0.06	<0.06	<0.1
BDE-205	0.052	0.031	<0.1	<0.01	0.08	0.044	0.042	0.047	0.066	0.098
BDE-206	56	7.9	15	8.8	61	18	27	11	33	30
BDE-207	35	12	12	7.1	41	18	14	10	23	22
BDE-208	15	3.2	6.2	3.5	17	6.2	8.1	5.1	11	13
BDE-209	1750	130	380	190	2000	360	650	240	900	720
Fraction of BDE 209, %	80.5	43.7	70.0	48.2	86.9	67.8	47.2	47.5	76.1	72.1
Sum of congeners	**2173.6**	**297.5**	**542.8**	**394.6**	**2302.6**	**531.2**	**1377.7**	**505.5**	**1182.7**	**998.7**

Table E 5. Ambient concentrations of PBDE congeners measured in air indoors and outdoors of 10 dwellings (pg m^{-3}).

PBDE Congener	POP-1 in	POP-1out	POP-2 in	POP-2out	POP-3 in	POP-3out	POP-4 in	POP-4out	POP-5in	POP-5out
BDE-17	4.23	0.16	1.19	0.11	1.81	0.24	2.24	0.24	1.36	0.24
BDE-28 + 33	<2.85	<2.85	1.82	<2.85	<2.85	<2.85	<2.85	<2.85	2.53	<2.85
BDE-30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
BDE-47	68.95	7.69	18.19	1.89	26.81	8.05	11.44	7.54	18.09	<5.19
BDE-49	3.23	0.46	1.01	0.28	1.77	0.52	1.29	0.33	1.21	0.49
BDE-66	1.40	0.31	0.43	0.21	0.79	0.37	0.69	0.18	0.55	0.19
BDE-71	0.24	0.06	0.07	0.02	<0.01	<0.01	0.13	<0.01	0.08	0.05
BDE-77	0.05	0.02	0.005	<0.01	<0.01	0.02	0.02	<0.01	0.02	<0.01
BDE-85	0.30	<0.07	0.07	0.05	0.25	0.17	<0.07	0.13	<0.07	<0.07
BDE-99	14.46	5.84	3.06	1.80	9.77	6.35	3.05	<1.83	4.55	<1.83
BDE-100	5.18	1.54	1.05	0.57	2.97	1.61	0.91	<0.44	1.36	0.68
BDE-119	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-138 + 166	<0.07	<0.07	<0.07	<0.07	0.06	<0.07	0.08	<0.07	<0.07	<0.07
BDE-139	0.01	<0.02	0.02	0.02	<0.02	<0.02	0.01	0.02	<0.02	0.03
BDE-140	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
BDE-153	0.61	0.22	0.33	0.12	0.62	<0.09	<0.09	<0.09	0.18	<0.09
BDE-154	0.52	0.21	0.21	0.12	0.57	0.31	<0.08	<0.08	<0.08	<0.08
BDE-156 + 169	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
BB-153	<0.02	0.05	0.76	2.31	0.34	<0.02	0.18	<0.02	0.05	0.06
BDE-171	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01
BDE-180	<0.01	<0.01	0.02	<0.01	0.16	<0.01	0.03	<0.01	<0.01	<0.01
BDE-183	0.56	0.22	1.43	0.18	0.47	0.31	0.52	<0.02	0.28	0.13
BDE-184	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-191	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-196	0.07	<0.02	0.12	0.12	2.86	0.06	0.30	0.03	0.04	0.07

Table E 5. Continued

PBDE Congener	POP-1 in	POP-1out	POP-2 in	POP-2out	POP-3 in	POP-3out	POP-4 in	POP-4out	POP-5in	POP-5out
BDE-197	0.09	<0.02	0.15	0.04	1.18	0.14	0.24	0.02	0.05	0.04
BDE-201	<0.02	<0.02	0.01	<0.02	1.34	0.05	<0.02	0.01	<0.02	0.04
BDE-203	<0.04	<0.04	0.10	<0.04	3.57	0.10	0.29	0.07	0.06	0.06
BDE-204	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BDE-205	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
BDE-206	0.10	0.65	0.17	0.21	45.94	0.79	0.44	0.42	0.35	0.93
BDE-207	0.08	0.34	0.13	0.18	32.07	0.51	<0.05	<0.05	0.26	0.48
BDE-208	<0.02	<0.02	0.07	0.09	20.10	0.21	0.11	0.09	<0.02	0.30
BDE-209	1.09	6.61	1.48	2.70	253.20	8.00	5.19	6.48	6.14	14.05
Sum of congeners	**101.17**	**24.39**	**31.90**	**11.03**	**406.63**	**27.81**	**27.18**	**15.55**	**37.16**	**17.86**

Table E 5. Continued

PBDE Congener	POP-6 In	POP-6 Out	POP-7 In	POP-7 Out	POP-8 In	POP-8 Out	POP-9 In	POP-9 Out	POP-10 In	POP-10 Out
BDE-17	1.90	0.31	2.02	0.22	5.98	0.18	3.90	0.11	8.12	0.15
BDE-28 + 33	<2.85	<2.85	5.22	<2.85	17.38	<2.85	12.83	<2.85	20.37	1.99
BDE-30	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.03	<0.05
BDE-47	13.02	14.42	30.41	9.31	227.52	<5.19	97.29	<5.19	134.68	11.15
BDE-49	0.99	0.65	1.64	0.46	7.99	0.31	4.77	<0.05	6.64	0.32
BDE-66	0.39	0.46	0.71	0.31	4.19	0.18	2.10	0.10	2.27	0.27
BDE-71	0.10	<0.01	0.17	0.04	0.54	0.03	0.32	<0.01	0.39	0.01
BDE-77	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
BDE-85	<0.07	<0.07	0.25	<0.07	0.99	<0.07	0.24	<0.07	0.23	<0.07
BDE-99	<1.83	7.56	8.64	6.61	53.44	<1.83	13.34	<1.83	15.12	3.67
BDE-100	0.99	2.14	2.32	1.76	17.16	<1.83	4.72	<0.44	6.11	1.19
BDE-119	<0.01	<0.01	<0.01	<0.01	0.10	<0.01	0.04	<0.01	0.06	<0.01
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-138 + 166	<0.07	<0.07	<0.07	<0.07	0.07	<0.07	<0.07	<0.07	<0.07	<0.07
BDE-139	<0.02	<0.02	<0.02	0.03	0.12	0.003	0.046	<0.02	<0.02	<0.02
BDE-140	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
BDE-153	0.22	0.22	0.46	<0.09	0.82	<0.09	0.35	0.19	0.24	<0.09
BDE-154	<0.08	0.27	0.38	<0.08	1.47	<0.08	0.45	<0.08	0.40	<0.08
BDE-156 + 169	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
BB-153	0.30	0.16	0.06	0.11	10.00	0.13	0.06	<0.02	<0.02	0.40
BDE-171	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-180	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-183	0.22	0.08	0.30	0.20	0.15	0.15	0.23	0.11	0.13	0.09
BDE-184	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-191	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table E5. Continued

PBDE Congener	POP-6 In	POP-6 Out	POP-7 In	POP-7 Out	POP-8 In	POP-8 Out	POP-9 In	POP-9 Out	POP-10 In	POP-10 Out
BDE-196	<0.02	<0.02	0.19	0.13	0.07	0.10	0.06	<0.02	<0.02	<0.02
BDE-197	0.06	0.06	0.14	0.07	0.05	0.08	0.05	<0.02	<0.02	<0.02
BDE-201	<0.02	<0.02	0.07	0.05	0.02	<0.02	0.04	<0.02	<0.02	0.03
BDE-203	<0.04	0.04	0.16	0.12	0.08	0.11	<0.04	<0.04	<0.04	<0.04
BDE-204	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BDE-205	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
BDE-206	<0.05	<0.05	1.03	1.78	0.45	0.94	0.41	0.45	0.40	0.34
BDE-207	0.10	0.20	0.70	0.98	0.29	0.65	0.22	0.26	<0.05	0.20
BDE-208	0.07	0.14	0.42	0.56	0.13	0.36	0.11	0.19	0.15	0.13
BDE-209	<0.61	5.10	10.29	41.51	6.55	24.04	5.75	9.76	6.17	9.65
Sum of congeners	**18.37**	**31.81**	**65.63**	**64.26**	**355.57**	**27.25**	**147.30**	**11.17**	**201.56**	**29.57**

Phthalates

Table E 6 gives the indoor concentrations of the 16 phthalates measured in air during this study. The other 11 phthalates analysed during the study were not detected in any of the indoor samples. The limit of reporting for those compounds was <0.1 ng m^{-3}.

Table E 6. Concentrations of the phthalate esters measured in air indoors of 10 dwellings.

Compound	POP-1 ng m^{-3}	POP-2 ng m^{-3}	POP-3 ng m^{-3}	POP-4 ng m^{-3}	POP-5 ng m^{-3}	POP-6 ng m^{-3}	POP-7 ng m^{-3}	POP-8 ng m^{-3}	POP-9 ng m^{-3}	POP-10 ng m^{-3}
DMP	8.9	14.2	21.9	3.12	15.1	3.04	11.1	5.88	2.30	2.04
DEP	78.3	83.6	117.1	173.7	73.7	<0.01	95.0	67.4	41.0	59.7
DIBP	<105	<105	<103	<150	96.9	686.3	137.4	141.8	59.6	63.8
DNBP	108.8	157.4	190.9	<20	80.5	354.7	106.8	104.6	67.2	66.5
BBP	1.65	10.7	<3	<1	1.94	7.92	14.8	15.2	1.54	0.47
DCHP	<2	<3	<3	<4	<1	<4	<3	<0.1	<0.6	<2
BEHP	117.3	142.0	<0.14	<94	<17	<12	<20	<20	<17	<0.14
DNOP	<0.6	<1	<0.6	<2	<0.6	<0.6	<1	<0.4	<0.4	<1
BMEP	<1	<1	<2	<1	<0.1	<2	<1	<0.6	<0.6	<0.4
BEEP	<1	<1	<1	<1	<1	<1	<1	<1	<0.8	<0.8
DPP	<0.1	<0.3	<0.1	<0.2	<0.1	<0.4	<0.1	<0.4	<0.1	<0.1
BMPP	<0.7	<0.7	<1	<1	<0.1	<0.2	<0.7	<1	<0.7	<0.3
DNHP	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.2	<0.3	<0.1	<0.1
BBEP	<0.9	<1.8	<4	<1	<0.4	<3	<1	<0.9	<0.4	<1
DNP	<0.1	<0.8	<0.2	<0.2	<0.1	<1	<0.3	<1	<0.1	<0.1
BEHA	<1.4	<1	<2	<2	2.2	8.96	<2.9	<3	<1	<2

Endosulfan

The results of the concentrations of α-endosulfan, β-endosulfan and endosulfan sulfate measured in air outside of 10 dwellings in Melbourne are presented in Table E 7.

Table E 7. Concentrations of α-endosulfan, β-endosulfan and endosulfan sulfate in air outdoors of 10 dwellings.

Compound	POP-1 pg m^{-3}	POP-2 pg m^{-3}	POP-3 pg m^{-3}	POP-4 pg m^{-3}	POP-5 pg m^{-3}	POP-6 pg m^{-3}	POP-7 pg m^{-3}	POP-8 pg m^{-3}	POP-9 pg m^{-3}	POP-10 pg m^{-3}
α-Endosulfan	2.7	2.8	8.3	6.4	6.9	8.5	13.8	10.8	6.5	8.0
β-Endosulfan	<0.02	<0.02	1.3	0.9	<0.02	<0.02	1.5	1.3	<0.02	<0.02
Endosulfan Sulfate	0.03	<0.02	<0.02	0.12	<0.02	<0.02	0.6	0.4	<0.02	<0.02

Short Chain Chlorinated Paraffins

The concentrations of total short chain chlorinated paraffins in air are presented in Table E 8.

Table E 8. Concentration of SCCPs measured in air indoors and outdoors of 10 dwellings.

Sample	Σ SCCPs ng m^{-3}
POP-1 In	42.0
POP-1 Out	91.4
POP-2 In	51.9
POP-2 Out	70.2
POP-3 In	51.9
POP-3 Out	112.9
POP-4 In	56.4
POP-4 Out	60.2
POP-5 In	46.9
POP-5 Out	140.3
POP-6 In	86.8
POP-6 Out	164.0
POP-7 In	121.2
POP-7 Out	163.1
POP-8 In	64.3
POP-8 Out	56.5
POP-9 In	34.5
POP-9 Out	70.5
POP-10 In	43.4
POP-10 Out	56.7

Perfluorinated Compounds

The concentrations of perfluorinated compounds in air are presented in Table E 9.

Table E 9. Concentrations of perfluorinated compounds measured in air indoors and outdoors of 10 dwellings.

Sample	PFOS pg m^{-3}	PFOA pg m^{-3}	PFHS pg m^{-3}	PFNA pg m^{-3}
POP-1 In	5.53	8.19	<1.0	8.32
POP-1 Out	1.56	2.88	<1.0	<1.2
POP-2 In	15.62	30.27	<1.0	3.21
POP-2 Out	1.96	1.05	<1.0	<1.2
POP-3 In	9.88	11.60	<1.0	2.30
POP-3 Out	2.55	<1.8	<1.0	<1.2
POP-4 In	5.07	9.64	<1.0	3.38
POP-4 Out	1.24	<1.8	<1.0	<1.2
POP-5 In	25.57	22.99	0.84	7.87
POP-5 Out	5.00	2.17	<1.0	<1.2
POP-6 In	22.21	85.78	<1.0	7.54
POP-6 Out	5.64	2.24	<1.0	<1.2
POP-7 In	6.65	20.12	<1.0	2.54
POP-7 Out	5.13	4.45	<1.0	<1.2
POP-8 In	4.78	30.16	<1.0	18.28
POP-8 Out	7.11	<1.8	<1.0	<1.2
POP-9 In	31.29	6.89	1.63	0.44
POP-9 Out	3.06	2.77	<1.0	0.86
POP-10 In	349.49	109.87	17.90	4.61
POP-10 Out	3.28	3.46	<1.0	<1.2

Polychlorinated Biphenyls

Table E 10 presents the concentrations of the range of PCBs measured in air indoors and outdoors of the 10 dwellings measured during this study.

Table E 10. Concentrations of polychlorinated biphenyls measured in air indoors and outdoors of 10 dwellings.

Sample	PCB 77 pg m^{-3}	PCB 81 pg m^{-3}	PCB 126 pg m^{-3}	PCB 169 pg m^{-3}	PCB 105 pg m^{-3}	PCB 114 pg m^{-3}	PCB 118 pg m^{-3}	PCB 123 pg m^{-3}	PCB 156 pg m^{-3}	PCB 157 pg m^{-3}	PCB 167 pg m^{-3}	PCB 189 pg m^{-3}	ΣPCB pg m^{-3}
POP-1 In	1.98	0.11	0.02	<0.001	5.23	0.47	16.51	0.24	0.41	0.09	0.21	<0.01	25.26
POP-1 Out	0.20	0.01	0.01	<0.001	1.34	0.08	4.16	0.07	0.20	0.05	0.10	<0.01	6.21
POP-2 In	2.79	0.13	0.04	<0.001	17.71	1.30	55.89	0.80	1.70	0.38	0.75	0.01	81.51
POP-2 Out	0.24	0.01	0.02	<0.001	1.31	0.09	3.76	0.06	0.21	0.04	0.09	<0.01	5.83
POP-3 In	2.84	0.18	0.03	<0.001	19.79	1.65	67.11	1.12	1.85	0.31	0.74	0.07	95.70
POP-3 Out	0.29	0.01	0.01	<0.001	1.71	0.12	4.56	0.09	<0.2	<0.02	<0.08	<0.01	6.81
POP-4 In	1.08	0.07	0.01	<0.001	3.77	0.37	11.52	0.26	<0.2	0.07	<0.08	<0.01	17.15
POP-4 Out	0.13	0.01	<0.008	<0.001	0.89	0.06	<0.80	<0.06	<0.2	<0.02	<0.08	<0.01	1.09
POP-5 In	1.33	0.08	0.02	<0.001	3.93	0.34	12.93	0.20	0.41	0.08	0.18	0.01	19.51
POP-5 Out	0.45	0.02	0.03	0.001	1.99	0.15	6.18	0.08	<0.2	0.06	0.13	<0.01	9.10
POP-6 In	4.05	0.28	<0.008	<0.001	11.87	1.16	42.60	0.73	0.68	0.14	0.34	<0.01	61.87
POP-6 Out	0.38	0.02	<0.008	<0.001	1.65	0.12	5.05	0.06	<0.2	0.08	0.16	<0.01	7.51
POP-7 In	15.59	0.97	0.16	0.002	65.20	5.11	243.40	3.13	5.64	1.05	2.51	0.06	342.82
POP-7 Out	0.62	0.03	0.03	<0.001	2.65	0.21	8.11	0.12	0.33	0.06	0.14	0.01	12.30
POP-8 In	7.89	0.47	0.06	<0.001	19.68	1.74	57.46	1.05	1.70	0.30	0.75	<0.01	91.10
POP-8 Out	0.28	0.01	0.01	<0.001	1.08	<0.02	2.97	0.04	0.12	0.03	0.09	0.01	4.63
POP-9 In	1.73	0.11	0.01	<0.001	5.90	0.51	18.31	0.32	0.41	0.09	0.16	0.01	27.56
POP-9 Out	0.23	0.01	<0.008	<0.001	<0.3	<0.02	<0.80	<0.06	<0.2	0.03	<0.08	<0.01	0.27
POP-10 In	0.26	<0.002	0.01	<0.001	3.07	0.36	12.48	0.17	0.40	0.07	0.15	0.06	17.04
POP-10 Out	0.75	0.04	0.00	<0.001	1.00	0.08	3.14	0.05	0.14	<0.02	<0.08	<0.01	5.19