Grenfell Investigation into Potential Land Contamination Impacts

Technical Note 07: Review of Fire Effluent Environmental Fate and Transport

Royal Borough of Kensington and Chelsea

Project number: 60595731

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Quality information

Prepared by	Checked by	Verified by	Approved by
	Kevin Shepherd	Philp	Philp
Simon Cole Technical Director	Kevin Shepherd Associate Director	Liz Philp Technical Director	Liz Philp Technical Director

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Prepared for:

Royal Borough of Kensington and Chelsea

Prepared by:

AECOM Infrastructure & Environment UK Limited
Sunley House
4 Bedford Park, Surrey
Croydon CRO 2AP
United Kingdom

T: +44 20 8639 3500
aecom.com

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1. Introduction

This Technical Memo presents the methodology and findings of an evidence review into the environmental fate and transport of contaminants that may have been generated by the Grenfell Tower fire and which may potentially have been deposited on the surrounding soils.

The primary question to be answered by this review is:

- What is the environmental fate of the contaminants of potential concern (COPCs) deposited to soil as a result of the Grenfell Tower fire?
- Are the COPCs deposited likely to be persistent in the soil environment?

2. Methodology

Guidance on evidence reviews was published by Defra in 2015 in the form of two reports[1][2]. These describe four types of evidence review (ER), spanning from literature reviews (LR), quick scoping reviews (QSR), and rapid evidence assessments (REA), to systematic reviews (SR). The QSR approach has been used for this work for the following reasons:

- The intent of the work is to provide a general understanding of the evidence base; through the identification of the evidence available and summarising it.
- A critical appraisal of the robustness of individual studies is not required.
- Evidence bias is sufficiently mitigated by the review approach – focusing on common consensus in studies from independent sources.
- It involves the search and review of a selection of sources, rather than an extensive review of all possible sources of evidence, which is compatible with the programme for this work.

Table TN07-01 sets out the review protocol followed in this review.

Table TN07-01: Review Protocol – COPC Environmental Fate and Transport Quick Scoping Review

Protocol Element	
Authors:	AECOM
Background rationale:	Requirement to understand the nature of and differences between fire effluent chemicals in the environment and the relevance to public health.
Objective:	Identify the environmental fate and transport of the chemicals of potential concern (COPC) identified by the fire chemistry evidence review.
Scope:	Focus on environmental persistence, mobility, and degradation. Qualitative information only. No geographic or date restriction. Limited to English language only.
Method: Search keywords	Environmental fate, persistence, mobility, (bio)degrada(tion)(bility), hazard summary, exposure, [names of COPC].
Method: Search strategy[3]	Published reviews or opinions identified using the following sources: Defra, Environment Agency, HPA/PHE, EFSA, LQM/CIEH. Searchable chemical databases: US NLM NIH TOXNET HSDB, WHO IPCS INCHEM, PubChem, OECD eChemPortal, ECHA. Inclusion of relevant sources identified in the fire chemistry evidence review: Agency for Toxic Substances and Disease Registry.

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[1] Collins, A.M., Coughlin, D., Miller, J., Kirk, S. 2015. The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide

[2] Defra. 2015. Emerging Tools and Techniques to Deliver Timely and Cost Effective Evidence Reviews. Final report WT1552

Protocol Element	
Method: Inclusion and exclusion criteria	Include compounds identified during fire chemistry evidence review
Method: Information extraction	Initial extraction from abstract only. Selection of full papers to be based on the results of the first phase screening. Information to be recorded as per the evidence template below
Information synthesis	To include: Descriptive characteristics of evidence identified A narrative synthesis of the evidence

3. Sources of Evidence

Sources of evidence were identified by:

- Web searches as presented in **Appendix TN07-A.**

The sources of evidence used in this QSR are presented in **Appendix TN07-B.**

4. Summary of Evidence

The classes of contaminants that have been identified in the evidence as potential contaminants arising from building fires are listed in **Table TN07-02**. For each class of contaminants, a summary of the available fate and transport evidence is provided.

Table TN07-02: List of Contaminants of Potential Concern

Category	Specific compounds or elements
Metals	
	Lead
Polycyclic Aromatic Hydrocarbons	
	USEPA priority 16 PAH 7,12-dimethylbenzo(a)anthracene
Dioxins and Furans	
	PCDD
	PCDF
	PBDD
	PBDF
	PXDD
	PXDF
Isocyanates	
	Isocyanic acid
	Methyl isocyanate
	Ethyl isocyanate
	Propyl isocyanate
	Phenyl isocyanate
	Hexamethylene di-isocyanate
	Toluene-2,4-diisocyanate
	Toluene-2,6-diisocyanate
	Methylene-bis-(phenylisocyanate)
	Isophorone diisocyanate
Volatile Organic Compounds	
	Benzene
Organophosphorus Compounds	
	2-Propanol, 1-chloro-,2,2',2''-phosphate (TCIPP, previously known as TCPP)
	Phosphoric acid, triphenyl ester (TPHP)
	Ethanol, 2-butoxy-,1,1',1''-phosphate (TBOEP, previously known as TBEP)
	Phosphoric acid, triethyl ester (TEP)

Category	Specific compounds or elements
	Phosphoric acid tris(methylphenyl) ester (TMPP, previously known as TCP)
	Tris(2-ethylhexyl) phosphate (TEHP)
Cyanides	
	Free cyanide
Brominated Fire Retardants	
	Polybrominated biphenyls (PBBs)
	Tetrabromobisphenol A
	Polybrominated diphenyl ethers (PBDEs)
	Hexabromocyclododecane
Fibres	
	Asbestos
	Synthetic Vitreous Fibres

4.1 Metals - Lead

Transport

(US National Library of Medicine, 2016a) reports that for lead compounds:

- Particulates of lead compounds can be removed from the atmosphere by wet or dry deposition.
- If released or deposited on soil, mobility will be limited; adsorption at mineral surfaces (or on hydrous iron oxides), formation of stable organic complexes, and precipitation of sparingly soluble lead compounds (sulphates, phosphates, carbonates), act to limit lead availability to plants from the soil.
- Most soluble lead compounds will be retained in the upper 2-5 cm of soil, especially in soils with at least 5% organic matter or a pH 5 or above. In soil, the transformation of soluble lead compounds to relatively insoluble sulphate or phosphate derivatives occurs.

(US National Library of Medicine, 2016b) reports that, when released in soil, elemental lead is expected to convert to other forms such as $PbSO_4$, $Pb_3(PO_4)_2$, PbS, and PbO.

Fate

As a chemical element, lead (and other metals) may change their chemical state but will not be subject to degradation in the environment (US National Library of Medicine, 2016b).

4.2 Polycyclic Aromatic Hydrocarbons (PAH)

A summary of the fate and transport of PAHs in soils is provided in (Environment Agency, 2003), which makes the following observations:

Transport

- The transport processes which may occur once PAHs enter the soil environment are sorption to the soil matrix, re-volatilisation back into the air, degradation through biotic or abiotic processes, or release to groundwater or surface water systems.
- Volatilisation is only relevant as a loss process for naphthalene but may also likely to be significant for those PAHs with similar physicochemical properties to naphthalene (i.e. with two or three rings).
- For the other PAHs, i.e. those with four or more rings, volatilisation from soil surfaces is likely to be negligible.

- Strong sorption to soil organic matter results in heavier PAHs being relatively immobile in the soil environment relative to other PAHs. This, coupled with the low aqueous solubilities of these compounds, means that the transfer of these high molecular weight PAHs through soil into groundwater systems is unlikely.

Fate

- Once in soil or sediment, PAHs can persist for relatively long periods of time, with persistence increasing with increasing molecular weight of the compound. The persistence of PAHs in the soil is reported to be due to both their inherent resistance to biodegradation, and their poor bioavailability.
- The bioavailable fraction of PAHs in soil decreases and the recalcitrant fraction increases over time. This process is referred to as 'ageing' of the pollutant and although thought to be controlled by sorption, may also involve entrapment within soil micropores or soil organic matter. As a result, even lower molecular weight PAHs, such as naphthalene, are less susceptible to biodegradation if they have been in contact with the soil for a period of time. Long term contamination with the higher molecular weight PAHs, such as benzo(a)pyrene, results in the contaminant becoming almost completely resistant to biodegradative processes.

(Nathanail, et al., 2015) estimated that the half-life of acenaphthene (three rings) in soil is likely to be 0.2 -3 years and the half-life of benzo[ghi]perylene (six rings) in soil is 1-9 years. (Nathanail, et al., 2015). (Pulleyblank, et al., 2019) identified significant data gaps in understanding how PAHs breakdown in situ.

4.3 Polychlorinated Dibenzo Dioxins and Furans (PCDD/F)

Transport

With respect to environmental transport of dioxin-like compounds (DLC), the (Institute of Medicine Committee on the Implications of Dioxin in the Food Supply, 2003) makes the following observations:

- Atmospheric transport is a major dispersal mechanism for DLCs in the environment.
- DLCs are removed from the atmosphere by either dry or wet deposition. Dry deposition occurs for both the particle- and vapor-associated compounds. DLCs may be deposited onto soil, water, or vegetation via wet deposition, either suspended in the water or associated with precipitation particles.
- DLCs have low water solubility and are highly lipophilic and, as such, tend to partition from the atmosphere to soil and vegetation surfaces. As some DLCs are considered semi volatile, particularly the less chlorinated congeners, some small portion of deposited DLCs may re-enter the atmosphere as a result of volatilization from these surfaces or bound to airborne soil particles.
- Once below the soil surface, soil-bound DLCs do not appear to move up or down via volatilization without a carrier (i.e. a solvent); this is particularly true for the tetra- and higher chlorinated DLCs.
- As most DLCs that attach to soil particles have little potential for leaching through or volatilizing from soil, they are removed from soil surfaces primarily by soil erosion (wind or water) and runoff to water bodies. For DLCs that are not eroded, burial is the major fate process.

(Environment Agency, 2009b) reported that:

- PCDDs and PCDFs are highly persistent compounds and have been detected in air, water, soil, sediments, animals and foods. They partition strongly to soils and sediments where, due to their low vapour pressure, low aqueous solubility and strong sorption to organic matter, they become generally immobile.
- In general, higher chlorinated PCDDs are likely to volatilise more slowly from soil than lower chlorinated congeners. PCDDs and PCDFs have a strong affinity for lipids, as suggested by their high octanol–water partition coefficients (Kow) and have been shown to bioaccumulate in both aquatic and terrestrial organisms.
- The organic carbon content of soil is considered to be the most important factor governing the extent of adsorption of PCDDs and PCDFs. The range of organic carbon–water partition coefficients (Koc values) reported for PCDDs and PCDFs indicate that most congeners will be strongly bound to organic matter. Mobility of PCDDs and PCDFs may be increased by co-solvency and/or through the transport of dissolved organic matter /mobilised particulates in water and air.

Studies suggest that, due to the hydrophobicity of the compounds and the consequent strong adsorption to soil particles, root uptake of dioxins and furans and their translocation into other parts of the plant are minimal, although members of the Cucurbitaceae (cucumber) family have proved an exception to this, and are able to take up and translocate congeners from the soil to the fruit (Environment Agency, 2009d).

For the majority of plants, atmospheric deposition of dioxins and furans onto above-ground plant surfaces is considered the major process for plant uptake. However, for low chlorinated congeners, volatilisation from soil and subsequent absorption by leaves is also considered to be a likely pathway for uptake by green vegetables and fruit (Environment Agency, 2009d).

Fate

With respect to the environmental fate and degradation of DLCs, (Institute of Medicine Committee on the Implications of Dioxin in the Food Supply, 2003) makes the following observations:

- DLCs are stable compounds and are highly resistant to most environmental degradation processes and to hydrolysis
- In soils, DLCs bind strongly to organic matter with the result that degradation below the soil surface is virtually non-existent. DLCs at the soil surface are subject to some photolysis.
- DLCs appear to persist longer on soils with higher organic content
- Estimated 2,3,7,8-TCDD half-life of 25 to 100 years in subsurface soil and 9 to 15 years in the top 0.1 cm of soil
- Although microbial degradation has been demonstrated for some DLC congeners, this does not appear to be an important transformation process.

(Public Health England, 2008) reports that dioxins can remain in contaminated soils and sediments for long periods of time without being broken down. For hexachlorodibenzo-p-dioxin a half-life of 20 years has been reported for a sludge-amended soil field study. No biodegradation was reported in this study (McLachlan, et al., 1996).

Most biological and abiotic transformation and degradation processes for PCDDs are slow, with photolysis in sunlight being the most rapid: this is illustrated by the relatively shorter half-life of 2,3,7,8-TCDD in surface soils (9–15 years) compared with 25–100 years in the sub-surface (Environment Agency, 2009b).

4.4 Isocyanates

The collated fate and transport information for isocyanates is presented in Table TN07-03.

Table TN07-03. Isocyanates Fate and Transport Summary

Compound	Transport	Fate	Reference
Methyl Isocyanate	Methyl Isocyanate will exist solely as a vapour in the atmosphere. Methyl isocyanate may volatise from dry soil.	In the atmosphere, it will react with photochemically-produced hydroxyl radicals and degrade. This reaction has an estimated half-life of 118 days. It is unlikely to be susceptible to direct photolysis by sunlight. In soil and water, hydrolysis is expected to be the dominant fate process. The half-life of this reaction is in the range of 9 to 20 minutes depending on temperature. Hydrolysis may produce secondary chemicals including: N-carboxymethylamine, methylamine, carbon dioxide and N,N'-dimthylurea	(US National Library of Medicine, 2007b).
Toluene Diisocyanate	Toluene diisocyanate exists solely as a vapour in the atmosphere. It is not expected to adsorb to soil due to its rapid degradation reaction with water.	In the atmosphere it will be degraded by photochemically-produced hydroxyl radicals. This reaction has a half-life of 20 hours. Toluene diisocyanate released to soil had only 5% of the original compound remaining after 24 hours. If it is released to water, a crust forms around the compound and less than 0.5% of the original material will remain after 35 days. It is not expected to bioconcentrate in aquatic organisms	(US National Library of Medicine, 2012).

Compound	Transport	Fate	Reference
Phenyl Isocyanate	Phenyl isocyanate exists solely as a vapour in the atmosphere. It may volatise from dry soil.	It is degraded in the atmosphere by photochemically-produced hydroxyl radicals. This reaction has a half-life of 5 days. It is not expected to be photolysed by sunlight. Due to it hydrolysing in water, biodegradation, soil mobility and volatisation in moist soil are not important environmental fate processes. The hydrolysis reaction has a half-life in the range from 20 seconds to 75.5 minutes	(US National Library of Medicine, 2012).
Hexamethylene Diisocyanate	Hexamethylene diisocyanate will exists solely in the vapour phase in ambient atmosphere.	It is degraded in the atmosphere by photochemically-produced hydroxyl radicals. The half-life of this reaction in air is 1.3 days. It hydrolyses to form amines and polyureas. Hydrolysis is the dominant degradation route in both water and moist soil.	(US National Library of Medicine, 2012).
Ethyl Isocyanate	Ethyl isocyanate will exist in the atmosphere as a vapour.	The half-life for its reaction with photochemically-produced hydroxyl radicals in the air is 15 days. It will not photolyse in sunlight. The dominant fate process in water and moist soil is hydrolysis. The half-live for this reaction is reported to be under 10 minutes.	(US National Library of Medicine, 2007a).

4.5 Asbestos

Asbestos fibres do not volatilise or degrade in soil or water surfaces and only move through soil during runoff or erosion. Asbestos may re-suspend due to vehicular traffic (US National Library of Medicine, 2018d). Once liberated, asbestos can exist for unknown periods of time (Public Health England, 2014).

4.6 Volatile Organic Compounds - Benzene, Toluene, Ethylbenzene and Xylene(s) (BTEX)

Transport

According to (Environment Agency, 2003), since BTEX compounds have significant aqueous solubility, low molecular weight, and low octanol-water partition coefficient (K_{ow}), they are likely to be mobile in soil and leach to groundwater. Lighter BTEX compounds (e.g. benzene) are likely to be more mobile in soil. The adsorption of BTEX compounds to soils is one of the most influential soil characteristics with respect to contaminant migration. BTEX compounds (in common with other organic contaminants) adsorb to soil organic matter which hinders onward migration (Environment Agency, 2003).

With specific respect to benzene, (Environment Agency, 2009a) reported that:

- Benzene is considered by most authoritative organisations to be mobile in the soil environment.
- Upon release into the soil environment, benzene will tend to sink through the unsaturated zone until it reaches the saturated zone and will tend to collect at the water table if present in sufficient concentrations.
- Benzene can easily leach from soil based on its aqueous solubility, molecular weight and octanol-water partition coefficient (K_{ow}), and has a moderate tendency to adsorb to soil organic matter (reflected by its organic carbon water partition coefficient, K_{oc}).
- Benzene will readily volatilise from surface soil given its high vapour pressure, high air–water partition coefficient and moderate K_{oc}. Volatilisation from the sub-surface to air is the most important of the transport processes for benzene, and it will volatilise more readily from soils with a high air-filled porosity such as sands and gravels.
- Key aspects of benzene’s behaviour in the soil environment will be influenced by the presence of other compounds. The solubility and volatility of benzene are reported to decrease in the presence of other hydrocarbon compounds and after weathering of the hydrocarbon compounds has taken place.

- Benzene is moderately hydrophobic based on its K_{ow}. The uptake into plants from soil therefore has the potential to occur directly through the roots (from which benzene is transported throughout the plant), or indirectly following volatilization of benzene from the soil and subsequent vapour phase sorption by plant surfaces. On entering the leaves, benzene may be lost through transpiration or metabolised.

As benzene is only moderately hydrophobic, it should easily enter the transpiration stream through roots and be transported to stems and leaves: upon entering the leaves, benzene may be lost through transpiration or metabolised. Any resulting metabolites can either be transpired, or retained in the leaves as bound residues, or incorporated into cell structures (Environment Agency, 2009c). These processes vary between plant species. Benzene can be taken up from the atmosphere by plant leaves and other aboveground parts, although this is balanced to various extents – depending on plant species – by loss through volatilisation and transpiration (Environment Agency, 2009c).

Fate

The (Environment Agency, 2003) reports that biodegradation of BTEX compounds occurs under both aerobic and anaerobic conditions. Biodegradation in aerobic conditions is generally more rapid, and based on their physicochemical properties and degradation pathways, the BTEX contaminants should be rapidly lost from the soil and groundwater, but that their presence on some historically contaminated sites indicates that there are circumstances in which this may not be the case.

(Nathanail, et al., 2015) report that benzene is expected to biodegrade in aerobic environmental conditions in soil, with a half-life in the range of 5 to 16 days. (Environment Agency, 2009a) reported that benzene is subject to microbial degradation under both aerobic and anaerobic conditions; the former is typically much more rapid. Biodegradation rates are dependent on several factors including: the presence of sunlight; the type and population of microbes present; initial concentration of benzene; soil temperature; soil oxygen content; and the potential presence of other electron receptors.

4.7 Organophosphorus Compounds

The collated fate and transport information for isocyanates is presented in Table TN07-04.

Table TN07-04. Organophosphorus Compounds Fate and Transport Summary

Compound	Transport	Fate	Reference
Triphenyl Phosphate	Triphenyl phosphate exists in both the vapour and particulate phase in the atmosphere.states it will be degraded in the atmosphere; this reaction has a half-life of 12 hours. Adsorption to soil is expected to limit the potential for volatilisation.	If released to soil, it is expected to have slight mobility. Biodegradation is reported to be an important environmental degradation mechanism. In rivers biodegradation has a half-life of 2-4 days. Hydrolysis is expected to occur under alkaline conditions with a reported half-life of 3 to 19 days depending on pH.	(US National Library of Medicine, 2018f)
Tri(2-butoxyethyl) Phosphate	In atmosphere, tri(2-butoxyethyl) phosphate may exist as both a vapour and a particulate. It has low mobility in soil. Tri(2-butoxyethyl) phosphate is not expected to volatise from wet or dry soil surfaces, or water surfaces. In water, tri(2-butoxyethyl) phosphate is expected to adsorb to suspended solids and sediment.	The half-life of the degradation reaction by photochemically-produced hydroxyl radicals in atmosphere is 3 hours. Biodegradation is not an important environmental fate process. In one cited study, tri(2-butoxyethyl) phosphate degraded completely in one of three experiments in a river.	(US National Library of Medicine, 2015b)
Triethyl Phosphate	Triethyl phosphate exists solely as a vapour in atmosphere. It has high mobility in soil.	It is degraded in atmosphere by photochemically-produced hydroxyl radicals. This has a half-life of 7 hours.	(US National Library of Medicine, 2006b)

4.8 Hydrogen Cyanide

Transport

Hydrogen cyanide has high mobility in soil. It will exist in the anionic form in the environment in neutral soil conditions due to having a pKa[4] of 9.2. Hydrogen cyanide is expected to volatise from wet and dry soil surfaces and from water. Volatilisation half-lives for a river and lake are 5 hours and 3 days, respectively. (US National Library of Medicine, 2018e)

Fate

It can be biodegraded by acclimated microbial cultures and sludges, but it is potentially toxic to those microbial communities in high concentrations. This indicates that biodegradation is potentially not an important environmental fate process (US National Library of Medicine, 2018e).

4.9 Brominated Fire Retardants

Brominated fire retardants are not generally readily biodegradable and will persist in the environment although adapted microorganisms may degrade the compounds (European Food Saftey Authority Panel on Contaminants in the Food Chain, 2013).

Information for specific brominated fire retardant compounds is provided in Table TN07-05 below.

Table TN07-05. Brominated Fire Retardants Fate and Transport Summary

Compound	Transport	Fate	Reference
Polybrominated Diphenyl Ethers	In water, polybrominated diphenyl ethers are likely to bind to solid particulates or sediment. They are reportedly not readily mobile in soil and are likely to bind strongly to soil particles. They may leach through the soil to groundwater. The adsorption to soil is likely to limit the potential for volatilisation from moist soil surfaces. As a consequence, polybrominated diphenyl ethers are not expected to volatise from dry surface soils.	Vapour-phase mono-thru hexa-bromodiphenyl ethers are degraded in the atmosphere with a reaction half-life of 3 to 46 days. Of the 209 congeners, fifteen polybrominated diphenyl ethers are susceptible to direct photolysis. Hydrolysis is not expected to be an important environmental fate process (US National Library of Medicine, 2011).	(Agency for Toxic Substances and Disease Registry, 2017).
Polybrominated Biphenyls	They have low water solubility and low vapour pressure. Hexa-, octa-, and deca-bromobiphenyl are expected to have negligible mobility in soil. Volatilisation is not expected to be an important process. The solubility of polybrominated biphenyls in water is directly correlated with the levels of dissolved oxygen in the water. In water, polybrominated biphenyls are expected to adsorb to suspended solids and sediment.	PBB congeners are highly persistent in the environment and in biological tissues. Primarily hydrophobic, PBBs adsorb strongly to soils and sediments. Hydrophobic adsorption generally increases with the bromine content of the PBB congener and the organic content of the soil or sediment. PBBs degrade slowly in the environment. Microorganisms are capable of debrominating PBB congeners, although this process can be inhibited by organic co-contaminants, petroleum products, and heavy metals. Ultraviolet light can degrade PBB congeners, especially at ortho positions.	(International Agency for Research on Cancer, 2016) (US National Library of Medicine, 2006a).
2,2’,6,6’-Tetrabromobisphenol A	2,2’,6,6’-tetrabromobisphenol A exists in both the vapour and particulate phase.	Susceptible to direct photolysis by sunlight. Volatilisation from soil surfaces is not expected to be an important fate process.	(US National Library of Medicine, 2018a).

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[4] pKa is a measure of acid strength in a solution. The lower the pKa , the stronger the acid.

Compound	Transport	Fate	Reference
	2,2’,6,6’-tetrabromobisphenol A therefore has negligible mobility in soil.	Vapour phase 2,2’,6,6’-tetrabromobisphenol A is likely to degrade in the atmosphere, this reaction has a reported half-life of 5.4 days. Aerobic biodegradation in soil has a half-life range of 9 to 93 days. Anaerobic biodegradation in soil is nearly complete within 10- 64 days in some studies. Anaerobic biodegradation produces a final product of bisphenol A via tri- and dibromobisphenol A. In water, 2,2’,6,6’-tetrabromobisphenol A is expected to adsorb to suspended solids and sediment. In anaerobic sediment, the half-life of the biodegradation reaction ranges from 5 to less than 130 days. Aerobic biodegradation has a half-life of 48 to 84 days. Volatilisation from water surfaces is not expected to be an important fate process. Direct photolysis has a half-life of 17 minutes to 5.8 hours in aqueous solutions. In sunlit natural water, photo-oxidation may have some importance as a fate process. Hydrolysis is not expected to be an important environmental fate process.	
Hexabromocyclododecane	Hexabromocyclododecane exists in both the vapour and particulate phases in atmosphere. The compound is subject to long-range environmental transport in the atmosphere. The majority of this occurs when the compound is in aerosol form. In the soil, hexabromocyclododecane is considered to be immobile. The adsorption to the soil limits the potential for volatilisation from moist soil.	Vapour phase hexabromocyclododecane will degrade in the atmosphere. The half-life for this reaction is 2.6 days. Hexabromocyclododecane ranges from not degradable to being inherently biodegradable depending on test conditions. Half-lives range, in aerobic soil degradation, from 63 to 441 days. Dissipation half-lives are 2-4 times longer in biologically-inhibited soil, meaning that biodegradation is an important fate process in soil. It has biotransformation half-lives of 63 and 6.9 days in aerobic and anaerobic soil, respectively. In water, it is expected to adsorb to suspended solids and sediment. It has biotransformation half-lives of 11-32 and 1.1 -1.5 days in aerobic and anaerobic river water, respectively. The estimated half-life for volatilisation from water surfaces is over 10 years if adsorption is considered. Hydrolysis is not an important environmental fate process.	(US National Library of Medicine, 2015a).

4.10 Synthetic Vitreous Fibres

According to (Agency for Toxic Substances and Disease Registry, 2004), synthetic vitreous fibres tend to settle out of air and water and deposit in the soil or sediment. They are non-volatile and insoluble. They do not degrade or undergo significant transport in either water, soil or air. They can be attacked by acid or alkaline solutions, but this does not occur to any significant extent under environmentally relevant conditions

5. Adequacy of Evidence

The QSR process identified a number of recent papers and reports which directly address the primary review question, and a number of additional sources of evidence on the more general issue of the fate and transport of chemicals of potential concern arising from combustion products from fires. This study particularly relates to the fate and transport of contaminants after their deposition in the soil environment. The search is limited by the search phases and terms used and the information held in the databases themselves. AECOM considers that the QSR process has been successfully implemented in the intended manner and that it has identified the most recent and relevant information and provides an adequate basis for answering the primary review question.

6. Conclusions

Based on the results of this Quick Scoping Review, the following conclusions regarding the environmental fate and transport of the contaminants researched are described below.

- Lead is relatively immobile in soils and, as a chemical element, will not be subject to biodegradation.
- PAHs vary in mobility and degradability depending on ring number and molecular weight, but in general are relatively immobile and persistent.
- Dioxins and furans are likely to be immobile in soils and environmentally persistent.
- Isocyanates have short half-lives in soil, atmosphere and water, and are likely to have largely degraded from the soil.
- Asbestos and synthetic vitreous fibres are unlikely to have undergone either transport within soil horizons or to have degraded.
- BTEX compounds (including benzene) degrade in aerobic soils, and their solubility means that they may have leached to groundwater.
- Brominated fire retardants are not generally readily biodegradable and will persist in the environment.

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Appendix TN07-A - Web Search

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
1	environmental fate pah	26/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+pah&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12376	50	1
2	environmental fate dioxin	29/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+dioxin&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12385	50	1
3	environmental fate furan	29/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+furan&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12381	50	0
4	environmental fate metal	30/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+metal&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	13631	50	0
5	environmental fate asbestos	30/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+asbestos&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12642	50	1
6	environmental fate isocyanate	30/04/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+Isocyanate&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12388	50	0
7	environmental fate isocyanic acid	30/04/2019	GOV.UK	https://www.gov.uk/search/all?keywords=environmental+fate+isocyanic+acid&order=relevance&page=5&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=	13155	50	0
8	environmental fate benzene	01/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+benzene&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12405	50	0
9	environmental fate cyanide	01/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+cyanide&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12414	50	1

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
10	environmetal fate phosphorus	01/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+phosphorus&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12517	50	0
11	environmental fate lead	02/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+lead&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	43286	50	0
12	environmental fate polybrominated biphenyls	02/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+polybrominated+biphenyls+&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12490	50	0
13	environmental fate tetrabromobisphenol A	02/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=environmental+fate+tetrabromobisphenol+A&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	12483	50	0
14	environmental fate synthetic vitreous fibres	02/05/2019	GOV.UK	https://www.gov.uk/search/all?keywords=environmental+fate+synthetic+vitreous+fibres&order=relevance&page=5&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=	13527	50	0
15	synthetic vitreous fibres	02/05/2019	GOV.UK	https://www.gov.uk/search/all?keywords=synthetic+vitreous+fibres&order=relevance&page=4	1172	50	0
16	synthetic vitreous fibres exposure	02/05/2019	GOV.UK	https://www.gov.uk/search/all?keywords=synthetic+vitreous+fibres+exposure&order=relevance&page=5&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=	3320	50	0
17	exposure pah	02/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=exposure+pah&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	2226	50	0
18	exposure	02/05/2019	GOV.UK	https://www.gov.uk/search/all?keywords=exposure&order=relevance&page=5&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=	2555	50	0
19	persistence pah	02/05/2019	GOV.UK	https://www.gov.uk/search/all?keywords=persistence+pah&order=relevance&page=2&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=	2849	50	0
20	biodegradation	02/0	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=biodegradation&level_one_tax	109	50	0

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
		5/2019		on=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance			
21	hazard summary pah	02/05/2019	GOV.UK	https://www.gov.uk/search/all?parent=&keywords=hazard+summary+pah&level_one_taxon=&manual=&public_timestamp%5Bfrom%5D=&public_timestamp%5Bto%5D=&order=relevance	26721	50	0
22	environmental fate	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/environmental%20fate	34	34	0
23	exposure pah	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20pah	5	5	1
24	exposure isocyanate	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20isocyanate	0	0	0
25	exposure benzene	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20benzene	2	2	0
26	exposure furans	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20furans	16	16	0
27	exposure dioxins	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20dioxins	21	21	4
28	exposure lead	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20lead?_sm_au_=iVVRS56880RpZkW6	113	30	0
29	exposure metals	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20metals	26	26	0
30	exposure cyanide	02/05/20	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20cyanide	6	6	0

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
		19					
31	exposure polybrominated biphenyls	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20polybrominated%20biphenyls	2	2	1
32	exposure tetrabromobisphenol A	02/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20tetrabromobisphenol%20A	2	0	0
33	exposure synthetic vitreous fibres	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/exposure%20synthetic%20vitreous%20fibres	0	0	0
34	persistence pah	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/persistence%20pah	0	0	0
35	persistence metal	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/persistence%20metal	3	3	0
36	persistence dioxins	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/persistence%20dioxins	13	13	1
37	persistence benzene	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/persistence%20benzene	0	0	0
38	persistence furans	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/persistence%20furans	2	2	0
39	mobility	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/mobility	15	15	0
40	biodegradation	03/05/2019	EFSA	http://www.efsa.europa.eu/en/search/site/biodegradation	4	4	0

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
41	lead	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	1636	10	1
42	pah	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	182	10	1
43	dioxins	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	82	10	3
44	furans	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	27	10	2
45	isocyanate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	126	50	0
46	isocyanic acid	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	18	18	0
47	propyl isocyanate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	0	0	0
48	methylene bis phenyl isocyanate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	858	10	0
49	isophorane diisocyanate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	0	0	0
50	2-propanol, 1-chloro-,2,2’,2’’-phosphate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	5832	10	0
51	phosphoric acid,	03/0	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	1600	10	0

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
	triphenyl ester	5/2019					
52	Triphenyl phosphate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~JaNTm1:1	26	10	1
53	phosphoric acid	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	251	10	0
54	ethanol, 2-butoxy phosphate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	1	10	1
55	phosphoric acid, triethyl ester	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	60	10	1
56	phosphoric acid tris(methylphenyl) ester	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	82	20	0
57	tris(2-ethylhexyl) phosphate	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	9	9	0
58	cyanide	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	389	10	1
59	polybrominated biphenyls	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	29	10	1
60	tetrabromobisphenol A	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	27	10	1
61	polybrominated diphenyl ethers	03/05/20	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	61	10	1

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
		19					
62	hexabromocyclododecane	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	13	10	1
63	asbestos	03/05/2019	TOXNET	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2	143	10	4
64	pah	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=pah&Search.x=0&Search.y=0&Search=Search	0	0	0
65	dioxin	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=dioxin&Search.x=0&Search.y=0&Search=Search	2	2	1
66	isocyanate	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=isocyanate&Search.x=0&Search.y=0&Search=Search	0	0	0
67	isocyanic acid	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=isocyanic+acid&Search.x=0&Search.y=0&Search=Search	0	0	0
68	phosphate	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=phosphate&Search.x=0&Search.y=0&Search=Search	2	2	0
69	phosphoric	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=phosphoric&Search.x=0&Search.y=0&Search=Search	0	0	0
70	cyanide	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=cyanide&Search.x=0&Search.y=0&Search=Search	2	2	0
71	polybrominated biphenyls	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=polybrominated+biphenyls&Search.x=25&Search.y=10&Search=Search	3	3	1

Search number	Keyword(s) / word string	Date of Search	Search tool/origin or other tracing information	Hyperlink to origin (URL)	Number of search hits	Number of hits screened	Number of hits taken forward to review (Table B)
72	tetrabromobisphenol A	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=tetrabromobisphenol+A&Search.x=45&Search.y=10&Search=Search	1	1	1
73	polybrominated diphenyl ethers	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=polybrominated+diphenyl+ethers&Search.x=62&Search.y=26&Search=Search	1	1	0
74	hexabromocyclododecane	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=hexabromocyclododecane&Search.x=53&Search.y=15&Search=Search	0	0	0
75	asbestos	03/05/2019	IPCS INCHEM	http://inchemsearch.ccohs.ca/inchem/jsp/search/search.jsp?inchemcasreg=1&Coll=inchemall&serverSpec=charlie.ccohs.ca%3A9900&QueryText1=&QueryText2=asbestos&Search.x=0&Search.y=0&Search=Search	5	5	0
76	pah	03/05/2019	PubCHEM	https://pubchem.ncbi.nlm.nih.gov/#query=pah&tab=pubmed	21711	10	0
77	dioxin	03/05/2019	PubCHEM	https://pubchem.ncbi.nlm.nih.gov/#query=dioxin	98715	10	0
78	detection of polycyclic aromatic hydrocarbon products in soil	03/05/2019	Google	https://www.google.com/search?q=detection+of+polycyclic+aromatic+hydrocarbon+products+in+soil&oq=detection+of+polycyclic+aromatic+hydrocarbon+products+in+soil&aqs=chrome..69i57j69i60l2&sourceid=chrome&ie=UTF-8	3970000	20	1
79	synthetic vitreous fibers	03/05/2019	Google	https://www.google.com/search?q=synthetic+vitreous+fibers&rlz=1C1EJFA_enGB672GB674&oq=synthetic+v&aqs=chrome.1.69i57j35i39j0l4.6703j0j7&sourceid=chrome&ie=UTF-8	433000	20	1
80	environmental fate transport 7,12-dimethylbenz(a)anthracene	27/06/19	Google Scholar	https://scholar.google.co.uk/scholar?hl=en&as_sdt=0%2C5&as_vis=1&q=environmental+fate+transport+7%2C12-dimethylbenz%28a%29anthracene&btnG=	2720	30	0

Appendix TN07-B – Summary of Evidence Identified

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
20	Agency for Toxic Substances and Disease Registry (ATSDR). 2009. Toxicity of Polycyclic Aromatic Hydrocarbons (PAHs).	https://www.atsdr.cdc.gov/csem/pah/docs/pah.pdf	Report	Fire Chemistry	Environmental fate of PAHs.
22	Agency for Toxic Substances and Disease Registry. 2017. Toxicological profile for polybrominated diphenyl ethers (PBDEs)	https://www.atsdr.cdc.gov/toxprofiles/tp207.pdf	Report	Fire Chemistry	Polybrominated diphenyl ethers
1	Review of the Fate and Transport of Selected Contaminants in the Soil Environment. 2003. Environmental Agency.	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/290383/scho0904biee-e-e.pdf	Report	1	Fate and transport data of PAHs and benzene.
2	Dioxins (2,3,7,8-Tetrachlorodibenzo-p-dioxin) General Information. 2008. Public Health England	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/339479/Dioxins_General_Information_phe_v1.pdf	Report	2	Dioxins can remain in the environment for a long time and soils and sediments, which are contaminated with dioxins, can release low levels back into the atmosphere. However, dioxins can be broken down following exposure to UV light.
3	Asbestos Toxicological Overview. 2014. Public Health England.	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/627190/Asbestos_toxicological_overview.pdf	Report	5	Toxicological overview of asbestos. Asbestos is prevalent in the three main environmental media, namely air, water and soil. The majority of asbestos exposure arises from air due to natural weathering of asbestos containing rock, which may be enhanced by human activity.
4	Hydrogen cyanide General Information. 2016. Public Health England.	https://assets.publishing.service.gov.uk/government/uploads/system/uploa	Report	11	A wide range of combustion processes produce hydrogen cyanide gas in the smoke or fumes; including building fires, cigarettes, vehicles

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		ds/attachment_data/file/570041/Hydrogen_Cyanide_general_information.pdf			exhausts and fires involving nitrogen containing materials such as polyurethane foams. Hydrogen cyanide does not generally enter soils and does not remain in water for a long time.
5	Polycyclic Aromatic Hydrocarbons in Food. 2008. European Food Safety Authority.	http://www.efsa.europa.eu/sites/default/files/scientific_output/files/main_documents/724.pdf	Scientific article	23	Environmental fate of PAHs.
6	Risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food. 2018. EFSA Panel on Contaminants in the Food Chain (CONTAM).	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2018.5333	Scientific article	25	The sources, characteristics and environmental fate of PCDD/Fs and DL-PCBs have been extensively reviewed in several earlier scientific EFSA opinions (EFSA CONTAM Panel, 2011, 2012), and EFSA reports (EFSA, 2010a, 2012). The following chapter is an excerpt of these reviews.
7	Scientific Opinion on the presence of dioxins (PCDD/Fs) and dioxin-like PCBs (DL-PCBs) in commercially available foods for infants and young children. 2013. EFSA Panel on Contaminants in the Food Chain (CONTAM).	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2012.2983	Scientific article	25	PCB pathways of human exposure.
8	Update of the monitoring of levels of dioxins and PCBs in food and feed. 2012. European Food Safety Authority (EFSA), Parma, Italy	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2012.2832	Scientific article	27	Dioxins and polychlorinated biphenyls (PCBs) are environmentally persistent substances that have been associated with human health effects. Their presence in food and feed available on the European market is monitored.
9	Scientific Opinion on the risk to public health related to the presence of high levels of dioxins and dioxin-like PCBs in liver from sheep and deer. 2011	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2011.2297	Scientific article	27	EFSA was asked by the European Commission to deliver a scientific opinion on the risk to public health related to the presence of high levels of dioxins and dioxin-like PCBs in liver from sheep and deer.
10	Scientific Opinion on Polybrominated Biphenyls (PBBs) in Food. 2010.	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.29	Scientific article	31	PBBs are lipophilic compounds with a low vapour pressure and low water solubility which decreases

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
	European Food Safety Authority (EFSA)	03/j.efsa.2010.1789			with increasing degree of bromination. They are generally chemically stable, persistent in the environment and bioaccumulative. It has been reported that higher brominated biphenyls can undergo photolysis and reductive debromination, thereby producing lower brominated congeners.
11	Scientific Opinion on Brominated Flame Retardants (BFRs) in Food: Brominated Phenols and their Derivatives. 2012. European Food Safety Authority (EFSA)	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2012.2634	Scientific article	31	Brominated phenols are not generally readily biodegradable and will persist in the environment for a longer or shorter time depending on the conditions. However, adapted communities of microorganisms and specialist communities (such as anaerobic or sulfidogenic) may degrade the compounds.
12	Results of the monitoring of dioxin levels in food and feed. 2010. European Food Safety Authority (EFSA).	https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2010.1385	Scientific article	36	Environmentally persistent dioxins and dioxin-like compounds include 29 congeners of dioxins, furans and polychlorinated biphenyls (PCB) with similar toxic effects, their quantification commonly expressed as toxic equivalent units according to their varying potency. While the amount of those compounds in the environment has declined since the late 1970s, there is a continued concern because of their accumulation in the food chain, particularly in animal fat.
13	HSDB: Lead, Elemental.	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~t5mk2T:1	Report	41	Environmental fate of lead.
14	Polycyclic aromatic hydrocarbons	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~7thi0O:1	Report	42	Environmental fate of PAHs.
15	HSDB: octachlorodibenzo-p-dioxin	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/	Report	43	Environmental fate of Octachlorodibenzo-p-dioxin.

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		~0qOSA3:1			
16	HSDB: 2,3,7,8-tetrachlorodibenzo-p-dioxin	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~7WjLM1:1	Report	43	Environmental fate of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD).
17	HSDB: hexachlorodibenzo-p-dioxin	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~7WjLM1:2	Report	43	Environmental fate of hexachlorodibenzo-p-dioxin.
18	HSDB: 2,3,7,8-tetrachlorodibenzofuran	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~p2Tp0h:2	Report	44	Environmental fate of 2,3,7,8-Tetrachlorobenzofuran
19	HSDB: 2,3,4,7,8-pentachlorodibenzofuran	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~p2Tp0h:7	Report	44	Environmental fate of 2,3,4,7,8-pentachlorodibenzofuran.
20	HSDB: methyl isocyanate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~puMcU5:1	Report	45	Environmental fate of methyl isocyanate
21	HSDB: toluene diisocyanate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~rRDYAd:2:@od@@/cgi-bin/sis/search2/d?./temp/~1Tpsfd:0@	Report	45	Environmental fate of toluene diisocyanate.
22	HSDB: phenyl isocyanate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~rRDYAd:3:@od@@/cgi-bin/sis/search2/d?./temp/	Report	45	Environmental fate of phenyl isocyanate.

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		~1Tpsfd:0@			
23	HSDB: hexamethylene diisocyanate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~rRDYAd:6:@od@@/cgi-bin/sis/search2/d?./temp/~1Tpsfd:0@	Report	45	Environmental fate of hexamethylene diisocyanate
24	HSDB: ethyl isocyanate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~rRDYAd:7:@od@@/cgi-bin/sis/search2/d?./temp/~1Tpsfd:0@	Report	45	Environmental fate of ethyl isocyanate.
25	HSDB: triphenyl phosphate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~JaNTm1:1	Report	52	Environmental fate of triphenyl phosphate.
26	HSDB: tris(2-butoxyethyl) phosphate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~DBeQfD:1	Report	54	Environmental fate of tris(2-butoxyethyl) phosphate
27	HSDB: triethyl phosphate	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~XupcVn:3	Report	55	Environmental fate of triethyl phosphate
28	HSDB: hydrogen cyanide	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~239UFG:2	Report	58	Environmental fate of hydrogen cyanide
29	HSDB: polybrominated biphenyls	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/	Report	59	Environmental fate of polybrominated biphenyls

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		~ZNGM9A:1			
30	HSDB: 2,2',6,6'-tetrabromobisphenol a	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~533KJz:1	Report	60	Environmental fate of tetrabromobisphenol A
31	HSDB: polybrominated diphenyl ethers	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~4k9tik:1	Report	61	Environmental fate of polybrominated diphenyl ethers
32	HSDB: hexabromocyclododecane	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~EvfkWk:1	Report	62	Environmental fate of hexabromocyclododecane
33	HSDB: asbestos	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~NO5doq:1	Report	63	Environmental fate of asbestos
34	HSDB: chrysotile asbestos	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~NO5doq:2	Report	63	Environmental fate of asbestos
35	HSDB: amosite asbestos	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~NO5doq:3	Report	63	Environmental fate of asbestos
36	HSDB: synthetic vitreous fibers	https://toxnet.nlm.nih.gov/cgi-bin/sis/search2/f?./temp/~NO5doq:5	Report	63	Environmental fate of synthetic vitreous fibres
37	Polychlorinated dibenso- para-dioxins and dibenzofurans. 1989. World Health Organisation	http://www.inchem.org/documents/ehc/ehc/ehc88.htm	Report	65	Environmental fate of polychlorinated dibenso-para-dioxins and dibenzofurans
38	Polybrominated biphenyls. 1994. World Health Organisation	http://www.inchem.org/documents/ehc/ehc/ehc15	Report	70	Environmental fate of polybrominated biphenyls

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		2.htm			
39	Tetrabromobisphenol A and derivatives. 1995. World Health Organisation	http://www.inchem.org/documents/ehc/ehc/ehc172.htm	Report	71	Environmental fate of tetrabromobisphenol A
40	The LQM/CIEH S4ULs for Human Health Risk Assessment. 2015. Nathanail, C.P.; McCaffrey,C.; Gillett, A.G.; Ogden, R.C. & Nathanail, J.F.		Book		Environmental fate of metals, benzene and PAHs.
41	Analytical progress and challenges for the detection of oxygenated polycyclic aromatic hydrocarbon transformation products in aqueous and soil environmental matrices: A review. 2019. Coren Pulleyblank, Sabrina Cipullo, Pablo Campo, Brian Kelleher & Frederic Coulon.	https://www.tandfonline.com/doi/full/10.1080/10643389.2018.1547622	Scientific article	78	Over the past 20 years, a growing body of research has raised concerns about the toxicity, fate, and transport of oxygenated transformation products of polycyclic aromatic hydrocarbons. Research targeting these diverse compounds in soil and water systems has been challenged by a lack of standard analytical techniques and suitable reference materials.
42	Toxicological profile for synthetic vitreous fibers. 2004. Agency for Toxic Substances and Disease Registry	https://www.atsdr.cdc.gov/toxprofiles/tp161.pdf	Scientific article	79	Synthetic vitreous fibres do not evaporate into air or dissolve in water. They are generally not broken down to other compounds in the environment and will remain virtually unchanged over long periods. Eventually, synthetic vitreous fibres will be broken down if the water or soil is very acidic or very alkaline. Fibres can enter the air, water, and soil from the manufacture, use, and disposal of synthetic vitreous fibre-containing materials. Fibres with small diameters become airborne more easily than thick fibres and can be transported by wind for longer distances. Synthetic vitreous fibres are not likely to move through soil.
43	Environment Agency. (2009). Soil Guideline Values for benzene in soil. Bristol: Environment Agency.	https://webarchive.nationalarchives.gov.uk/20140328153731/http://www.environment-agency.gov.uk/static/doc	Report	n/a	Summary of environmental fate and transport of benzene.

Evidence Number	Evidence Reference	Evidence hyperlink (if available)	Evidence Type	Corresponding search number	Brief summary of evidence available from source
		uments/Research/SCHO0309BPQI-e-e.pdf			
44	Environment Agency. (2009). Soil Guideline Values for dioxins, furans and dioxin-like PCBs in soil. Bristol: Environment Agency.	https://webarchive.nationalarchives.gov.uk/20140328153735/http://www.environment-agency.gov.uk/static/documents/Research/SCHO0909BQYQ-e-e.pdf	Report	n/a	Summary of environmental fate and transport of dioxins & furans.
45	Environment Agency. (2009). Supplementary information for the derivation of SGV for benzene. Bristol: Environment Agency.	https://webarchive.nationalarchives.gov.uk/20140328153756/http://www.environment-agency.gov.uk/static/documents/Research/SCHO0309BPQC-e-e.pdf	Report	n/a	Information on plant uptake of benzene.
46	Environment Agency. (2009). Supplementary information for the derivation of SGVs for dioxins, furans and dioxin-like PCBs. Bristol: Environment Agency	https://webarchive.nationalarchives.gov.uk/20140328153845/http://www.environment-agency.gov.uk/static/documents/Research/SCHO0909BQYS-e-e.pdf	Report	n/a	Information on plant uptake of dioxins & furans.

Appendix TN07-C – Evidence Extraction

Evidence Number (from Table B)	Detailed summary of evidence
20	Benzo(a)pyrene, a potent carcinogen, is commonly used as an environmental indicator for PAHs. Once emitted to the atmosphere, weight influences the fate of the gaseous PAH mixtures. Heavier PAHs (more than four rings) tend to adsorb to particulate matter, while lighter PAHs (less than four rings) tend to remain gaseous until removed via precipitation. PAH concentrations in water tend to be low (around 100 ng/L) due to their weak solubility. The weak solubility leads to accumulation in sediments and aquatic organisms. PAHs can be absorbed by plants and can accumulate in soil.
22	PBDEs can be released into the air, water, and soil at places where they are produced or used. They have very low water solubility, and when these substances are released to water, they typically bind to sediment. PBDEs in consumer items put in landfills may leach through the soil into groundwater. This is not likely to be a problem, however, because these substances generally bind strongly to soil particles, and therefore, do not move easily through soil layers. Soils and sediments are major sinks for PBDEs. Various food items, including fish, meat, and dairy products, have been shown to contain low concentrations of PBDEs. PBDEs are classes of structurally similar brominated hydrocarbons in which 2–10 bromine atoms are attached to the molecular structure (i.e., diphenyl ether). Monobrominated structures (i.e., one bromine atom attached to the molecule) are often included when describing PBDEs. There are 209 different molecular combinations, or congeners, that are possible for PBDEs, although only a limited number exist in commercial mixtures.

1	The degree of transfer of PAHs to the soil environment depends on the environmental characteristics (e.g. precipitation rates) and the physicochemical characteristics of the individual compounds, especially molecular weight, octanol-air partition coefficient (Koa), aqueous solubility, octanol-water partition coefficient (Kow), Henry's law constant and vapour pressure. As a group of compounds, aqueous solubility, Henry's law constant and vapour pressure decrease and Kow increases with increasing molecular weight, indicating a greater partitioning to the particulate or solid phase of an environment with increasing molecular weight. The preferential partitioning of the higher molecular weight PAHs (more than four rings) to particulate matter in the air mean that these compounds are less likely to undergo long range atmospheric transport and may be expected to be deposited (through wet or dry deposition) in the vicinity of the discharge point. However, gas/particle partitioning is strongly dependent on the ambient conditions such as temperature and particle loading. Information is presented for the following characteristics: · molecular weight (g mol-1) · boiling point (K) · aqueous solubility (mg l-1 or g cm-3) · vapour pressure (Pa) · Henry's Law constant (Pa-m3.mol-1) · log Kow · log Koc · coefficient of diffusion (m2 s-1) · enthalpy of vaporisation (cal mol-1) · critical temperature (K) Benzene is expected to biodegrade fairly readily under most aerobic environmental conditions, molecular breakdown occurring via cis-1,2-dihydroxy-1,2-dihydrobenzene to form catechol with subsequent ring cleavage. Benzene, toluene, ethylbenzene and xylene are often referred to collectively as BTEX compounds or simply BTEX. Consequently, the individual BTEX compounds are often released contemporaneously where they coexist in the environment by virtue of similarities in their physicochemical properties. There are therefore trends in their occurrence and behaviour which merit collective consideration. For this reason, the fate and transport of these monocyclic aromatic hydrocarbons has been considered in a combined literature review
2	Dioxins can remain in the environment for a long time and soils and sediments, which are contaminated with dioxins, can release low levels back into the atmosphere. However, dioxins can be broken down following exposure to UV light. Dioxins may be present in contaminated soils and sediments where they may remain for a long time without being broken down.
3	Asbestos is prevalent in the three main environmental media, namely air, water and soil. The majority of asbestos exposure arises from air due to natural weathering of asbestos containing rock, which may be enhanced by human activity. Once liberated in the environment asbestos persists for an unknown period of time.
4	Hydrogen cyanide may enter the environment from certain industrial processes, from release during combustion or from accidents involving its transport. A wide range of combustion processes produce hydrogen cyanide gas in the smoke or fumes; including building fires, cigarettes, vehicles exhausts and fires involving nitrogen containing materials such as polyurethane foams. Hydrogen cyanide does not generally enter soils and does not remain in water for a long time.

5	PAHs released to the atmosphere are subject to short- and long-range transport and are removed from the atmosphere by wet and dry deposition onto soil, water, and vegetation. In surface water, PAHs can be volatilised, photolysed, biodegraded and bind to suspended particles or sediments, or accumulate in aquatic organisms. The bioconcentration factors vary between 10 and 10,000 with species and type of PAH. PAHs in soil can be volatilised or undergo biotic or abiotic degradation, mainly photolysis and oxidation. PAHs in soil can also enter groundwater and be transported within an aquifer. Based on experimental results, the estimated half-lives of PAHs in soil are e.g. for chrysene 371-387 days, benzo[a]pyrene 229-309 days and dibenz[a,h]anthracene 361-420 days. In the atmosphere, PAHs are present in the gaseous phase or adsorbed to particles. In general, PAHs having two or three rings are present in air predominantly in the vapour phase. PAHs that have four rings exist both in the vapour and particulate phase, and PAHs having five or more rings are found predominantly bound to particles. Atmospheric residence time and transport distance depend on the size of particles to which PAHs are adsorbed and on climatic conditions. About 90-95% of particulate PAHs are associated with particle diameters less than 3.3 µm. Particles with diameter range of 0.1-3.0 µm, with which airborne PAHs are principally associated, remain airborne for a few days or longer and can thus be transported over long distances. In the air PAHs can undergo a number of chemical reactions. The most important are reactions between PAHs adsorbed on the particle surfaces and oxidant gases like NO2, O3, and SO3, and photo oxidation of PAHs irradiated under solar radiation. Photolysis is the most important factor in the decay of PAHs adsorbed to particles in the atmosphere. Many PAHs such as benzo[a]pyrene are, however, rapidly destroyed by UV light. In the absence of local sources, a pronounced seasonal trend has been demonstrated by the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmissions of Air Pollutants in Europe.
6	Once released into the environment, PCDD/Fs adhere to soil and sediment particles. Although it was shown that lower chlorinated dioxins can be degraded by aerobic bacteria from the genera of Sphingomonas, Pseudomonas and Burkholderia, and higher chlorinated PCDD/Fs are known to be reductively dechlorinated in anaerobic sediments (Field and Sierra-Alvarez, 2008), PCDD/Fs are only poorly degradable in the environment. To some extent, both PCDD/Fs in air and soil can be degraded naturally by photodegradation through exposure to ultraviolet radiation. PCDD/Fs in soil are generally bound tightly to particles; hence they are more difficult to destroy by sunlight as compared to PCDD/Fs in the air. As UV radiation cannot penetrate into soil, the photodegradation process of PCDD/Fs in contaminated soil almost exclusively occurs in the top few millimetres of the soil. PCDD/Fs are highly resistant to acids and bases, possess a low vapour pressure and are thermally stable below 600°C. PCDD/Fs are poorly soluble in water but highly soluble in lipids. The sources, physicochemical characteristics and environmental fate of DL-PCBs cannot be considered independently from non-dioxin-like PCBs (NDL-PCBs).
7	PCBs are a group of organochlorine compounds that were synthesised by catalysed chlorination of biphenyl. Due to their physicochemical properties, such as non-flammability, chemical stability, high boiling point, low heat conductivity and high dielectric constants, technical PCB mixtures were widely used in a number of industrial and commercial closed and open applications. As a result of their widespread use, leakages and improper disposal practices, PCBs, like dioxins, have a global distribution in the environment. Many PCBs are persistent because they are poorly degraded and thus they bioaccumulate in the food chain.
8	Dioxins and polychlorinated biphenyls (PCBs) are toxic chemicals that persist in the environment and accumulate in the food chain. Both dioxins and PCBs are very stable against chemical and microbiological degradation and therefore persistent in the environment. Due to their lipophilic properties, they accumulate in the food chain and are stored in fatty tissues. Investigations of the different pathways have indicated that dietary intake represents the main route of human exposure to dioxins and PCBs, with the exception of specific cases of accidental or occupational exposure.

9	Soil and particles suspended in water (in particular the world's oceans), are natural reservoirs of dioxins and PCBs. Soil and sediments tend to accumulate these chemicals. Dioxins and PCBs are poorly soluble in water. However, they are adsorbed onto suspended particles, and therefore ruminants can be exposed to these contaminants in water from rivers or ponds. However, dioxin and PCB intakes may be expected to be limited unless unusual conditions occur. Soil and sediments are natural sinks/reservoirs of dioxins and PCBs. Soil-to-plant transfer of dioxins and PCBs via the root apparatus is generally of minor importance.
10	The reactivity of PBB congeners is dependent on their structure and number of bromine substituents. Analyses of soil samples obtained from the former PBB manufacturing site in Michigan indicated significant degradation of the PBB residues in the soil. The degradation pattern observed supports a photochemical decomposition mechanism. The photochemical debromination of BB-209 leading to lower brominated compounds has also been reported. Based on a limited number of studies, biodegradation does not appear to be significant for PBBs. PBBs are additive flame retardants which were specially applied in synthetic fibres and polymers. As they are not chemically bound to the polymers, they can leach into the environment. PBBs were produced until the mid-1980s, except DecaBB which was produced up till around 2000. PBBs are lipophilic compounds with a low vapour pressure and low water solubility which decreases with increasing degree of bromination. They are generally chemically stable, persistent in the environment and bioaccumulative. It has been reported that higher brominated biphenyls can undergo photolysis and reductive debromination, thereby producing lower brominated congeners. PBBs are present in the environment at low concentrations and likewise in biota and in food and feed.
11	Brominated phenols are not generally readily biodegradable and will persist in the environment for a longer or shorter time depending on the conditions. However, adapted communities of microorganisms and specialist communities (such as anaerobic or sulfidogenic) may degrade the compounds. Log Kow values for the brominated phenols would give rise to estimates for bioaccumulation potential that increase with increasing bromination. Predicted bioconcentration factors (BCFs) of 24, 120 and 3 100 for 2,4-DBP, 2,4,6-TBP and PBP have been calculated. Measured BCFs for 2,4,6-TBP are similar to the predicted value
12	Dioxins and dioxin-like compounds include a range of toxic and environmentally persistent substances.
13	From an analysis of the distribution of lead in surface and subsurface soils at an outdoor shooting range in southeastern Michigan that had been in operation for 50 years, it was found that the distribution of lead in the subsurface corresponded to that in the surface soil horizon, suggesting that lead is mobilizing and migrating downward through the vadose zone. Mobilization appears to be occurring despite the clay-rich nature of the soils and is thought to be due to the transformation of metallic lead into soluble PbCO3 and PbSO4. Both compounds were found in crust material coating shot pellets below a depth of about 5 cm at the site, thus implying a reaction between the metallic lead and the soil. When released in soil, lead is expected to convert to other forms such as PbSO4, Pb3(PO4)2, PbS, and PbO. Elemental lead is not biodegradable.

14	If released to air, PAHs have a wide range of vapor pressures indicating they will exist in both the vapor and particulate phases in the atmosphere. In general, PAHs with 3 rings exist predominately in the vapor phase and those with 5 or more rings exist predominately in the particulate phase. Vapor-phase PAHs will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to range from about 1.9 to 19 hours. Under environmental conditions, PAHs with higher molecular weights are almost completely adsorbed onto fine particles and lower molecular weight PAHs are partially adsorbed; this adsorption may attenuate the degradation of PAHs. Particulate-phase PAHs may be removed from the air by wet and dry deposition. PAHs with 3 or more rings generally absorb UV light above 290 nm with multiple maximums in the 300-400 nm range, and therefore, are expected to be susceptible to direct photolysis by sunlight. If released to soil, Koc values in the range of 1X10+3 to 1X10+4 for low molecular weight (MW 152 to 178) PAHs, 1X10+4 for medium molecular weight (MW 202) PAHs, and 1X10+5 to 1X10+6 for high molecular weight (228 to 278) PAHs, indicate that low molecular weight PAHs are expected to have slight to no mobility in soil and medium and high molecular weight PAHs are expected to be immobile in soil. Volatilization of PAHs from moist soil surfaces may be an important fate process for low and medium molecular weight PAHs, given Henry's Law constants in the range of 1X10-3 to 1X10-5 atm-cu m/mole (low molecular weight PAHs) and of 1X10-6 atm-cu m/mole(medium molecular weight PAHs). Volatilization of high molecular weight PAHs from moist soil is not expected to be an important fate process, given Henry's Law constants of 1X10-7 atm-cu m/mole or less. Adsorption to soil is expected to attenuate volatilization for those PAHs that could volatilize. PAHs are not expected to volatilize from dry soil surfaces (SRC) based upon vapor pressures of <0.05 mm Hg at 25 deg C. Breakdown of PAHs in soil generally takes weeks to months for PAHs with 3 rings, primarily by action of microorganisms; PAHs with 4 or more rings are generally resistant to biodegradation. In laboratory studies, degradation of two-ring PAHs in sandy soils had half-lives of approximately 2 days while three-ring PAHs (anthracene, and phenanthrene) had half-lives of 16 and 134 days, respectively, and four- to six-ring PAHs generally had half-lives >200 days. If released into water, PAHs are expected to adsorb to suspended solids and sediment based upon the estimated Koc. In aquatic environments, low molecular weight PAHs generally biodegrade relatively rapidly, while PAHs with more than 3 rings appear to be resistant to biodegradation. Volatilization of PAHs from water surfaces may be an important fate process for low and medium molecular weight PAHs based on Henry's Law constants. Volatilization of high molecular weight PAHs from water surfaces is not expected to be an important fate process. Any volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column.

15	If released to air, a vapor pressure of 8.25X10-13 mm Hg at 25 deg C indicates octachlorodibenzo-p-dioxin will exist solely in the particulate phase in the ambient atmosphere. Particulate-phase octachlorodibenzo-p-dioxin will be removed from the atmosphere by wet and dry deposition. If released to soil, octachlorodibenzo-p-dioxin is expected to have no mobility based upon an estimated Koc of 690,000. Volatilization from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 6.7X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization from moist soil surfaces. Based on an aerobic digestion study in water, octachlorodibenzo-p-dioxin is not expected to degrade in soil. If released into water, octachlorodibenzo-p-dioxin is expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is expected to be an important fate process based upon this compound's estimated Henry's Law constant. Octachlorodibenzo-p-dioxin is not expected to undergo hydrolysis in the environment due to the lack of hydrolyzable functional groups. Octachlorodibenzo-p-dioxin absorbs UV light in the environmental spectra above 290 nm and is susceptible to direct photolysis in sunlight. Based upon quantum yield measurements and photolysis studies in water/acetonitrile solutions, the following photolysis half-lives (under conditions of midday sun) have been estimated for octachlorodibenzo-p-dioxin in aquatic bodies at a latitude of 40 deg N: spring-20.55 days, summer-17.85 days, fall-31.26 days and winter-50.45 days. The direct photolysis of octachlorodibenzo-p-dioxin proceeds by a photo-dechlorination process to yield lower chlorinated dibenzo-p-dioxins. Photodegradation of octachlorodibenzo-p-dioxin naturally adsorbed to five different fly ashes was examined in the solid-phase using a rotary photoreactor and a mercury vapor lamp to approximate the solar spectrum; no statistically significant photodegradation was observed on any of the fly ashes which ranged in color from black to gray to yellow; when the fly ashes were spiked with silica gel, photodegradation did occur (half-life of 270 hr); it was suggested that photodegradation of octachlorodibenzo-p-dioxin bound to atmospheric particles is not an important mechanism for its removal from the environment. The Koc of octachlorodibenzo-p-dioxin is estimated as 690,000(SRC), using a log Kow of 8.20 and a regression-derived equation. According to a classification scheme, this estimated Koc value suggests that octachlorodibenzo-p-dioxin is expected be immobile in soil (SRC).
16	If released to soil, TCDD is expected to have no mobility based upon a mean Koc value of 2.45X10+7. Volatilization from moist soil surfaces may be an important fate process based upon an estimated Henry's Law constant of 3.2X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. TCDD was photo-degraded 99.9% during and immediately after soil application in test site studies, indicating this is the most probable route of degradation. TCDD is not expected to volatilize from dry soil surfaces based upon its vapor pressure. The Henry's Law constant for TCDD is estimated as 3.2X10-6 atm-cu m/mole (SRC) derived from its vapor pressure, 1.5X10-9 mm Hg, and water solubility, 2.0X10-4 mg/L. This Henry's Law constant indicates that TCDD is expected to volatilize from water surfaces. Based on this Henry's Law constant, the volatilization half-life from a model river (1 m deep, flowing 1 m/sec, wind velocity of 3 m/sec) is estimated as 21 days (SRC). The volatilization half-life from a model lake (1 m deep, flowing 0.05 m/sec, wind velocity of 0.5 m/sec) is estimated as 160 days (SRC). However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column. The estimated volatilization half-life from a model pond is 5.1X10+4 years if adsorption is considered. TCDD's estimated Henry's Law constant indicates that volatilization from moist soil surfaces may occur (SRC). However, adsorption to soil is expected to attenuate volatilization (SRC). TCDD is not expected to volatilize from dry soil surfaces (SRC) based upon its vapor pressure. Volatilization of TCDD that has been mixed into soil depths beneath the upper surface boundary will volatilize extremely slowly.

17	If released to air, a vapor pressure of 4.4X10-11 mm Hg at 25 deg C indicates hexachlorodibenzo-p-dioxin will exist solely in the particulate phase in the ambient atmosphere. Particulate-phase hexachlorodibenzo-p-dioxin will be removed from the atmosphere by wet and dry deposition. If released to soil, hexachlorodibenzo-p-dioxin is expected to have no mobility based upon an estimated Koc of 420,000. Volatilization from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 5.7X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. No biodegradation was reported for hexachlorodibenzo-p-dioxin (as 1,2,3,6,7,8-/1,2,3,7,8,9-hexachlorodibenzo-p-dioxin) in a sludge-amended soil field study. A half-life of approx 20 years was reported for hexachlorodibenzo-p-dioxin (as 1,2,3,6,7,8-/1,2,3,7,8,9-hexachlorodibenzo-p-dioxin) in a sludge-amended soil field study. If released into water, hexachlorodibenzo-p-dioxin is expected to adsorb to suspended solids and sediment based upon the estimated Koc. According to a model of gas/particle partitioning of semivolatile organic compounds in the atmosphere, hexachlorodibenzo-p-dioxin, which has a vapor pressure of 4.4X10-11 mm Hg at 25 deg C exists solely in the particulate phase in the ambient atmosphere (SRC). Particulate-phase hexachlorodibenzo-p-dioxin may be removed from the air by wet and dry deposition (SRC). The rate constant for the vapor-phase reaction of hexachlorodibenzo-p-dioxin with photochemically-produced hydroxyl radicals has been estimated as 4.0X10-13 cu cm/molecule-sec at 25 deg C(SRC) using a structure estimation method. This corresponds to an atmospheric half-life of about 41 days at an atmospheric concentration of 5X10+5 hydroxyl radicals per cu cm. Hexachlorodibenzo-p-dioxin is not expected to undergo hydrolysis in the environment due to the lack of hydrolyzable functional groups nor to directly photolyze due to the lack of absorption in the environmental UV spectrum (>290 nm) (SRC).
18	If released to air, an estimated vapor pressure of 1.5X10-6 mm Hg at 25 deg C indicates 2,3,7,8-tetrachlorodibenzofuran will exist in both the vapor and particulate phases in the ambient atmosphere. Vapor-phase 2,3,7,8-tetrachlorodibenzofuran will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 63 days. Particulate-phase 2,3,7,8-tetrachlorodibenzofuran will be removed from the atmosphere by wet and dry deposition. If released to soil, 2,3,7,8-tetrachlorodibenzofuran is expected to be immobile based upon an estimated Koc of 85,000. Volatilization from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 1.5X10-5 atm-cu m/mole. This compound is expected to be biologically recalcitrant under aerobic conditions in both soil and water but may undergo reductive dechlorination at slow rates in anaerobic environments. Photolytic degradation may occur on soil and water surfaces. Photolysis half-lives in natural waters ranged from 5.9 hours to 1.2 days. If released into water, 2,3,7,8-tetrachlorodibenzofuran is expected to adsorb to suspended solids and sediment in water based upon the estimated Koc. Volatilization from water surfaces is expected to be an important fate process based upon this compound's estimated Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 4 and 37 days, respectively. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column.
19	If released to air, a vapor pressure of 2.63X10-9 mm Hg at 25 deg C indicates 2,3,4,7,8-pentachlorodibenzofuran will exist solely in the particulate phase in the ambient atmosphere. Particulate-phase 2,3,4,7,8-pentachlorodibenzofuran will be removed from the atmosphere by wet and dry deposition. If released to soil, 2,3,4,7,8-pentachlorodibenzofuran is expected to have no mobility based upon an estimated Koc of 140,000. Volatilization from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 5.0X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. This compound is expected to be biologically recalcitrant under aerobic conditions but may undergo reductive dechlorination at slow rates in anaerobic environments. If released into water, 2,3,4,7,8-pentachlorodibenzofuran is expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is expected to be an important fate process based upon this compound's estimated Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 9 and 106 days, respectively. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column.

20	If released to air, a vapor pressure of 348 mm Hg at 20 deg C indicates methyl isocyanate will exist solely as a vapor in the atmosphere. Vapor-phase methyl isocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 118 days. Methyl isocyanate does not contain chromophores that absorb at wavelengths >290 nm and therefore is not expected to be susceptible to direct photolysis by sunlight. Hydrolysis is expected to be the dominant fate process for methyl isocyanate in soil and water based upon half-lives of 20 and 9 min at 15 and 25 deg C, respectively, calculated from measured aqueous hydrolysis rate constants. If released to soil, adsorption, biodegradation, and volatilization from moist soil surfaces are not expected to compete with hydrolysis as important fate processes; however, methyl isocyanate may volatilize from dry soil surfaces based upon its vapor pressure. If released to water, adsorption to sediment, bioconcentration, biodegradation, and volatilization from water surfaces are not expected to compete with hydrolysis as important fate processes. The products of hydrolysis may include N-carboxymethylamine, methylamine, carbon dioxide, and N,N'-dimethylurea.
21	If released to air, a vapor pressure of 2.3X10-2 mm Hg at 25 deg C indicates toluene diisocyanate will exist solely as a vapor in the ambient atmosphere. Vapor-phase toluene diisocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 20 hrs. Atmospheric degradation may also occur through contact with clouds, fog or rain. Toluene diisocyanate does not contain chromophores that absorb at wavelengths >290 nm, and therefore, is not expected to be susceptible to direct photolysis by sunlight. If released to moist soil, toluene diisocyanate is not expected to adsorb to soil due to its rapid degradation reaction with water. In one experiment simulating a spill, 5.5% of the original tolulene diisocyanate remained after 24 hours and in a field situation, the concentration declined to the ppm level in 12 weeks. If released to water, toluene diisocyanate is not expected to leach or adsorb to solids or sediments due to its rapid degradation reaction with water. If toluene diisocyanate is released into water in a spill situation, a crust forms around the liquid toluene diisocyanate and <0.5% of the original material remains after 35 days. Low concentrations of toluene diisocyanate hydrolyze in the aqueous environment in approximately a day. Toluene diisocyanate is not expected to bioconcentrate in aquatic organisms.
22	If released to air, an extrapolated vapor pressure of 2.6 mm Hg at 25 deg C indicates phenyl isocyanate will exist solely as a vapor in the atmosphere. Vapor-phase phenyl isocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 5 days. Phenyl isocyanate does not contain chromophores that absorb at wavelengths >290 nm, and therefore is not expected to be susceptible to direct photolysis by sunlight. Isocyanates hydrolyze rapidly in water; therefore, soil mobility, biodegradation, and volatilization of phenyl isocyanate in moist soil are not expected to be important environmental fate processes. Phenyl isocyanate may volatilize from dry soil surfaces based upon its vapor pressure. Since isocyanates hydrolyze rapidly in water, hydrolysis half-lives of phenyl isocyanate range from 20 seconds to 75.5 minutes, biodegradation, aquatic bioconcentration, volatilization, and adsorption to sediment of phenyl isocyanate are not expected to be important environmental fate processes
23	If released to air, a vapor pressure of 0.05 mm Hg at 25 deg C indicates that hexamethylene diisocyanate will exist solely in the vapor phase in the ambient atmosphere. Vapor-phase hexamethylene diisocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 1.3 days. Aliphatic isocyanates do not absorb light at wavelengths >290 nm, and therefore hexamethylene diisocyanate is not expected to be susceptible to direct photolysis by sunlight. Atmospheric degradation may also occur through contact with clouds, fog or rain. Hexamethylene diisocyanate hydrolyzes to form amines and polyureas. If released to water or moist soil, hexamethylene diisocyanate is not expected to leach or adsorb to solids and sediments, volatilize from water surfaces, nor bioconcentrate due to its rapid hydrolysis.

24	If released to air, an estimated vapor pressure of 200 mm Hg at 25 deg C indicates ethyl isocyanate will exist solely as a vapor in the atmosphere. Vapor-phase ethyl isocyanate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 15 days. Ethyl isocyanate does not contain chromophores that absorb at wavelengths >290 nm and therefore is not expected to be susceptible to direct photolysis by sunlight. Isocyanates undergo rapid hydrolysis under environmental conditions with half-lives of less than 10 minutes. Therefore, hydrolysis is expected to be the dominant fate process for ethyl isocyanate in moist soil and water. If released to soil, adsorption, biodegradation, and volatilization from moist soil surfaces are not expected to compete with hydrolysis as important fate and transport processes; however, ethyl isocyanate may volatilize from dry soil surfaces based upon its vapor pressure. If released to water, adsorption to sediment, bioconcentration, biodegradation, and volatilization from water surfaces are not expected to compete with hydrolysis as important fate and transport processes.
25	If released to air, a vapor pressure of 2.00X10-6 mm Hg at 25 deg C indicates triphenyl phosphate will exist in both the vapor and particulate phases in the atmosphere. Vapor-phase triphenyl phosphate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 12 hours. Particulate-phase triphenyl phosphate will be removed from the atmosphere by wet and dry deposition. Triphenyl phosphate does not absorb light at wavelengths >290 nm and, therefore, is not expected to be susceptible to direct photolysis by sunlight. If released to soil, triphenyl phosphate is expected to have slight mobility based upon a Koc range of 2,514 to 3,561. Volatilization from moist soil surfaces is expected to be an important fate process based upon an estimated Henry's Law constant of 3.3X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. Mineralization half-lives of 37 and 32 days under aerobic and anaerobic conditions, respectively, in a loamy sand suggest that biodegradation is an important environmental fate process in soil. If released into water, triphenyl phosphate is expected to adsorb to suspended solids and sediment based upon the Koc values. Biodegradation half-lives of 2-4 days in river die-away tests suggest that biodegradation may be an important environmental fate process in water. Volatilization from water surfaces is expected to be an important fate process based upon this compound's estimated Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 20 and 152 days, respectively. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column. The estimated volatilization half-life from a model pond is 400 days if adsorption is considered. Hydrolysis is expected to occur, particularly under alkaline conditions; half-lives of 19 and 3 days were observed for triphenyl phosphate in buffered solutions at pH 7 and pH 9, respectively.

26	If released to air, an estimated vapor pressure of 1.2X10-6 mm Hg at 25 deg C indicates tri(2-butoxyethyl) phosphate will exist in both the vapor and particulate phases in the atmosphere. Vapor-phase tri(2-butoxyethyl) phosphate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 3 hours. Particulate-phase tri(2-butoxyethyl) phosphate will be removed from the atmosphere by wet and dry deposition. Tri(2-butoxyethyl) phosphate does not contain chromophores that absorb at wavelengths >290 nm and, therefore, is not expected to be susceptible to direct photolysis by sunlight. If released to soil, tri(2-butoxyethyl) phosphate is expected to have low mobility based upon an estimated Koc of 1260. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 1.2X10-11 atm-cu m/mole. Tri(2-butoxyethyl) phosphate is not expected to volatilize from dry soil surfaces based upon its estimated vapor pressure. Utilizing the Japanese MITI test, 0% of the theoretical BOD was reached in 4 weeks indicating that biodegradation is not an important environmental fate process. However, in river die-away studies tri(2-butoxyethyl) phosphate degraded 100% in 30 days in one of three experiments. If released into water, tri(2-butoxyethyl) phosphate is expected to adsorb to suspended solids and sediment based upon the estimated Koc. Studies have shown that tri(2-butoxyethyl) phosphate can be degraded in environmental conditions; however, the mode of degradation may be unclear. Tri(2-butoxyethyl) phosphate degraded 100% in 80 days aerobic pond water and pond water with sediment, but also degraded 20-75% in 80 days in sterilized experiments. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. Tri(2-butoxyethyl) phosphate may undergo environmental hydrolysis based on estimated half-lives of 95-93 days at pH 5-9.
27	If released to air, a vapor pressure of 0.393 mm Hg at 25 deg C indicates triethyl phosphate will exist solely as a vapor in the atmosphere. Vapor-phase triethyl phosphate will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 7.0 hours. Triethyl phosphate does not absorb light at wavelengths >290 nm and therefore is not expected to be susceptible to direct photolysis by sunlight. If released to soil, triethyl phosphate is expected to have high mobility based upon an estimated Koc of 65. Volatilization from moist soil surfaces is not expected to be an important fate process based upon a Henry's Law constant of 3.60X10-8 atm-cu m/mole. Triethyl phosphate is not expected to volatilize from dry soil surfaces based upon its vapor pressure. If released into water, triethyl phosphate is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Triethyl phosphate, present at 100 mg/L, reached 0% of its theoretical BOD in 4 weeks using an activated sludge inoculum at 30 mg/L and the Japanese MITI test and is therefore not expected to readily biodegrade in the environment. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's Henry's Law constant. A neutral rate of triethyl phosphate hydrolysis at 25 deg C was measured as 2.4X10-10/sec. Second-order alkaline hydrolysis rate constants of 1.75X10-5/M-sec (half-life of 1.3X10+3 years at pH 8) and 7.9X10-4 L/mol-min (half-life of 1.7X10+3 years at pH 8) were measured for triethyl phosphate at 27 and 25 deg C, respectively.

28 If released to air, a vapor pressure of 742 mm Hg at 25 deg C indicates hydrogen cyanide will exist solely as a vapor in the atmosphere. Vapor-phase hydrogen cyanide will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 530 days. Hydrogen cyanide does not contain chromophores that absorb at wavelengths >290 nm and, therefore, is not expected to be susceptible to direct photolysis by sunlight. If released to soil, hydrogen cyanide is expected to have very high mobility based upon an estimated Koc of 15. The pKa of hydrogen cyanide is 9.2, indicating that this compound will exist partially in the anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil surfaces is expected to be an important fate process based upon a Henry's Law constant of 1.33X10-4 atm-cu m/mole. Hydrogen cyanide may volatilize from dry soil surfaces based upon its vapor pressure. Hydrogen cyanide can be biodegraded by acclimated microbial cultures and sludges but is usually toxic at high concentrations to unacclimated microbial systems, indicating that biodegradation may not be an important environmental fate process in soil and water. If released into water, hydrogen cyanide is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Volatilization from water surfaces is expected to be an important fate process based upon this compound's Henry's Law constant. Estimated volatilization half-lives for a model river and model lake are 5 hrs and 3 days, respectively. Hydrolysis is not expected to be an important environmental fate process since this compound contains lacks functional groups that hydrolyze under environmental conditions (pH 5 to 9).

29 If released to air, vapor pressures of 5.25X10-8, 7X10-11 and 3.98X10-10 mm Hg for hexa-, octa-, and decabromobiphenyl, respectively, indicate that highly substituted PBBs will exist solely in the particulate phase in the ambient atmosphere. Particulate-phase PBBs will be removed from the atmosphere by wet and dry deposition. If released to soil, hexa-, octa-, and decabromobiphenyl are expected to have no mobility based upon estimated Koc values of 71,000, 24,000, and 1.1X10+6, respectively. Volatilization from moist soil surfaces is not expected to be an important fate process based upon estimated Henry's Law constants of 3.9X10-6, 2.9X10-9, and 4.2X10-8 atm-cu m/mole, for hexa-, octa-, and decabromobiphenyl, respectively. If released into water, hexa-, octa-, and decabromobiphenyl are expected to adsorb to suspended solids and sediment based upon their estimated Kocs. Lower substituted PBBs might biodegrade in aerobic water and sediment while higher substituted PBBs are resistant to aerobic biodegradation. It has been shown that anaerobic microorganisms obtained from polluted river sediments can biodegrade higher substituted PBBs. Based on studies in organic solvents, polybrominated biphenyls may photodegrade by reductive debromination at wavelengths greater than 290 nm with the formation of lower brominated biphenyls. The debromination usually occurs with the stepwise preferential loss of bromine from the ortho and para positions of the biphenyl ring. Volatilization from water surfaces is not expected to be an important fate process based upon these compounds' estimated Henry's Law constants. BCF values of >1,000 for PBBs suggest the potential for bioconcentration in aquatic organisms is high for isomers with 6 or less bromines. Hydrolysis is not expected to be an important environmental fate process since PBBs lack functional groups that hydrolyze under environmental conditions.

30	2,2',6,6'-Tetrabromobisphenol A is a ubiquitous environmental contaminant that is observed in both abiotic and biotic matrices. If released to air, a vapor pressure of 4.68X10-8 mm Hg at 25 deg C indicates 2,2',6,6'-tetrabromobisphenol A will exist in both the vapor and particulate phases in the atmosphere. Vapor-phase 2,2',6,6'-tetrabromobisphenol A will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 5.4 days. Particulate-phase 2,2',6,6'-tetrabromobisphenol A will be removed from the atmosphere by wet and dry deposition. 2,2',6,6'-Tetrabromobisphenol A absorbs UV light at wavelengths >290 and is susceptible to direct photolysis by sunlight. If released to soil, 2,2',6,6'-tetrabromobisphenol A is expected to have no mobility based upon an estimated Koc of 2.7X10+5. The pKa1 and pKa2 of 2,2',6,6'-tetrabromobisphenol A are 7.5 and 8.5 respectively, indicating that this compound will exist partially in anion form in the environment and anions generally do not adsorb more strongly to soils containing organic carbon and clay than their neutral counterparts. Volatilization from moist soil surfaces is not expected to be an important fate process based upon an estimated Henry's Law constant of 2.0X10-7 atm-cu m/mole. 2,2',6,6'-Tetrabromobisphenol A is not expected to volatilize from dry soil surfaces based upon its vapor pressure. Anaerobic biodegradation of 2,2',6,6'-tetrabromobisphenol A has been shown to occur in soil studies with primary degradation being nearly complete within 10-64 days in some tests. Anaerobic biodegradation occurs through a biodehalogenation through tri- and dibromobisphenol A with a final product of bisphenol A. Aerobic biodegradation in soil can also occur with reported half-lives ranging from 9 to 93 days. If released into water, 2,2',6,6'-tetrabromobisphenol A is expected to adsorb to suspended solids and sediment based upon the estimated Koc. Observed biodegradation half-lives in anaerobic sediment studies range from 5 to >130 days. Aerobic biodegradation may also occur based on a sediment/water study reporting half-lives from 48 to 84 days. Volatilization from water surfaces is not expected to be an important fate process based upon this compound's estimated Henry's Law constant. In laboratory tests, 2,2',6,6'-tetrabromobisphenol A had direct photolysis half-lives of 17 minutes to 5.8 hours in aqueous solutions of varying pH. Sensitized photo-oxidation may have some importance as a fate process for 2,2',6,6'-tetrabromobisphenol A in sunlit natural water. Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyze under environmental conditions.

31	If released to air, estimated vapor pressures of 1.5X10-3 and 1.1X10-4 mm Hg at 25 deg C indicate mono- and dibromodiphenyl ether will exist solely as a vapor in the atmosphere. Tri- thru hexabromodiphenyl ether have estimated vapor pressures of 2.2X10-6 to 5.1X10-8 mm Hg at 25 deg C and are expected to exist in both the vapor and particulate phases in the ambient atmosphere. Hepta- thru decabromodiphenyl ether have estimated vapor pressures of 1.3X10-9 to 4.7X10-12 mm Hg at 25 deg C and are expected to exist solely in the particulate phase in the ambient atmosphere. Vapor-phase mono- thru hexabromodiphenyl ethers are degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-lives for these reactions in air are estimated to be 3 to 46 days, calculated from rate constants of 5.1X10-12 to 3.5X10-13 cu cm/molecule-sec at 25 deg C. Particulate-phase tri- thru decabromodiphenyl ethers may be removed from the air by wet or dry deposition. Fifteen polybrominated diphenyl ethers, tetra- thru deca-isomers, were reported to absorb at wavelengths >290 nm and therefore are expected to be susceptible to direct photolysis by sunlight. If released to soil, polybrominated diphenyl ethers are expected to have no mobility based upon estimated Koc values of 3100 to 276,000. Volatilization from moist soil surfaces is expected to be an important fate process for mono- thru hexa-isomers based upon estimated Henry's Law constant of 0.29 to 8.5X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. Hepta- thru decabromodiphenyl ether are not expected to volatilize from water surfaces based upon estimated Henry's Law constants of 6.1X10-7 to 4.5X10-8 atm-cu m/mole. Polybrominated diphenyl ethers are not expected to volatilize from dry soil surfaces based upon their estimated vapor pressures from 1.5X10-4 to 4.7X10-12 mm Hg. Based on biodegradation screening tests in water, polybrominated diphenyl ethers are not expected to biodegrade in soil or water. No degradation (as CO2 evolution) was seen after 29 days for pentabromodiphenyl in an OECD 301B ready biodegradation test. The substance tested was a composite sample from two producers with the following composition: 33.7% tetrabromodiphenyl ether; 54.6% pentabromodiphenyl ether; and 11.7% hexabromodiphenyl ether. The test was extended to 93 days to allow sufficient opportunity for adaption to occur. At the end of 93 days, 2.4% of the theoretical amount of CO2 had been evolved. If released into water, polybrominated diphenyl ethers are expected to adsorb to suspended solids and sediment based upon the estimated Koc values. Volatilization from water surfaces is expected to be an important fate process for mono- thru hexa-isomers based upon estimated Henry's Law constants. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column. Hydrolysis is not expected to be an important environmental fate process since polybrominated diphenyl ethers lack functional groups that hydrolyze under environmental conditions.

32	If released to air, a vapor pressure of 4.7X10-7 mm Hg at 25 deg C indicates hexabromocyclododecane will exist in both the vapor and particulate phases in the atmosphere. Vapor-phase hexabromocyclododecane will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 2.6 days. Particulate-phase hexabromocyclododecane will be removed from the atmosphere by wet or dry deposition. UV spectral data suggest that hexabromocyclododecane does not absorb at wavelengths >290 nm and, therefore, is not expected to be susceptible to direct photolysis by sunlight. Monitoring data from remote areas of the globe indicate that hexabromocyclododecane is subject to long-range environmental transport in the atmosphere. The majority of long-range environmental transport is likely to occur in aerosol form. If released to soil, hexabromocyclododecance is expected to be immobile based upon an estimated Koc of 91,000. Volatilization from moist soil surfaces may occur based upon an estimated Henry's Law constant of 6.1X10-6 atm-cu m/mole. However, adsorption to soil is expected to attenuate volatilization. Results of screening studies indicate that biodegradation of hexabromocyclododecane can range from not degradable to being inherently biodegradable depending on test conditions. Aerobic soil degradation tests have determined half-lives ranging from 63-441 days. Dissipation half-lives were roughly 2-4 times longer in biologically-inhibited soil indicating that biodegradation is an important fate process in soil. One microcosm study found biotransformation half-lives of 63 and 6.9 days in aerobic and anaerobic soil, respectively. If released into water, hexabromocyclododecance is expected to adsorb to suspended solids and sediment based upon the estimated Koc. A microcosm study found biotransformation half-lives of 11-32 and 1.1-1.5 days in aerobic and anaerobic river water, respectively. Sediment half-lives of 101 and 191 days have been reported for 20 and 12 deg C, respectively. Volatilization from water surfaces is expected to be an important fate process based upon this compound's estimated Henry's Law constant. Using this Henry's Law constant and an estimation method, volatilization half-lives for a model river and model lake are 15.6 and 122 days, respectively. However, volatilization from water surfaces is expected to be attenuated by adsorption to suspended solids and sediment in the water column. The estimated volatilization half-life from a model pond is >10 years if adsorption is considered. Hydrolysis is not an important environmental fate process.
33	If released to air, asbestos fibers will eventually return to soil or water through gravitational settling and wet and dry deposition. Mean airborne concentrations of asbestos in US cities are roughly 2-4 ng/cu m, but much higher levels are typically observed near source dominated areas. Movement of asbestos fibers through soils only occur during runoff or erosion. Asbestos fibers will not volatilize or degrade in soils although they may be resuspended to the air by vehicular traffic or mining operations. Asbestos may be released to water from waste water in asbestos related industries, erosion of natural deposits or waste piles, corrosion of asbestos-cemented/asbestos-lined pipes, disintegration of asbestos containing roofing materials followed by subsequent runoff. Asbestos does not volatilize or degrade from water surfaces, nor does it appear to bioconcentrate in aquatic organisms.
34	Due to the positive zeta potential of chrysotile in environmental media, low viscosity suspensions could be prepared by means of the inherent charge of the chrysotile surfaces. This charge however, is so small in pure chrysotile that dispension was obtained only with short fibers and low fiber concentrations (1%). By increasing the concentration of certain metallic salts ... it was found that low viscosity suspensions could be prepared under almost any environmental condition. These observations suggest that the presence of trace metals will produce a suspension of chrysotile asbestos in water which will persist until sufficient magnesium has leached from the chrysotile structure to degrade the suspension. ... It is probable that under certain conditions asbestos will persist in the water column until its concentration becomes high enough to destroy the suspension or until leaching of the brucite layer decays the zeta potential to a point where it will become negative.

35	An increased risk is also associated with increased exposure to asbestos in water in municipalities such as San Francisco or Seattle where asbestos occurs naturally in water, in cities where there is a interaction between aggressive water and asbestos-cement pipe, or in cities whose water may be contaminated as a result of asbestos operations.
36	Fiber concentrations in the atmosphere have been generally low and range from undetectable to 4X10-5 to 9X10-3 fiber/cu cm.
37	They determined that the deposition of 2,3,7-8-tetraCDD from air to soil should follow an exponential decay pattern in the Gaussian-distribution along the cross-section of the downwind direction. Thibodeaux (1983) studied the air transport of 2,3,7,8-tetraCDD at a herbicide production facility in Jacksonville, Arkansas, USA. The solubility of 2,3,7,8-tetraCDD in water has been extensively studied (see section 2), but much less data are available for the other PCDDs and PCDFs. However, data from microbiological experiments indicate that 2,3,7,8-tetraCDD is highly adsorbed to sediments and biota. Matsumura et al. (1983) suggested that more than 90% of the2,3,7,8-tetraCDD in an aquatic medium could be present in the adsorbed state. Rappe et al studied a suspension of soot/dust in the wash water from a PCB fire. The suspension contained 100 ng/ml of various PCDFs, but when the soot was settled the water contained no detectable levels of PCDFs (detection level: 0.1 ng/ml of each isomer). Most of the PCDDs and PCDFs, if present in waterways, should be in the sediments or attached to suspended particles. The mobility of 2,3,7,8-tetraCDD and of a dichlorodioxin in soils has been studied by Helling et al. (1973). Both were found to be immobile in all soils and, therefore, would not be leached out by rainfall or irrigation, though lateral transport during surface erosion of the soil could occur. The probable media and modes of transport of PCDDs from soils are the following: (1) to air via contaminated airborne dust particles; (2) to surface water via eroded soil transported by water; (3) to groundwater via leaching; (4) to air via volatilization. Movement of particulate matter containing adsorbed PCDDs and PCDFs has been considered to be a much more important transport mechanism than leaching and volatilization because of the low water solubility and volatility of these compounds (Josephson, 1983). However, the monitoring of Seveso soil one year after the accident showed that the highest 2,3,7,8-tetraCDD levels were not present in the topmost soil layer (0.5 cm), but very often in the second (0.5-1.0 cm) or third (1.0-1.5 cm) layers. This disappearance of at least a part of the 2,3,7,8-tetraCDD from the topmost soil layer was speculated to be due to volatilization or vertical movement through the soil. Therefore, it appears that volatilization from soil and leaching to groundwater can be responsible for the transport of PCDDs and PCDFs from soils under certain conditions, namely, heavy rainfall on sandy soils. Studies by Young (1983) indicate that the half-life for 2,3,7,8-tetraCDD in soil is 10-12 years. Like other PCDDs and PCDFs, 2,3,7,8-tetraCDD is chemically quite stable, and is not likely to be degraded at a significant rate by hydrolytic reactions under environmental conditions. Under these conditions, TCDD seems also to be rather stable to photochemical degradation. The half-life of TCDD of about 10-12 years, as found by Young et al. (1983) for soil, is in agreement with this observation.

38 Secondary ways of entrance of PBBs into the atmosphere, e.g., through evaporation from contaminated soils, are thought to be negligible, though small losses of PBBs from soil during long-term (6 months) incubation studies were observed, which were associated with volatilization rather than sorption or masking. Because compounds like PBB are very poorly soluble, they are primarily found in sediments of polluted lakes and rivers. In laboratory experiments, Simmons & Kotz (1982) determined the "percent adsorption" of PBBs in sediments from sites at Lake Michigan and the Huron River and concluded from values ranging from 9 to 32% that the capacity of the sediments for PBB was small to moderate. Gas-phase reactions with hydroxyl (OH) radicals also influence the lifetimes of organic compounds emitted into the atmosphere. Atkinson et al. (1984) determined rate constants for the gas-phase reaction of OH radicals with biphenyl and predicted, from their findings, that the chlorine - and bromine-substituted biphenyls would have OH radical rate constants of < 8 x 10-12 cm3/molecule per second at room temperature. Sediments are potential sources as well as sinks for most chemicals. Desorption of a contaminant from the sediments is favoured where a high concentration of organic matter exists in the water column. The presence of organic matter may also enhance the partitioning of the contaminant in the water phase and, thus, facilitate further movement with the water mass. Laboratory studies on the mode of action that PBBs may take in their movement through the water column have verified that the total organic content of the natural water will decrease the adsorption of PBB onto sediment and therefore keep the PBB in the water phase. For example, comparing the distilled water versus natural water systems, in river water with an organic content of 11-12 mg C/litre, the % PBB-adsorption was decreased by 33-43%; for lake water with an organic content of 3.8 mg/litre, the % PBB-adsorption was reduced by about 12%. Another investigation indicated that the solubilities of PBBs were directly correlated with the levels of dissolved organics in the water. However, in the natural environment, upon settling out, the association of the contaminant with the sediment may become the dominant process in the water/sediment system. Transport of PBBs is thought to take place, when mixing or bioturbation of sediments causes redistribution of the contaminant in the water column, and through transport of the sediment itself. The mobility in soils of a chemical like PBBs will largely be governed by its solubility in water and its adsorption, or interaction, with soil particles. Compounds like PBBs are very stable to hydrolysis, chemical oxidation, and thermal decomposition. Degradation by purely abiotic chemical reactions (excluding photochemical reactions) is therefore considered an unlikely environmental sink.

39 The calculated half-life of decomposition of TBBPA in water by UVR was 10.2 days in spring, 6.6 in summer, 25.9 in autumn, and 80.7 days in winter. Cloud cover lengthened the calculated half-life by a factor of 2. The water depth influenced the direct photodegradation more as the UV-absorption of the given body of water increased. Because of its partition coefficient and low water solubility, TBBPA in the environment is expected to sorb to a large extent onto sediment and organic matter in the soil. Where detected in the environment, TBBPA is mainly found in soil and sediment samples. A relatively high bioconcentration factor seems to be balanced by rapid excretion and the compound has not normally been found in environmental biological samples. The phenolic groups of TBBPA may be methylated in the environment and the resulting Me2-TBBPA is more lipophilic. Five derivatives of TBBPA were identified as being in commercial use as flame retardants. These are: tetrabromobisphenol A dibromopropylether, tetrabromobisphenol A bis(allylether), tetrabromobisphenol A bis(2-hydroxyethyl ether), tetrabromobisphenol A carbonate oligomers, and tetrabromobisphenol A brominated epoxy oligomer. In addition, the dimethylated derivative of TBBPA has been identified in a few environmental samples. This dimethylated-TBBPA derivative is suspected of being an environmental metabolite of TBBPA.

40	Benzene is the most soluble and volatile of the BTEX but its exact solubility varies in the presence of these, and other, hydrocarbons in a mixture. Benzene in soil may volatilise into the atmosphere or leach into surface and ground water. In soils and groundwater, benzene primarily degrades aerobically. Parameters used in deriving the LQM/CIEJ s4ULs values for benzene including diffusion coefficient in water, vapour pressure and water solubility. Most PAHs have low vapour pressure and so in the air tend to adsorb onto airborne particulates. They are found widely throughout the environment in the air, water and soil. PAHs, being structurally similar to the humic components of soil, become closely associated with this organic component. The half-lives of PAHs in soils have been estimated to be from 0.2 – 3 years for acenaphthene and up to 1-9 years for benzo[ghi]perylene. Soil concentrations tend to reflect aggregate atmospheric levels over a considerable time period. Most PAHs reach soil or herbage by atmospheric deposition. In soils, PAHs can be transferred to the air, to pore or ground water, or undergo biological or non-biological degradation. Estimated half-lives for PAHs in soil vary: benzo[a]pyrene 229-309 days, chrysene 371-387 days, dibenzo[ah]anthracene 361 – 420 days. Arsenate is considered to be more mobile in soils and to be the main species at low pH under reducing conditions. Arsenate is believed to bind strongly to iron and manganese oxides and therefore remain in the surface layer of the soil after deposition. The relationship between arsenate and arsenite in soils and water systems is complicated by the presence of organic matter, redox potential and pH, clay minerals, iron and aluminium oxides and microbial action which influence the relative stability of the two anions in solution and the rate of oxidation between the two forms in soil. The behaviour of beryllium in soil depends on its chemical form. Some beryllium compounds are highly soluble in water whereas others are practically insoluble. Beryllium in solution binds strongly to soil fulvic acid, with binding increasing with increasing pH. However, beryllium generally has a much stronger affinity to clay minerals than for soil organic carbon and tends to displace other divalent cations. In highly alkaline soils, the mobility of beryllium may increase as a result of the formation of soluble hydroxide complexes such as [Be(OH)4]2-. In acidic soils, the most common form of beryllium in soil pore-water is Be2+ which is likely to be relatively mobile. The mobility and thus leaching of beryllium is expected to be lower in less acidic soils. The water solubility of different beryllium compounds ranges from insoluble to extremely soluble. Boron is present in soils as a non-ionised molecule over pH ranges suitable for plant growth. In soil, boron is present in three forms: inside silicate minerals; adsorbed on clay minerals and aluminium and iron hydroxide; and in organic matter. In soil water with an acid pH, boron exists as undissociated boric acid. Boron exists as borate ions in alkaline soil solutions. Once in soil water, boron may resorb to mineral and organic particles present in the soil. The water solubility varies considerably from insoluble elemental boron to more soluble boron compounds such as boron trifluoride. However, insoluble elemental boron is not encountered in the soil environment. Once released to the soil cadmium is able to form a range of neutral and anionic complexes with other species in soil such as chloride, sulphate, and carbonate. However, cadmium is most commonly present in soil as the free ion (Cd2+). In most natural soil systems the most stable and common forms are Chromium III and chromium VI. Chromium III chloride, hexahydrate exhibits the greatest solubility at environmentally relevant temperatures. Elemental copper is very stable in dry environments at low temperatures but undergoes a slow reaction in moist environments to produce a hydroxycarbonate or hydroxysulphate that forms a greenish-grey amorphous surface film which protects the underlying metal from further attack. Inorganic mercury may occur in three different valent states in soil depending on other factors such as pH, soil organic matter content, redox potential and chloride ion concentration. The HgII valent state is the most stable in soils and thus most likely encountered. Elemental selenium is essentially insoluble in soils. Vanadium is found in soils in its relatively insoluble trivalent form (V3+) and can also be present in the pentavalent form (V5+) as vanadates of Cu, Zn, Pb, U, Fe3+, Mn, Ca or K.

41	Significant gaps remain in understanding how PAH breakdown occurs in situ, what aromatic co-factors may modulate bioremediation strategies, and how to monitor and assess the extent to which PAH breakdown products contribute to risk at both contaminated and remediated sites, as well as for downstream receptors. These questions must continue to be supported by the development of robust analytical techniques that capture a sufficient range of PAH transformation products. In soils, OPAH analyses may be the first to be standardized, but a concerted effort to formulate best practices to address OPAH rearrangement during extraction and analysis is still needed, as well as other parameters that may improve OPAH inter-laboratory data comparability and further push forward the certification of suitable CRMs. At the same time, more polar compounds which may more readily enter water systems should not be ignored, and continued extension of techniques should be undertaken.
42	The transport, distribution, and degradation of synthetic vitreous fibres in the environment have not been studied. However, synthetic vitreous fibres are non-volatile and generally insoluble, so their natural tendency is to settle out of air and water, and deposit in soil or sediment. Synthetic vitreous fibres are not known to undergo any significant transformation or degradation in air. Synthetic vitreous fibres are not known to undergo any significant transformation or degradation in water. The silicate network of all synthetic vitreous fibres can be attacked by acids or alkaline solutions, but this does not occur to any significant extent under environmentally relevant conditions. Using in vitro tests at 37 °C with simulated extracellular fluid (pH 7.4), the dissolution rates of glass, rock, and slag wools with diameters of 1 µm were reported as 0.4, 1.2, and 2.0 years, respectively. Lifetimes for refractory ceramic fibres were about 5 years. Because of their larger surface area, fine fibres will undergo dissolution more readily than course fibres (see Section 3.4 for more details regarding dissolution in biological media). Synthetic vitreous fibres are not known to undergo any significant transformation or degradation in soil or sediment.
43	Benzene is considered by most authoritative organisations to be mobile in the soil environment. Upon release into the soil environment, benzene will tend to sink through the unsaturated zone until it reaches the saturated zone and will tend to collect at the water table if present in sufficient concentrations. Benzene can easily leach from soil based on its aqueous solubility, molecular weight and octanol-water partition coefficient (Kow), and has a moderate tendency to adsorb to soil organic matter (reflected by its organic carbon water partition coefficient, Koc). Benzene will readily volatilise from surface soil given its high vapour pressure, high air–water partition coefficient and moderate Koc. Volatilisation from the sub-surface to air is the most important of the transport processes for benzene, and it will volatilise more readily from soils with a high air-filled porosity such as sands and gravels. Key aspects of benzene's behaviour in the soil environment will be influenced by the presence of other compounds. The solubility and volatility of benzene are reported to decrease in the presence of other hydrocarbon compounds and after weathering of the hydrocarbon compounds has taken place. Benzene is moderately hydrophobic based on its Kow. The uptake into plants from soil therefore has the potential to occur directly through the roots (from which benzene is transported throughout the plant), or indirectly following volatilization of benzene from the soil and subsequent vapour phase sorption by plant surfaces. On entering the leaves, benzene may be lost through transpiration or metabolised.
44	PCDDs and PCDFs are highly persistent compounds and have been detected in air, water, soil, sediments, animals and foods. They partition strongly to soils and sediments where, due to their low vapour pressure, low aqueous solubility and strong sorption to organic matter, they become generally immobile. In general, higher chlorinated PCDDs are likely to volatilise more slowly from soil than lower chlorinated congeners. PCDDs and PCDFs have a strong affinity for lipids, as suggested by their high octanol–water partition coefficients (Kow) and have been shown to bioaccumulate in both aquatic and terrestrial organisms.The organic carbon content of soil is considered to be the most important factor governing the extent of adsorption of PCDDs and PCDFs. The range of organic carbon–water partition coefficients (Koc values) reported for PCDDs and PCDFs indicate that most congeners will be strongly bound to organic matter. Mobility of PCDDs and PCDFs may be increased by co-solvency and/or through the transport of dissolved organic matter /mobilised particulates in water and air.

45	As benzene is only moderately hydrophobic, it should easily enter the transpiration stream through roots and be transported to stems and leaves. Upon entering the leaves, benzene may be lost through transpiration or metabolised. Any resulting metabolites can either be transpired, or retained in the leaves as bound residues, or incorporated into cell structures. These processes vary between plant species. Benzene can be taken up from the atmosphere by plant leaves and other aboveground parts, although this is balanced to various extents – depending on plant species – by loss through volatilisation and transpiration.
46	Many studies suggest that, due to the hydrophobicity of the compounds and the consequent strong adsorption to soil particles, root uptake of dioxins and furans and their translocation into other parts of the plant are minimal, although members of the Cucurbitaceae (cucumber) family have proved an exception to this, and are able to take up and translocate congeners from the soil to the fruit For the majority of plants, atmospheric deposition of dioxins and furans onto above-ground plant surfaces is considered the major process for plant uptake. However, for low chlorinated congeners, volatilisation from soil and subsequent absorption by leaves is also considered to be a likely pathway for uptake by green vegetables and fruit.

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