DEVELOPMENT OF WOOD SURFACE TARGET QUANTITY FOR ARSENIC BASED ON EXPOSURE TO DECKS OR PLAYGROUND EQUIPMENT CONSTRUCTED OF CCA-TREATED WOOD

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Revised April, 2001

TABLE OF CONTENTS **Page**

1.	OVERVIEW	1
2.	EXISTING STUDIES	1
3.	TOXICITY ASSESSMENT	1
4.	EXPOSURE ASSESSMENT	4
5.	DEVELOPMENT OF TARGET CONCENTRATION	7
6.	UNCERTAINTIES	8
7.	SUMMARY AND CONCLUSIONS	9
8.	REFERENCES	11
9.	APPENDICES	14

APPENDIX A	TABLES
	TABLE 1
	TABLE 2
	TABLE 3
APPENDIX B	Exposure Equations
APPENDIX C	Derivation of Exposure Assumptions

1. OVERVIEW

The purpose of this report is to determine a target quantity of arsenic in association with residues on the surface of wood that would pose no significant risk of adverse health effects to humans who may frequently come in contact with wood which has been treated with chromated copper arsenate, or CCA. This focused report specifically addresses potential hand-to-mouth activity and dermal contact with treated wood used for residential decks and for playground equipment.

2. EXISTING STUDIES

Several studies have been conducted which, in part, include estimates of arsenic quantities on the surface of CCA-treated wood products (CPSC, 1990a; CPSC, 1990b). In general, these studies were conducted using wipe sampling techniques and the reported results typically are below 1 microgram per square centimeter (ug/cm^2), which is equivalent to <100 ug/100 cm^2 by the wipe methods employed. Table 1 in Appendix A presents a summary of selected studies and a brief presentation of their results. In the current report, rather than evaluate the potential risk from contact with experimental wood samples, we have developed a Wood Surface Target Quantity (WSTQ), expressed in units of ug/100 cm^2, which will provide a benchmark against which future sampling results can be compared. Such comparisons are influenced by the uncertainties associated with the exposure assumptions used in development of the WSTQ, since that route of exposure has not received a great deal of attention in the literature (see Section 6).

3. TOXICITY ASSESSMENT

Arsenic is a naturally occurring element. Pure arsenic is a gray metal-like material (e.g., solid) that is usually found in the environment combined with other elements. Arsenic combined with elements such as oxygen and sulfur is termed "inorganic" arsenic. Arsenic combined with carbon and hydrogen is termed "organic" arsenic. Inorganic arsenic occurs naturally in many kinds of rock, especially in ores that also contain copper or lead. When these ores are heated to release or extract the copper or lead, much of the arsenic enters the air as a fine dust and is collected at the smelter and purified. One major use of this arsenic is as a preservative for wood, in combination with copper and chromium, to make it resistant to rotting and decay (ATSDR, 2000).

Inorganic arsenic, whether naturally occurring or introduced anthropogenically, usually exists as either arsenate (As^{5+}) or arsenite (As^{3+}; ATSDR, 2000). Concentrations of arsenic detected in environmental media are generally reported as "total" arsenic (i.e., without regard to speciation; U.S. EPA, 1983; U.S. EPA, 1986a; U.S. EPA, 1986b). The literature generally shows that arsenites are somewhat more toxic than arsenates (ATSDR, 2000). In addition, once absorbed, both arsenate or arsenite can be converted to the other valence state in varying degrees, which confounds the toxicological distinction of the two species (ATSDR, 2000).

Studies of organic arsenicals in animals have demonstrated a fairly low order of toxicity, which has been further demonstrated in humans. The organic forms of arsenic found in food, particularly fish, present little or no hazard to human health (Adams et al., 1994). In addition, if seafood wastes are burned, a practice which occurs in coastal areas, the organic arsenic is largely converted to inorganic arsenic. A recent unpublished review indicates that, although organic and inorganic forms of arsenic may be toxicologically distinct, it is not straightforward to measure the different arsenic forms as separate entities at a site. The estimated risk for the separate forms would be relevant only for contemporary exposures, not for future conditions. It is suggested that hypothetical conversion of organoarsenicals to inorganic forms over weeks or months could change organic and inorganic arsenic concentrations, altering the attendant risks (Tonner-Navarro et al., 1998). It is difficult to extrapolate to projected transformation rates in the environment, absent empirical data. In the case of environmental arsenic whose origin is CCA-treated wood, the form is inorganic; thus, the organic/inorganic toxicity comparison is a moot point.

In this document, the linear slope factor has been used for assessing the carcinogenic effects of arsenic. This is a very conservative assumption. The U.S. EPA Expert Panel on Arsenic Carcinogenicity (U.S. EPA, 1997c) concluded that there is a sufficient body of evidence to support the use of a nonlinear or threshold model in describing the relationship between arsenic and skin cancer and that there is no evidence that arsenic represents a direct acting carcinogen (i.e., one which interacts directly with DNA). According to the Panel, the possibility that arsenic is an essential dietary component also supports the hypothesis that low dose exposures do not pose a carcinogenic hazard to humans. In addition, some reports from animal studies have suggested that there is a threshold for arsenic methylation, which would imply that the dose-response curve for arsenic-induced cancer is sublinear at low doses (e.g., produces lower rates of cancer than would be predicted by a linear dose response). In concluding that the dose-response curve is probably nonlinear, the panel reasoned that there is some low dose at which arsenic is probably safe, although that level is unidentified at present. For that reason, the calculations presented in this document address both potential carcinogenic effects of arsenic, based upon the U.S. EPA Cancer Slope Factor (CSF), and potential noncarcinogenic effects, based upon the U.S. EPA Reference Dose (RfD).

In order to assess potential dermal exposures, the oral toxicity guidance values [e.g., Reference Dose (RfD) and Cancer Slope Factor (CSF)] typically are used in modified form, since no values have been established specifically for the dermal route of exposure. However, the oral guidance values typically are based on studies which employ an administered dose. Thus, in calculations of dermal exposures based on an internal dose, a correction factor historically has been applied to the oral values, in order to account for the percent gastrointestinal absorption of a specific compound. In cases where the gastrointestinal absorption of a compound is 100% (e.g., benzene), the oral guidance value typically is used in uncorrected fashion for dermal exposure circumstances (i.e., the applied dose is equal to the internal dose). In cases where the reported gastrointestinal absorption of a chemical is less than 100%, the oral guidance value typically is reduced for use in dermal exposure calculations (U.S. EPA, 1992). The oral RfDs are multiplied by these correction factors, also known as dermal equivalency factors (DE), to yield dermal RfDs. Oral CSFs are divided by the DE to yield dermal CSFs. For arsenic, the gastrointestinal absorption is reported to be 95% (ATSDR, 2000), thus only a small correction from the oral RfD or CSF is required in order to estimate a dermal RfD or CSF.

Selected toxicological guidance values for arsenic are presented on Table 2 in Appendix A.

4. EXPOSURE ASSESSMENT

Human health considerations related to potential exposure to CCA-treated wood that may be used to build decks or playground equipment can be evaluated using typical risk assessment techniques, with some minor adjustments. Most human health risk assessments evaluate exposure to chemicals in environmental media via the oral, dermal and/or inhalation routes of exposure. In this instance, the exposure medium itself (CCA-treated wood) is not directly respirable and arsenic is not volatile, nor is it expected to become airborne in wood particles. Therefore, only hand-to-mouth activity resulting in intake of dislodgeable arsenic, coupled with potential direct dermal contact and absorption, is considered for evaluating potential exposure to chemicals in CCA-treated wood. Appendix B presents the equation that was used to calculate a protective concentration of arsenic on treated wood surfaces.

The populations that were assumed to be exposed were young children residents or visitors (five years of exposure from age 2-6) and aggregate resident/visitors (30 years of exposure from age 2-31). Children are typically assumed to be at greater risk for non-cancer health effects as a result of their greater reported environmental medium intake rate combined with their lower body weight. Therefore, systemic effects (i.e., non-carcinogenic risks) were evaluated for a young child resident/visitor. For assessing potential carcinogenic effects, cumulative exposure may occur both as a child and as an adult. In this latter situation, it is appropriate to use time-weighted values reflecting the continuum of both childhood and adult exposures. This person is termed an aggregate resident/visitor. This exposure of the aggregate resident/visitor is very conservative, as it is assumed that this aggregate resident/visitor could have exposure to the treated deck material or playground equipment for a period of 30 years, beginning in childhood.

For this evaluation, some of the most significant assumptions, and their derivations or sources, are discussed below and are presented in detail in Appendix C. Section 6 of this report addresses several uncertainties that may be associated with this evaluation, some of which relate to these specific exposure assumptions.

Hand Surface Area (assumed) – The Consumer Products Safety Commission (CPSC, 1975; CPSC, 1989) reported a hand surface area of 66 cm^2 for one side of one hand of a child between ages two to six. More recent studies, as reported in the U.S. EPA Exposure Factors Handbook (EFH; U.S. EPA, 1997a), suggest a 50^{th} percentile hand surface area of 98.6 cm^2 for one-half of one hand of a child between two and six years of age (U.S. EPA, 1997a; Tables 6-6, 6-7 and 6-8). The 95^{th} percentile value is 115.4 cm^2. A larger handsize in this instance (see Appendix B) is the more conservative assumption. Therefore, the 95^{th} percentile value of 115.4 cm^2 conservatively was assumed for the child resident/visitor. The aggregate resident/visitor hand surface area was developed assuming five years of the child hand size (age 2 to 6) in conjunction with 25 years of an adult hand size (age 7 to 31) as reported in U.S. EPA (1997a). Appendix C contains details on the derivation of the child resident/visitor and aggregate resident/visitor hand surface areas.

Handloads per Day – While there is limited quantitative or qualitative information regarding hand-to-mouth behavior, beyond anecdotal information, a value of 0.374 “handloads” per day for a child between two and six years old has been proposed by the CPSC (1989). This is based on a relationship between estimated daily intake of soil by children and soil adherence rates for the childhood hand (see Appendix C). Upon further review of the original study materials for the CPSC value, it is apparent that only male children were included in the 0.374 estimate. However, the cited report includes information for female children as well and, because the female handloads per day estimates are greater than the males, the current evaluation was based on a recalculated average handloads per day value for male and female children of 0.528, a more conservative value than the 1989 CPSC assumption. Less information is available for hand-to-mouth activity for older children and adults. The handloads per day value for the aggregate resident/visitor (0.132) was developed by assuming five years of the child values combined with 25 years at one-tenth of those values [e.g., (0.528 X 5 + 0.0528 X 25)/30 = 0.132 handloads per day; see Appendix C], to reflect a presumed greater degree of care in older children and adults, with regard to contact activities and a decreased level of hand-to-mouth activities. Stated differently, this 0.132 handloads per day estimate suggests that 0.132 (or 13.2%) of the hand is mouthed and that all of the material in that 13.2% is transferred in an ingested amount on a daily basis. This percentage is consistent with the 10 to 20% transfer efficiency cited by U.S. EPA (1999) for adult hand-to-mouth activity.

Exposure Frequency - Given the practical likelihood of childhood play on a deck or playground equipment, it was assumed that a child resident/visitor may have such exposure for five years (ages 2 through 6) for 3 days per week for 12 months/year (150 days/year for 5 years). It was assumed that an older child and adult (ages 7-31), could have exposure for 1 day per week for every other week of the year (e.g., 25 days/year). Thus, the aggregate resident/visitor is assumed to have an Exposure Frequency of 46 days/year [(5 x 150 + 25 x 25)/30 = 46]. These Exposure Frequencies are supported by the U.S. EPA Exposure Factors Handbook (U.S. EPA, 1997c) which indicates that children spend 5 hrs/day outdoors on weekdays and 7 hrs/day on weekends and adults spend approximately 1.5 hrs/day outdoors. If one considers that a 12 hr day is approximately the daylight hours, then 5 hrs/day (5 weekdays x 5 hours = 25 hours) and 7 hrs/day (2 weekend days x 7 hrs = 14 hours) for the child resident/visitor is equivalent to approximately 3 days/week [(25 + 14) hours/12 hours/day = 3 days]. For the aggregate resident/visitor, 1.5 hrs/day for 365 days/year is equivalent to approximately 46 days/year [(1.5 hrs/day x 365 days)/12 hours/day = 46 days].

Skin Surface Area Available for Exposure and Dermal Absorption - To evaluate the potential dermal component of the presumed exposure, we conservatively have assumed that one-half of both hands (approximate area of palms) and one-half of both feet (approximate area of soles) are available for contact with the CCA-treated decking material. Appendix C contains detailed information regarding the derivation of the skin surface area (SA) assumptions.

Transfer Efficiency - Consistent with U.S. EPA (1999), it was assumed that not all of the dislodgeable arsenic on the surface of the wood in the area of contact would be transferred to the hand (i.e., less than 100% transfer efficiency from wood to hand). The U.S. EPA (1999) default Transfer Efficiency (TE) of 5% for modeling exposure to chemical residues based on dermal contact with smooth surfaces was used in all calculations to implement these assumptions.

5. DEVELOPMENT OF TARGET CONCENTRATION

The Wood Surface Target Quantity (WSTQ) was determined in order to achieve circumstances where the routinely accepted Target Hazard Quotient (THQ) of 1.0 for noncarcinogenic effects (i.e., child resident/visitor in this case) would not be exceeded. The WSTQ for possible carcinogenic effects (i.e., aggregate resident/visitor in this case) was developed in order to maintain the carcinogenic risk below a potential Target Risk (TR) of 1.0E-06. For ease of presentation, the TR term on Exposure Equation 1 in Appendix B refers to both noncarcinogenic risk and potential carcinogenic risk.

6. UNCERTAINTIES

Assumptions, calculations, and conclusions which are presented in this report include uncertainties which may arise from a variety of sources. However, the intent was to take a reasonable and conservative approach. The factors which may lead to either an overestimation or an underestimation of the potential adverse human health effects and associated environmental risks posed by exposures to CCA-treated wood, depending on the relationship of actual conditions to the assumptions employed in the calculations, include the following:

- In the dermal contact assessment, the hand size and foot size assumptions include 1/2 of the total area of the hand or foot. This overestimates the actual area available for contact with the wood material, which more appropriately would be defined by the approximate area of the palmside of the hand and sole of the foot only for walking on or handling wood.

- One possible approach would be to assume that all of the dislodgeable arsenic on the surface of the wood in the area of contact would be transferred to the hand (i.e., 100% transfer efficiency from wood to hand). However, realistically, this is not likely to happen. In fact, reported chemical-specific hand press transfer efficiencies range from 0.04% to 4%, and U.S. EPA employs a default Transfer Efficiency (TE) of 5% for modeling exposure to chemical residues based on dermal contact, in the absence of chemical-specific information (U.S. EPA, 1999). This TE of 5% was used in the calculations presented in this report.

- The aggregate resident/visitor assumption for "handloads per day" was based on five years of the reported child rate and 25 years of one-tenth of the child rate. No information was found regarding handloads per day for older children or adults, and this value may approach zero, especially in adults. The value of one-tenth the young child rate is based on best professional judgment, and is supported in part by the 10-20% adult hand-to-mouth transfer efficiency range reported by U.S. EPA (1999).

- For bioavailability, it was conservatively assumed that the arsenic which contacted the hands from the wood surface was 100% bioavailable.

It is worth noting that, for those uncertainties identified above, the assumptions were selected to err on the side of conservatism where possible.

7. SUMMARY AND CONCLUSIONS

The WSTQ based on the young child resident/visitor scenario is approximately 420 ug/100 cm^2 based on potential noncarcinogenic endpoints. The WSTQ based on the aggregate resident/visitor is approximately 40 ug/100 cm^2 based on potential carcinogenic endpoints (Table 3, Appendix A).

The calculated systemic and carcinogenic effects WSTQ values are in the range of the identified dislodgeable arsenic levels from many of the available studies, indicating that health effects from direct exposure to deck or playground treated wood surfaces are unlikely. When wood samples from major U.S. playground equipment manufacturers were tested for dislodgeable arsenic, most (5/7) of the samples had levels below the detection limit (reported as 6.3 ug/100 cm^2; CPSC, 1990a; CPSC, 1990b; CPSC, 1990c; CPSC, 1990d; Table 1, Appendix A), a few samples had average levels less than 35 ug/100 cm^2, and the highest concentration reported in the CPSC studies was 68 ug/100 cm^2. Therefore, 6 of the 7 samples had values less than the two WSTQ values identified in this report. All playground samples were less than either of the WSTQ values. The highest concentration was found in a comparison sample of unfinished pressure treated lumber (not playground equipment wood; CPSC, 1990b; CPSC, 1990d). In another wipe study (SCS, 1998), a range of 4-96 ug arsenic/100 cm^2 on various coated and uncoated samples of CCA-treated wood was detected. The mean concentration was 19 ug arsenic/100 cm^2 and the 95% UCL of the mean concentration was 31.5 ug arsenic/100 cm^2. Other studies have conducted analysis of residues on treated wood products and have detected from 0.05 - 632 ug/100 cm^2

dislodgeable arsenic from wipe samples of aged playscapes, municipal playscape surfaces and support poles (Stilwell, 1998; Galarneau et al., 1990; Carlson-Lynch and Smith, 1999; see Table 1, Appendix A).

This evaluation is consistent with the recent summary material from the U.S. EPA Office of Pesticide Programs which specifically stated, "the EPA reviewed the use of CCA in pressure treated wood extensively during the 1980's. This study concluded that pressure treated wood did not pose unreasonable risks to children or adults, either from direct contact with the wood (e.g., as used for playgrounds and decks) or from direct contact with surrounding soil where some releases may have occurred" (U.S. EPA, 1997b), though the wipe methods and variability of techniques are not presented in the study. More vigorous wipe procedures will result in indicated surface residues that may be greater than residues that would be associated with typical hand-to-wood contact. U.S. EPA also reviewed a separate study that concluded that CCA does not pose a short-term or long-term toxic hazard to children playing on playground equipment (Lee, 1990; CPSC, 1990a; CPSC, 1990b; CPSC, 2000; U.S. EPA, 1997b).

Values presented in this report are not meant to be precise comparisons, but rather serve to illustrate that protective values typically are in the range of those reported to be present on the surface of CCA-treated wood. Thus, typical exposures, even on a regular, prolonged basis are unlikely to be of health significance to children or adults.

8. REFERENCES

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9. APPENDICES

APPENDIX A **Tables**

APPENDIX B **Exposure Equations**

APPENDIX C **Derivation of Exposure Assumptions**

APPENDIX A

Tables

Table 1
Summary of Selected Studies of Dislodgeable Arsenic Concentrations on the Surface of CCA-Treated Wood Products

Study	Conclusions
CPSC, 1990a	Estimated risks for 5/7 samples (CPSC, 1990b; CPSC, 1990d) which were below the detection limit (BDL) of dislodgeable arsenic was <1.0E-06. Estimated risks for 2/7 samples (CPSC, 1990b; CPSC, 1990d) that had detectable levels of arsenic was 3.0E-06 to 4.0E-06
CPSC, 1990b; CPSC, 1990c; CPSC, 1990d	<6.25 ug/100 cm^2 - 68.84 ug/100 cm^2 of dislodgeable arsenic (7 samples of playground wood and one unfinished wood sample). Dislodgeable arsenic was not detected in five samples. The highest concentration was on an unfinished CCA-treated board (construction grade wood)
SCS, 1998	4 - 96 ug arsenic/100 cm^2 of CCA-treated wood from wipe sampling (the highest result was from CCA-treated hemlock fir; the highest non-hemlock fir value was 33 ug/100 cm^2); the mean concentration was 19 ug/100 cm^2 and the 95% UCL of the mean concentration was 31.5 ug/100 cm^2
Stilwell, 1998	2 - 45 ug/100 cm^2 (average of 8.8) for 45 wipe samples from municipal playscape surfaces; 7 - 122 ug/100 cm^2 (average of 35) for lumber samples; and 5 - 632 ug/100 cm^2 (average of 105) for vertical playscape support poles - all results are from nylon wipe samplings
Galarneau et al., 1990	0.05 - 32.2 ug/100 cm^2 dislodgeable arsenic from wipe samples of aged playscapes

Table 2

Selected Toxicological Guidance Values for Arsenic

Constituent of Potential Concern	Oral RfD [a] (mg/kg/day)	Dermal Equivalency Factor [b] (unitless)	Dermal RfD [c] (mg/kg/day)	Oral CSF [a] $(mg/kg/day)^{-1}$	Dermal CSF [c] $(mg/kg/day)^{-1}$
Arsenic	3.0E-04	0.95	2.85E-04	1.5E+00	1.6E+00

a The information presented was obtained from IRIS (U.S. EPA, 2000).
b The value presented is the reported gastrointestinal absorption percentage (ATSDR, 2000).
c The dermal RfD value was calculated by multiplying the oral RfD by the Dermal Equivalency Factor and the dermal CSF value was calculated by dividing the oral CSF by the Dermal Equivalency Factor.

Table 3

Wood Surface Target Quantity of Arsenic from Decks or Playground Equipment Constructed of CCA-Treated Wood

Scenario[a]	Wood Surface Target Quantity of Arsenic
Child resident / visitor	423 ug / 100 cm^2
Aggregate resident / visitor	40 ug / 100 cm^2

[a] For exposure parameters, see Exposure Equation 1 (Appendix B).

APPENDIX B

Exposure Equations

Exposure Equation 1

Wood Surface Target Quantity Based on Hand-to-Mouth Exposure to Arsenic in CCA-Treated Wood

$$\mathbf{WSTQ} = \frac{\mathbf{TR \times BW \times AT}}{\mathbf{EF \times ED \times (A + B)}}$$

where, for noncarcinogenic effects;

$$A = \frac{1}{RfD_o} \times CF_1 \times HS_a \times HLD \times TE$$

$$B = \frac{1}{RfD_d} \times CF_1 \times SA \times DA \times TE$$

and , for carcinogenic effects;

$$A = CSF_o \times CF_1 \times HS_a \times HLD \times TE$$

$$B = CSF_d \times CF_1 \times SA \times DA \times TE$$

Exposure Parameter	**Description**	**Scenario-Specific Values for the**	
		Young Child Resident/Visitor Scenario	**Aggregate Resident/Visitor Scenario**
WSTQ [a]	Wood Surface Target Quantity of arsenic expressed in ug / 100 cm^2.	**423**	**40**
TR	Target Risk.	1.0	1.0E-06
BW	Body Weight expressed in kg (see Appendix C).	18	52
AT **(noncarcinogens)**	Averaging Time (period over which exposure is averaged) for noncarcinogens expressed in days.	1,825	**NA**
AT (carcinogens)	Averaging Time (period over which exposure is averaged) for carcinogens expressed in days.	**NA**	25,550
EF	Exposure Frequency expressed in days / yr.	150	46
ED	Exposure Duration expressed in years.	5	30
RfD_o	Oral Reference Dose expressed in mg / kg • day.	3.00E-04	**NA**
RfD_d	Dermal Reference Dose expressed in mg / kg • day.	2.85E-04	**NA**
CF_1	Conversion Factor expressed in mg / ug.	1.0E-03	1.0E-03
HS_a	Assumed Hand Surface Area available for contact expressed in cm^2 / hand (1 / 2 of one hand; see Appendix C).	115.4	242
HLD	Handloads / day, number of handloads that may be ingested (see Appendix C).	0.528	0.132
TE	Transfer Efficiency from wood surface to hand surface (default value; U.S. EPA, 1999).	0.05	0.05
SA	Assumed Skin Surface Area available for daily contact expressed in cm^2 / day (1 / 2 of both hands + 1 / 2 of both feet; see Appendix C).	533	1,123
DA (inorganics)	Dermal Absorption factor for inorganics (dimensionless; U.S. EPA, 1995 default).	0.001	0.001
CSF_o	Oral Carcinogenic Slope Factor expressed in $(mg / kg \cdot day)^{-1}$.	**NA**	1.50E+00
CSF_d	Dermal Carcinogenic Slope Factor expressed in $(mg / kg \cdot day)^{-1}$.	**NA**	1.579E+00

APPENDIX C

Derivation of Exposure Assumptions

Derivation of Young Child Resident/Visitor Hand Surface Area

95th percentile

	total body surface area				hand
	male	female	overall avg	hand % of total	size
age	m^2	m^2	m^2		m^2
2	0.682	0.653	0.6675	5.30%	0.0353775
3	0.764	0.737	0.7505	6.07%	0.0455554
4	0.845	0.82	0.8325	5.70%	0.0474525
5	0.918	0.952	0.935	5.70%	0.053295
6	1.06	1.03	1.045	4.71%	0.0492195

average	0.04618	m^2
2 hands	461.7997	cm^2
1 hand	230.89985	cm^2
1/2 of 1 hand	115.44993	cm^2

From Exposure Factors Handbook Tables 6-6, 6-7, 6-8

Derivation of the Aggregate Resident/Visitor Hand Surface Area

Adult Hand Surface Area

	male m^2	female m^2	2 hands avg m^2	2 hands avg cm^2	1 hand avg cm^2	1/2 of 1 hand cm^2
95th percentile	0.117	0.0966	0.1068	1068	534	267.0

Source: Exposure Factors Handbook Tables 6-2, 6-3

Aggregate Resident/Visitor

hand size = (5 * child hand size + 25 * adult hand size) / 30

Aggregate Resident/Visitor	= (5 * 115.45 + 25 * 267.0) / 30	=	241.742	cm^2

Derivation of Handloads per Day

handloads per day - child resident/visitor

	boys median	girls median	average
2-yr olds	0.42 [a]	0.76	0.59
5-yr olds	0.31	0.56	0.435

Young child Resident or Visitor 0.528 = 3 yrs at 2-yr old value and 2 yrs at 5-yr old value / 5 - boys and girls average

a As an example, this value is based on the reported median soil ingestion rate (30 mg / d) from Calabrese et al (1989), divided by the amount of soil reported on one hand (71 mg / hand) as cited in CPSC, 1989. The median value was identified by Calabrese as the appropriate value according to CPSC (1989).

handloads per day - aggregate resident/visitor

Assumed 5 years of child exposure and 25 years of 1 / 10 of child exposure as best professional judgment for adult hand-to-mouth activity.

Aggregate Visitor 0.132 = ((5 * .528)+(25 * .0528)) / 30

Derivation of Young Child Resident/Visitor Feet Surface Area

95th percentile

age	total body surface area male m^2	female m^2	overall avg m^2	feet % of total	feet size m^2
2	0.682	0.653	0.6675	7.07%	0.04719225
3	0.764	0.737	0.7505	7.21%	0.05411105
4	0.845	0.82	0.8325	7.29%	0.06068925
5	0.918	0.952	0.935	7.29%	0.0681615
6	1.06	1.03	1.045	6.90%	0.072105

2 feet 0.06045181 m^2

2 feet 604.5181 cm^2

1/2 both feet	302.26	cm^2

total body surface area

hand

Derivation of the Aggregate Resident/Visitor Feet Surface Area

Adult Feet Surface Area (both feet)

	male m^2	female m^2	avg m^2	avg cm^2	1/2 both feet cm^2
95th percentile	0.149	0.134	0.1415	1,415	707.5

Source: Exposure Factors Handbook Tables 6-2, 6-3

Aggregate Resident/Visitor Feet Surface Area (1/2 both feet)

feet surface area = (5 * child feet size + 25 * adult feet size) / 30

Aggregate Resident/Visitor	= (5 * 302.26 + 25 * 707.5) / 30	=	639.960	cm^2

Derivation of Body Weight

Body weight

Young Child Resident/Visitor

Mean for boys and girls

Age	kg
2 year old	13.3
3 year old	15.3
4 year old	17.4
5 year old	19.7
6 year old	22.6
Average	17.66

Aggregate Resident/Visitor

Age	kg	Average 2-31
7 year old	24.9	51.78
8 year old	28.1	
9 year old	31.5	
10 year old	36.3	
11 year old	41.1	
12 year old	45.3	
13 year old	50.4	
14 year old	56	
15 year old	58.1	
16 year old	62.6	
17 year old	63.2	
18 year old	65.1	
19 year old	66	
20 year old	67.2	
21 year old	67.2	
22 year old	67.2	
23 year old	67.2	
24 year old	67.2	
25 year old	71.5	
26 year old	71.5	
27 year old	71.5	
28 year old	71.5	
29 year old	71.5	
30 year old	71.5	
31 year old	71.5	

Source: Exposure Factors Handbook, Volume I. Tables 7-2 and 7-3.