ASSESSMENT OF CHILDREN'S EXPOSURE TO SURFACE METHAMPHETAMINE RESIDUES IN FORMER CLANDESTINE METHAMPHETAMINE LABS, AND IDENTIFICATION OF A RISK-BASED CLEANUP STANDARD FOR SURFACE METHAMPHETAMINE CONTAMINATION

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Assessment of Children's Exposure to Surface Methamphetamine Residues in Former Clandestine Methamphetamine Labs, and Identification of a Risk-Based Cleanup Standard for Surface Methamphetamine Contamination

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Introduction

The Natural History of a Clandestine Methamphetamine Lab

From its initial establishment through its ultimate re-occupancy, a clandestine methamphetamine lab goes through four phases that vary with the nature of operations, the chemicals present, the exposure pathways, and the potentially exposed populations. The four phases may generally be described as

- *Operational*: clandestine methamphetamine synthesis takes place
- *Discovery & Removal*: the lab is "busted" (discovered by law enforcement) and bulk chemicals and equipment are removed
- *Remediation & Verification*: samples are collected to characterize the distribution of contaminants within the residence, the contaminants are remediated, and samples are collected to verify that residual contaminant levels are below target cleanup standards
- *Re-Occupancy*: a new group of residents occupies the residence which housed the former clandestine lab

Each phase represents a distinct exposure scenario with different primary contaminants, contaminant sources, exposure pathways and potentially exposed populations. Contaminant classes, sources and potentially exposed populations are summarize in Table 1. During the first two phases, inhalation of airborne contaminants (such as methamphetamine, acidic and corrosive gases, and phosphine) probably represents the greatest hazard. Once the primary sources[1] of airborne contaminants have been physically removed, secondary sources may still remain in the residence. Secondary sources include solvent spills and "soft" media (such as upholstered furniture, drapes, carpet and wallboard) that have absorbed solvent vapors and volatile contaminants during the operational phase of the clandestine laboratory. Re-release (or "off-gassing") of volatile chemicals that have been absorbed into soft media appears to represent the primary inhalation hazard during cleanup and verification activities. For reasons discussed in the following section ("Timeline for Remediation of a Clandestine Methamphetamine Lab"), we assume that airborne contaminants have largely dissipated by the time the residence is ready for re-occupancy. Thus, as the laboratory progresses through these four phases, the significance of inhalation as a pathway of exposure declines markedly.

Non-volatile compounds, such as the hydrochloride salt of methamphetamine, represent another general class of contaminants encountered at clandestine labs. Methamphetamine has been detected on interior surfaces at former labs and appears to be persistent (Martyny et al., 2004). Pathways of exposure to these compounds include dermal absorption following skin contact with contaminated surfaces, and ingestion following skin contact and subsequent hand-to-mouth activities. With few exceptions, remediation efforts at former clandestine labs focus exclusively on methamphetamine

[1] Primary sources include reaction vessels, solvents stored in their original containers, solvents transferred to other containers, and tanks of compressed gases such as ammonia and hydrogen chloride.

levels. Therefore, the magnitude of exposure to surface methamphetamine residues – and the consequent health risk – is controlled by the target remediation goal for methamphetamine.

The objective of this report is to describe the processes for assessing the exposure to surface methamphetamine residues, so that potential health hazards may be controlled by establishing a clean-up standard that ensures that total exposure via all relevant pathway does not exceed the reference dose (RfD) for methamphetamine. The exposure estimates are based on a re-occupancy scenario, with very young children (approximately 6 months to 2 years of age) as the sub-population of greatest concern. Additional assumptions that were used to develop the exposure estimates are discussed in the following two sections.

Table 1. Summary of the exposure scenarios (contaminants, exposure pathways, and potentially exposed populations) associated with different phases in the life of a clandestine methamphetamine lab.

Scenario	Potentially Exposed Populations	Contaminants & Exposure Pathways
Operational Clandestine Lab	Operators Visitors Innocent by-standers Neighbors	Primary: Inhalation of volatile contaminants, Intentional dosing (all routes) Secondary: Dermal contact with non-volatile residues on surfaces Non-dietary ingestion via hand-to-mouth activities
Discovery and Removal	Law enforcement Removal personnel Industrial hygienists	Inhalation of volatile contaminants stored in original containers Inhalation of re-suspended, particle-adsorbed contaminants Dermal contact with non-volatile residues on surfaces Exposure minimized by personal protective equipment
Cleanup and Verification	Cleanup personnel Industrial hygienists	Inhalation of volatile contaminants off-gassing from "soft" media[2] Inhalation of re-suspended, particle-adsorbed contaminants Exposure minimized by personal protective equipment
Re-occupancy	Residents (includes all sensitive sub-populations)	Dermal contact with methamphetamine residues[3] Dermal contact with non-volatile chemicals on surfaces that lack cleanup standards Inhalation of volatile contaminants off-gassing from "soft" media (likely to be minimal)[4] Inhalation of re-suspended contaminants that lack cleanup standards

[2] "Soft" media include upholstered furniture, drapes and carpet (assuming they have not been removed as part of cleanup operations), and wallboard. During this phase, the primary sources of volatile contaminants - storage containers - will have been removed. Secondary sources, such as solvents that were spilled or improperly disposed of, will still be present.

[3] For re-occupancy to occur in California, methamphetamine residues on surfaces *must* be cleaned up to the specified cleanup standard

[4] Based on the 6-month cleanup timeline specified in Chapter 6.9.1 of the Health and Safety Code, off-gassing of volatile chemicals from soft media is assumed to be minimal. Limited data from 24-hour studies by Martyny et al. (2005, Table IV) indicate that airborne methamphetamine dissipates rapidly after the drug is synthesized, although additional research on the long-term time course of airborne methamphetamine dissipation is warranted.

Timeline for Remediation of a Clandestine Methamphetamine Lab

The provisions of Chapter 6.9.1 of the Health and Safety Code specify a time frame for completing the investigation and remediation of a former clandestine methamphetamine lab. A summary of the mandated tasks and deadlines that must be achieved by the local health officer (LHO) or the property owner is shown in the table below.

Table 2. Action items and statutory timetable for remediation of a former clandestine methamphetamine laboratory, according to provisions of Chapter 6.9.1 of the Health and Safety Code.

Action Item	***Statutory Timetable***
Law enforcement agency notifies LHO*	Day 0
LHO records property lien and issues order prohibiting property use and occupancy	Day 15
Authorized contractor retained	Day 45
Site assessment work plan submitted to LHO	Day 75
Work plan found deficient or approved	Day 100
Remediation complete	Day 190
Site assessment report submitted to LHO	Not specified
LHO reviews site assessment report and determines if no further action (NFA) is required	Not specified
LHO releases property lien	10 Days after NFA determination

* LHO: Local Health Officer or the Designated Local Agency authorized to implement the responsibilities of the LHO.

It is noteworthy that the time required to complete all phases of the investigation and remediation exceeds six months. The process can take even longer if the property owner requests an extension and the request is approved by the LHO. In practice, it is difficult to complete the entire statutorily-mandated remediation and review process within the stipulated timeframe (C. Yep, Cal/EPA, Department of Toxic Substances Control, personal communication). Therefore, six months should probably be viewed as the minimum time required to complete the remediation process. This long duration would likely provide ample time for airborne methamphetamine residues to dissipate and supports the conclusion that inhalation does not represent a significant exposure pathway in a post-remediation re-occupancy exposure scenario. The inhalation pathway is also discussed below as the sixth exposure scenario assumption.

Exposure Scenario Assumptions

1. <u>All interior surfaces are uniformly contaminated, and the surface concentration of methamphetamine[5] is equivalent to the specified cleanup standard.</u>

   The exposure scenario modeled in this report presumes a post-cleanup, residential exposure scenario. The maximum concentration of methamphetamine on all interior surfaces is assumed to equal the cleanup standard. This might be regarded as a health protective assumption since the synthesis of methamphetamine in a clandestine lab usually occurs in a specific location within the residence (typically the kitchen), and portions of the residence distant from the source of contamination (such as the bedrooms) may be uncontaminated or only lightly contaminated. Nevertheless, studies conducted by Martyny et al. (2004) suggest that methamphetamine residues are transported throughout the residence to locations distant from the site of synthesis. Therefore, assuming a post-cleanup scenario, a uniform maximum residue level throughout the residence is not entirely unreasonable.

2. <u>The source concentration does not decline over time, i.e., there is no depletion of the surface methamphetamine concentration.</u>

   Data from environmental studies of former clandestine methamphetamine labs (Martyny et al., 2004) clearly demonstrate that methamphetamine levels persist long after lab activities have ceased.[6] Samples from abandoned clandestine methamphetamine labs collected years after drug synthesis activities have ceased indicate that methamphetamine residues can persist for years.[7]
   These results support a non-depletion assumption *when the residence is unoccupied*. However, as a practical reality, there are several mechanisms that will cause surface contaminant concentrations to decline over time. For example, cleaning with common household cleaning agents will reduce contaminant concentrations on surfaces. In addition, contact by the skin, clothing and shoes of persons living in the residence will result in transfer of methamphetamine residues away from contaminated surfaces. Slowly, these residues will be removed from the environment when the residents bathe, wash their clothing or leave the residence, the latter resulting in the transfer from the source area (the interior of the residence) to uncontaminated areas (outside the residence). Over the very long term, re-painting and replacement of carpets and linoleum will also reduce surface contaminant levels. Therefore, the assumption that methamphetamine concentrations are constant over time should be regarded as health protective insofar as it will lead to over-estimation of the time-weighted average daily exposure.

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[5] The surface concentration is expressed in units of mass per area, e.g., µg of methamphetamine/100 cm^2.
[6] Martyny et al. (2004) state, "Even labs that had been busted several months prior to testing still had high contamination levels of methamphetamine present on many surfaces within the building."
[7] Carolyn Comeau, Washington Department of Health, personal communication.

3. There are no additional sources or reservoirs of methamphetamine (e.g., contaminated air ducts).that would have the potential to elevate the concentration of methamphetamine on surfaces above the target cleanup standard.

   It is assumed that the cleanup standard will be applied to all surfaces in the residence, even those that are unlikely to be contacted directly by residents. Furthermore, assuming the presence of an unremediated source within in the residence would also add a significant layer of complexity to the exposure model, since it would require assumptions about the mass of contaminant present at the source, the efficacy of the release mechanism (e.g., air blowing through an air duct) and the rate of release, and contaminant dispersion and deposition within the residence.

4. The primary population of concern is children in the age range of 6 months to 2 years. These children, by virtue of age-specific behaviors and frequent contact with the floor, constitute a "most exposed" population in an indoor residential exposure scenario.

   Age-specific behaviors that greatly increase the exposure of young children to surface residues were recently summarized in a report by Firestone et al. (2007). Beginning at 6 months of age, children's "floor mobility" increases, leading to more frequent contact with surfaces. Also, children in this age bracket are increasingly likely to place non-food item in their mouth. Between 1 and 2 years of age, participation in play activities increase, and extreme curiosity and poor judgment (based in part on lack of knowledge of potential consequences) motivate exploratory and/or "risky" behaviors. The frequency of mouthing of hand and objects in children in this age range is high. Between ages 2 and 3, the frequency of mouthing of hands and objects begins to moderate and the amount of time spent outdoors increases.

   In justifying specific values for individual exposure parameters, age-specific exposure and behavioral data for children in the 6 months to 2 years age range are frequently limited. Nevertheless, a number of published reports have investigated the exposure of children in this approximate age range to surface contaminants (e.g., Cohen-Hubal et al., 2006), and additional studies are currently underway. In conducting the exposure assessment presented in this report, an attempt was made to utilize parameter values specific for the 6 months to 2 years age range when age-specific supporting data were available.

5. The exposed individual spends 100% of his/her time in the remediated former methamphetamine lab environment.

   In a residential exposure scenario, it is appropriate to account for the time spent away from the residence. For an adult with a job away from the home, it would be reasonable to assume that this individual spends 9-10 hours/day, 5 days/week

at his/her job, with 2 weeks of vacation each year. However, it is not unreasonable to assume that a 6 month to 2 year old child will spend most if not all of his/her time indoors, particularly if the period of residence coincides with the cold winter months or the hot summer months.

6. Inhalation of airborne methamphetamine residues does *not* represent a significant exposure pathway.

   While inhalation of airborne methamphetamine is likely to occur during the operational, discovery and removal, and cleanup and verification phases in the life of a clandestine methamphetamine lab, it is unlikely to be a significant exposure route during the post-cleanup re-occupancy phase. During this phase, surface methamphetamine residues have been remediated to the designated cleanup standard, so the mass of contaminant available for re-suspension is exceedingly small. Additionally, methamphetamine base has a relatively low octanol:water partition coefficient (log P = 2.07), suggesting that it does not readily adsorb to soil and dust particles. Therefore, resuspension of soil and dust by normal activities such as walking and vacuuming is unlikely to generate significant levels of airborne methamphetamine.

   Data characterizing airborne methamphetamine concentrations in former clandestine labs after the labs have been remediated are lacking. Martyny et al. (2005) measured airborne methamphetamine concentrations in a small single story residence during two methamphetamine "cooks" and 13-18 hours thereafter. Concentrations detected at the later time points were approximately 10-30% of the concentrations detected during synthesis, suggesting that airborne methamphetamine dissipates quickly once the source of indoor emissions has been eliminated.

7. A sub-chronic duration of exposure (3-4 months) is assumed.

   In the quantitative analysis presented below, two methods are used to estimate daily exposure to surface methamphetamine residues in units of mg methamphetamine per kilogram body weight (mg/kg-day). Both estimates are based on the assumptions that the source concentration is constant (non-depleting) and that the exposed child spends 100% of his/her time in the remediated environment. For this reason, the duration of exposure does not affect the estimates of daily exposure to methamphetamine.[8]

   We recognize that the activities of the individuals living in the residence will reduce surface methamphetamine concentrations over time. As discussed earlier, mechanisms of contaminant depletion include routine cleaning and contact with

[8] While the output from the SHEDS-multimedia model was based on a 90-day exposure duration, the surface concentration of methamphetamine was assumed to be constant. Therefore, the 90-day exposure estimates simply reflect variation in the behavior (surface contact rates, mouthing frequencies, etc.) of children in the 1-2 year old age range.

uncontaminated skin, clothing and other objects. In reality, these removal processes will cause the daily exposure to decline over time. This reality was taken into consideration in the decision to develop a *sub-chronic* reference dose (RfD) for methamphetamine, insofar as an additional uncertainty factor that would routinely be used to extrapolate to a chronic RfD from the results of a sub-chronic exposure study was *not* incorporated into the calculation.

Exposure Estimation Models

During methamphetamine synthesis, the fate and transport processes that lead to deposition of methamphetamine on interior surfaces have yet to be completely characterized. Clearly, additional studies in this area are warranted. Based on current knowledge, it appears that one or more steps in the methamphetamine synthesis process generate an aerosol or vapor of airborne methamphetamine which is transported widely throughout the interior of a residence (Martyny et al., 2005). When the vapor contacts a surface, it condenses and forms a film, similar to film that deposits on surfaces when pesticides are applied using broadcast spraying or an indoor fogger. Since the film of methamphetamine generated during clandestine methamphetamine synthesis is physically similar to the chemical film produced by indoor application of pesticides, models that have been developed to estimate indoor exposure to pesticide residues can also be used to estimate indoor exposure to methamphetamine residues. A central assumption in this report is that the pathways and mechanisms of exposure to pesticide residues on surfaces are the same as the pathways and mechanisms of exposure to surface methamphetamine residues.

Two models were used to calculate estimates of exposure. The first is based on the U.S. EPA's draft guidance document, *Standard Operating Procedures (SOPs) for Residential Exposure Assessments* (U.S.EPA, 1997; revised 2001). The SOPs provide standard default methods for exposure assessments in a residential scenario when chemical- and/or site-specific information are limited. They provide algorithms for calculating *screening level* exposure estimates for each complete pathway. The algorithms are deterministic; that is, they specify point values for each exposure parameter and generate a single point estimate of exposure. The document also provides different default parameter values to calculate individual exposure estimates for children and adults. The SOPs account for exposure via the following three pathways:

- Dermal exposure following contact with contaminants on carpet
- Dermal exposure following contact with contaminants on hard surfaces (e.g., linoleum floors, plastic laminate counter tops) in the kitchen or bathroom
- Incidental non-dietary ingestion following hand-to-mouth transfer

In a document prepared for the FIFRA Scientific Advisory Panel in 1999, the U.S. EPA stated "These SOPs are the backbone of the Agency's current approach for completing residential exposure assessments." The SOPs were intended to be used both as a screening tool, and for more refined risk assessments when chemical-specific data and information are available.

Alternative exposure estimates were derived using the Stochastic Human Exposure and Dose Simulation for multimedia, multi-route/pathway chemicals (SHEDS-Multimedia) model (Version 3). This model has been in development by the U.S. EPA Office of Research and Development (ORD), National Exposure Research Laboratory (NERL) since 1998. According to its developers, SHEDS-Multimedia "…is a state-of-science computer model for improving estimates of aggregate (single-chemical, multi-route/pathway) and cumulative (multi-chemical, multi-route/pathway) human exposure and dose." It is designed to simulate aggregate exposures and doses for user-specified population cohorts and multi-media chemicals, and relies on data from time-location-activity diaries compiled in U. S. EPA's Consolidated Human Activity Database (CHAD). The history of development of SHEDS-Multimedia is reviewed in the technical manual for the current version (U.S. EPA, 2007). From 2002-2004, a scenario-specific version of the model, SHEDS-Wood, was developed to estimate the exposure and dose of children to chromated copper arsenate (CCA) wood preservatives that had been applied to play structures and decks. In 2005 and 2006, NERL and its contractor Alion Science and Technology developed a graphic user interface (GUI) for SHEDS-Multimedia version 3, along with user and technical manuals for the model. The most recent revisions to SHEDS-Multimedia, made in March, 2007, consisted primarily of correcting several minor "bugs" in the model and modifying the GUI. The model was again reviewed by FIFRA Scientific Advisory Panel (SAP) in August 2007.

SHEDS-Multimedia is a probabilistic model that estimates exposures via inhalation of contaminated air, dermal absorption following contact with contaminated surfaces, and ingestion from hand-to-mouth or object-to-mouth activities. The model generates time series exposure for user-specified population cohorts. Monte Carlo simulation is used to produce distributions of exposure that reflect the variability and/or uncertainty in the input variables.

According to the developers of the model, "SHEDS-Multimedia is the EPA/ORD's principal model for simulating human exposures to a variety of multimedia, multipathway environmental chemicals such as pesticides, metals and persistent bioaccumulative toxins."

The following sections summarize the exposure estimates provided by the two models (i.e., the residential SOPs and SHEDS-Multimedia), and provide analysis and interpretation of their results.

Exposure Estimates based on Algorithms Presented in *Standard Operating Procedures for Residential Exposure Assessments* (U.S.EPA, 1997; revised 2001)

Introduction

Standard Operating Procedures (SOPs) for Residential Exposure Assessment is a draft guidance document prepared in 1997 by the Residential Exposure Assessment Work Group. The work group was composed of staff from the Health Effects Division of the USEPA's Office of Pesticide Programs and Versar, Inc. The SOPs provide standard default methods for exposure assessments in a residential scenario when chemical- and/or site-specific information are limited. They were developed in response to passage of the Food Quality Protection Act (FQPA) in 1996, which mandated the U.S. EPA to immediately begin considering aggregate exposure to pesticides. Non-dietary and non-occupational pesticide exposures for the general population were a primary focus of this effort. Examples of these exposure pathways include inhalation of vapors following pesticide application inside a home and dermal contact with pesticide residues by children playing on a treated lawn. The SOPs provide a means of calculating single pathway, screening level exposure estimates. In a document prepared for the FIFRA Scientific Advisory Panel in 1999, the U.S. EPA stated, "These SOPs are the backbone of the Agency's current approach for completing residential exposure assessments." The SOPs were intended to be used both as a screening tool, and for more refined risk assessments when chemical-specific data and information are available. They address two different exposure scenarios:

- Homeowner, handler exposures that result when an individual applies a pesticide, when such activity is not a condition of his employment
- Residential, post-application exposure that results from activity in an environment previously treated with a pesticide. These exposures, which may result from occupational or homeowner applications, may occur in any number of settings such as homes, schools, and day care centers.

In an indoor residential environment, certain types of pesticide application produce the same widespread surface contamination that results when methamphetamine is synthesized. For example, an indoor fogger is an effective means of applying a pesticide indoors because disperses a film of pesticide on interior surfaces. Similarly, emissions from methamphetamine synthesis deposit a film of chemical residue throughout an entire house or apartment. For this reason, SOPs that were developed to estimate residential exposure to pesticides applied using an indoor fogger may be adopted to estimate residential exposure to post-cleanup methamphetamine residues on interior surfaces. The following calculations are based on SOP algorithms to estimate

- Dermal exposure following contact with contaminants on carpet
- Dermal exposure following contact with contaminants on hard surfaces (floors and counter tops) in the kitchen or bathroom
- Incidental non-dietary ingestion following hand-to-mouth transfer

Post-Application Dermal Dose from Pesticide Residues on Carpets[9]

Exposure scenario: Pesticide residues are transferred to the skin of adults, toddlers and infants who come in contact with treated carpets for recreation, housework and other occupant activities.

Assumptions[10]:

1. **5%** of the application rate (from broadcast or crack and crevice treatments) is available on the carpet as dislodgable residue.
2. Homeowners can contact the treated carpet immediately after pesticide application.
3. Dissipation of pesticide residues should be based on chemical-specific data.
4. Dermal transfer coefficients[11] are assumed to be
    1. Adults: **16,700 cm^2/hr**
    2. Children (1 to 6 years of age): **6,000 cm^2/hr**
5. Body weights are assumed to be
    1. Adults: 71.8 kg
    2. Adult females (for reproductive or developmental toxicity): 60 kg
    3. Children[12]: 15 kg
6. Duration of exposure: 8 hours/day

Calculation: potential dermal dose rate on day "t" [PDR_t (mg/day)]

$$PDR_t = ISR_t * CF1 * Tc * ET$$

where:

ISR_t	=	indoor surface residue on day "t" (mg/cm^2)
CF1	=	conversion factor (0.001 mg/µg)
Tc	=	transfer coefficient (cm^2/hr)
ET	=	exposure time (hr/day)

and

$$ISR_t = AR * F * (1-D)^t * CF2 * CF3$$

where:

AR	=	application rate (pounds active ingredient/ft^2)
F	=	fraction of active ingredient retained on carpet (unitless)
D	=	fraction of residue dissipating daily (unitless)
t	=	post-application day on which exposure is assessed
CF2	=	conversion factor (4.54×10^8 µg/pound)

[9] See U.S. EPA (1997), Section 8.2.1; and U.S. EPA (2001), p. 6. Parameter values in **BOLD** were revised per Policy 12 of the Science Advisory Council for Exposure (2001).

[10] The methodology is based on assumptions when adequate chemical- specific field data are unavailable.

[11] The revised value for adults is based on Jazzercise data published by Ross et al. (1990 and 1991). The value for children is based on data from an adult crawling across treated carpet (U.S. EPA, 1996).

[12] The 1997 SOP document provided separate transfer coefficients and associated body weights for toddlers (3 years of age) and infants (6 months to 1 ½ years of age). The 2001 revisions only specified a transfer coefficient for children 1-6 years of age and did not specify a body weight, so 15 kg was assumed.

CF3 = conversion factor (1.08×10^{-3} ft^2/cm^2)

For former meth labs, the post-cleanup concentration of methamphetamine residues on surfaces (i.e., the indoor surface residue) is the target cleanup level, which in most states is 0.1 µg/100 cm^2 (0.001 µg/cm^2). Since dissipation data for methamphetamine are not available, it is conservatively assumed that dissipation does not occur. Therefore, using the above equations, it is not necessary to calculate ISR_t; the value for this parameter is simply the target cleanup level. *In the absence of chemical-specific data, it is conservatively assumed that 100% of the methamphetamine residue present on carpet is dislodgeable*[13].

Therefore, the dermal dose rate for an child contacting carpet is

$$0.001\ \mu g/cm^2 * 0.001\ mg/\mu g * 6{,}000\ cm^2/hr * 8\ hr/day = 0.048\ mg/day$$

Normalized to the average body weight of a 2-3 year-old child (15 kg), the estimated exposure resulting from contact with methamphetamine residue on carpets would be 0.0032 mg/kg-day. The SOP does not include any assumptions about dermal absorption, indicating that the calculated daily dose rate "…be used in conjunction with toxicity data to assess risk." This implies that it is appropriate to assume 100% dermal absorption. Given that the experimentally determined dermal absorption of methamphetamine is approximately 60-70%, this assumption produces approximately a 50% over-estimation of the dermally absorbed dose.

Post-Application Dermal Dose from Pesticide Residues on Hard Surfaces[14]

The exposure scenario and assumptions are identical to those specified for calculating the dermal dose from residues on carpets, although the duration of exposure is assumed to be just 4 hours/day. The latter value is justified on the basis that it represents the mean of the 90th percentile values for time spent on the kitchen and bathroom for all age groups (adults and children).

Calculation: The equations and parameters that are used to calculate the dermal dose from residues on hard surfaces are identical to those used for calculating the dermal dose from carpets. Therefore, using the same equation described above for calculating potential dermal dose rate on day "t" (PDR_t), the dermal dose rate for a child contacting hard surfaces is

$$0.001\ \mu g/cm^2 * 0.001\ mg/\mu g * 6{,}000\ cm^2/hr * 4\ hr/day = 0.024\ mg/day$$

Normalized to a child's body weight (15 kg), the estimated exposure resulting from contact with methamphetamine residues on carpets would be 0.0016 mg/kg-day. The SOP does not include any assumptions about dermal absorption, indicating that the calculated daily dose rate "…be used in conjunction with toxicity data to assess risk." This implies that it is appropriate to assume 100% dermal absorption. Given that the experimentally determined

[13] The assumption is consistent with the procedure used to assess compliance with a cleanup standard, since the amount detected on a wipe sample is by definition dislodgeable.
[14] See U.S. EPA (1997), Section 8.2.1; and U.S. EPA (2001), p. 6.

dermal absorption of methamphetamine is approximately 60-70%, this assumption produces approximately a 50% over-estimation of the dermally absorbed dose.

Post-Application Dose Estimate for Toddlers from Incidental Non-Dietary Ingestion of Pesticide Residues on Indoor Surfaces from Hand-to-Mouth Transfer[15]

[Note: Parameter values for this pathway were not revised in Policy 12 of the Science Advisory Council for Exposure (2001).]

Exposure scenario: Pesticide residues are transferred to the skin of toddlers during post-application contact with treated indoor areas and are subsequently ingested as a result of hand-to-mouth transfer. The 3 year old age group was selected for his scenario because, at the time the SOP was written, this was the youngest age group for which data on hand-to-mouth activity were available.

Assumptions:

1. 50% of the application rate from broadcast or crack and crevice treatments) is available as dislodgable residue.
2. Homeowners can contact the treated carpet immediately after pesticide application.
3. Dissipation of pesticide residues should be based on chemical-specific data.
4. The average surface area of both hands is 350 cm^2 for a toddler (3 years of age).[16]
5. Replenishment of the hands with pesticide residues is an implicit factor in this assessment, suggesting that there is no maximum dermal loading value.
6. *The surface-to-skin transfer efficiency of dislodgable residues is 100%.*[17]
7. The average rate of hand-to-mouth activity is 0.026 events/minute (1.56 events/hour) for toddlers (3-5 year olds).
8. The duration of exposure to indoor surfaces is 4 hours/day. (See justification in Section II above.)
9. The average weight of a toddler (age 3 years) is 15 kg.

Calculation: potential dose rates from ingestion [PDR (mg/day)]

$$PDR = ISR * SA * FQ * ET$$

where:

ISR	=	indoor surface residue (mg/cm^2)
SA	=	surface area of the hands that contact indoor surfaces and subsequently transfer residues to the mouth during a given event (cm^2/event)
FQ	=	frequency of hand-to-mouth events (events/hour)

[15] See U.S. EPA (1997), Section 8.4.
[16] Based on the 1996 U.S. EPA exposure Factors Handbook
[17] The guidance document is explicit in this regard: "…if the dislodgable residue on the indoor surface is 1 mg/cm^2, the residue on skin is also 1 mg/cm^2 after contacting the surface."

ET = exposure time (hours/day)

As discussed above, the post-cleanup concentration of methamphetamine residues on surfaces at former meth labs (i.e., the indoor surface residue) is the target cleanup level, which in most states is 0.1 µg/100 cm^2 (0.001 µg/cm^2, or 0.001 x 10^{-3} mg/cm^2). Since dissipation data for methamphetamine residues on surfaces are not available, it is conservatively assumed that dissipation does not occur.

Therefore, the incidental ingestion dose among toddlers following contact with contaminated surfaces and subsequent hand-to-mouth activity is

0.001 x 10^{-3} mg/cm^2 ∗ 350 cm^2/event ∗1.56 events/hour ∗ 4 hours/day = 0.0022 mg/day

Normalized to a toddler's body weight (15 kg), the estimated exposure would be 0.00015 mg/kg-day.

Total Estimated Exposure via All Three Pathways

Dermal Dose from Pesticide Residues on Carpets:	0.0032 mg/kg-day
Dermal Dose from Pesticide Residues on Hard Surfaces:	0.0016 mg/kg-day
Incidental Ingestion Dose from Hand-to-Mouth Activity:	0.00015 mg/kg-day
TOTAL:	**0.00495 mg/kg-day**

For comparison, using the same surface residue level, the SHEDS model estimated an average total absorbed dose of 0.000015 mg/kg-day, or 330 times less than the residential SOPs. If the experimentally determined dermal absorption efficiency for methamphetamine had been used in the SOP equations, the dose estimates for the two dermal absorption pathways would have been reduced by approximately one-third, but the estimate of total dose still would have been 220 times greater than the dose estimate generated by the SHEDS model.

Analysis and Interpretation

Based on the SOP algorithms, 97% of total exposure for a child results from dermal contact with "soft" surfaces such as carpet and hard surfaces such as linoleum. Ingestion, which occurs secondarily to dermal contact with contaminated surfaces and subsequent hand-to-mouth activity, accounts for just 3% of total exposure. These results are largely driven by the default value for the dermal transfer coefficient for a child 1 to 6 years of age (6,000 cm^2/hour). The guidance document does not provide justification for this value. However, the results of a recent study conducted by Cohen Hubal et al. (2006) suggest that this default value appears to be very health protective. In this study, children's exposure to surface pesticide residues was evaluated in a child care center where the pesticide esfenvalerate had been applied the previous day. Transfer coefficients were based on surface sampling data and pesticide loadings on cotton body suits that the children wore to monitor their dermal exposure. Transfer coefficients were calculated using the equation

Dermal transfer coefficient = dermal exposure / surface loading

where the dermal exposure was the mass of pesticide on the body suit divided by the monitoring duration (nanograms/hour) and the surface loading was based on the results of surface wipe sampling (micrograms/square centimeter). Transfer coefficients were calculated for infants (6-12 months of age) and pre-schoolers (2-3 years of age).

Dermal transfer coefficients calculated using the data obtained from this study ranged from 10 to 6,000 cm^2/hour. Therefore, the SOPs specify a default value for the transfer coefficient for a child that is equivalent to the maximum value obtained by Cohen Hubal et al. The authors of this study concluded, "…results of this work suggest that the default assumption used by the U.S. EPA OPP [i.e., the SOPs] is reasonable." An alternative interpretation would be that dermal transfer coefficients for children have a wide range of variability, and that dermal exposures would be more appropriately estimated using a stochastic model, such as SHEDS-Multimedia, which accounts for the wide range of children's behaviors and activities. The algorithms and default parameter values prescribed by the SOPs appear to be appropriate for obtaining very health protective, screening level estimates of exposure.

Exposure Estimates based on the Stochastic Exposure and Dose Simulation Model for Multimedia, Multipathway Chemicals (SHEDS-Multimedia), Version 3

Introduction: Overview of SHEDS-Multimedia

The Stochastic Human Exposure and Dose Simulation for multimedia, multi-route/pathway chemicals (SHEDS-Multimedia) model (Version 3) has been in development by the U.S. EPA Office of Research and Development (ORD), National Exposure Research Laboratory (NERL) since 1998. According to its developers, SHEDS-Multimedia "…is a state-of-science computer model for improving estimates of aggregate (single-chemical, multi-route/pathway) and cumulative (multi-chemical, multi-route/pathway) human exposure and dose." It simulates aggregate exposures and doses for user-specified population cohorts and multi-media chemicals, and relies on data from time-location-activity diaries compiled in U. S. EPA's Consolidated Human Activity Database (CHAD).

As defined in the Technical Manual for the model, *exposure* is the contact between the chemical agent and the human "target" at the skin, lung and gastrointestinal tract exposure surfaces. *Dose* is defined as the amount of chemical that enters the target after crossing the exposure surfaces.

SHEDS-Multimedia estimates absorbed doses that are the result of exposure via inhalation, ingestion (from mouthing the hands or objects) and dermal contact in a residential setting. The model uses Monte Carlo simulation to simulate a population of stochastically created "virtual" persons whose collective characteristics reflect the simulated population and input distributions for exposure-related variables. For each individual, SHEDS-Multimedia generates a series of activities, media concentrations, and resulting exposures over the selected simulation period. These individual exposure time series are then aggregated over time to produce time-integrated or time-averaged exposures, as shown in the hypothetical individual exposure profile in Figure 1.

Exposure estimates presented in this report were generated by a "standard" SHEDS-Multimedia run, also called a "variability run," which generates exposures for a random sample of individuals in the target population using Monte Carol sampling. The fundamental modeling unit in SHEDS-Multimedia is the individual, and each individual is generated as a representative random sample. These individual exposure estimates provide the basis for the exposure distribution for the population.

SHEDS-Multimedia can also be run as a two-stage Monte Carlo model (also called an "uncertainty run"), which consists of a series of variability runs with the input variables modified between each variability run to represent uncertainty in the input parameters of the variability runs. However, two stage Monte Carlo simulations were *not* completed for this report.

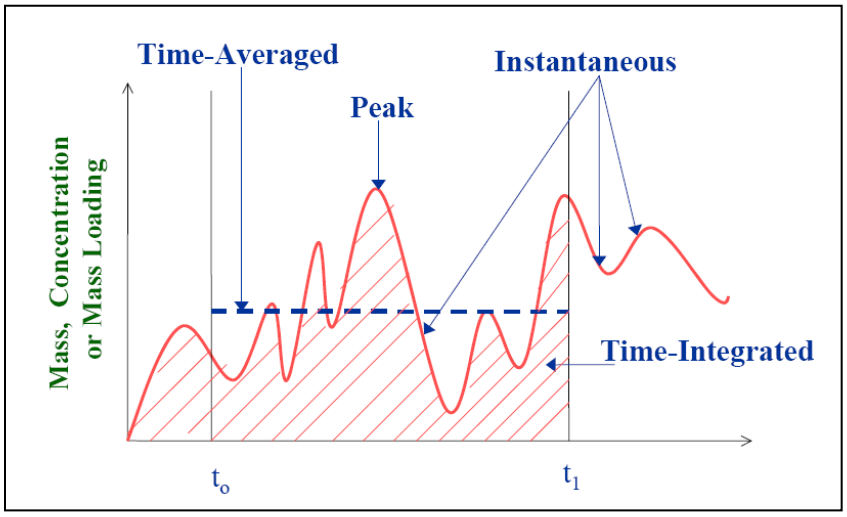


Figure 1. Hypothetical exposure profile for an individual over time. (Reproduced from USEPA, 2007)

As outlined in the Technical Manual for SHEDS-Multimedia version 3 (U.S. EPA, 2007), the following general steps are applied for each individual in a SHEDS run:

1. Given the distribution of the target population, randomly select the age, gender and other demographic properties of interest.
2. Using the CHAD diaries that are built into the model, generate a longitudinal activity diary that indicates the sequence and duration of activities and locations for the individual.
3. Generate concentration-time series for each potential contact medium (e.g., indoor air, indoor smooth surfaces, indoor textured surfaces, indoor dust).[18]
4. Simulate the contacts between the individual and the affected media. These depend on the diary activity and location information and user-specified contact probabilities.[19]
5. Calculate exposure-time series for the individual using the results from steps 3 and 4 and user-specified distributions for exposure factors.
6. Generate an approximation for the dose time series, if desired, using the simple physiologically-based pharmacokinetic (PBPK) model in SHEDS.
7. Export exposure time series for use in a PBPK model, or extract desired metrics or summary statistics from the exposure or dose time series.

SHEDS-Multimedia repeats this process for an individual many times (the number of iterations is specified by the user) using Monte Carlo simulation to obtain population

[18] As discussed in the following section, concentrations on smooth and textured surfaces are assumed to equal the target cleanup level for methamphetamine. Concentrations on both types of surfaces are assumed to be constant (non-depleting) for the entire 90-day exposure duration. The indoor air concentration is assumed to be zero, and the concentration in indoor dust is assumed to be zero. These assumptions are consistent with the goal of identifying a risk-based cleanup standard for methamphetamine on surfaces.
[19] Contact probabilities and exposure parameters are age-specific, to the extent that age-specific data are available for them.

estimates. A diagram of the steps involved in generating exposure and dose estimates using the SHEDS model is shown in Figure 2.

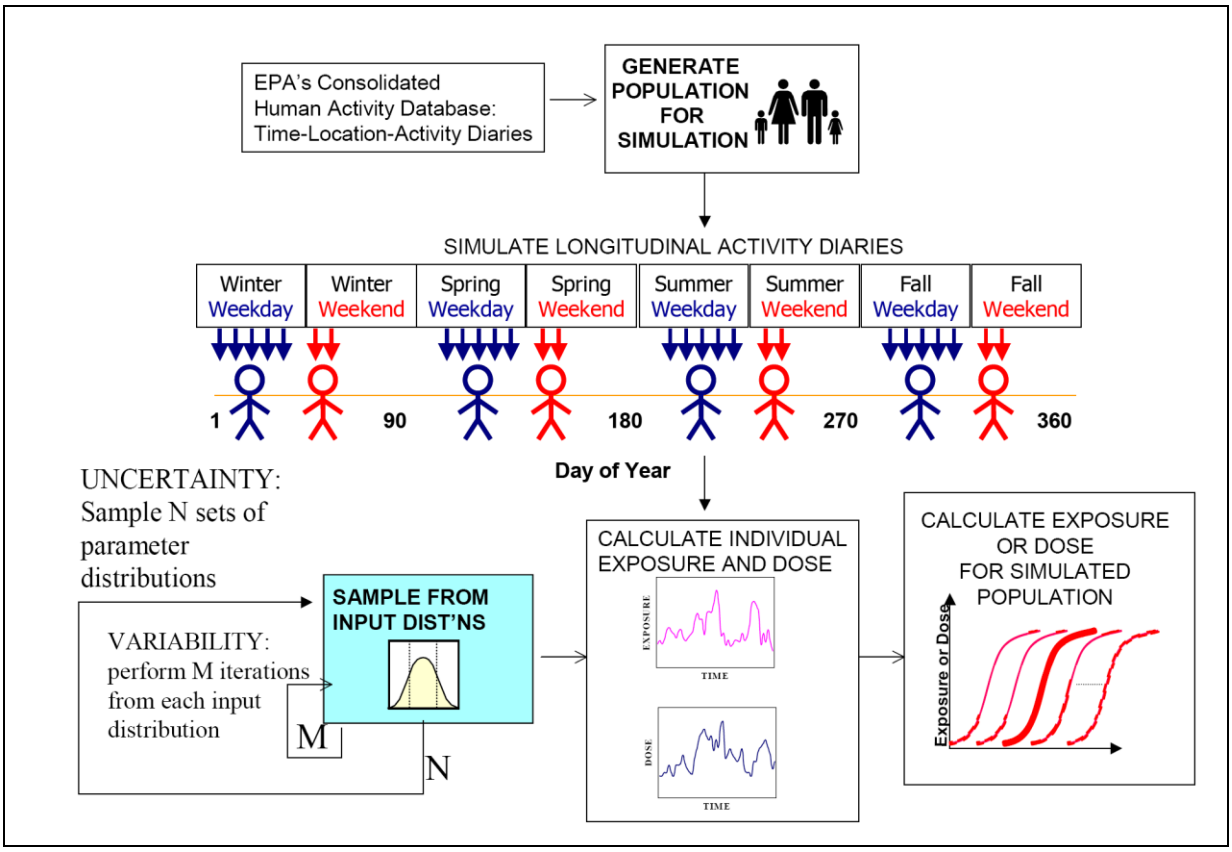


Figure 2. Diagrammatic overview of the SHEDS methodology. (Reproduced from Zartarian et al., 2006)

Additional Exposure Assumptions for SHEDS-Multimedia

In addition to the exposure assumptions discussed on pages 9-12, the following additional assumptions are required to run SHEDS-Multimedia.

1. <u>The oral bioavailability of ingested methamphetamine residues following hand-to-mouth or object-to-mouth movements was assumed to be 100%.</u>

   An oral bioavailability of 100% may be regarded as somewhat health protective because few chemicals are completely absorbed following ingestion. Nevertheless, methamphetamine is known to be well absorbed by all routes of exposure, including ingestion. In addition, its rapid rate of dermal absorption suggests the drug passes readily through biological membranes.

   Since the post-remediation surface concentration of methamphetamine is anticipated to be extremely low (the prevailing default cleanup standard is 1 ng/cm^2) and the residue-to-skin transfer efficiency is assumed to have a mean

value of just 7%, the mass of the drug transferred to the mouth via hand-to-mouth activities is anticipated to be extremely small. Therefore the extremely low rate of intake of the drug is not expected to limit its absorption efficiency.

2. Based on experimental data, the mean dermal absorption efficiency of methamphetamine was estimated to be 57 ± 7.6% (mean ± SD).

   In vitro studies of the dermal absorption of methamphetamine were recently completed by Drs. Xiaoying Hui and Howard Maibach at the University of California San Francisco (UCSF).[20] These studies, which were based on a standard protocol utilizing Franz diffusion cells and human skin samples, indicate that methamphetamine is well absorbed across the skin. Experimental details are provided in a draft report of the UCSF studies, included as an appendix to this report.

   Interpreting data from these studies requires an understanding of the basic cellular structure of skin. Simply described, skin is composed of three distinct layers: the outermost epidermis, the intermediate dermis, and an underlying layer of subcutaneous fat. The stratum corneum consists only of dead cells, called corneocytes, which lack any contact with the circulation in living skin. As noted in a recent review by Van de Sandt et al. (2007), the outermost layer of the epidermis, the stratum corneum, is the rate-limiting barrier of skin. These authors also made the following recommendations for interpretation of data from dermal absorption studies:

   > *For risk assessment purposes, the chemical adsorbed to the stratum corneum at the end of the experiment is considered as non-bio-available. The amount of penetrated substance found in the receptor fluid (in vitro)…at the end of the experiment is considered systemically available. In addition, amounts present in the epidermis (minus the stratum corneum) and dermis at that time are often considered to be systemically available as a conservative assumption.*

   The UCSF data were interpreted in a manner consistent with these recommendations. The overall estimate of dermal absorption efficiency is based on cumulative data collected over a 24-hour incubation period.

3. The maximum dermal loading of methamphetamine residues on the skin (body and hands) was assumed to be ten times greater than the target cleanup concentration for methamphetamine on surfaces.

   SHEDS-Multimedia incorporates separate variables for maximum dermal loading on the hands and body, although the values for the two variables are usually identical. They are included in the model to prevent multiple contacts from

[20] These studies were conducted under contract with funding provided by the California Environmental Protection Agency, Department of Toxic Substances Control.

adding to the dermal load indefinitely. Therefore, when the maximum dermal loading is obtained, no additional contaminant can be transferred to the skin.

The target cleanup standard first proposed by the state of Washington and subsequently adopted by several other states is 0.1 μg/100 cm^2, or 1 ng/cm^2. Since the surface cleanup standard is so low, we have assumed that the skin can accumulate up to ten times the state of Washington's cleanup standard. This assumption, combined with methamphetamine's high rate of dermal uptake and an assumed average residue-to-skin transfer efficiency of 7%, strongly suggests that dermal loading is the limiting factor in the mass of methamphetamine taken up via the dermal pathway.

4. <u>The mean surface residue-to-skin transfer efficiency for methamphetamine was estimated to be 7% for all types of surfaces.</u>

   Residue-to-skin transfer efficiency is likely dependent on the chemical properties of the contaminating substance and (if applicable) the carrier in which the chemical is present. Nevertheless, the transfer efficiencies reported by Camann et al. (2000) for chlorpyrifos, pyrethrin I and piperonyl butoxide – three chemically distinct substances – were not remarkably different in most cases.[21] The default distributions for the transfer efficiency parameter (beta distribution; shape 1: 0.6; shape 2: 8.4; mean 0.07) that were supplied with the SHEDS model is based on two references, one conducted by Nishioka (2003) under contract to U.S. EPA and the other published by Cohen Hubal et al. (2005).

   Data from the *in vitro* surface-to-skin transfer studies conducted at UC San Francisco were *not* used to estimate a value for residue-to-skin transfer efficiency in SHEDS-Multimedia. This decision was based primarily on the fact that the experimental techniques developed by UCSF should at present be regarded as experimental. The methodology has not been validated by comparing its results with data from *in vivo* hand press transfer studies of other chemicals [e.g., chlorpyrifos, pyrethrin I and piperonyl butoxide (Camann et al., 2000)].

   Furthermore, in the UCSF studies, the contact durations required for significant transfer to occur were significantly longer than those employed in standard "hand press" studies. For example, the transfer of methamphetamine from vinyl tile to skin after contact durations of 15 seconds and 5 minutes was just 0.15% and 5.41%, respectively. In contrast, in an evaluation of a cotton glove press test for assessing transfer of pesticides from plush carpet, Roberts and Camann (1989) utilized a contact duration of two seconds. In two more recent studies, Camann et al. (2000) and Clothier (2000) utilized contact durations of just one second.

[21] Typically, a two-fold difference in transfer efficiency for the three chemicals was observed. The nature of the surface had a much greater effect on transfer efficiency: transfers from vinyl flooring were 2- to 10-fold greater than from plush carpets.

The UCSF studies indicated that residue to skin transfer *in vitro* was highly dependent on contact duration, a result that contrasts markedly with the results obtained *in vivo* by Cohen Hubal et al. (2005), where transfer was found *not* to depend on contact duration. The duration-dependence of transfer efficiency found in the UCSF studies is also problematic because the SHEDS model does not incorporate a parameter for contact duration.

In summary, the results of the UCSF studies are not easily reconciled with the published literature. In part, this may the result of the physical and mechanical differences between the hand press technique and the in vitro methods developed by UCSF. Nevertheless, validation studies of the UCSF methodology have not been completed. For this reason, we decided to incorporate the default SHEDS distribution into our analysis of methamphetamine exposure.

5. Contact with uncontaminated surfaces or objects was assumed *not* to deplete methamphetamine residues from the skin.

   SHEDS allows the user to specify a value for contaminant depletion from the skin as result of contact with uncontaminated surfaces (parameter 3 (d), "removal efficiency during events without water"). The exposure scenario that this exposure analysis is based on assumes that all surfaces are uniformly contaminated with methamphetamine, so contact with uncontaminated surfaces would be unlikely to occur. We have conservatively assumed that contact with uncontaminated surfaces is not a mechanism of contaminant depletion from the skin; all the residue that adheres to the skin as a result of contact with contaminated surfaces is assumed to remain on the skin until removed (albeit partially) by washing.[22]

6. Methamphetamine is assumed to be present on surfaces as a chemical film or residue; soil and dust inside the home were assumed *not* to be contaminated with methamphetamine.

   SHEDS-Multimedia has separate inputs for contaminant concentration as a "residue" on surfaces and as a constituent of soil and dust in the home. We have assumed that methamphetamine is only present as a surface residue; the concentration in soil and dust inside the residence is assumed to be zero. This assumption is based in part on the relatively low octanol:water partition coefficient of methamphetamine (log P = 2.07). In the outdoor environment, chemicals with partition coefficients this low do not adsorb readily to soil and translocate readily from the surface to groundwater if spilled onto soil. There are no data available on the physical form of methamphetamine as a contaminant inside a residence. A portion of the chemical may indeed be adsorbed to soil or dust particles, but there is no basis for estimating the percentage that is adsorbed to particles and the percentage that is not. Since a

[22] See section VI ("Other Sources of Uncertainty") for discussion of the effectiveness of washing with soap and water as a means of removing methamphetamine residue from the skin.

single distribution was used to characterize the surface-to-skin transfer of methamphetamine residues, this assumption should not have a material effect on the exposure estimates generated by the model.

Justification for Parameter Values used in SHEDS-Multimedia

SHEDS-Wood and SHEDS-Multimedia have been reviewed on several occasions by the FIFRA Scientific Advisory Panel. A report from a December 2003 meeting on the use of SHEDS-Wood to assess children's exposure to residues from wood treated with chromated copper arsenic (CCA) stated,

> *It was the consensus of the Panel that, by and large, the best information on input variables at this time has been used…Even though on can question specific choices of distributional assumptions, overall the work seemed a reasonable effort and a sound basis for risk assessment within the limitations of available information…Even though one can question specific choices of distributional assumptions, overall the work seemed a reasonable effort and a sound basis for risk assessment within the limitations of available information.*

To estimate exposure to surface methamphetamine residues, data supporting methamphetamine-specific parameter values and distributions are not available, and it is unlikely that they will become available in the foreseeable future. For this reason, several of the parameter values and distributions utilized for analysis of methamphetamine exposure were the values and distributions that were provided with the model, which are based on experimental data for other chemicals. In some cases, support for selecting a particular value or distribution could be gained by comparing the similarity, or dissimilarity, of chemical and physical properties of methamphetamine with the chemical and physical properties of chemicals for which relevant data are available.

Values for several parameters were adopted because they were judged to be health protective and not entirely unreasonable, or because their effect on the total exposure estimate was found to be minimal. For example, assuming 100% oral bioavailability of ingested methamphetamine residues may indeed be conservative, but the effect of this assumption on the SHEDS-Multimedia estimate of exposure was small because the ingestion pathway only accounted for about 10% of total exposure. Therefore, even if the bioavailability of ingested methamphetamine had been assumed to be 50%, the net effect would be just a 5% decrease in the total exposure estimate. Similar results were found for several other parameters. These are discussed in the section, "Sensitivity Analysis: Evaluation of Changes in the Values of Individual Parameter on Estimates of Exposure" below.

Values and distributions for a number of exposure parameters were developed in consultation with Drs. Luther Smith and Graham Glen of Alion Science and Technology, U.S. EPA's primary contractor for development of the SHEDS-Multimedia model. The far right column of parameter values table (Table 3) notes several references to this correspondence.

Table 3. SHEDS Multimedia Model Version 3, General exposure and dose factors: Data & information supporting selected parameter values and distributions

Variability Groups and Variable Descriptions	Variable	Units	Default[23] Distribution	Default[23] Parameters	Comments	USEPA (2005; Table 10) or Hore et al. (2006; Table 3)
1. Activity-related						
a) Probability of having a vegetable garden	[has_garden_p]	[-]	point	1	not applicable; **assume 0**	
b) Probability of having a lawn	[has_lawn_p]	[-]	point	1	not applicable; **assume 0**	
c) Probability of having a dog or cat	[has_pet_p]	[-]	point	1	**assume 0**	
2. Transfer-related						
a) Soil-skin adherence factor	[adherence]	mg/cm^2	point	0	not applicable; **assume 0**[24] (soil pathway incomplete)	
b) Body-surface fractional contact rate	[contactb]	hr^{-1}	triangle	min: 0 mode: 0.36 max: 1.08	**use default**	p. 61 ($F_{contact,\ res,\ body}$) & pp. 70-71 values >1 account for multiple contacts
c) Hand-surface fractional contact rate	[contacth]	hr^{-1}	triangle	min: 0.6 mode: 1.2 max: 1.5	**use default**	p. 61 ($F_{contact,\ res,\ hand}$) & p. 70 values >1 account for multiple contacts see 12/15 & 12/19 notes from Dr. Glen
d) Fraction of body unclothed (non-hand)	[f_uncloth]	[-]	beta	shape1: 3 shape2: 6.7	same as SHEDS-Wood **use default**	p. 61 ($F_{uncl,body}$); p. 70
e) Fraction of surface of one hand that enters mouth	[hm_fraction]	[-]	beta	shape 1: 3.7 shape 2: 25 (mean = 0.13)	same as SHEDS-Wood **use default**	p. 62 ($F_{hand\text{-}mouth}$); p. 73 0.085 ("default SHEDS"); $Frac_{HM}$
f) Hand mouthing events per hour[25]	[hm_freq]	events/hr	triangle	min: 0.4 mode: 8.5 max: 25.7	**use** age-specific (1 to <2 yrs) indoor data from Xue: **(Weibull; 18.79, 0.91)** 19.6 ± 19.6 (mean ± SD)	Weibull: scale 6.93, shape 0.73 p. 62 (N_{hm}); p.74 10 ± 7 (range: 1-18); $Freq_{HM}$

[23] These distributions and parameter values were included with the SHEDS model as received.
[24] The log K_{OW} for methamphetamine is 2.07, suggesting that methamphetamine does not readily adhere to soil particles.
[25] Values for this parameter could also be based on "mouth-hand" data for children ≤ 24 months published by Tulve et al. (2002; Table 2; children ≤ 24 months): mean 18, median 12, 95% CI 9-16 events/hour

Table 3. Continued

Variability Groups and Variable Descriptions	Variable	Units	Default[26]		Comments	USEPA (2005; Table 10) or Hore et al. (2006; Table 3)
			Distribution	Parameters		
g) Dust ingestion rate (indoor, direct only)	[ingestion_indoor]	mg/hour	point	1	no dust data; **assume 0**	
h) Soil ingestion rate (outdoor, direct only)	[ingestion_outdoor]	mg/hr	point	1	not applicable; **assume 0**	p. 62 (IR_{soil}); pp. 71-2
i) Object-surface concentration ratio[27]	[object_ratio]	[-]	point	0	**use uniform: 0 (min), 0.2 (max)** per information from Drs. Glen & Smith	not evaluated in SHEDS-Wood 0.5 ("default SHEDS"); $Ratio_{OBJ\text{-}SURF}$ see 12/19/06 and 1/16/07 notes from Dr. Glen
j) Object-mouth contact area	[om_area]	cm^2	uniform	min: 0; max: 20	**use exponential: 1 (min), 10 (mean), 50 (max)**	see 1/16/07 note from Glen/Smith 35 ("default SHEDS"); SA_{OBJ}
k) Object-mouth contact rate[28]	[om_freq]	events/hr	point	0	**use Hore et al. distribution**[29]	**5 ± 4 (range: 1.4 – 15)**; $Freq_{OM}$
l) Object-mouth transfer efficiency	[om _transfer]	[-]	uniform	min: 0.1; max: 0.5	**use default**	0.3 ("default SHEDS"); $Eff_{SAL\text{-}REM}$
m) Residue-skin transfer efficiency	[transfer_dermal]	[-]	beta	shape1: 0.6 shape2: 8.4	**use default**	references from Glen/Smith (12/15/06)

[26] These distributions and parameter values were included with the SHEDS model as received.

[27] "This variable refers to the ratio of the mass loading of chemical residue on an object sitting on a surface (e.g., a toy on the floor) to the mass loading of the surface that the object is sitting on." (Ref: November 2, 2006 Draft SHEDS-Multimedia Technical Manual, page 38). Drs. Glen & Smith stated, "We consider it [this variable] to be one of the most uncertain variables in our model" (see email note dated 1/16/07). Values for this parameter depend on the specific details of the poet-cleanup exposure scenario (e.g., whether or not toys and mouthable objects are disposed of or decontaminated to the same target remediation level as interior surfaces).

[28] Values for this parameter could also be based on "mouth-toy" data for children ≤ 24 months published by Tulve et al. (Table 2): mean 45 and median 39; 95% CI on the median: 31-48 events/hour

[29] Assume lognormal distribution with arithmetic mean of 5 and arithmetic standard deviation of 4. See distribution generated by Crystal Ball. Parameter values cited by Hore et al. (2006) were based on child-specific microlevel activity data obtained from the Children's Post-Pesticide Application Exposure Study (CPPAES). Original reference is Paromita Hore's PhD dissertation (2003). Drs. Glen & Smith noted "The [object-mouth] contact frequency rates cited by Paromita Hore seem reasonable to us" (12/19/06).

Table 3. Continued

Variability Groups and Variable Descriptions	Variable	Units	Default[30] Distribution	Default[30] Parameters	Comments	USEPA (2005; Table 10) or Hore et al. (2006; Table 3)
3. Removal-related						
a) Maximum dermal loading for body	[dermaxb]	ug/cm^2	uniform	min: 0.4; max: 2.0	**assume point value: 0.01** (10x "default" cleanup level)	see 12/15 & 12/19 notes from Dr. Glen
b) Maximum dermal loading for hands[31]	[dermaxh]	ug/cm^2	uniform	min: 0.4; max: 2.0	**assume point value: 0.01**[32] (10x "default" cleanup level)	see 12/15 & 12/19 notes from Dr. Glen
c) Removal efficiency during bath/shower	[remv_bath]	[-]	beta	shape1: 17.1 shape 2: 5.1 (mean = 0.77)	same as SHEDS-Wood **use default**	p. 62 (F_{bath}); p. 74 0.85 ("default SHEDS")
d) Removal efficiency during events w/o water	[remv_dry]	[-]	point	0	**assume 0**[33]	
e) Removal efficiency during mouthing (skin-to-mouth only)	[remv_mouth]	[-]	triangle	min: 0 mode: 0.16 max: 0.32	default apparently based on Kissel et al. (1998) **use uniform: 0.1 (min), 0.5 (max)**[34]	p. 63 ($F_{hm\text{-}remov}$) & p. 75 (mean = 0.78) 0.3 ("default SHEDS"); $Eff_{SAL\text{-}REM}$
f) Removal efficiency during hand washing	[remv_wash]	[-]	beta	shape1: 32 shape2: 22 (mean = 0.59)	same as SHEDS-Wood **use uniform: 0.3 (min), 0.45 (max)**[35]	p. 62 (F_{hw}); p. 74 0.15 ("default SHEDS")
g) Mean # hand washes/day per person	[washprob]	day^{-1}	lognormal	geo mean: 3.74 geo std dev: 2.63	same as SHEDS-Wood **use default**	p. 62; p. 74

[30] These distributions and parameter values were included with the SHEDS model as received.

[31] Both 5(c) and 5(d) are variables that limit dermal loading. These limits, which are usually given the same value, apply to the sum of the chemical across all phases (soil, dust and residue). They are included to prevent multiple contacts from adding to the dermal loading indefinitely, i.e., when the maximum loading is attained, no more contaminant can be transferred to skin. Dr. Glen's 12/15 recommendation: assume the ratio of dermal loading to surface concentration is one, meaning that skin loadings cannot exceed the surface concentration. However, since the surface cleanup standard is so low (1 ng/cm^2), we have assumed the skin can accumulate 10x the cleanup standard. Dr. Glen's note of 12/19 supports this logic: "…your suggestion of using 10 ng/cm^2 sounds reasonable." This value may need to be changed if the cleanup standard changes significantly.

[32] Assumed values for maximum dermal loading of hands and body are 10x the current target remediation goal for methamphetamine residues on surfaces (0.001 µg/cm^2). This assumption may need to be re-evaluated if it is apparent that the risk-based target cleanup goal is considerably higher than the current value

[33] This conservative assumption is based on the uneven texture of the skin, and takes into consideration the small mass of contaminant loading on the skin that is anticipated to occur under the post-cleanup exposure scenario.

[34] See Zartarian et al. (2000), using data generated by Camann et al. (1995) for saliva removal of chlorpyrifos on freshly spiked human hands. The mid-point of a 0.1 to 0.5 uniform distribution is 0.3, which is the default point value adopted for the SHEDS-Wood model. Zartarian et al. (2000) state, "It is estimated that 50% represents the maximum mouthing removal efficiency for fresh and dried pesticide residues" by human saliva and reference a personal communication from Robert Lewis (U.S.EPA, NERL). The SHEDS-Wood documentation also references a personal communication from R. Lewis.

[35] Based on Dr. Glen's note of January 16, 2007. Obtaining appropriate values for this parameter is problematic. The reference for SHEDS-Wood parameter values is Wester et al. (1993), in which two concentrations of arsenic-73 mixed in soil or water was applied to skin of rhesus monkeys. Whether these data are applicable to methamphetamine residues on the skin is uncertain. Also problematic is the "wash-in" phenomenon described by Moody and Maibach (2006), where dermal absorption of some contaminants is enhanced by washing with soap and water. The wash-in effect for DEET (an amide with a log K_{OW} nearly identical to that of methamphetamine) is very strong. If the wash-in effect applies to methamphetamine, the value for "remv_wash" and "remv_bath" may be considerably lower than the SHEDS defaults.

Table 3. Continued

Variability Groups and Variable Descriptions	Variable	Units	Default[36] Distribution	Default[36] Parameters	Comments	USEPA (2005;Table 10) or Hore et al. (2006; Table 3)
4. Dose-related						
a) Absorption fraction for lungs	[absf_lung]	[-]	point	1	not applicable **assume 0**[37]	
b) Dermal absorption rate/day for dust or soil	[absr_dm]	day^{-1}	uniform	min: 0.001 max: 0.3	not applicable **assume 0**	
c) Dermal absorption rate/day for surface residues	[absr_dr]	day^{-1}	point	0.03	**use uniform: 0.5 (min), 0.9 (max)** (preliminary UCSF data)	
d) GI tract absorption rate per day for dust or soil	[absr_gm]	day^{-1}	triangle	min: 0.01 mode: 0.1 max: 1.0	not applicable **assume 0**	
e) GI tract absorption rate/day for surface residue	[absr_gr]	day^{-1}	triangle	min: 0.01 mode: 0.1 max: 1.0	**assume 1**	
f) Bioavailability fraction for dust/soil	[bioavm]	[-]	point	1	not applicable[38] **assume 0**	
g) Bioavailability fraction of surface residues	[bioavr]	[-]	point	1	**assume 1**[39]	
h) Elimination rate from the blood	[elimr_blood]	day^{-1}	lognormal	geo mean: 0.6 geo st dev: 1.2	**use default**[40]	
i) Molecular weight mass ratio of the metabolite to the parent compound[41]	[metab_ratio]	[-]	point	1	**assume 1**	
5. Baths						
a) Maximum number of days between baths	[bathdays]	days	probability vector **1:** 0.75; **2:** 0.14; **3:** 0.07; **4:** 0.01; **5:** 0.01; **6:** 0.01; **7:** 0.01		same as SHEDS-Wood **use default**	p. 75, Table 11 see also EFH, Table 15-9

[36] These distributions and parameter values were included with the SHEDS model as received.

[37] In the post-remediation exposure scenario, airborne levels of methamphetamine will be extremely low because (1) meth-HCl is non-volatile, (2) while methamphetamine base is volatile, it will have evaporated from all contaminated surfaces by the time a residential structure is re-occupied, and (3) on account of the relatively low K_{OW} of methamphetamine base (2.07), adsorption of methamphetamine to soil and dust particles is not expected, and re-suspension of surface dust is unlikely to generate significant airborne levels of methamphetamine.

[38] Significant adsorption of soil or dust is not anticipated given the relatively low K_{OW} of methamphetamine (2.07)

[39] Assumption of 100% bioavailability based on (1) the high water solubility of meth-HCl, (2) the low molecular weight of methamphetamine, and (3) the small mass of dermal loading that is anticipated to occur under the post-cleanup exposure scenario

[40] The current version of SHEDS incorporates a simple pharmacokinetic module to estimate blood concentration. The values for the elimination rate and the parent compound:metabolite MW mass ration do not affect the estimate of absorbed dose (Luther Smith and Graham Glen, Alion Science and Technology, personal communication).

[41] The parameter is required for the SHEDS pharmacokinetic module to estimate blood concentration. The primary metabolite of methamphetamine (MW 149.2) is amphetamine (MW 135.2), so this ratio is 0.91. In humans, a significant traction of ingested methamphetamine is excreted unchanged in the urine. (See November 2, 2006 Draft SHEDS-Multimedia Technical Manual, page 39)

Pathway-Specific and Total Absorbed Dose Estimates Using SHEDS-Multimedia

Absorbed dose estimates based on SHEDS-Multimedia were initially calculated based on a "unit" surface residue concentration of 0.001 µg methamphetamine/cm^2 (equivalent to 0.1 µg/100 cm^2), which is the cleanup originally developed by the state of Washington and subsequently adopted by several states. The Washington standard was based on technical feasibility, that is, the lowest amount of methamphetamine that could be reliably detected in surface wipes using a standardized sampling protocol. It is *not* based on in-depth analysis of the toxicity of methamphetamine or quantitative evaluation of potential exposure to surface methamphetamine residues.

The model was run for a population of 100 children 1-2 years age. The exposure duration was assumed to be 90 days, but assuming longer or shorted durations would not alter the dose estimates because the residue concentration was assumed to be constant for the entire duration of exposure and doses were calculated on a mg/kg-day basis. However, assuming a 90-day exposure duration is advantageous because SHEDS-Multimedia generates graphical output of the day-to-day variation in absorbed dose estimates for an individual, and this visual representation facilitates appreciation for the variability of exposure even under "static" (constant source concentration) conditions.

Since SHEDS-Multimedia is a stochastic model, each run will generate slightly different results. However, in this application of the model, run-to-run variability is minimized because mean daily dose estimates are based on 100 children and the surface methamphetamine residue concentration is a fixed value for the entire 90-day exposure period. Therefore, the estimate of each child's absorbed dose is calculated as the average of 90 single-day dose estimates, leading to minimal variation between runs.

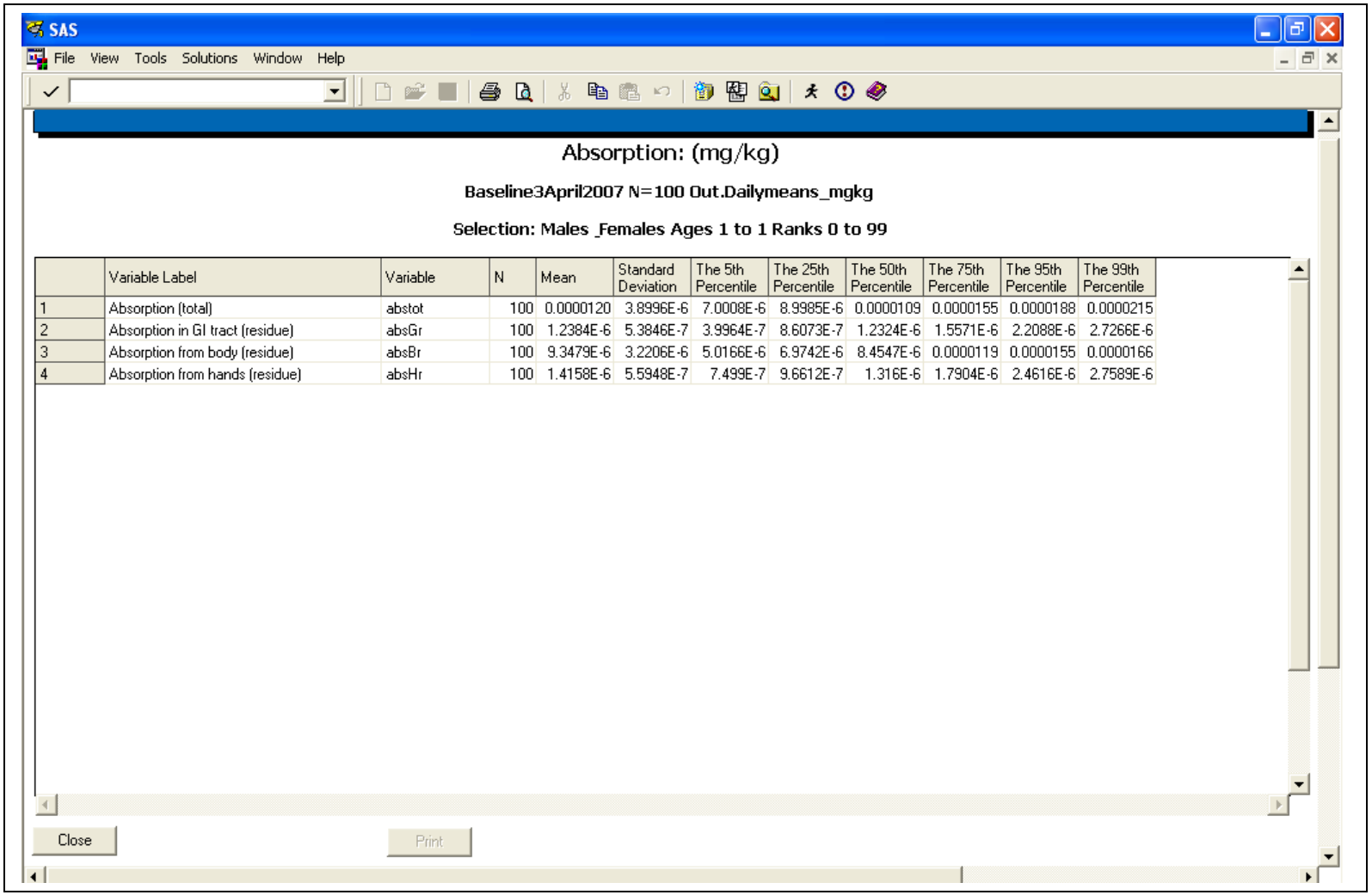
Total and pathway-specific estimates of absorbed dose are provided in Table 4, reproduced directly from the computer image of the model output. Average exposure via all three complete pathways (dermal absorption of methamphetamine residues on the body, dermal absorption of methamphetamine residues on the hands, and ingestion of methamphetamine following hand-to-mouth or body-to-mouth activity) was estimated to be 0.012 ± 0.004 µg/kg-day (mean ± SD). Percentile exposure estimates were 0.011, 0.016 and 0.021 mg/kg-day for the 50^{th}, 75^{th} and 95^{th} percentiles, respectively. The relative contributions of each pathway to total exposure are shown in Figure 3, and it is clear that dermal absorption of methamphetamine residues on the body is by far the most significant exposure pathway, accounting for approximately 78% of the total absorbed dose. Dermal absorption of methamphetamine residues on the hands, and inadvertent ingestion resulting from hand-to-mouth activity, account for the remaining 12 and 10% of the total, respectively.

An example of the day-to-day variation in the absorbed dose estimates for a single individual is shown in Figure 4, with the black line representing total absorbed dose, the blue line representing dermal absorption of residues on the body, green representing inadvertent ingestion of residues on the hands and body, and red representing dermal absorption of residues on the hands. Note that all three pathways generally move in

parallel with one another, so that days when exposure via transdermal absorption of residues on the body spike upward are days when exposure via the other two pathways spike upward as well. In this example, daily absorbed dose estimates for a single individual range from approximately 0.002 to 0.024 μg/kg-day, or about 12-fold. Figure 5 provides a second example of the day-to-day variation in absorbed dose for an individual. In this case the variation on daily absorbed dose is only about 7-fold (0.005 to 0.035 μg/kg-day), while the significance of inadvertent ingestion and dermal absorption of methamphetamine residues on the hands is not as pronounced as it is in the first example. Comparing boys *vs.* girls, no dramatic differences were apparent: the estimate of absorbed dose was 0.0117 ± 0.0039 μg/kg-day for boys and 0.0125 ± 0.0039 μg/kg-day (mean ± SD) for girls.[42]

Note that exposure via all other potential pathways (e.g., inhalation airborne methamphetamine, dermal contact with soil and dust contaminated with methamphetamine and subsequent transdermal absorption and inadvertent ingestion) is zero because the concentration of methamphetamine in the source media (e.g., air, soil and dust) was assumed to be zero. Justification for these assumptions was provided in previous sections of this report.

[42] In this particular model run, absorbed dose estimates were made for 60 boys and 40 girls. This ratio will vary from run to run; the sex of each child is randomly selected by the model.



	Variable Label	Variable	N	Mean	Standard Deviation	The 5th Percentile	The 25th Percentile	The 50th Percentile	The 75th Percentile	The 95th Percentile	The 99th Percentile
1	Absorption (total)	abstot	100	0.0000120	3.8996E-6	7.0008E-6	8.9985E-6	0.0000109	0.0000155	0.0000188	0.0000215
2	Absorption in GI tract (residue)	absGr	100	1.2384E-6	5.3846E-7	3.9964E-7	8.6073E-7	1.2324E-6	1.5571E-6	2.2088E-6	2.7266E-6
3	Absorption from body (residue)	absBr	100	9.3479E-6	3.2206E-6	5.0166E-6	6.9742E-6	8.4547E-6	0.0000119	0.0000155	0.0000166
4	Absorption from hands (residue)	absHr	100	1.4158E-6	5.5948E-7	7.499E-7	9.6612E-7	1.316E-6	1.7904E-6	2.4616E-6	2.7589E-6

Table 4. SHEDS output: total absorbed dose and pathway-specific doses of methamphetamine for a population of 100 children 1-2 years of age. Surface residue concentration assumed to be 0.001 µg/cm^2.

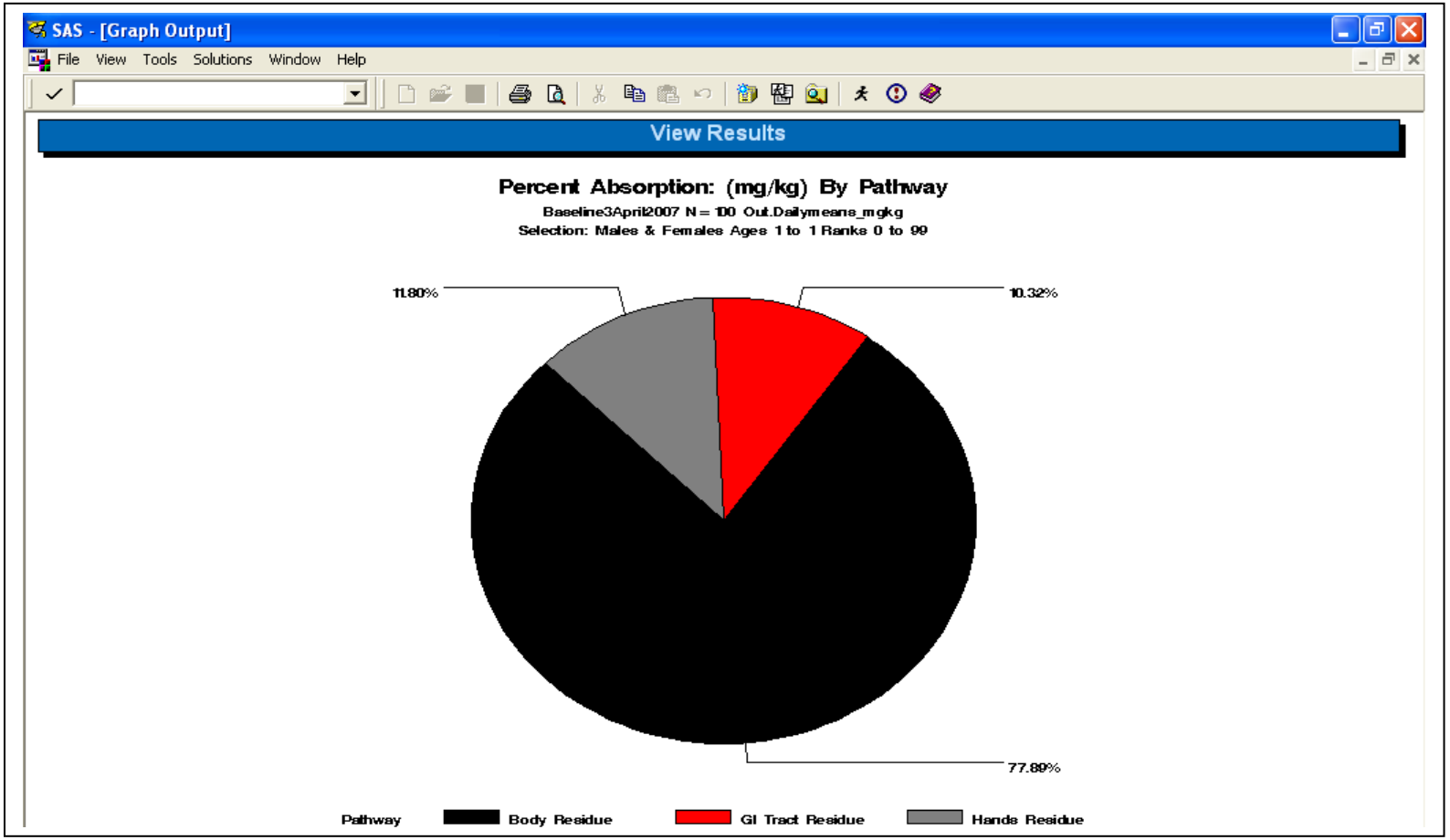


Figure 3. SHEDS output: pathway-specific doses of methamphetamine as a percentage of total dose for a population of 100 children 1-2 years of age.

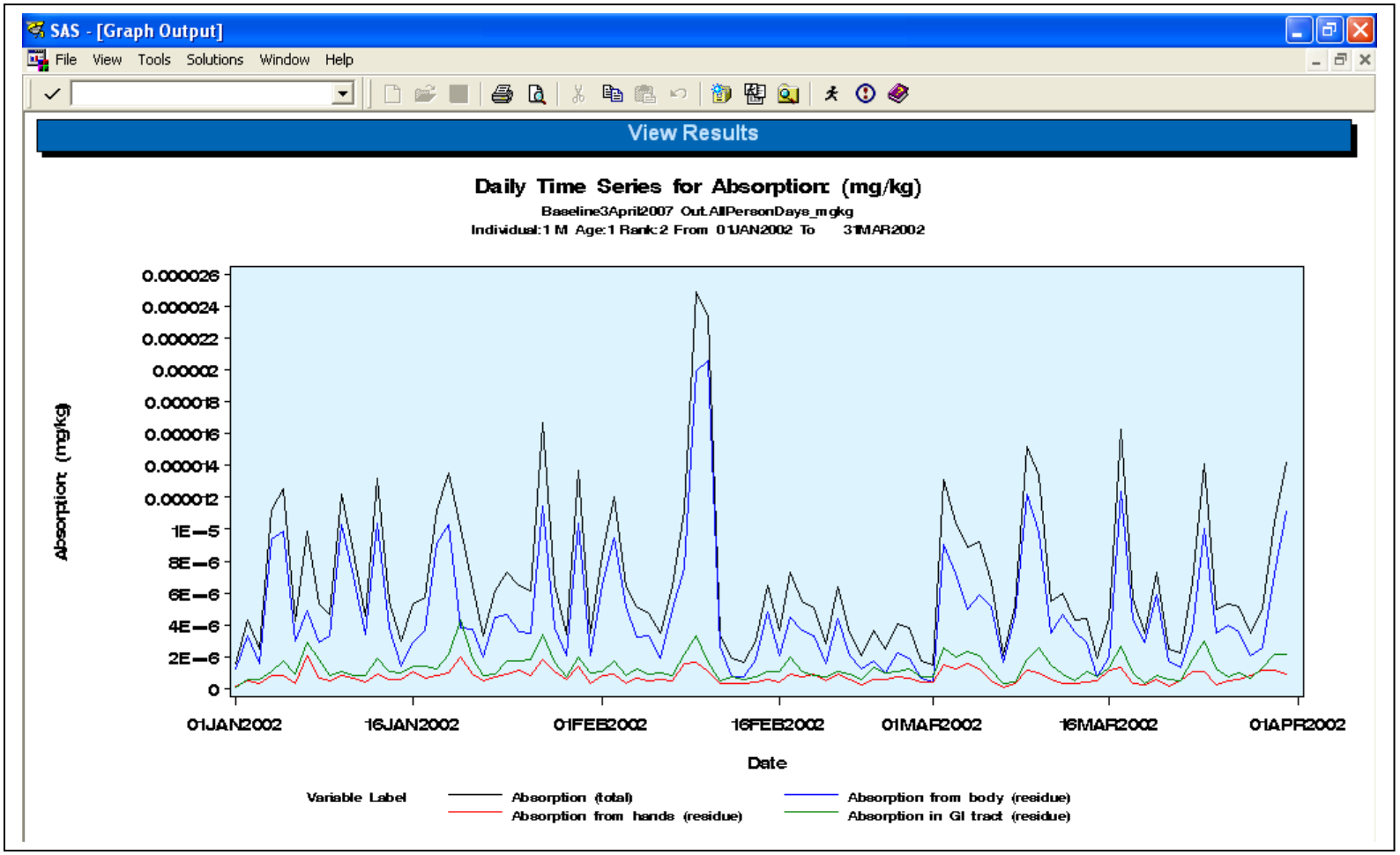


Figure 4. SHEDS output: example #1 of pathway-specific daily time series of absorbed methamphetamine dose for an individual (a one-year-old boy) over a 90-day exposure period.

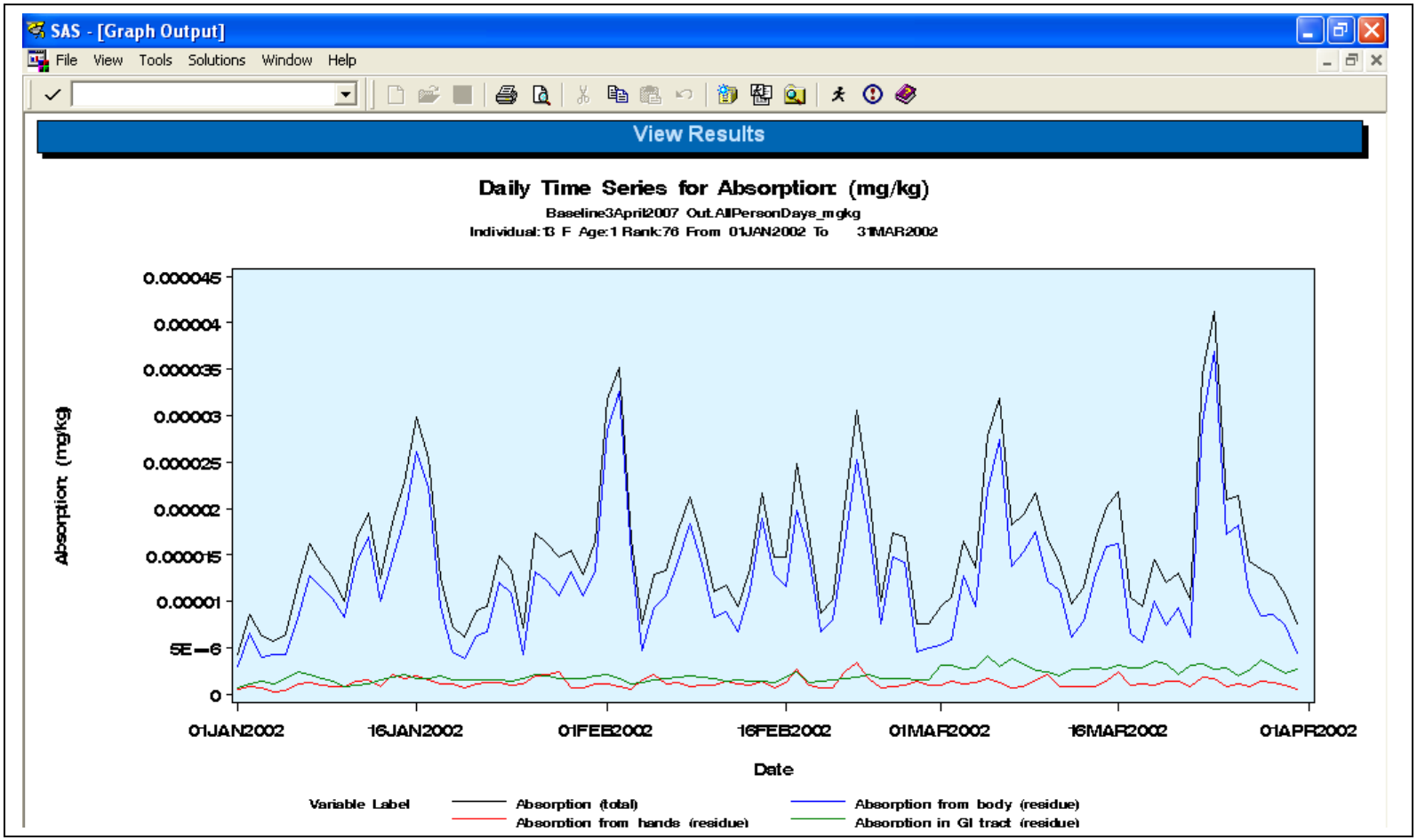


Figure 5. SHEDS output: example #2 of pathway-specific daily time series of absorbed methamphetamine dose for an individual (a one-year-old boy) over a 90-day exposure period.

Sensitivity Analysis: Evaluation of Changes in the Values of Individual Parameters on Estimates of Absorbed Dose

The effect of individual exposure parameters on the absorbed dose estimates calculated by SHEDS-Multimedia was analyzed by changing the value of different parameters one at a time. The parameters evaluated were

- Residue-skin transfer efficiency
- Maximum dermal loading for hands and body
- Removal efficiency during hand washing
- Object:surface concentration ratio
- Maximum diary event length

The results of this analysis are shown in Table 5. In this table, the 95th percentile estimate of absorbed dose differs from the value shown in Table 4 because a higher value was used for the dermal absorption of methamphetamine. Two- to three-fold increases or decreases in maximum dermal loading for hands and body, removal efficiency during hand washing, object:surface concentration ratio[43] and maximum diary event length had no appreciable effect on the 95th percentile absorbed dose estimate. However, a three-fold increase in the residue-skin transfer efficiency produced a corresponding 3-fold increase in the absorbed dose estimate. This latter result indicates that the transdermal absorption of methamphetamine is sufficiently high that any increase in methamphetamine loading on the skin leads to a proportional increase in absorbed dose.

[43] See footnote 26 for a definition of this parameter.

Table 5. SHEDS Sensitivity Analysis: Effect of Changing Values for Individual Exposure Parameters on the 95th Percentile Estimates of Absorbed Dose

Variable[44]	Default	Changed to:	95th Percentile Estimate[45]
No changes			0.000023
Residue-skin transfer efficiency [2m: transfer_dermal]	beta distribution, shape1: 0.6 shape 2: 8.4 (mean: 0.07)	point value: 0.20 (~3-fold increase)	0.000075 (~3-fold increase)
Maximum dermal loading for hands and body [3a & 3b: dermaxb & dermaxh]	point values 0.01 & 0.01	point values 0.003 & 0.003 (~3-fold decrease)	0.000023 (no change)
		point values 0.03 & 0.03 (~3-fold increase)	0.000024 (no change)
Removal efficiency during hand washing [3f: remv_wash]	uniform distribution, range: 0.3 – 0.45	point value: 0.15[46]	0.000024 (minor increase)
Object:surface concentration ratio 2i: object_ratio]	uniform distribution, 0.0 – 0.2	point value: 0.5	0.000024 (minor increase)
Maximum diary event length	60 minutes	20 minutes	0.000025 (minor increase)

[44] Parameter designations from SHEDS-Multimedia Technical Manual
[45] All exposure estimates are based on a uniform surface methamphetamine concentration of 0.001 µg/cm^2.
[46] This value was used in a 2006 report on the SHEDS model by Hore et al., Table 3

Effectiveness of Washing: Another Source of Uncertainty

As a means of removing methamphetamine residue from the skin, the effectiveness of washing with soap and water is uncertain, and experimental investigation of this and other decontamination procedures is warranted. Concern that routine washing is not particularly effective and may actually accelerate the transdermal uptake of methamphetamine was raised in a recent report by Moody and Maibach (2006), who cited studies demonstrated that dermal uptake of the insect repellant DEET (N,N-diethyl-*m*-toluamide). In *in vitro* tests of three commercial formulations of DEET, transdermal absorption across human skin was profoundly increased (up to 32-fold) by soap wash of the skin.

Experimental results obtained with DEET may be directly applicable to predicting the effectiveness of soap and water as a means of removing methamphetamine residues from the skin. Among other factors, the dermal absorption of chemicals is correlated with their molecular weight and octanol:water partition coefficient (also called the K_{ow}). Methamphetamine and DEET both have molecular weights below 200 (149 and 191, respectively), and their octanol:water partition coefficients are essentially identical: the log K_{ow} values for methamphetamine and DEET are 2.07 and 2.18, respectively. Therefore, by extrapolation, it would be reasonable to predict that factors influencing the dermal uptake methamphetamine are similar to those that affect the dermal uptake of DEET, and that "wash in" is a likely mechanism for enhancing the uptake of methamphetamine. Nevertheless, experimental data supporting this hypothesis are lacking.

In the previous section, the effect of washing efficiency was evaluated by reducing the assumed efficiency of hand washing from a uniform distribution with a range of 0.3 to 0.45 (i.e., a removal efficiency of 30-45%) to a point value of 0.15. This two- to three-fold reduction in washing removal efficiency produced a very slight increase in the estimate of total absorbed dose. In large part, this lack of a significant effect probably reflects the fact that dermal absorption of methamphetamine residues on the hands only account for 12% of the total absorbed dose, so an increase in the post-washing residue concentration would be expected to have a small effect. Since bathing involves immersion of a significant portion of the body for a period of several minutes, the DEET *in vitro* data were regarded as being less relevant, and a corresponding evaluation of the effect of reducing removal efficiency during bathing (remv_bath; Table 3) was not conducted.

Knowing whether absorption of methamphetamine across the skin is enhanced by washing with soap and water is important for predicting the daily exposure of an individual residing in a former clandestine methamphetamine lab, the acute exposure of a first responder conducting a removal action, and the dose received by a child removed from an operational lab immediately after it is discovered. Clearly, additional research in the effectiveness of different decontamination procedures is warranted.

Comparison of Exposure Estimates based on SHEDS-Multimedia and the Standard Operating Procedures (SOPs) for Residential Exposure, and Rationale for Use of SHEDS-Multimedia to Derive a Risk-Based Cleanup Level for Methamphetamine

SHEDS-Multimedia (and its predecessor SHEDS-Wood) have been under development by the U.S. EPA since 1998. The model "…is a state-of-science computer model for improving estimates of aggregate (single-chemical, multi-route/pathway) and cumulative (multi-chemical, multi-route/pathway) human exposure and dose." It is designed to simulate exposures and doses for a variety of user-specified population cohorts and relies on data from time-location-activity diaries compiled in U. S. EPA's Consolidated Human Activity Database (CHAD). SHEDS-Multimedia has undergone extensive peer review, having been evaluated in depth by the FIFRA Scientific Advisory Panel (SAP) in August 2002, December 2003, and August 2007. The most recent version of SHEDS-Multimedia became available in March, 2007.

Because SHEDS-Multimedia permits the user to specify chemical- and scenario-specific parameter values and distributions as inputs, it provides less conservative and more realistic estimates of potential exposure. Critical exposure parameters such as surface-to-skin transfer efficiency and dermal absorption efficiency are based on experimental data, not conservatively estimated defaults. Furthermore, model estimates can be improved as scenario- and chemical-specific research data become available. The model also accounts for exposure via pathways (e.g., object-to-mouth) that are not considered using the Standard Operating Procedures methodology.

The *Standard Operating Procedures (SOPs) for Residential Exposure Assessment* was originally prepared in 1997. Minor modifications to the document were made in 2001. While still available on the U.S. EPA's web site, the document still includes "DRAFT - DO NOT CITE OR QUOTE" as a footer on each page. The SOPs provide algorithms for calculating *screening level* exposure estimates for via dermal contact with pesticide residues on smooth surfaces (e.g., linoleum), dermal contact with residues on carpet, and inadvertent ingestion resulting from hand contact with a contaminated surface followed by hand-to-mouth movements. As noted previously, this model is intended for use when chemical- and/or site-specific information are limited or unavailable, and the U.S. EPA's continues to accept exposure analyses that are based on this protocol (Jeffrey Dawson, U. S. EPA Office of Pesticide Programs; personal communication).

A critical parameter in the equations for estimating dermal contact with pesticide residues on hard surfaces and carpet is the dermal transfer coefficient, which has a default value of 6,000 cm^2/hour for a child 1 to 6 years of age. The degree of conservatism incorporated into the default value for this parameter was examined experimentally in a recent report by Cohen Hubal et al. (2006). In this study, dermal transfer coefficients were derived empirically by measuring surface pesticide concentrations in a daycare center dermal loading of pesticide residues on full-body cotton garments.[47] Based on data from nine children and two visits to the daycare center, dermal transfer coefficients ranged from 7.5

[47] Dermal transfer coefficients (in units of cm^2/hour) were calculated as the mass of pesticide on the whole body garment divided by the monitoring duration (ng/hr) divided by the surface pesticide concentration (ng/cm^2).

to 6,200 cm^2/hour, a range of over 800-fold. These values were obtained after the calculated transfer coefficients were increased 40% (somewhat arbitrarily) to account for transfer to the hands and feet, which were not covered by the body suits during the study. Therefore, the default transfer coefficient prescribed using the SOP methodology is equivalent to the upper end of the range of transfer coefficients estimated by these researchers.

The authors of this study concluded that "…the results of this work suggest that the default assumption [i.e., the default transfer coefficient for children prescribed in the SOP methodology] used by the U. S. EPA OPP [Office of Pesticide Programs} is reasonable." As noted earlier in this report, an alternative interpretation would be that dermal transfer coefficients for children span a very wide range, and that dermal exposures would be more appropriately estimated using a stochastic model such as SHEDS-Multimedia, which accounts for the range of children's behaviors and activities. The algorithms and default parameter values prescribed by the SOPs appear to be appropriate for obtaining very conservative, screening level estimates of exposure and do not appear to be well supported by the available research data.

Identification of a Risk-Based Cleanup Level for Methamphetamine

The rationale and justification for the development of a reference dose (RfD) for methamphetamine are described in a separate report.[48] RfDs are concentrations or daily doses at or below which adverse health effects are not likely to occur. The RfD for methamphetamine was calculated to be 0.3 µg/kg-day, and the target remediation standard must be set at a level that ensures that the daily exposure to surface methamphetamine residues produces an absorbed dose that does not exceed the RfD. Using SHEDS-Multimedia iteratively to estimate the absorbed dose of methamphetamine at different residue concentrations, it was found that a residue concentration of 0.015 µg/cm^2 would result in an absorbed dose that is just below the RfD for methamphetamine.

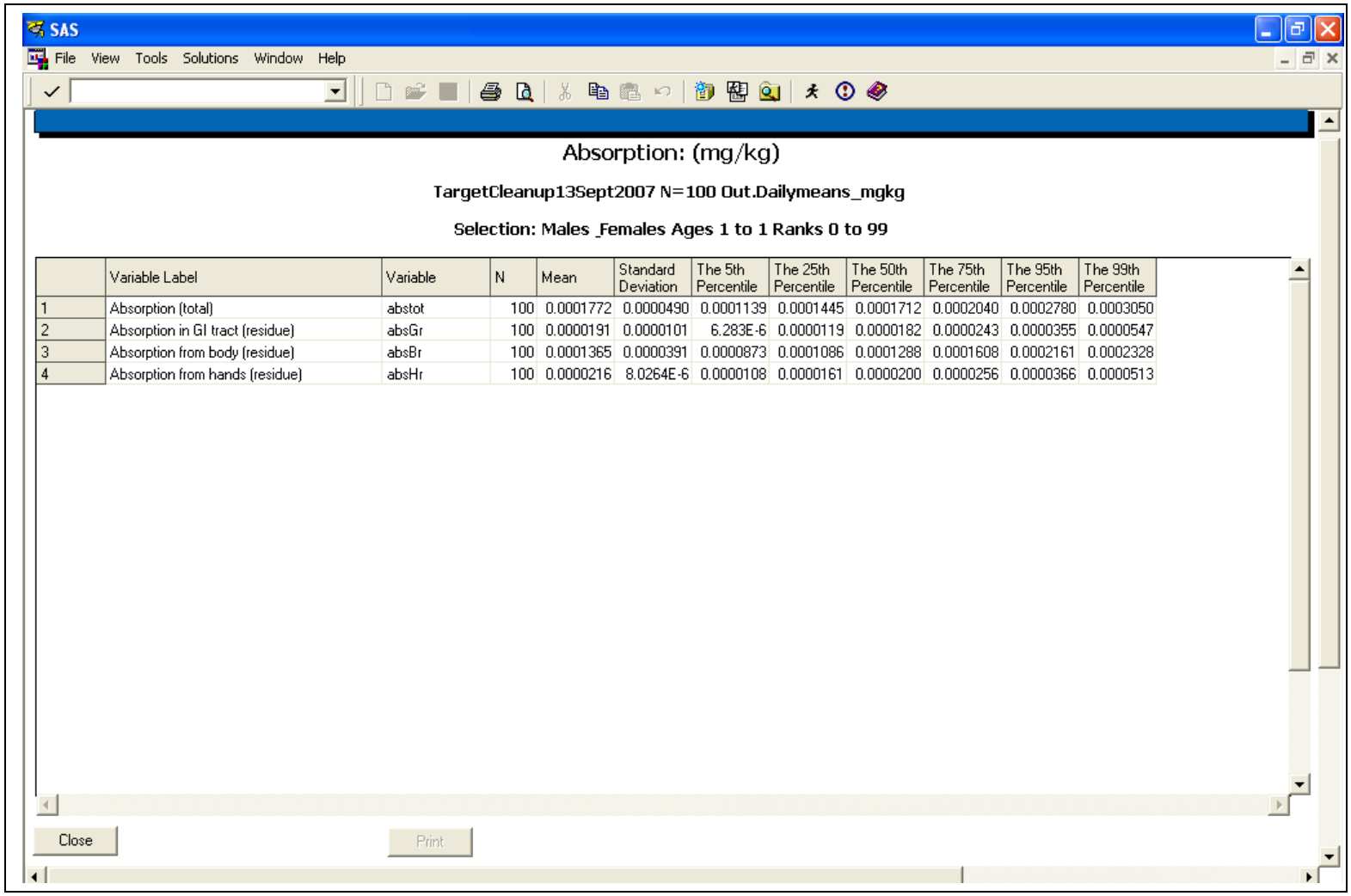
Total absorbed dose estimates calculated by SHEDS-Multimedia assuming a surface residue concentration of 0.015 µg methamphetamine/cm^2 (equivalent to 1.5 µg/100 cm^2) are shown in Table 6. The 95th and 99th percentile estimates of absorbed dose are 0.278 and 0.305 µg/kg-day, respectively, which are just below or equivalent to the RfD value of 0.3 µg/kg-day.[49] Therefore, based on the analysis presented in this report, the risk-based target remediation standard for methamphetamine on interior residential surfaces is 0.015 µg methamphetamine/cm^2, or 1.5 µg/100 cm^2.

Based the exposure parameter values adopted for the analysis presented in this report, both the 95th and the 99th percentile estimates of absorbed dose support the adoption of 1.5 µg/100 cm^2 as a target remediation standard.

An alternative analysis based on different parameter values would generate different results that might require a decision regarding the appropriateness of the 95th or the 99th percentile estimate as a basis for determination of a cleanup standard. For example, using different parameter values, the 95th percentile estimate of exposure may generate an estimate of total absorbed dose that is below the methamphetamine RfD while the 99th percentile dose estimate exceeds the RfD. If this were the case, we would recommend use of the 95th percentile estimate because of the greater uncertainty associated with estimates at extreme right tail of the dose distribution.

[48] *Development of a Reference Dose (RfD) for Methamphetamine.* External Peer Review Draft, October 2007. California EPA, Office of Environmental Health Hazard Assessment, Integrated Risk Assessment Branch.

[49] Based on a surface residue concentration of 0.015 µg/cm^2, the relative contributions of the three complete exposure pathways (expressed as a percentage of the total absorbed dose) are essentially identical to those presented in Figure 3, which was based on a residue concentration of 0.001 µg/cm^2.



	Variable Label	Variable	N	Mean	Standard Deviation	The 5th Percentile	The 25th Percentile	The 50th Percentile	The 75th Percentile	The 95th Percentile	The 99th Percentile
1	Absorption (total)	abstot	100	0.0001772	0.0000490	0.0001139	0.0001445	0.0001712	0.0002040	0.0002780	0.0003050
2	Absorption in GI tract (residue)	absGr	100	0.0000191	0.0000101	6.283E-6	0.0000119	0.0000182	0.0000243	0.0000355	0.0000547
3	Absorption from body (residue)	absBr	100	0.0001365	0.0000391	0.0000873	0.0001086	0.0001288	0.0001608	0.0002161	0.0002328
4	Absorption from hands (residue)	absHr	100	0.0000216	8.0264E-6	0.0000108	0.0000161	0.0000200	0.0000256	0.0000366	0.0000513

Table 6. SHEDS output: total absorbed dose and pathway-specific doses of methamphetamine for a population of 100 children 1-2 years of age. The surface residue concentration was assumed to be 0.015 µg/cm^2, and maximum dermal loading on the hands and body was assumed to be 0.15 µg/cm^2.

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