

7. Dermal Exposure Factors

7.1 Introduction

Dermal exposure can occur during a variety of activities in different environmental media and microenvironments (U.S. EPA, 1992a, 1992b, 2004). These include:

- water (e.g., bathing, washing, swimming);
- soil (e.g., outdoor recreation, gardening, construction);
- sediment (e.g., wading, fishing);
- liquids (e.g., use of commercial products);
- vapors/fumes (e.g., use of commercial products); and
- solids or residues (e.g., soil/dust or chemical residues on carpets, floors, counter tops, outdoor surfaces, or clothing).

Chapter 7 of the *Exposure Factors Handbook* provides information on factors that affect dermal exposure, including body surface area, dermal adherence of solids to the skin, film thickness of liquids on the skin, transfer of chemical residues from surfaces to the skin, and other factors. However, recommended values are only provided for skin surface area and adherence of solids to the skin. Factors that influence dermal uptake (i.e., absorption) and internal dose, including chemical-specific factors, are not provided in the Handbook.

7.2 Recommended Exposure Factors

Body Surface Area: The recommended mean and 95th percentile total body surface area values are summarized in Table 7-1. These data are based on body weight and height data, used with empirical formulae, to estimate skin surface area for various age groups. For children under 21 years of age, the recommendations for total body surface area are based on the U.S. EPA analysis of NHANES 1999-2006 body weight and height data. These data are presented for the standard age groupings recommended by U.S. EPA (2005) for male and female children combined. For adults 21 years and over, the recommendations for total body surface area are based on the U.S. EPA analysis of NHANES 2005-2006 body weight and height data for males and females. The recommendations for the percentage of the total body surface area represented by individual body parts are provided in Table 7-2. The percentages are based on data

from U.S. EPA (1985) for children under 2 years of age and adults, and Boniol et al. (2007) for children over 2 years of age. Table 7-2 also provides age-specific body part surface areas (m²) that were obtained by multiplying the mean body part percentages by the total body surface areas presented in Table 7-1. Overall confidence in the body surface area factors is medium for total surface area and low for surface area of individual body parts.

Adherence of Solids to Skin: The adherence factor (AF) describes the amount of material that adheres to the skin per unit of surface area. Although most research in this area has focused on soils, a variety of other solid residues can accumulate on the skin, including household dust, sediments, and commercial powders. The recommended dermal AFs represent the amount of material on the skin at the time of measurement. U.S. EPA (1992b) recommends interpreting AFs as representative of contact events. Assuming that the amount of solids measured on the skin represents accumulation between washings and that people wash at least once per day, these adherence values can be interpreted as daily contact rates (U.S. EPA, 1992b). The rate of solids accumulation on skin over time has not been well studied, but probably occurs fairly quickly. Therefore, pro-rating the adherence values for exposure time periods of less than one day is not recommended.



Soil adherence values are based on field studies that considered factors such as activity, sex, age, field conditions, and clothing worn (Holmes et al., 1999; Kissel et al., 1996;

Shoaf et al., 2005). Recommended mean AF values are summarized in Table 7-3 according to common activities. Overall confidence in the soil AFs is low.

Table 7 1. Recommended Values for Total Body Surface Area, Children (Males and Females Combined) and Adults by Sex

Age Group	Mean	95 th Percentile ^a
m ²		
Males and Females Combined^b		
Birth to <1 month	0.29	0.34
1 to <3 months	0.33	0.38
3 to <6 months	0.38	0.44
6 to <12 months	0.45	0.51
1 to <2 years	0.53	0.61
2 to <3 years	0.61	0.70
3 to <6 years	0.76	0.95
6 to <11 years	1.08	1.48
11 to <16 years	1.59	2.06
16 to <21 years	1.84	2.33
Adult Males^c		
21 to 30 years	2.05	2.52
30 to <40 years	2.10	2.50
40 to <50 years	2.15	2.56
50 to <60 years	2.11	2.55
60 to <70 years	2.08	2.46
70 to <80 years	2.05	2.45
80 years and over	1.92	2.22
Adult Females^c		
21 to 30 years	1.81	2.25
30 to <40 years	1.85	2.31
40 to <50 years	1.88	2.36
50 to <60 years	1.89	2.38
60 to <70 years	1.88	2.34
70 to <80 years	1.77	2.13
80 years and over	1.69	1.98

^a For multiple percentiles, see Tables 7-9 (for males and females-combined data), 7-10, and 7-11 in the *Exposure Factors Handbook*.
^b Source: U.S. EPA Analysis of NHANES 1999-2006 data.
^c Source: U.S. EPA Analysis of NHANES 2005-2006 data.

Table 7-2. Recommended Values for Surface Area of Body Parts

Age Group	Head	Trunk	Arms	Hands	Legs	Feet	Source
Mean Percent of Total Surface Area							
Birth to <1 month	18.2	35.7	13.7	5.3	20.6	6.5	a
1 to <3 months	18.2	35.7	13.7	5.3	20.6	6.5	
3 to <6 months	18.2	35.7	13.7	5.3	20.6	6.5	
6 to <12 months	18.2	35.7	13.7	5.3	20.6	6.5	
1 to <2 years	16.5	35.5	13.0	5.7	23.1	6.3	
2 to <3 years	8.4	41.0	14.4	4.7	25.3	6.3	b
3 to <6 years	8.0	41.2	14.0	4.9	25.7	6.4	
6 to <11 years	6.1	39.6	14.0	4.7	28.8	6.8	
11 to <16 years	4.6	39.6	14.3	4.5	30.4	6.6	
16 to <21 years	4.1	41.2	14.6	4.5	29.5	6.1	
Adult Males—21+ years	6.6	40.1	15.2	5.2	33.1	6.7	c
Adult Females—21+ years	6.2	35.4	12.8	4.8	32.3	6.6	
Mean Surface Area by Body Part^d m²							
Birth to <1 month	0.053	0.104	0.040	0.015	0.060	0.019	e
1 to <3 months	0.060	0.118	0.045	0.017	0.068	0.021	
3 to <6 months	0.069	0.136	0.052	0.020	0.078	0.025	
6 to <12 months	0.082	0.161	0.062	0.024	0.093	0.029	
1 to <2 years	0.087	0.188	0.069	0.030	0.122	0.033	
2 to <3 years	0.051	0.250	0.088	0.028	0.154	0.038	f
3 to <6 years	0.061	0.313	0.106	0.037	0.195	0.049	
6 to <11 years	0.066	0.428	0.151	0.051	0.311	0.073	
11 to <16 years	0.073	0.630	0.227	0.072	0.483	0.105	
16 to <21 years	0.075	0.759	0.269	0.083	0.543	0.112	
Adult Males—21+ years	0.136	0.827	0.314	0.107	0.682	0.137	c
Adult Females—21+ years	0.114	0.654	0.237	0.089	0.598	0.122	
95th Percentile Surface Area by Body Part^g m²							
Birth to <1 month	0.062	0.121	0.047	0.018	0.070	0.022	e
1 to <3 months	0.069	0.136	0.052	0.020	0.078	0.025	
3 to <6 months	0.080	0.157	0.060	0.023	0.091	0.029	
6 to <12 months	0.093	0.182	0.070	0.027	0.105	0.033	
1 to <2 years	0.101	0.217	0.079	0.035	0.141	0.038	
2 to <3 years	0.059	0.287	0.101	0.033	0.177	0.044	f
3 to <6 years	0.076	0.391	0.133	0.046	0.244	0.061	
6 to <11 years	0.090	0.586	0.207	0.070	0.426	0.100	
11 to <16 years	0.095	0.816	0.295	0.093	0.626	0.136	
16 to <21 years	0.096	0.960	0.340	0.105	0.687	0.142	
Adult Males—21+ years	0.154	1.10	0.399	0.131	0.847	0.161	c
Adult Females—21+ years	0.121	0.850	0.266	0.106	0.764	0.146	

^a Source: U.S. EPA, 1985.

^b Source: Boniol et al., 2007.

^c U.S. EPA analysis of NHANES 2005-2006 data and U.S. EPA, 1985.

^d Children’s values calculated as mean percentages of body part times mean total body surface area.

^e U.S. EPA analysis of NHANES 1999-2006 data and U.S. EPA, 1985. Percentages based on small number of observations for this age group.

^f Boniol et al., 2007 and U.S. EPA Analysis of NHANES 1999-2006 data; some body parts and age groups presented by Boniol et al. (2007) were combined to be consistent with the body part categories and age groups used here.

^g Children’s values calculated as mean percentage of body part times 95th percentile total body surface area.

Note: Surface area values reported in m² can be converted to cm² by multiplying by 10,000 cm²/m².

Table 7-3. Recommended Values for Mean Solids Adherence to Skin

	Face	Arms	Hands	Legs	Feet
	mg/cm ²				
Children					
Residential (indoors) ^a	-	0.0041	0.011	0.0035	0.010
Daycare (indoors & outdoors) ^b	-	0.024	0.099	0.020	0.071
Outdoor sports ^c	0.012	0.011	0.11	0.031	-
Indoor sports ^d	-	0.0019	0.0063	0.0020	0.0022
Activities with soil ^e	0.054	0.046	0.17	0.051	0.20
Playing in mud ^f	-	11	47	23	15
Playing in sediment ^g	0.040	0.17	0.49	0.70	21
Adults					
Outdoor sports ^h	0.0314	0.0872	0.1336	0.1223	-
Activities with soil ⁱ	0.0240	0.0379	0.1595	0.0189	0.1393
Construction Activities ^j	0.0982	0.1859	0.2763	0.0660	-

^a Based on weighted average of geometric mean soil loadings for 2 groups of children (ages 3 to 13 years; N = 10) playing indoors. Source: Holmes et al., 1999.

^b Based on weighted average of geometric mean soil loadings for 4 groups of daycare children (ages 1 to 6.5 years; N = 21) playing both indoors and outdoors. Source: Holmes et al., 1999.

^c Based on geometric mean soil loadings of 8 children (ages 13 to 15 years) playing soccer. Source: Kissel et al., 1996.

^d Based on geometric mean soil loadings of 6 children (ages ≥ 8 years) and 1 adult engaging in Tae Kwon Do. Source: Kissel et al., 1996.

^e Based on weighted average of geometric mean soil loadings for gardeners and archeologists (ages 16 to 35 years). Source: Holmes et al., 1999.

^f Based on weighted average of geometric mean soil loadings of 2 groups of children (age 9 to 14 years; N = 12) playing in mud. Source: Kissel et al., 1996.

^g Based on geometric mean soil loadings of 9 children (ages 7 to 12 years) playing in tidal flats. Source: Shoaf et al., 2005.

^h Based on weighted average of geometric mean soil loadings of 3 groups of adults (ages 23 to 33 years) playing rugby and 2 groups of adults (ages 24 to 34 years) playing soccer. Source: Holmes et al., 1999; Kissel et al., 1996.

ⁱ Based on weighted average of geometric mean soil loadings for 69 gardeners, farmers, groundskeepers, landscapers, and archeologists (ages 16 to 64 years) for faces, arms, and hands; 65 gardeners, farmers, groundskeepers, and archeologists (ages 16 to 64 years) for legs; and 36 gardeners, groundskeepers, and archeologists (ages 16 to 62 years) for feet. Source: Holmes et al., 1999; Kissel et al., 1996.

^j Based on weighted average of geometric mean soil loadings for 27 construction workers, utility workers, and equipment operators (ages 21 to 54 years) for faces, arms and hands; and based on geometric mean soil loadings for 8 construction workers (ages 21 to 30 years) for legs. Source: Holmes et al., 1999.

- No data.

For more information about the key studies used to derive the dermal exposure factors, refer to **Chapter 7 of the *Exposure Factors Handbook*** at <http://www.epa.gov/ncea/efh/pdfs/efh-chapter07.pdf>. Detailed information on surface area studies is included in Section 7.3, and studies regarding adherence of solids to the skin are described in Section 7.4. Data on the film thickness of liquids on human skin is provided in Section 7.5, and information on residue transfer studies is provided in Section 7.6 of the Handbook. Information on other factors that may affect dermal exposure (e.g., frequency and duration of hand contact and thickness of the skin) is provided in Section 7.7.

For guidance on how to use skin surface area and dermal AFs, as well as other factors, readers are referred to *Dermal Exposure Assessment: Principles and Applications* (U.S. EPA, 1992b) and *Risk Assessment Guidelines for Superfund (RAGs) Part E* (U.S. EPA, 2004). Additional information on consumer products use and activity factors that may affect dermal exposure is presented in Chapters 16 and 17 of the *Exposure Factors Handbook*.



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