Rapid Methods to Estimate Potential Exposure to Semivolatile Organic Compounds in the Indoor Environment

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Supporting Information

Simple Models to Estimate SVOC Concentrations in Indoor Air

SVOC emission model. The mechanisms governing emissions of SVOCs from a solid material in which it is present as an additive (for example, DEHP in vinyl flooring or BDE-47 in polyurethane foam) are illustrated in Figure 1 [1]. The variables are defined as follows: V is the room volume, A is the surface area of the source, Q is the ventilation rate, and y is the bulk gas-phase concentration of the SVOC. The SVOC in the solid material, at a material-phase concentration of C_0, is assumed to be in equilibrium with the SVOC in the air in immediate contact with the solid material, which has a gas-phase concentration of y_0. For SVOCs present as additives, the depletion of the source occurs so slowly that C_0 and hence y_0 are usually effectively constant, which simplifies conditions so that the emission rate is given by

$$E = h \times (y_0 - y) \qquad \text{S.1}$$

where the product of h, the convective mass transfer coefficient, and $(y_0 - y)$, the concentration driving force, determines the rate at which the SVOC moves through the boundary layer of air into the bulk air in the room. SVOCs have low volatility (by definition), and consequently they partition strongly to surfaces in contact with the air. The resulting mass transfer between the bulk air and all interior surfaces (for example, walls, ceilings, windows, carpets, curtains, airborne particles, dust, clothing, human hair and skin) strongly influences the rate of change of the gas-phase concentration, y, and this in turn affects the emission rate, as shown in equation S.1. A simple linear and reversible equilibrium relationship is assumed to exist between the exposed interior surface area A_s and the gas-phase concentration of the SVOC in immediate contact with the surface, or

$$q_s = K_s \times y_s \qquad \text{S.2}$$

where q_s is the sorbed SVOC concentration on the surface, K_s is the surface/air partition coefficient, and y_s is the gas-phase SVOC concentration in the air in immediate contact with the surface. As with emission from the source, there is a boundary layer through which the SVOC must transfer to get either to or from the surface, and E_s, the mass transfer rate, is given by

$$E_s = h_s \times (y - y_s) \qquad\qquad \text{S.3}$$

where h_s is the convective mass transfer coefficient associated with the surface.

A linear and instantaneously reversible equilibrium relationship is also assumed to exist between the airborne particles and SVOCs in the air, or

$$q_p = K_p \times y \times TSP \qquad\qquad \text{S.4}$$

Here, q_p is the sorbed SVOC particle phase concentration, K_p is the particle/air partition coefficient, and TSP is the total suspended particle concentration. Because airborne particles are small, the rate of mass transport to particles can usually be neglected for common indoor-air residence time scales, which are on the order of an hour [2]. For emissions of DEHP from vinyl flooring, major elements of the model have been validated [1, 3] or are in the process of being validated. The model is illustrated here for DEHP in vinyl flooring placed in an idealized room. The model parameters used for the simulation are provided in Table S.1 with predictions shown in Figure S.1.
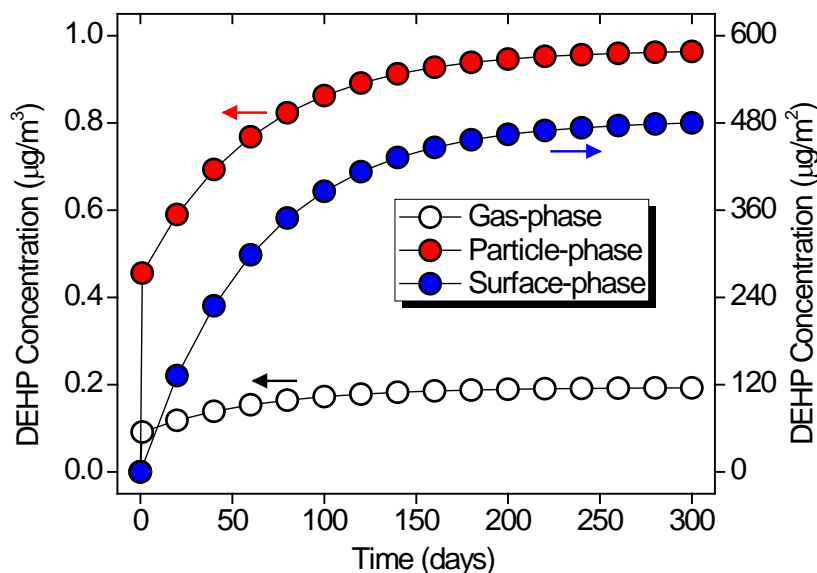

Figure S.1. Predicted gas-, particle- and interior surface-phase concentrations of DEHP emitted from vinyl flooring.

According to the simple model, during the first 100 days, approximately 150 mg of DEHP is emitted from the vinyl flooring. Of this, about 12% leaves the room in the gas phase, 57% leaves the room sorbed to particles suspended in the air, and the remaining 31% accumulates on

the interior surfaces. Insight into SVOC persistence can be gleaned by comparing the amounts in the various compartments. On day 300, for example, there would be ~10 µg of DEHP in the air, ~50 µg present on the airborne particles in the air and ~ 58,000 µg present on the interior surfaces. Table 3 in a previous paper [4] provides similar information for a wide range of compounds. If, in an effort to remove the SVOC from the indoor environment, the windows in the room were opened, the air in the room would be rapidly replaced with fresh air and the 60 µg of airborne DEHP would be ventilated away. However, shortly after the windows were shut again, continued volatilization from the vinyl flooring (at ~1.2 µg/min) plus desorption from the interior surfaces (at ~1.4 µg/min initially) would rapidly restore the airborne levels to the same value as before opening the windows. Because of the large reservoirs associated both with primary sources and with secondary sorbed SVOCs, the system tends towards homeostasis, restoring itself to the former conditions after transient perturbations.

Clearly, the processes taken into account in Figure 1 constitute a highly idealized representation of reality. For example, all interior surface interactions are considered to be on "hard" surfaces with no diffusion of the DEHP into the many soft or porous materials that are commonly found in indoor environments. In addition, a large variety of interior surfaces are lumped into a single surface represented by a "typical" DEHP partition coefficient of 2,500 m [5]. Although this idealization may seem extreme, it has been suggested that indoor environments age in a way that leads to thin organic films with fairly constant properties covering indoor surfaces [2]. The relatively narrow range of partition coefficients estimated for different interior surfaces [5] supports this view. The assumed interior surface area of 120 m^2 is only about twice the nominal surface area associated with walls and ceilings, and the actual interior surface in many indoor environments may be higher than this value. Finally, it is well known that DEHP sorbs strongly to dust [6, 7]. Such partitioning is not taken into account in this simple model, but is accounted for in the exposure assessment.

Rapid Methods to Estimate Exposure

Estimating exposure to SVOCs present in a single product
Di-n-butyl phthalate (DnBP). DnBP is used as a plasticizer in polymers such as PVC products, fiberglass and rubber. With higher volatility than DEHP, DnBP is often used as a gelling aid in combination with other plasticizers [8]. The concentration of DnBP in PVC products tends to be lower than DEHP and may vary greatly. The steady-state gas-phase concentration of DnBP in a chamber with PVC flooring was found to be about 0.1 µg/m^3 [9]. In this case, y_0 can be estimated to be 0.13 µg/m^3 using equation 2. This value is close to those for wallpapers and floorings obtained by Fujie et al. [10] but much lower than the vapor pressure, which corresponds to about 400 µg/m^3. In contrast, the chamber concentration of DnBP from wall paint is as high as 100 µg/m^3 [11]. Therefore, y_0 for DnBP in PVC products cannot be approximated by the vapor pressure and its dependence on the material-phase concentration is unknown.

In the current illustrative example, PVC flooring with DnBP as plasticizer is the only emission source of DnBP in a room, with the parameters listed in Table S.2. Assuming a steady-state gas-phase concentration of DnBP of about 0.6 µg/m^3, which falls within the typical indoor

concentration range [12], y_0 is back-calculated to be 1 µg/m^3 based on equation 2. Exposure is then estimated as shown in Tables 2 and 3.

2,2',4,4'-tetrabromodiphenyl ether (BDE-47). BDE-47 is one of the most prevalent of the polybrominated diphenyl ethers (PBDEs), a group of organobromine compounds added to polymer products as flame retardants [13, 14]. BDE-47 is traditionally used in polyurethane foam products. However, in contrast to DEHP and DnBP, which are liquids at room temperature, BDE-47 is a solid at room temperature. Furthermore, the fraction of BDE-47 in the polymer may vary substantially from case to case. For example, the mass fraction of BDE-47 in a polyurethane foam and a carpet vary from 0.01 µg/g to 1 µg/g [15] while the percentage of penta-BDE (BDE 47 is one of the major congeners of penta-BDE [13]) in foam can reach 30% by weight [16]. Therefore, y_0 for BDE-47 in a polymer product cannot simply be approximated by the vapor pressure and may vary widely for different products.

In the current example, it is assumed that a sofa made of polyurethane foam is the only source of BDE-47 in a room with parameters listed in Table S.3. Assuming that the steady-state gas-phase concentration of BDE-47 is 2×10^{-4} µg/m^3, a typical value of indoor BDE-47 concentration [14, 17], y_0 is back-calculated to be 5×10^{-4} µg/m^3 based on equation 2. Exposure estimation is then performed, as shown in Tables 2 and 3. Because the foam is highly porous (porosity is about 97%), air within the foam pores (which is assumed to have a BDE 47 concentration equal to y_0) would be expelled into the room when people sit on the sofa, causing release of BDE-47 in addition to surface emissions. A similar effect may occur when temperature increases and air in the pores expands out of the foam. The following rough calculations show that the amount of BDE-47 released through these two mechanisms is insignificant compared to diffusive emissions from the nominal exterior surface.

Assume that people sit on the sofa 5 times each day and that 1 L of air contained in the foam pores is expelled each time. Then the volume of air expelled per day is 0.005 m^3, and the amount of BDE 47 released is 0.005·y_0 µg/day, or 3×10^{-11} µg/s assuming an equivalent constant source rate. For comparison, the emission rate from the surface according to equation S.1 is about 4×10^{-6} µg/s, which is several orders of magnitude higher. Therefore, the release of BDE-47 due to sitting is expected to be small compared to surface emissions. We note that more complicated effects, including the effect of normal and increased bouncing, have been evaluated by Zhang et al. [15].

Regarding the impact of a temperature increase, consider a relatively large diurnal temperature variation of between 10 °C and 30 °C. Air in the sofa expands uniformly when the temperature increases and, according to the ideal gas law, roughly 7% of the air in the sofa would be expelled into the room. Assuming that the total volume of the sofa block is 3 m^3 and that the air in the block is approximately the same volume and has a gas-phase concentration of y_0, an equivalent constant source rate is $3 \times 7\% \times y_0$ µg/day, or 10^{-9} µg/s. Therefore, the release of BDE-47 due to the temperature variation effect is also small compared to surface emissions.

The approach used to estimate steady-state concentration neglecting these two effects appears reasonable, although we caution that knowledge of emissions from foams remains rudimentary. For example, the friability of the foam, the influence of dust within the foam that can sorb BDE-

47 and then be expelled from the foam, and the effect of a fabric cover has not been considered in our analysis.

Table S.1. Parameters used to estimate DEHP concentrations in indoor environment.

Parameter	Value	Units	Source/Reference
Room volume (V)	50	m^3	-
Ventilation rate (Q)	50	m^3/h	-
Emission surface area (A)	20	m^2	-
Interior surface area (A_s)	120	m^2	-
Total suspended particle concentration (TSP)	20	$\mu g/m^3$	[7]
Gas-phase concentration in contact with the emission surface (y_0)	1	$\mu g/m^3$	[1, 3]
Convective mass-transfer coefficient over emission surface (h)	3.6	m/h	[18, 19]
Convective mass-transfer coefficient over interior surface (h_s)	3.6	m/h	[18, 19]
Interior surface/air partition coefficient (K_s)	2500	m	[5]
Vapor pressure (VP)	1.9×10^{-5}	Pa	[5]
Airborne particle/air partition coefficient (K_p)	3.2	$m^3/\mu g$	Equation in Table 1
Dust/air partition coefficient (K_{dust})	790	m^3/mg	Equation in Table 1
Octanol/water partition coefficient (log K_{ow}) [a]	7.4		SPARC online calculator v4.5 (32 °C)
Octanol/air partition coefficient (log K_{oa}) [a]	12.9		SPARC online calculator v4.5 (25 °C)
Water/air partition coefficient (log K_{wa}) [a]	5.1		SPARC online calculator v4.5 (32 °C)
Coefficient for transport through boundary layer of air adjacent to skin (v_d)	0.167	cm/s	[2]
Permeability through stratum corneum of an SVOC when its concentration is measured in water in contact with skin (k_{p_cw})	0.00012	cm/s	Equation in Table 1
Ratio of stratum corneum permeability to viable epidermis permeability (B)	3.2		Equation in Table 1
Permeability through stratum corneum/viable epidermis composite of SVOC when its concentration is measured in water in contact with skin (k_{p_w})	2.8×10^{-5}	cm/s	Equation in Table 1
Permeability from the boundary layer at the skin surface through the stratum corneum/viable epidermis composite to dermal capillaries (k_{p_b})	3.5	cm/s	Equation in Table 1
Overall permeability from bulk air to dermal capillaries (k_{p_g})	137	m/d	Equation in Table 1

[a] K_{oa} at 25 °C is used to estimate K_p and K_{dust} in the room at 25 °C; K_{ow} and K_{wa} at 32 °C are used to estimate permeability through skin at 32 °C, as done in Table S.2, Table S.3, and Table S.4.

Table S.2. Parameters used to estimate DnBP concentrations in indoor environment.

Parameter	Value	Units	Source/Reference
Room volume (V)	50	m^3	-
Ventilation rate (Q)	50	m^3/h	-
Emission surface area (A)	20	m^2	-
Total suspended particle concentration (TSP)	20	µg/m^3	[7]
Gas-phase concentration in contact with the emission surface (y_0)	1	µg/m^3	Back calculated from typical indoor concentrations
Convective mass-transfer coefficient over emission surface (h)	3.6	m/h	[18, 19]
Vapor pressure (VP)	3.6×10^{-3}	Pa	[20]
Airborne particle/air partition coefficient (K_p)	0.0025	m^3/µg	Equation in Table 1
Dust/air partition coefficient (K_{dust})	0.63	m^3/mg	Equation in Table 1
Octanol/water partition coefficient (log K_{ow})	4.6		SPARC online calculator v4.5 (32 ^{o}C)
Octanol/air partition coefficient (log K_{oa})	9.8		SPARC online calculator v4.5 (25 ^{o}C)
Water/air partition coefficient (log K_{wa})	5.0		SPARC online calculator v4.5 (32 ^{o}C)
Coefficient for transport through boundary layer of air adjacent to skin (v_d)	0.167	cm/s	[2]
Permeability through stratum corneum of an SVOC when its concentration is measured in water in contact with skin (k_{p_cw})	7.77×10^{-6}	cm/s	Equation in Table 1
Ratio of stratum corneum permeability to viable epidermis permeability (B)	0.18		Equation in Table 1
Permeability through stratum corneum/viable epidermis composite of SVOC when its concentration is measured in water in contact with skin (k_{p_w})	6.59×10^{-6}	cm/s	Equation in Table 1
Permeability from the boundary layer at the skin surface through the stratum corneum/viable epidermis composite to dermal capillaries (k_{p_b})	0.66	cm/s	Equation in Table 1
Overall permeability from bulk air to dermal capillaries (k_{p_g})	115	m/d	Equation in Table 1

Table S.3. Parameters used to estimate BDE-47 concentrations in indoor environment.

Parameter	Value	Units	Source/Reference
Room volume (V)	50	m^3	-
Ventilation rate (Q)	50	m^3/h	-
Emission surface area (A)	15	m^2	-
Total suspended particle concentration (TSP)	20	$\mu g/m^3$	[7]
Gas-phase concentration in contact with the emission surface (y_0)	5×10^{-4}	$\mu g/m^3$	Back calculated from typical indoor concentrations
Convective mass-transfer coefficient over emission surface (h)	3.6	m/h	[18, 19]
Vapor pressure (VP)	2.5×10^{-4}	Pa	[21]
Airborne particle/air partition coefficient (K_p)	0.01	$m^3/\mu g$	Equation in Table 1
Dust/air partition coefficient (K_{dust})	3.16	m^3/mg	Equation in Table 1
Octanol/water partition coefficient (log K_{ow})	7.0		SPARC online calculator v4.5 (32 °C)
Octanol/air partition coefficient (log K_{oa})	10.5		SPARC online calculator v4.5 (25 °C)
Water/air partition coefficient (log K_{wa})	3.1		SPARC online calculator v4.5 (32 °C)
Coefficient for transport through boundary layer of air adjacent to skin (v_d)	0.167	cm/s	[2]
Permeability through stratum corneum of an SVOC when its concentration is measured in water in contact with skin (k_{p_cw})	1.5×10^{-5}	cm/s	Equation in Table 1
Ratio of stratum corneum permeability to viable epidermis permeability (B)	0.47		Equation in Table 1
Permeability through stratum corneum/viable epidermis composite of SVOC when its concentration is measured in water in contact with skin (k_{p_w})	1.05×10^{-5}	cm/s	Equation in Table 1
Permeability from the boundary layer at the skin surface through the stratum corneum/viable epidermis composite to dermal capillaries (k_{p_b})	0.01	cm/s	Equation in Table 1
Overall permeability from bulk air to dermal capillaries (k_{p_g})	10.5	m/d	Equation in Table 1

Table S.4. Parameters used to estimate chlorpyrifos concentrations in indoor environment.

Parameter	Value	Units	Source/Reference
Room volume (V)	290	m^3	Total area 122 m^2 and room height 2.4 m [22]
Ventilation rate (Q)	439.2	m^3/h	Air exchange rate of 36 d^{-1} [22]
Treated area (A)	0.75	m^2	[22]
Interior surface area (A_s)	360	m^2	Assume the plan view of house is about 17×7 m
Total suspended particle concentration (TSP)	21.6	$\mu g/m^3$	Sum of TSP in different size ranges [22]
Gas-phase concentration in contact with the emission surface (y_0)	350	$\mu g/m^3$	Vapor pressure expressed in unit of concentration
Convective mass-transfer coefficient over emission surface (h)	3.6	m/h	[18, 19]
Convective mass-transfer coefficient over interior surface (h_s)	3.6	m/h	[18, 19]
Initial applied amount (M_0)	1.29	g	[22]
Vapor pressure (VP)	0.0025	Pa	[22]
Airborne particle/air partition coefficient (K_p)	0.001	$m^3/\mu g$	Equation in Table 1
Dust/air partition coefficient (K_{dust})	0.25	m^3/mg	Equation in Table 1
Octanol/water partition coefficient (log K_{ow})	6.4		SPARC online calculator v4.5 (32 ^{o}C)
Octanol/air partition coefficient (log K_{oa})	9.4		SPARC online calculator v4.5 (25 ^{o}C)
Water/air partition coefficient (log K_{wa})	2.8		SPARC online calculator v4.5 (32 ^{o}C)
Coefficient for transport through boundary layer of air adjacent to skin (v_d)	0.167	cm/s	[2]
Permeability through stratum corneum of an SVOC when its concentration is measured in water in contact with skin (k_{p_cw})	4.3×10^{-5}	cm/s	Equation in Table 1
Ratio of stratum corneum permeability to viable epidermis permeability (B)	1.1		Equation in Table 1
Permeability through stratum corneum/viable epidermis composite of SVOC when its concentration is measured in water in contact with skin (k_{p_w})	2.0×10^{-5}	cm/s	Equation in Table 1
Permeability from the boundary layer at the skin surface through the stratum corneum/viable epidermis composite to dermal capillaries (k_{p_b})	0.013	cm/s	Equation in Table 1
Overall permeability from bulk air to dermal capillaries (k_{p_g})	10.3	m/d	Equation in Table 1

Estimating exposure to SVOCs present in a range of similar products

Table S.5. DEHP end-product use per person in the European Union.

	End-product use of DEHP [a] (t/y)	In-service life [b] (y)	DEHP content [b] (w/w)	Product mass [c] (g/person)	Weight per unit area [b] (kg/m²)	Product area [c] (m²/person)
Flooring	30,200	20	0.2	6040	2.9	2.1
Wall covering	10,100	20	0.3	1350	2	0.67
Film and sheet	41,200	10	0.3	2750	0.1	27
Wires and cables	52,600	25	0.225	11700	0.7	17
Hoses and profiles	29,600	10	0.3	1970	3.3	0.6
Coated fabric	31,800	10	0.3	2120	0.6	3.5
Moulded products	5,000	5	0.3	170	10	0.02
Other	20,100	10	0.3	1340	2	0.67

[a] Data are obtained from Table 2-5 [23].
[b] Data are obtained from Table 2-10 [23].
[c] Data are calculated as the end-product use rate multiplied by the in-service life, divided by the DEHP content, and divided by the EU population of 500 million persons.

Table S.6. Parameters for estimating exposure to DEHP via indoor air in a typical household.

Parameter	Value	Source
Household size (persons)	2.6	U.S. Census Bureau, Census 2000 (http://factfinder.census.gov/servlet/SAFFFacts)
V (m³)	400	[24]
Q (m³/h)	180	[24]
A (m²)	134	Function of household size and product area per person
TSP (µg/m³)	20	[25]
y_0 (µg/m³)	1	[25]
h (m/h)	1.8	[25] [a]

[a] Considering that a large portion of the emission area may be located in stagnant regions, an average h of half the mean value for flat indoor surfaces is used.

Estimating exposure to SVOCs proposed as substitutes in specific products
If exposure to a high-risk SVOC is roughly known, then the unknown exposure for a substitute SVOC can be estimated. If y_0 is not known, we assume that y_0 scales linearly with *VP*. We can then evaluate the ratio of the "unknown" exposure to the "known" exposure for each of the three indoor exposure pathways. We can do this for either class of SVOCs (those that are present as additives and those that are directly sprayed or applied to interior surfaces).

In the case of SVOCs present as additives, we can simplify the calculation if both SVOCs of interest have a $\log(K_{oa})$ that is less than 9.8, which implies that $Q^* \sim Q$ because sorption to particles is relatively small. To illustrate, we have:

$$Q^* = (1 + K_p \times TSP) \times Q = \{1 + ((f_{om\_part} \times K_{oa} \times TSP)/\rho_{pa}\} \times Q$$

For typical indoor conditions:
$\rho_{part} \sim 1 \times 10^{12} \ \mu g/m^3$
$f_{om\_part} \sim 0.4$
$TSP \sim 20 \ \mu g/m^3$

Substituting, we obtain:
$(f_{om\_part} \times TSP)/\rho_{part} \sim 8 \times 10^{-12} \sim 10^{-11}$

$Q^* = (1 + 10^{-11} K_{oa}) \times Q$ and therefore $Q^* \sim Q$ if $\log(K_{oa})$ is less than 9.8.

Inhalation. For gas-phase inhalation, the ratio of unknown exposure to known exposure is given by the ratio of ($y_{unknown}/y_{known}$). Because $Q^* \sim Q$, we have $y = h \times y_0 \times A/(h \times A + Q)$ and hence:

$y_{unknown}/y_{known} \sim \{h \times y_{0\_unknown} \times A/(h \times A + Q)\}/\{h \times y_{0\_known} \times A/(h \times A + Q)\}$
$= y_{0\_unknown}/y_{0\_known} = (VP_{unknown}/VP_{known})$

For inhalation of airborne particles, the ratio of unknown exposure to known exposure is:

$y_{unknown} \times K_{p\_unknown}/y_{known} \times K_{p\_known}$
$= \{VP_{unknown} \times (h \times A + Q) \times K_{oa\_unknown}\}/\{VP_{known} \times (h \times A + Q) \times K_{oa\_known}\}$
$= (VP_{unknown} K_{oa\_unknown})/(VP_{known} K_{oa\_known})$

Ingestion of dust. For ingestion of dust, the ratio of unknown exposure to known exposure is:

$y_{unknown} K_{dust\_unknown}/y_{known} K_{dust\_known} = y_{unknown} K_{oa\_unknown}/y_{known} K_{oa\_known}$
$= (VP_{unknown} K_{oa\_unknown})/(VP_{known} K_{oa\_known})$

Dermal absorption. For dermal absorption, the ratio of unknown exposure to known exposure is:

$y_{unknown} k_{p\_g\_unknown}/y_{known} k_{p\_g\_known}$
$= (VP_{unknown} k_{p\_g\_unknown})/(VP_{known} k_{p\_g\_known})$

If either of the SVOCs of interest has a log (K_{oa}) that is greater than 9.8, then we cannot simplify the calculation.

In the general case of SVOCs present as additives, the ratio of unknown exposure to known exposure can be calculated as follows.

Inhalation. For gas-phase inhalation, the ratio of unknown exposure to known exposure is:

$y_{unknown}/y_{known} = \{y_{0\_unknown}/(h \times A + Q^*_{unknown})\}/\{y_{0\_known}/(h \times A + Q^*_{known})\}$
$= \{y_{0\_unknown} \times (h \times A + Q^*_{known})\}/\{y_{0\_known} \times (h \times A + Q^*_{unknown})\}$
$= \{VP_{unknown} \times (h \times A + Q^*_{known})\}/\{VP_{known} \times (h \times A + Q^*_{unknown})\}$

For the inhalation of airborne particles, the ratio of unknown exposure to known exposure is:

$y_{unknown} \times K_{p\_unknown}/ y_{known} \times K_{p\_known}$
$= \{VP_{unknown} \times (h \times A + Q^*_{known}) \times K_{oa\_unknown} \}/\{VP_{known} \times (h \times A + Q^*_{unknown}) \times K_{oa\_known}\}$

Ingestion of dust. For ingestion of dust, the ratio of unknown exposure to known exposure is:

$y_{unknown} K_{dust\_unknown}/y_{known} K_{dust\_known}$
$= \{VP_{unknown} \times (h \times A + Q^*_{known}) \times K_{oa\_unknown} \}/\{VP_{known} \times (h \times A + Q^*_{unknown}) \times K_{oa\_known}\}$

Dermal absorption. For dermal absorption, the ratio of unknown exposure to known exposure is:

$y_{unknown} k_{p\_g\_unknown}/y_{known} k_{p\_g\_known}$
$= \{VP_{unknown} \times (h \times A + Q^*_{known}) \times k_{p\_g\_unknown} \}/\{VP_{known} \times (h \times A + Q^*_{unknown}) \times k_{p\_g\_known}\}$

In the general case of SVOCs that are sprayed or applied to interior surfaces, similar ratios can be calculated.

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