United States Environmental Protection Agency

Office of Chemical Safety and Pollution Prevention

Draft Risk Evaluation for 1-Bromopropane

1-BP Supplemental File:

Supplemental Information on Consumer Exposure Assessment

CASRN: 106-94-5

August 2019

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1 CONSUMER EXPOSURE

The United States Environmental Protection Agency (U.S. EPA) evaluated 1-Bromopropane (1-BP) exposure resulting from the use of consumer products. The U.S. EPA utilized a modeling approach to evaluate exposure because chemical specific personal monitoring data was not identified for consumers during data gathering and literature searches performed as part of Systematic Review.

1.1 CONSUMER EXPOSURE

Consumer products containing 1-BP are readily available at retail stores and via the internet for purchase and use. Use of these products can result in exposures of the consumer user and bystanders to 1-BP during and after product use. Consumer exposure can occur via inhalation, dermal, and oral routes.

Consumer products containing 1-BP were identified through review and searches of a variety of sources, including the National Institutes of Health (NIH) Household Products Database, various government and trade association sources for products containing 1-BP, company websites for Safety Data Sheets (SDS), Kirk-Othmer Encyclopedia of Chemical Technology, and the internet in general. Identified consumer products were then categorized into nine consumer use groups considering (1) consumer use patterns, (2) information reported in SDS, (3) product availability to the public, and (4) potential risk to consumers. Table 1-1 summarizes the nine consumer use groups evaluated as well as the routes of exposure for which they were evaluated.

Table 1-1 Consumer Uses and Routes of Exposure Assessed

Consumer Uses	Routes of Exposure
1. Adhesive Accelerant (Liquid Pump Spray) 2. General Purpose Spray Cleaner (Liquid Spray/Aerosol) 3. Spot Cleaner and Stain Remover (Liquid Spray/Aerosol) 4. Mold Cleaning and Release Product (Liquid Spray/Aerosol) 5. General Cleaners and Degreasers (Liquid Spray/Aerosol) 6. Electronics Degreasers (Liquid Spray/Aerosol)	Inhalation and Dermal
7. Coin and Scissors Cleaner (Liquid Bath) 8. Automobile AC Flush (Liquid)	Inhalation and Dermal
9. Insulation (Off-gassing)	Inhalation

The U.S. EPA evaluated acute inhalation and dermal exposure of the consumer to 1-BP for this evaluation. Acute inhalation exposure is an expected route of exposure for all nine consumer use groups. Acute dermal exposure is a possible route of exposure for the first eight consumer use groups, however, this evaluation only considered dermal exposure for three of the eight consumer use groups (General Cleaners and Degreasers, Coin and Scissors Cleaner, and

Automobile AC Flush) due to the possibility of continuous supply of product against the skin. The U.S. EPA does not expect exposure under any of the nine consumer use groups evaluated to be chronic in nature and therefore does not present chronic exposure for consumers. The U.S. EPA does not expect oral exposure to occur under any of the nine consumer use groups evaluated and therefore did not evaluate the oral route of exposure.

The U.S. EPA evaluated inhalation and dermal exposure for the consumer user and evaluated only inhalation exposure for a non-user (bystander) located within the residence during product use. The consumer user consisted of three age groups (adult, greater than 21 years of age; Youth A, 16-20 years of age; and Youth B, 11-15 years of age) which includes the susceptible sub-population woman of childbearing age. The bystander can include individuals of any age (infant through elderly).

1.2 CONSUMER MODELING

Three models were used to evaluate consumer exposures, EPA's Consumer Exposure Model (CEM), EPA's Multi-Chamber Concentration and Exposure Model (MCCEM), and EPA's Indoor Environment Concentrations in Buildings with Conditioned and Unconditioned Zones (IECCU) model. A general overview and some details about each of these models are provided in the respective sections below. Readers can learn more about equations within the models, detailed input and output parameters, pre-defined scenarios, default values used, and supporting documentation by reviewing the CEM user guide (U.S. EPA, 2019a), CEM user guide appendices (U.S. EPA, 2019b), MCCEM user guide (U.S, 2019), and IECCU user guide (U.S. EPA, 2019c). Table 1-2 summarizes the specific models used for each consumer use group and the associated routes of exposure evaluated.

Table 1-2 Models Used for Routes of Exposure Evaluated

Consumer Uses	Routes of Exposure	
	Inhalation	Dermal
1. Adhesive Accelerant	CEM	
2. General Purpose Spray Cleaner	CEM	
3. Spot Cleaner and Stain Remover	CEM	
4. Mold Cleaning and Release Product	CEM	
5. General Cleaners and Degreasers	CEM	CEM
6. Electronics Degreasers	CEM	
7. Coin and Scissors Cleaner	MCCEM	CEM
8. Automobile AC Flush	MCCEM	CEM
9. Insulation	IECCU	

Each model is peer reviewed. Default values within CEM and MCCEM are a combination of high end and mean or central tendency values derived from U.S. EPA's Exposure Factors Handbook (U.S. EPA, 2011), literature, and other studies. IECCU currently does not provide default values for input parameters, instead, inputs are derived from empirical data or modeled estimates including U.S. EPA’s Exposure Factors Handbook (U.S. EPA, 2011), literature, and other studies.

1.2.1 CEM Approach

CEM is a deterministic model which utilizes user provided input parameters and various assumptions (or defaults) to generate exposure estimates. In addition to pre-defined scenarios, which align well with the first six consumer uses identified in Table 1-1, CEM is peer reviewed, provides flexibility to the user by allowing modification of certain default parameters when chemical-specific information is available, and does not require chemical-specific emissions data (which may be required to run more complex indoor/consumer models).

CEM predicts indoor air concentrations from consumer product use through a deterministic, mass-balance calculation derived from emission calculation profiles within the model. There are six emission calculation profiles within CEM (E1-E6) which are summarized in the CEM users guide and associated appendices. If selected, CEM provides a time series air concentration profile for each run. These are intermediate values produced prior to applying pre-defined activity patterns.

CEM uses a two-zone representation of the building of use when predicting indoor air concentrations. Zone 1 represents the room where the consumer product is used. Zone 2 represents the remainder of the building. Each zone is considered well mixed. CEM allows further division of Zone 1 into a near field and far field to accommodate situations where a higher concentration of product is expected very near the product user when the product is initially used. Zone 1-near field represents the breathing zone of the user at the location of the product use while Zone 1 far field represents the remainder of the Zone 1 room.

Inhalation exposure is estimated in CEM based on zones and pre-defined activity patterns. The simulation run by CEM places the product user within Zone 1 for the duration of product use while the bystander is placed in Zone 2 for the duration of product use. Following the duration of product use, the user and bystander follow one of three pre-defined activity patterns established within CEM, based on modeler selection. The selected activity pattern takes the user and bystander in and out of Zone 1 and Zone 2 for the period of the simulation. The user and bystander inhale airborne concentrations within those zones, which will vary over time, resulting in the overall estimated exposure to the user and bystander.

CEM contains two methodologies for estimating dermal exposure to chemicals in products, the permeability method (P-DER1) and the fraction absorbed method (A-DER1). Each of these methodologies further has two model types, one designed for dermal exposure from use of a product (P-DER1a and A-DER1a), the other designed for dermal exposure from use of an article (P-DER1b and A-DER1b). Each methodology has associated assumptions, uncertainties, and data input needs within the CEM model. Both methodologies factor in the dermal surface area to body weight ratio and weight fraction of chemical in a consumer product.

The permeability model is based on the ability of a chemical to penetrate the skin layer once contact occurs. The permeability model assumes a constant supply of chemical, directly in contact with the skin, throughout the exposure duration. The ability to use the permeability method can be beneficial when chemical-specific skin permeability coefficients are available in the scientific literature. However, the permeability model within CEM does not consider evaporative losses when it estimates dermal exposure and therefore may be more representative of a dermal exposure resulting from a constant supply of chemical to the skin due to a barrier or other factor that may restrict evaporation of the chemical of interest from the skin (a product soaked rag against the hand while using a product), or immersion of a body part into a pool of product. Either of these examples has the potential to cause an increased duration of dermal contact and permeation of the chemical into the skin resulting in dermal exposure.

The fraction absorbed method is based on the absorbed dose of a chemical. This method essentially measures two competing processes, evaporation of the chemical from the skin and penetration of the chemical deeper into the skin. This methodology assumes the application of the chemical of concern occurs once to an input thickness and then absorption occurs over an estimated absorption time. The fraction absorbed method can be beneficial when chemical specific fractional absorption measurements are available in the scientific literature. The consideration of evaporative losses by the fraction absorbed method within CEM may make this model more representative of a dermal exposure resulting from scenarios that allow for continuous evaporation and typically would not involve a constant supply of product against the skin for dermal permeation. Examples of such scenarios include spraying a product onto a mirror and a small amount of mist falling onto an unprotected hand.

All consumer use groups identified in Table 1-2 and evaluated with CEM used CEM's E3 emission model and profile for inhalation exposure. This model and profile assume a percentage of a consumer product used is aerosolized (e.g. overspray) and therefore immediately available for uptake by inhalation. The associated inhalation model within CEM is P-INH2. The U.S. EPA also used the near-field and far-field option within CEM for all consumer use groups evaluated with CEM. All three consumer use groups evaluated for dermal exposure with CEM used the permeability method. The associated dermal model within CEM is P-DER1b.

In an effort to characterize a potential range of consumer inhalation exposures, the EPA varied three key parameters within the CEM model while keeping all other input parameters constant. The key parameters varied were duration of use per event (minutes/use), amount of chemical in the product (weight fraction), and mass of product used per event (gram(s)/use). These key parameters were varied because they provide representative consumer behavior patterns for product use. Additionally, CEM is highly sensitive to two of these three parameters (duration of use and weight fraction) which can be seen in the sensitivity analysis performed on CEM and included within the CEM users guide and associated CEM user guide appendices. Finally, all three parameters had a range of documented values within literature identified as part of Systematic Review allowing the EPA to evaluate inhalation exposures across a spectrum of use conditions.

To characterize a potential range of consumer dermal exposures, the EPA varied two key parameters within CEM while keeping all other input parameters constant. The key parameters varied for dermal exposure evaluation were weight fraction and duration of use per event. The mass of product used is not a factor in the dermal exposure equations within CEM and therefore was not varied.

Once the data was gathered for the parameters varied, modeling was performed to cover all possible combinations of these three parameters. This approach results in a maximum of 27 different iterations for each consumer use. Table 1-3 summarizes these 27 combinations.

Table 1-3 Example Structure of CEM Cases for Each Consumer Use Group Scenario Modeled

CEM Set	Scenario Characterization (Duration-Weight Fraction-Product Mass)	Duration of Product Use Per Event (min/use) [not scalable]	Weight Fraction of Chemical in Product (unitless) [scalable]	Mass of Product Used (g/use) [scalable]
Set 1 (Low Intensity Use)	Case 1: Low-Low-Low	Low	Low	Low
	Case 2: Low-Low-Mid			Mid
	Case 3: Low-Low-High			High
	Case 4: Low-Mid-Low		Mid	Low
	Case 5: Low-Mid-Mid			Mid
	Case 6: Low-Mid-High			High
	Case 7: Low-High-Low		High	Low
	Case 8: Low-High-Mid			Mid
	Case 9: Low-High-High			High
Set 2 (Moderate Intensity Use)	Case 10: Mid-Low-Low	Mid	Low	Low
	Case 11: Mid-Low-Mid			Mid
	Case 12: Mid-Low-High			High
	Case 13: Mid-Mid-Low		Mid	Low
	Case 14: Mid-Mid-Mid			Mid
	Case 15: Mid-Mid-High			High
	Case 16: Mid-High-Low		High	Low
	Case 17: Mid-High-Mid			Mid
	Case 18: Mid-High-High			High
Set 3	Case 19: High-Low-Low	High	Low	Low
	Case 20: High-Low-Mid			Mid

(High Intensity Use)	Case 21: High-Low-High			High
	Case 22: High-Mid-Low		Mid	Low
	Case 23: High-Mid-Mid			Mid
	Case 24: High-Mid-High			High
	Case 25: High-High-Low		High	Low
	Case 26: High-High-Mid			Mid
	Case 27: High-High-High			High

The U.S. EPA utilized an option within CEM to obtain the intermediate time series concentration values from each model run. These values are calculated for every 30 seconds (0.5 minute) period for each zone for the entire length of the model run. This approach allowed the U.S. EPA to perform post-processing within Excel to determine personal concentration exposures for the user and bystander. This post-processing was conducted by independently assigning the Zone 1, Zone 2, and outside (zero) concentration to the user and bystander. These zone concentrations were assigned based on the pre-defined activity patterns within CEM. Time-weighted average concentration exposures were then calculated from the personal exposure time series to develop estimates for all iterations within each consumer use category. Time weighted average (TWA) concentrations were determined for 1 hour, 3 hours, 8 hours, and 24 hours, although for this evaluation the 24-hour TWA concentration was utilized based on health endpoints used to calculate risks.

1.2.1.1 CEM Inputs

Numerous input parameters are required to generate exposure estimates within CEM. These parameters include physical chemical properties of the chemical of concern, product information (product density, water solubility, vapor pressure, etc.), model selection and scenario inputs (pathways, CEM emission model(s), emission rate, activity pattern, product user, background concentration, etc.), product or article property inputs (frequency of use, aerosol fraction, etc.), environmental inputs (building volume, room of use, near-field volume in room of use, air exchange rates, etc.), and receptor exposure factor inputs (body weight, averaging time, exposure duration inhalation rate, etc.). Several of these input parameters have default values within CEM based on the pre-defined use scenario selected. Default parameters within CEM are a combination of high end and mean or median values found within the literature or based on data taken from U.S. EPA's Exposure Factors Handbook (U.S. EPA, 2011). Details on those parameters can be found within the CEM User Guide (U.S. EPA, 2019a) and associated User Guide Appendices (U.S. EPA, 2019b) or can be cross referenced to U.S. EPA's Exposure Factors Handbook (U.S. EPA, 2011). As discussed earlier, while default values are initially set in pre-defined use scenarios, CEM has flexibility which allows users to change certain pre-set default parameters and input several other parameters.

Key input parameters for the consumer uses evaluated with CEM as identified in Table 1-2 are discussed below. Detailed spreadsheets of all input parameters used for each consumer use evaluated with CEM are provided in 1-BP Supplemental File: Information on Consumer Exposure Assessment Model Input Parameters (EPA, 2019a).

Physical chemical properties of 1-BP were kept constant across all consumer uses and iterations evaluated. A chemical-specific skin permeability coefficient of 9.05E-03 centimeters per hour was found in literature (DHHS, 2017) and utilized for all scenarios modeled for dermal exposure.

Model selection is discussed in the previous section. Exposure scenario inputs were also kept constant across all consumer uses and iterations. Emission rate was estimated using CEM. The activity pattern selected within CEM was stay-at-home. The start time for product use was 9:00 AM and the product user was adult (>21 years of age) and Youth (11-15 years of age and 16 - 20 years of age). The background concentration of 1-BP for this evaluation was considered negligible and therefore set at zero milligrams per cubic meter.

Frequency of use for acute exposure calculations was held constant at one event per day. The aerosol fraction (amount of overspray immediately available for uptake via inhalation) selected within CEM for all consumer uses evaluated was six percent. Building volume used for all consumer uses was the default value for a residence within CEM (492 cubic meters). The near-field volume selected for all consumer uses was one cubic meter. Averaging time for acute exposure was held constant at one day.

Certain model input parameters were varied across consumer use scenarios but kept constant for all model iterations run for a specific consumer use. These input parameters include product density, room of use, and pre-defined product scenarios within CEM. Product densities were extracted from product-specific SDS. Room of use was extracted from a published EPA directed survey of consumer behavior patterns in the United States titled Household Solvent Products: A National Usage Survey (U.S. EPA, 1987) (Westat Survey), identified in the literature search as part of systematic review. The Westat survey is a nationwide survey which provides information on product usage habits for thirty-two different product categories. The information was collected via questionnaire or telephone from 4,920 respondents across the United States. The Westat Survey was rated as a high-quality study during data evaluation within the systematic review process. The room of use selected for this evaluation is based on the room in which the Westat Survey results reported the highest percentage of respondents that last used a product within the room. When the Westat Survey identified the room of use where the highest percentage of respondents last used the product as “other inside room”, the utility room was selected within CEM for modeling. The pre-defined product scenarios within CEM were selected based on a cross-walk to similar product categories within the Westat Survey. A crosswalk between the 1-BP Consumer Use Scenarios and the corresponding Westat product category selected to represent the exposure scenario is in Table-1-4.

Table-1-4. Crosswalk Between 1-BP Consumer Use Scenarios and Westat Product Category

1-BP Consumer Use Scenario	Representative Westat Product Category
1. Adhesive Accelerant	Contact Cement, Super Glues, And Spray Adhesives
2. General Spray Cleaner	Solvent Type Cleaning Fluids Or Degreasers
3. Spot Cleaner-Stain Remover	Spot Removers
4. Mold Cleaning-Release Product	Solvent Type Cleaning Fluids Or Degreasers
5. General Cleaner-Degreaser	Engine Degreasers
6. Degreasers-Electronic	Specialized Electronics Cleaners (TV, VCR, Razor, Etc.)
7. Coin Cleaner/Scissors	Not Applicable
8. Automobile Ac Flush	Not Applicable
9. Insulation	Not Applicable

Additional key model input parameters were varied across both consumer use scenario and model iterations. These key parameters were duration of use per event (minutes/use), amount of chemical in the product (weight fraction), and mass of product used per event (gram(s)/use). Duration of use and mass of product used per event values were both extracted from the Westat Survey (U.S. EPA, 1987). To allow evaluation across a spectrum of use conditions, the EPA chose the Westat Survey results for these two parameters from the above cross-walked product categories representing the tenth, fiftieth (median), and ninety-fifth percentile data, as presented in the Westat Survey.

The amount of chemical in the product (weight fraction) was extracted from product specific SDS. This value was varied across the given range of products within the same category to obtain three values, when available. Unlike the Westat survey results which gave percentile data, however, product specific SDS across products did not have percentile data so the values chosen represented the lowest weight fraction, mean weight fraction (of the range available), and the highest weight fraction found. Even using this approach, some SDS were only available for a single product with a single weight fraction or very small range, or multiple products which only provided a single weight fraction or a very small range. For these product scenarios, only a single weight fraction was used in CEM for modeling. Table 1-5 summarizes the input parameter values used for these three parameters by consumer use.

Table 1-5 Model Input Parameters Varied by Consumer Use

Consumer Use	Duration of Use			Mass of Product Used			Amount of Chemical In Product		
	(minutes/use)			(gram(s)/use)			(weight fraction)		
	10th	50th	95th	10th	50th	95th	Low	Mean	High
Adhesive Accelerant	0.5	4.25	60	1.20	9.98	172.45		0.99 (single)	
General Spray Cleaner	2	15	120	21.86	126.86	1249.04		0.94 (single)	
Spot Cleaner/Stain Remover	0.5	5	30	9.76	51.91	434.43	0.276	0.58	0.922
Mold Cleaning/Release	0.5	2	30	3.84	21.14	192.21	0.32	0.6	0.915
General Cleaner-Degreaser	5	15	120	111.86	445.92	1845.17	0.109	0.505	0.9505

Consumer Use	**Duration of Use**			**Mass of Product Used**			**Amount of Chemical In Product**		
	(minutes/use)			**(gram(s)/use)**			**(weight fraction)**		
	10th	**50th**	**95th**	**10th**	**50th**	**95th**	**Low**	**Mean**	**High**
Degreaser-Electronic	0.5	2	30	1.56	19.52	292.74	0.496	0.72	0.972

1.2.2 MCCEM Approach

Like CEM, MCCEM is peer reviewed and includes several distinct models appropriate for evaluating specific product and article types and use scenarios. Two of the distinct models (M32 and M33) can evaluate emission rates due to evaporation from a liquid in a container (a "solvent pool"). Model M32 applies to an evaporating solvent or solvent pool with a fixed surface area. At a given temperature, the emission rate in this model is determined by (1) the gas-phase mass transfer coefficient, (2) the vapor pressure, and (3) the back-pressure effect.

Model M33 was developed for sublimation of p-dichlorobenzene from moth cakes. However, because sublimation and evaporation of pure compounds share similar mechanisms, M33 can also be applied to emissions from solvent pools. At a given temperature, the emission rate in this model is dependent on the gas-phase mass transfer coefficient, the saturation concentration for a pure compound, and the prevailing indoor air concentration.

For both M32 and M33 models, the emission rate is governed by the source area and is not dependent on chemical mass, provided the duration of use is less than the time it takes for all of the chemical of concern to evaporate. Therefore, the emission rate determined using either model is assumed to be constant and in-effect until all available mass of the chemical of concern is evaporated.

MCCEM uses a two-zone representation of the building of use when predicting indoor air concentrations similar to CEM. MCCEM also is capable of further division of Zone 1 into near field and far field. Inhalation exposure is estimated in MCCEM based on zones and pre-defined activity patterns again, similar to CEM.

Consumer uses 7 and 8 identified in Table 1-2 (coin/scissors cleaner and automobile AC flush, respectively) were assessed for inhalation exposure using MCCEM. A general internet search and investigation into coin cleaning revealed an expected use pattern is to place the coin cleaner product into a small, open top dish or bowl. Coins to be cleaned are then placed within the pool of product, soaked, scrubbed/wiped, and then removed for drying. A similar search and investigation into automobile AC flush activities revealed an expected use pattern is to directly spray the flush product into the opened automobile AC system, which is then transfered via pressure through the system to the opposite end and flushed out into an open top bucket where it is collected. Considering these expected use patterns, exposure to 1-BP within these products is assessed as evaporation from a liquid in a container. The M33 model was utilized to evaluate inhalation exposure for each consumer use evaluated with MCCEM and applied by assuming a constant emission rate during the entire period when the source is active (product is used and remains open to the use environment). Use of the M33 model for these scenarios causes the emission rate to be governed by the source area and not chemical mass (weight fraction and mass of product used). Since the emission rate is not dependent on chemical mass for these two scenarios, only duration of use was varied for the multiple iterations run. This results in three exposure cases per consumer use modeled with MCCEM, rather than the maximum of 27 exposure cases for those modeled with CEM. Consistent with the CEM approach, U.S. EPA evaluated utilized the near-field and far-field option for inhalation exposure.

CEM was used to evaluate dermal exposure from the coin and scissors cleaner and automobile AC flush consumer use scenarios because MCCEM does not have a representative dermal model for these two scenarios. The U.S. EPA utilized the permeability methodology and model (P-DER1b) within CEM for dermal exposure.

1.2.2.1 MCCEM Inputs

The inputs needed for MCCEM include: (1) the emission rate; (2) product amount and duration of use; (3) house and zone volumes; and (3) airflows to and from each zone. Like the CEM modeling approach, the activity pattern was applied to the modeled concentrations during post-processing to determine inhalation exposure concentrations. Detailed spreadsheets of all input parameters used for each consumer use evaluated with MCCEM are provided in 1-BP Supplemental File: Information on Consumer Exposure Assessment Model Input Parameters (EPA, 2019a).

1.2.2.1.1 Emission Rate

The emission rate when using the M33 model and assuming zero for the prevailing indoor air concentration, as we did for these two scenarios, is the product of three quantities: (1) mass-transfer coefficient; (2) saturation concentration; and (3) exposed surface area. To estimate the mass-transfer coefficient, EPA used the program PARAMS, which involves the following components:

- Air Density, calculated at 23 C and 50% RH;
- Viscosity of Air, calculated at 23 C;
- Velocity, the midpoint of the recommended range of 5-10 cm/s;
- Diffusivity in air, calculated using the Wilke Lee method; and
- Characteristic length – PARAMS describes this parameter as follows: "Characteristic length is often approximated by the square root of the source area."

The source area is used in estimating both the mass-transfer coefficient and the emission rate. For the coin cleaner, EPA chose a small bowl as the product reservoir with a 4-inch diameter, giving a source area of 81 cm2, a characteristic length of 9 cm, and an estimated mass-transfer coefficient of 6.01 m/h. For the automobile AC flush, EPA chose a bucket as the flushed product reservoir with a 12-inch diameter, giving a source area of 730 cm^2, a characteristic length of 27.0 cm, and an estimated mass-transfer coefficient of 3.47 m/h.

The saturation concentration for 1-BP is 966,000 mg/m^3 (966 g/m^3). For the coin cleaner, multiplication by the mass-transfer rate (6.01 m/h) and the source area (81 cm^2 or 0.0081 m^2)

gives an emission rate of 47,026 mg/h (47 g/h). For the AC auto flush, multiplication by the mass-transfer rate (3.47 m/h) and the source area (730 cm^2 or 0.073 m^2) gives an emission rate of 244,697 mg/h (244.7 g/h).

1.2.2.1.2 Product Amount and Duration of Use

As discussed above, the emission rate is governed by surface area of the solvent pool and not chemical mass. Therefore, only duration of use is varied for inhalation exposure. Based on the expected use conditions described above, and in an effort to characterize a potential range of consumer inhalation exposures, the EPA chose three durations of use for the coin cleaner (15, 30, and 60 minutes) and three durations of use for the automobile AC flush (5, 15, and 30 minutes).

While inhalation exposure for the coin cleaner consumer use is determined for 15, 30, and 60 minutes, we do not expect dermal contact to occur for the entire period of time the product is being used. Coin cleaning is expected to be a somewhat passive activity where coins may remain undisturbed within the pool for an extended period of time. As a result, dermal exposure will occur for a shorter period of time when coins are placed into the product, potentially scrubbed/wiped within the product, and taken out for drying. Outside of these activities, dermal exposure is not expected to occur although the user remains within the room inhaling the vapors expelled from the pool. For dermal exposure to coin cleaner product, we present the exposure values representing the total exposure from use (cumulative which is beginning and end of use) for 2 minutes, 4 minutes, and 6 minutes of ongoing dermal exposure.

Unlike coin cleaning, automobile AC flushing is an active process where material is constantly sprayed into the system, flushed through, and exits the system. Inhalation exposure occurs for the entire period of time and since it is an active process, dermal exposure can also occur for the entire period of time. As a result, for inhalation and dermal exposure to the automobile AC flush, we present the exposure values representing 5, 15, and 30 minutes of ongoing exposure.

1.2.2.1.3 Zone Definitions, Volumes, and Airflow Rates

The zone volumes and airflow rates for the coin cleaner consumer use are discussed below. For this consumer use, EPA is assuming the zone of use to be the utility room, with a volume of 20 m^3 that is further split into near-field and far-field zones for which the respective volumes (1 m^3 and 19-m^3) are consistent with CEM defaults. The assumed house volume is 446 m^3, resulting in a volume of 426 m^3 for the third zone, termed the "rest of house" or ROH.

The air exchange rate for the house (0.45) is the same as the CEM default. The interzonal airflow rate was 100 m^3/h. EPA assumed there was no air flow between the near field and outdoors (Zone 0). For the interzonal airflow rate between the utility room and ROH, the CEM default rate of 107.1 m^3/h was used.

For the auto AC flush scenario, EPA assumed the zone of use to be the garage with a volume of 118 m^3. This volume is the average for 15 single-family homes with attached garages as reported by Batterman et al. (Batterman et al., 2007). The garage was further split into a 4-m^3 near field and a 114-m^3 far field. Zone 3 was defined as the entire house volume of 446 m^3, which did not include the garage.

The air exchange rate for the house (0.45) matches that used for the coin cleaner consumer use. Relatively few measurements have been taken of garage air exchange rates. Emmerich et al. (Emmerich et al., 2003) used a blower door to measure the airtightness of garages under induced-pressurization conditions for a limited sample of homes but with a range of house ages, styles, and sizes. The average airtightness measured was 48 air changes per hour at 50 Pa (ACH50). This is consistent with values used by energy engineers and technicians who have performed such tests for many years, and corresponds to an air exchange rate of ~ 2.5 air exchanges/h (giving an airflow rate of 295 m^3/h) under naturally occurring conditions. EPA also assumed an airflow rate of 107.1 m3/h between the garage and house as well as an airflow rate of zero between the near field and outdoors.

1.2.3 IECCU Approach

IECCU is a peer reviewed simulation program which can be used as (1) a general-purpose indoor exposure model in buildings with multiple zones, multiple chemicals and multiple sources and sinks or (2) as a special-purpose concentration model for simulating the effects of sources in unconditioned zones on the indoor environmental concentrations in conditioned zones. IECCU was developed by combining existing code and algorithms implemented in other EPA indoor exposure models and by adding new components and methods.

The general mass balance equation used by IECCU to determine the change in the concentration of a chemical of concern in air within a given zone is determined by six factors: (1) the emissions from the sources in the zone, (2) the rate of chemical removed from the zone by the ventilation and interzonal air flows, (3) the rate of chemical carried into the zone by the infiltration and interzonal air flows, (4) the rate of chemical sorption by interior surfaces, (5) the rate of chemical sorption by airborne particles, and (6) the rate of chemical sorption by settled dust. Since 1-BP is highly volatile, once it is in the vapor phase it is expected to remain in the vapor phase. As a result, the U.S. EPA only considered the first three factors listed above. Input parameters for the IECCU model were obtained from the U.S. EPA's Exposure Factors Handbook, Literature, or empirical and QSAR models.

The final consumer use identified in Table 1-2 (Insulation, off-gassing) was evaluated for inhalation exposure using IECCU. Modeling efforts estimated the air concentration of 1-BP by conducting a series of simulations for a "typical" residential building by using existing mass transfer models and simulation tools. Most parameters were either obtained from data in the literature or estimated with empirical and QSAR models. The insulation source of 1-BP was Polyiso insulation boards.

A three-zone configuration described by Bevington et al. in Developing Consensus Standards for Measuring Chemical Emissions from Spray Polyurethane Foam (SPF) insulation (Sebroski, 2017) was used to represent a generic residential building, where the insulation is applied to both the attic and crawlspace. The baseline ventilation and interzonal air flows are shown in Figure 1. The ventilation rates for the three zones are shown in Table 1-6. The EPA used the ventilation rates for the "vented" attic and crawlspace in this evaluation.

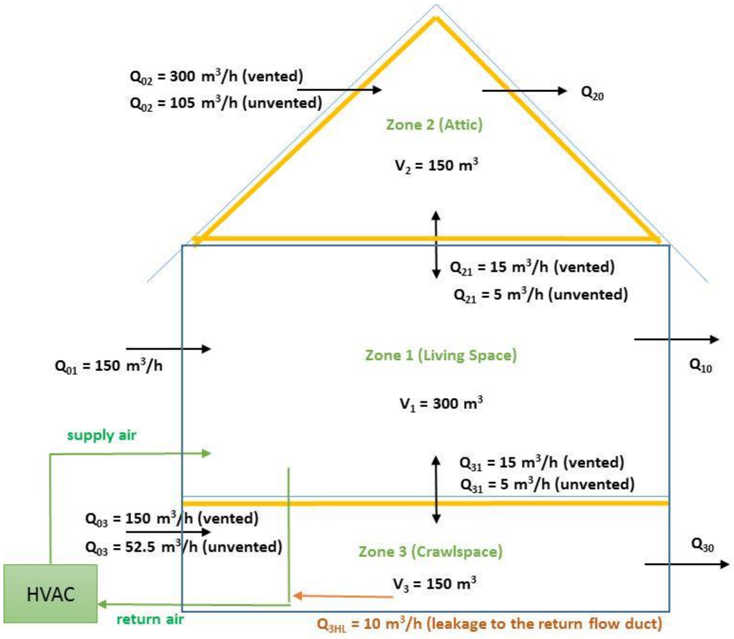

Figure 1 The three-zone configuration for a generic residential setting and baseline ventilation and interzonal air flows.

Table 1-6. Zone Names, Volumes, and Baseline Ventilation Rates

Zone name	Zone volume (m^3)	Ventilation rate (h^{-1})
Living space	300	0.5
Attic	150	2.0 (vented) 0.7 (unvented)
Crawlspace	150	1.0 (vented) 0.35 (unvented)

Unlike CEM and MCCEM, IECCU does not yet provide default values for input parameters. As a result, model inputs are derived from empirical data or modeled estimates. It is the user's responsibility to choose appropriate modeling inputs for the chemical and exposure scenario of interest. A detailed spreadsheet of all input parameters used for the insulation consumer use evaluated with IECCU for this evaluation is provided in 1-BP Supplemental File: Information on Consumer Exposure Assessment Model Input Parameters (EPA, 2019a).

1.2.4 Consumer Exposure Results

All modeling results were exported into Excel workbooks for additional processing and summarizing. All modeling outputs for each condition of use evaluated are included by condition of use in 1-BP Supplemental File: Information on Consumer Exposure Assessment Model Outputs (EPA, 2019b).

Outputs from the models used for consumer exposure were in units of mg/m^3. Health endpoints were provided in parts per million (ppm), therefore the U.S. EPA converted units from mg/m^3 to ppm by multiplying the concentration output by the molar volume (24.45) and dividing by the molecular weight of 1-BP (122.99 g/mol) using the following equation.

Concentration (ppm) = 24.45 X concentration (mg/m^3)/MW

2 MODEL SENSITIVITY ANALYSES

Model sensitivity analyses conducted on the models used for this evaluation enable users to identify what input parameters have a greater impact on the model results (either positive or negative). This information was used for this evaluation to help justify the approaches used and input parameters varied for our modeling.

2.1 CEM SENSITIVITY ANALYSIS

The CEM developers conducted a detailed sensitivity analysis for CEM version 1.5, as described in Appendix C of the CEM User Guide.

In brief, the analysis was conducted on non-linear, continuous variables and categorical variables that were used in CEM models. A base run of different models using various product or article categories along with CEM defaults was used. Individual variables were modified, one at a time, and the resulting Chronic Average Daily Dose (CADD) and Acute Dose Rate (ADR) were then compared to the corresponding results for the base run. Two chemicals were used in the analysis: bis(2-ethylhexyl) phthalate was chosen for the SVOC Article model (emission model E6) and benzyl alcohol for other models. These chemicals were selected because bis(2-ethylhexyl) phthalate is a SVOC, better modeled by the Article model, and benzyl alcohol is a VOC, better modeled by other equations.

All model parameters were increased by 10% except those in the SVOC Article model (increased by 900% because a 10% change in model parameters resulted in very small differences). The measure of sensitivity for continuous variables was elasticity, defined as the ratio of percent change in each result to the corresponding percent change in model input. A positive elasticity means that an increase in the model parameter resulted in an increase in the model output whereas a negative elasticity had an associated decrease in the model output. For categorical variables such as receptor and room type, the percent difference in model outputs for different category pairs was used as the measure of sensitivity. The results are summarized below for inhalation vs. dermal exposure models and for categorical vs. continuous user-defined variables.

Exposure Models

For the first five inhalation models (E1-E5) a negative elasticity was observed when increasing the use environment, building size, air zone exchange rate, and interzone ventilation rate. All of these factors decrease the chemical concentration, either by increasing the volume or by replacing the indoor air with cleaner (outdoor) air. Increasing the weight fraction or amount of product used had a positive elasticity because this change increases the amount of chemical added to the air, resulting in higher exposure. Vapor pressure and molecular weight also tended to have positive elasticities.

For most inhalation models, the saturation concentration did not have a notable effect on the ADR or the CADD. Mass of product used and weight fraction both had a positive linear relationship with dose. All negative parameters had elasticities less than 0.4, indicating that some terms (e.g., air exchange rates, building volume) mitigated the full effect of dilution. That is, even though the concentration is lowered, the effect of removal/dilution is not stronger than that of the chemical emission rate. Most models had an increase in dose with increasing duration of use. Increasing this parameter typically increases the peak concentration of the product, thus giving a higher overall exposure.

The results for the dermal model were different from the inhalation models, in that the elasticities for CADD and ADR were nearly the same. This outcome is consistent with the model structure, in that the chemical is placed on the skin so there is no time factor for a peak concentration to occur. The modeled exposure is based on the ability of a chemical to penetrate the skin layer once contact occurs. Dermal permeability had a near linear elasticity whereas log K_{OW} and molecular weight had zero elasticities.

User-defined Variables

These variables were separated into categorical vs. continuous. For categorical variables there were multiple parameters that affected other model inputs. For example, varying the room type changed the ventilation rates, volume size and the amount of time per day that a person spent in the room. Thus, each modeling result was calculated as the percent difference from the base run. For continuous variables, each modeling result was calculated as elasticity.

Among the categorical variables, both inhalation and dermal model results had a positive change when comparing an adult to a child and to a youth, with dermal having a smaller change between receptors than inhalation and the largest difference occurring between an adult and a child for both models. The time of day when the product was used and the duration of use occurred while the person was at home; thus, there was no effect on the ADR because the acute exposure period was too short to be affected by work schedule. Most rooms had a negative percent difference for inhalation, with the single exception of the bedroom where the receptor spent a large amount of time with a smaller volume than the living room. For dermal, the only room that resulted in a large percent difference was office/school, due to the fact that the person spent only ½ hour at that location when the stay-at-home activity pattern was selected. For inhalation, changing from a far field to a near field base resulted in a higher ADR and CADD, likely because the near field has a smaller volume than that of the total room.

There are three input parameters for the near-field, far-field option for CEM product inhalation models. To determine the sensitivity of model results to these inputs, CEM first was run in base scenario with the near-field option, after which separate runs were performed whereby the near-field volume was increased by 10%, the far-field volume was increased by 10%, and the air exchange rate was increased by 10%. For inhalation, both the air exchange rate and volume had negative elasticities, but the air exchange rate had a much higher elasticity (near one) than the volume (0.11).

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