October 2015

ATTACHMENT H

Part 201 Generic Exposure Assumption Values Update

TECHNICAL SUPPORT DOCUMENT

SUBJECT: SKIN SURFACE AREA (SA)

MDEQ Introduction

MDEQ contracted SRC, Inc. to evaluate and update the exposure assumptions and fate and transport values, consistent with the Collaborative Stakeholder Advisory (CSA) recommendations. This work is a component of the DEQ's comprehensive cleanup criteria update and is incorporated into the calculations of health-based cleanup values. The CSA recommendations pertinent to exposure assumptions and fate and transport values are presented in the Decision Framework for Determination of Exposure Values (CSA, 2014). To satisfy the "best available information" requirement of the Framework, SRC followed the Framework's process for evaluating data against the Data Quality Objectives (DQOs) and selecting values for their recommendations. Refer to the CSA Report (2014) and Cleanup Criteria and Screening Levels Development and Application Resource Materials Section 4.3.

Background

This Technical Support Document (TSD) describes the process used to update generic exposure assumption values for skin surface area (SA) for use in the derivation of Michigan Department of Environmental Quality (MDEQ) Part 201 Soil Direct Contact Criteria (DCC). The TSD follows the Decision Framework for Updating the Michigan Part 201 Generic Cleanup Criteria Exposure Assumptions (TAG, 2014). As outlined in the Decision Framework, the update process involves searching for Michigan-specific data pertinent to each exposure assumption, revised U.S. Environmental Protection Agency (EPA) exposure assumptions, and other sources of relevant data (e.g., state and federal government agencies, published literature), and evaluating both the existing and any new information against the Data Quality Objectives (DQOs) provided in the Decision Framework.

To identify new information pertinent to each exposure assumption, the following search process was as follows. First, Michigan government agencies and select research universities were contacted to determine if relevant data could be provided. Second, exposure parameters recommended by U.S. EPA's most recent (2011) Exposure Factors Handbook and U.S. EPA's (2014) Office of Solid Waste and Emergency Response (OSWER) were considered. Third,

searches of the published scientific literature for data or analyses specific to Michigan or to the U.S. as a whole were conducted. U.S. EPA (2011) performed comprehensive searches of scientific literature and other data sources, and indicated that the document included published literature through July, 2011. For the purpose of this TSD, searches of the published literature were restricted to papers published in 2009 or later. An earlier date than 2011 was selected to ensure that no papers published near the time of completion of the 2011 document were missed. Fourth, websites for U.S. governmental organizations were searched for readily accessible data relevant to the exposure assumptions. Fifth, selected state (including Illinois, Indiana, Minnesota, Ohio, Wisconsin, California, Oregon, Washington, Texas, and Massachusetts) and international (Health Canada and Environment Canada, Ontario Ministry of the Environment, European Commission Joint Research Centre [ECJRC], and the European Centre for Ecotoxicology and Toxicology of Chemicals [ECETOC]) environmental agency websites were searched to identify default exposure assumptions used by these agencies.

The TSD describes the results of each of the searches and the evaluation of new, relevant information against the DQOs. The DQOs in the framework (TAG, 2014) address the following:

- Relevant and applicable to Michigan;
- Clear and comprehensive;
- Sound and credible;
- Transparent and objective; and
- Certainty.

The 2005 exposure assumptions and new relevant information were evaluated against the DQOs and given a rating of high, medium, or low; an explanation of the ratings is provided as Appendix A of this document. Based on the ratings the data or information that best meets the DQOs, are recommended as the basis for updated values.

The algorithms used by MDEQ to derive Part 201 DCC employ a combination of central tendency and upper percentile estimates for exposure parameters. Specifically, in accordance with U.S. EPA guidance (1992), central tendency values are used for life span, body weight, and surface area, while high-end values are used for exposure duration, exposure frequency, soil ingestion rate, and soil adherence factor. Thus, the recommendations for SA presented in this TSD are based on central tendency values.

Introduction

SA is used in the assessment of exposure to soil contaminants through dermal contact with soil. SA in contact with soil is a function of age, size, and clothing cover.
This TSD consists of one section. Table 1 below provides a comparison of the MDEQ (2005) and 2015 updated values for SA.

Table 1. Summary of Existing and Updated MDEQ Values for Skin Surface Area (cm^2/day)

Parameter	MDEQ (2005) Value	2015 Updated Value
$SA_{ages <2}$ = Skin surface area: ages < 2	NV	2,000
$SA_{ages 2-<6}$= Skin surface area: ages 2 to <6	NV	2,600
$SA_{ages birth-<6}$ = Skin surface area: ages birth to <6	2,670	2,400
$SA_{ages 6-<16}$= Skin surface area: ages 6 to <16	NV	3,700
$SA_{ages 16-<EDr}$= Skin surface area: ages 16 to <EDr[a]	NV	5,700
$SA_{ages 6-<EDr}$= Skin surface area: ages 6 to <EDr[a]	5,800 (up to 30 yrs)	4,900 (up to 32 yrs)
SAn= Skin surface area: adult, nonresidential	3,300	3,500
SAnrdev = skin surface area, nonresidential, developmental toxicant	NV	3,100

NV = no value.
[a]EDr is exposure duration for the residential scenario. MDEQ (2005) used 30 years for EDr (and thus $BW_{ages 6-30}$ and $BW_{ages 16-30}$), while the 2015 updated value for EDr is 32 years.

Section 1. Skin Surface Area (SA)

1.1 Introduction

For the residential scenario, MDEQ (2005) assumed that the head, hands, forearms, and lower legs of an adult resident were exposed to soil, and that the head, hands, forearms, lower legs, and feet of a child (<6 years of age) were exposed to soil. For the nonresidential scenario, MDEQ (2005) assumed that the head, hands, and forearms are exposed to soil.

1.2 MDEQ (2005) Value

1.2.1 Description of Current Values

MDEQ (2005) recommended SA values of 2,670 cm^2 for young children (<6 years old) and 5,800 cm^2 for youth and adults (7-30 years old) for the residential scenario; for the nonresidential scenario, MDEQ (2005) recommended a SA of 3,300 cm^2.

MDEQ SA estimates were calculated using total SA and percentage total SA by body part from the U.S. EPA (1997) Exposure Factors Handbook. MDEQ (2005) indicated that the SA values were 50th percentile estimates of body part-specific SAs.

SA estimates recommended by U.S. EPA (1997) were based on analyses performed by U.S. EPA (1985). Few studies reporting direct measurements of SA were available. Using the data available at the time (from a study in 1935 in which SA measurements were made for 1,114 individuals), U.S. EPA (1985) developed regression equations relating direct measurements of total body SA to height and weight. Complete data for height, weight, and age were only

available for 401 of the 1,114 individuals for whom SA measurements were made, so the regression analysis was limited to the smaller dataset. U.S. EPA (1985) used the resulting regression equations together with height and weight data obtained from the Centers of Disease Control and Prevention's (CDC) 1976 – 1980 cycle of the National Health and Examination Survey (NHANES II) survey to estimate a distribution of total body SAs for the U.S. population.

NHANES, conducted annually by CDC's National Center for Health Statistics, began in the 1960s to assess the health and nutritional status of children and adults in the U.S. Beginning in 1999, the survey became a continuous program with data collection every two years. NHANES is a national survey in which a sample of the U.S. population answers questions regarding health and nutrition and undergoes a medical examination that includes measurement of BW and height. NHANES is intended to sample a broad distribution of the population, and subjects include children of all ages, as well as pregnant women and other adults.

Percentages of total SA by body part for adults were also estimated by U.S. EPA (1985) using regression equations relating measured SA by body part to height and BW using the same data as for total SA. Data were not sufficient to obtain regression equations for children; raw data (i.e., mean, minimum, and maximum measured percentage by body part) were reported where available. U.S. EPA (1997) used the analysis by U.S. EPA (1985) without changes, and these data were adopted by MDEQ (2005) and used to calculate SAs for specific body parts.

1.2.2 Evaluation of Data Quality Objectives

The SA values recommended by MDEQ (2005) were evaluated using the Part 201 DQOs. A summary of the evaluation follows.

Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness). SA as a function of height and weight is not expected to vary geographically or temporally, so the regression equations used by U.S. EPA (1985) to estimate total SA and SA by BW are assumed to remain relevant. The height and BW data used by U.S. EPA (1985) to estimate SAs used by MDEQ (2005) and U.S. EPA (1997) were obtained from NHANES II. NHANES II was conducted between 1976 and 1980 and was designed to represent the non-institutionalized civilian population of the United States. As noted in the TSD for BW, a study by Moffatt et al. (1980) reported that BWs of Michigan residents in 1978 differed from national averages in 1971-1974; it is uncertain whether this disparity persisted through the time frame of the NHANES survey. However, the NHANES data upon which the MDEQ (2005) SA values are based were collected ~35 years ago, and it is likely that SAs of U.S. and Michigan residents have changed over time with changes in BWs. Rating: Low.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). The information considered by U.S. EPA (1985, 1997) as potentially relevant to the selection of SA values appears to be comprehensive, and the documents provide a thorough discussion of the basis for the values recommended. U.S. EPA (1985) provided a thorough description of the statistical modeling that was used to estimate SA. Rating: High.

Soundness and credibility (adequacy of approach; intrinsic sources of bias; sample size). NHANES II collected BW and height data on over 28,000 participants, a sample size designed to obtain data representative of the U.S. population. The equations used to estimate SA based on BW, height, and age were based on regression analysis of measured SAs for a small number of persons (401). The measured SAs were obtained in a study conducted in 1935; more recent measurements of SA were not available. Rating: Medium.

Transparency and objectivity (availability of supporting data; funding source; peer-review). U.S. EPA (1985) was a report prepared by GCA Corporation under contract to the U.S. EPA. The report does not indicate whether the analysis contained therein was subjected to peer review; presumably, it did receive internal U.S. EPA review prior to publication. The U.S. EPA (1997) Exposure Factors Handbook, which also used the BW and height data from U.S. EPA (1985), received both internal and external peer review. Both reports are available on the internet. NHANES II was a major program of the National Center for Health Statistics (NCHS) within the Centers for Disease Control and Prevention (CDC), which provided the funding for the survey and data collection. Rating: High.

Certainty (number and agreement of studies). The SA values used by MDEQ (2005) are based on analysis and recommendations published in U.S. EPA (1985, 1997), which used BW and height data from the NHANES II (NCHS, 1983). U.S. EPA (1997) considered other published information on SAs. Although only a single NHANES dataset was used, NHANES is a large survey intended to generate data representative of the entire U.S. Rating: Medium.

1.3 Evaluation of New Information Using Decision Framework

1.3.1 Michigan-Specific Data

MDEQ Remediation and Redevelopment Division (RRD) was contacted by email and phone to determine if the agency was aware of research or could provide data pertinent to SA of Michigan residents; however, the Department was not aware of research or data relevant to this exposure parameter. As discussed below, additional agencies and research universities were also contacted by email and phone to determine if any was aware of research or could provide data pertinent to BW and heights of Michigan residents.

As discussed in more detail in the TSD for BW, several Michigan government departments (Michigan Department of Community Health; The Michigan Care Improvement Registry, within the Michigan Department of Health and Human Services [MDHHS]; Injury and Violence Prevention Section of MDHHS; Lifecourse Epidemiology and Genomics Division of the Bureau of Disease Control, Prevention and Epidemiology in MDHHS; Women, Infant and Children's Supplemental Nutrition Program; and the Secretary of State) collect data on BW and/or height (which together could be used to estimate total skin surface area using established algorithms) of Michigan residents; however, the data are either self-reported (and thus not reliable) or are collected on a voluntary basis and/or collected only from particular segments of the population (and thus not representative of the Michigan population as a whole). Thus, these data are not useful for the estimation of SA.

The following research universities were contacted by email and phone to determine if each was aware of research or could provide data: University of Michigan, Michigan State University, Western Michigan University, and Michigan Technological University. Additional research or relevant data were not provided within the time-frame of the development of this TSD.

1.3.2 Most Recent EPA Recommended Values

The U.S. EPA (2011) Exposure Factors Handbooks recommended mean total SAs based on using the regression equations from U.S. EPA (1985) and NHANES data on body weight, height, and age from 1999-2006 or 2005-2006. For individuals under 21 years of age, NHANES data from 1999-2006 were used; for individuals 21 years and older, NHANES data from 2005-2006 were used. The larger dataset was used for children in order to ensure a large enough sample size. For percentage of total SA by body part, U.S. EPA (2011) recommended using data from an analysis by Boniol et al. (2008) for children 2 years and older, and using data from U.S. EPA (1985) for children under 2 years old. The analysis by Boniol et al. (2008) involved computer modeling of SA for specific body parts using measurement data collected in the late 1970s on 2,050 children.

U.S. EPA (2014) recommended a SA of 2,373 cm^2 for a child resident (<6 years of age), a SA of 6,032 cm^2 for an adult resident (based on SA values for ages 21+), and a SA of 3,527 cm^2 for an adult worker based on data reported by U.S. EPA (2011). To obtain the child value, U.S. EPA (2014) assumed exposure to the head, hands, forearms, lower legs, and feet. Age-weighted mean values for males and females ages birth to < 6 years old were calculated using data in U.S. EPA (2011). To obtain the adult values, U.S. EPA (2014) assumed exposure to the head, hands, forearms, and lower legs for the resident and exposure to the head, hands and forearms for the worker.

Table2 summarizes the body part specific mean SAs from U.S. EPA (2011; Table 7-2). Forearm SA was only reported for adult males (Table 7-12), and lower leg SAs were only reported for adult males and females (Tables 7-12 and 7-13). For age groups <21 years, U.S. EPA (2004, 2011) recommend using a forearm-to-arm ratio of 0.45 and a lower leg-to-leg ratio of 0.4 based on adult SA data to calculate the body part-specific SAs for the respective age groups. The forearm SA for an adult female was calculated for this TSD by multiplying the reported mean arm SA for an adult female by the ratio of the reported forearm SA to arm SA for an adult male.

Table 2. Mean SA (cm^2) by Body Part based on U.S. EPA (2011)

	Head	Hands	Forearms	Lower Legs	Feet
Birth to <1 month	530	150	180	240	190
1 to <3 months	600	170	200	270	210
3 to <6 months	690	200	230	310	250
6 to <12 months	820	240	280	370	290
1 to <2 years	870	300	310	490	330
2 to <3 years	510	280	400	620	380
3 to <6 years	610	370	480	780	490
6 to <11 years	660	510	680	1,240	730
11 to <16 years	730	720	1,020	1,930	1,050
16 to <21 years	750	830	1,210	2,170	1,120
Average Adult 21+[a]	1,250	980	1,300	2,510	1,295

[a]Adult data were reported separately by sex and averaged for this analysis.

The SA values above can be age-weighted to obtain estimates for the age groups used by MDEQ (for example, assuming that one year is spent in the 2 to <3 year age group and three years are spent in the 3 to <6 year age group to estimate a SA for the 2 to 6 year age group). Appendix B includes detailed calculations and Table 3 summarizes the exposed SAs by body part and age group.

Table 3. Mean SA by body part (cm^2) for MDEQ Age Ranges and Assumptions Based on U.S. EPA (2011) Data

Age Group	Head	Hands	Forearms	Lower Legs	Feet	Total
Ages < 2	798	255	279	409	294	2,035[a]
Ages 2 to 6	585	348	457	739	463	2,592[a]
Ages birth to 6	656	317	397	629	406	2,405[a]
Ages 6 to <16	695	615	851	1588	NA	3,749[b]
Ages 16 to <EDr	1094	933	1271	2401	NA	5,699[b]
Ages 6 to <EDr	940	811	1109	2088	NA	4,948[b]
Adult nonresident	1250	980	1299	NA	NA	3,529[c]

[a]Based on exposure to head, hands, forearms, lower legs, and feet.
[b]Based on exposure to head, hands, forearms, and lower legs.
[c]Based on exposure to head, hands, and forearms.

1.3.2.2 Evaluation of Data Quality Objectives

The SAs recommended by U.S. EPA (2011) were evaluated using the Part 201 DQOs. A summary of the evaluation follows.

Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness). The total SAs recommended by U.S. EPA (2011) were based on the same regression equations as U.S. EPA (1985, 1997) and MDEQ (2005) but used updated NHANES data (from 1999 to 2006 for children and 2005-2006 for adults). The percentage of total SA by body part for individuals over 2 years of age were updated by U.S. EPA (2011) using data from

Boniol et al. (2008). Boniol et al. (2008) used SA measurement data collected in the 1970s from 2,050 children ages 2 to 18 years in a computer model to estimate the percentage of total SA for individual body parts.

As described earlier, NHANES is a nationally representative sample of the non-institutionalized civilian U.S. population. There are no data with which to assess the extent to which current BWs and heights (as surrogates for SA) among Michigan residents are well represented by the NHANES data from 1999 to 2006; however, these data better reflect current conditions in the U.S. than data used by U.S. EPA (1985, 1997) and MDEQ (2005). Rating: Medium.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). The information considered by U.S. EPA (2011) as potentially relevant to the selection of SA values appears to be comprehensive, and the document provides a thorough discussion of the basis for the values recommended. The sampling design, data collection, and data analysis methods of NHANES surveys are well described[1], and the analysis by Boniol et al. (2008) is likewise well-documented. U.S. EPA (2011) based its SA recommendations on the most recent cycles of NHANES data available at the time the report was prepared, and used more cycles for children in order to enhance the sample size. Rating: High.

Soundness and credibility (adequacy of approach; intrinsic sources of bias; sample size). U.S. EPA (2011) described the NHANES data used as the basis for their SA values. As described by U.S. EPA (2011), the NHANES 1999-2006 survey consisted of a large sample size: approximately 40,000 persons of all ages, of which approximately 20,000 were children. The following subpopulations were oversampled: low-income persons, adolescents 12-19 years old, adults over 60 years of age, and African and Mexican Americans. As with previous NHANES surveys, BWs and heights were measured during examination by trained medical professionals. Boniol et al. (2008) used measurement data from 2,050 children ages 2 to 18 years collected in schools in the 1970s in models used to predict body-part specific SA. U.S. EPA (2011) used this analysis instead of the previous U.S. EPA (1985, 1997) recommendations because the number of children was much larger. For ages <2 years, values reported by U.S. EPA (1985) were used in the absence of more credible data. Rating: Medium-High.

Transparency and objectivity (availability of supporting data; funding source; peer-review). The U.S. EPA (2011) report is available on the internet. Prior to publication, the report was reviewed internally by U.S. EPA staff, and also reviewed by a Science Advisory Board and a Peer Review Panel consisting of scientists from academia, other governmental agencies, industry, and consultants. Funding for the NHANES data upon which the U.S. EPA (2011) recommendations were based is provided by the CDC. Boniol et al. (2008) was performed by researchers with the International Agency for Research on Cancer (IARC), the French National Institute of Health and Medical Research, and the French National Institute for Research on Transportation and Security. The study was published in a peer-review journal, and the study authors stated in the publication that they had no conflicts of interest. Rating: High.

[1] http://www.cdc.gov/nchs/nhanes/survey_methods.htm

Certainty (number and agreement of studies). The SAs recommended by U.S. EPA (2011) are based on analysis of NHANES data (1999-2006 or 2005-2006). U.S. EPA (2011) considered other published data on SA, but used estimates based on height and BW data from NHANES (1999-2006) because the NHANES data were representative of the U.S. population and based on a large number of subjects. Rating: Medium.

1.3.3 New Scientific Literature

A search of the open scientific literature (PubMed and ToxLine) for data on SA for both children and adults since 2009 was conducted. No studies with data relevant to the SA assumptions were identified.

1.3.4 New Federal Data Sources

A search of federal sources of data on SA was conducted. The search included evaluating publicly available databases, reports, data briefs, and publications from federal agencies including CDC and NHANES. NHANES data collected since 2006 have not been published in a summary report that is readily available. When available, these data could be used to update or supplement the SA estimates, but extensive analysis of the data would be required. According to Johnson et al. (2014), single years of NHANES data are not released as public-use data files, but are only available for analysis in the NCHS Research Data Center[2].

1.3.5 State and International Data Sources

State and international agencies listed in the introduction to this TSD were searched for recommended SA values. The SA values identified in the searches were almost exclusively based on values reported by U.S. EPA (1985, 1997, 2011, 2014), but used varying assumptions regarding the body parts that were exposed to soil; thus, these values cannot be readily compared and are not presented here. The agency that did not use U.S. EPA data exclusively was MADEP (1995), which calculated total SA values for children under 3 years of age using BW and height values from a pediatric growth chart generated by Massachusetts General Hospital in 1976. Further evaluation of DQOs for these values was not conducted.

1.3.6 Comparison of Results of DQO Evaluations

Table 4 provides a comparison of the DQO evaluations for the MDEQ (2005) SA values and those recommended by U.S. EPA (2011). For each DQO, the assessments have been rated low, medium, or high.

[2] http://www.cdc.gov/rdc/

Table 4. Summary of DQO evaluation for SA

Exposure Population	MDEQ (2005) value	Updated Values based on U.S. EPA (2011)
$SA_{ages <2}$ = Skin surface area: ages < 2	NV	2,000
$SA_{ages 2-<6}$= Skin surface area: ages 2 to <6	NV	2,600
$SA_{ages birth-<6}$ = Skin surface area: ages birth to <6	2,670	2,400
$SA_{ages 6-<16}$= Skin surface area: ages 6 to <16	NV	3,700
$SA_{ages 16-<EDr}$= Skin surface area: ages 16 to <EDr[a]	NV	5,700
$SA_{ages 6-<EDr}$= Skin surface area: ages 6 to <EDr[a]	5,800	4,900
SAn= Skin surface area: adult, nonresident	3,300	3,500
Relevance and applicability to Michigan	L	M
Clarity and comprehensiveness	H	H
Soundness and credibility	M	M-H
Transparency and objectivity	H	H
Certainty	M	M

NV = no value; H = high; M = medium; L = low

1.4 Conclusion

The U.S. EPA (2011) data best meet the DQOs for SA. U.S. EPA (2011) SA values are derived from NHANES 1999-2006 data, and these are the most recent NHANES data publically available in summary form, as well as more robust data for percentage total SA by body part. Thus, it is recommended that weighted averages of the U.S. EPA (2011) central tendency estimates be used for the age ranges of interest to MDEQ (see Tables 3, 4,and 6).

There are no data on SA of pregnant women for use in assessing nonresidential exposure to developmental toxicants. However, for the body parts that are assumed to be in contact with soil in the nonresidential scenario (e.g., head, hands, and forearms), it is reasonable to assume that SA is not markedly changed by pregnancy except in cases of toxemia (when edema of the face, hands, and arms is possible). Thus, the SAs recommended by U.S. EPA for nonpregnant women (see Table 5 below) should also be used to assess exposure to developmental toxicants in a pregnant worker. Table 5 below shows the input data and calculated exposed SA for the pregnant worker.

Table 5. Mean SA (cm^2) by Body Part[a] for Women based on U.S. EPA (2011)

	Head	Hands	Forearms	Total
Average Adult Female 21+	1,140	890	1,117	3,147

[a]Calculated as product of mean total surface area (Table 7-1 in U.S. EPA, 2011) and mean percentage by body part (Table 7-2). Forearm SA for an adult female was calculated for this TSD by multiplying the reported SA for arms for an adult female by the ratio of the SAs for forearms and arms in males.

Table 6 summarizes the recommended exposed skin SAs obtained based on the DQO evaluations described in this TSD.

Table 6. Summary of 2015 Updated MDEQ Values for Skin Surface Area (cm^2/day)

Parameter	2015 Updated Value
$SA_{ages <2}$ = Skin surface area: ages < 2	2,000
$SA_{ages 2-<6}$= Skin surface area: ages 2 to <6	2,600
$SA_{ages birth-<6}$ = Skin surface area: ages birth to <6	2,400
$SA_{ages 6-<16}$= Skin surface area: ages 6 to <16	3,700
$SA_{ages 16-<EDr}$= Skin surface area: ages 16 to <EDr[a]	5,700
$SA_{ages 6-<EDr}$= Skin surface area: ages 6 to <EDr[a]	4,900
SAn= Skin surface area: adult, nonresidential	3,500
SAnrdev = Skin surface area: adult, nonresidential, developmental toxicant	3,100

[a]EDr is exposure duration for the residential scenario. The 2015 updated value for EDr is 32 years.

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APPENDIX A

EXPLANATION OF RELATIVE DQO RATINGS

This appendix provides a broad outline of how the DQO ratings were applied. To some extent, professional judgment was used in the application of the ratings, as a set of rating characteristics that would apply to the many different data sources used to develop exposure assumptions was not feasible. The ratings should be considered relative rather than absolute. In other words, the ratings may be compared across sources of data for a single exposure assumption, but a rating of high for one exposure assumption may not be equivalent to a rating of high for another exposure assumption.

Relevance and applicability to Michigan (g*eographic, temporal, and demographic representativeness*).

High: Based on recent data obtained in Michigan, in members of its population, or developed based on data specific to Michigan (e.g., exposure frequency based on climate conditions in Michigan).

Medium: Based on recent data obtained outside Michigan or its population, but in an area or population with comparable geographic, temporal, and demographic conditions.

Low: Based on data obtained outside Michigan or its population, in an area or population with different geographic, temporal, and demographic conditions, or with unknown geographic, temporal, and demographic conditions.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search).

High: Derived value with complete documentation of the selection process, and based on known or apparently thorough literature search, OR, single study with thorough description of methods and results.

Medium: Derived value with incomplete documentation of the selection process, and/or based on limited literature search, OR, single study with some noncritical information missing from methods and results.

Low: Derived value with little or no documentation of the selection process, and/or without accompanying literature search, OR, single study lacking critical information from method or results.

Soundness and credibility (adequacy of approach; intrinsic sources of bias; sample size).

High: Using an established method to estimate the parameter, without intrinsic sources of bias, and with adequate sample size(s).

Medium: Using an established method to estimate the parameter, with some known or expected intrinsic sources of bias, and with adequate sample size(s).

Low: Using a novel or uncertain method to estimate the parameter, with or without intrinsic sources of bias, and with inadequate sample size(s).

Transparency and objectivity (availability of supporting data; funding source; peer-review).

High: Based on peer-reviewed study(s) performed by researcher(s) without demonstrable conflict of interest and supported by other studies.

Medium: Based on peer-reviewed study(s) performed by researcher(s) without demonstrable conflict of interest but without support from other studies.

Low: Based on unpublished study(s) and/or performed by researcher(s) with potential conflict of interest and/or based on professional judgment, without support from other studies.

Certainty (number and agreement of studies).

High: Based on > 3 studies with values ranging up to ±50% from the selected value.

Medium: Based on at least 2 or 3 studies with values ranging up to ±100% from the selected value.

Low: Based on a single study or more than one study with variability ranging >±100% from the selected value, or based on professional judgment.

APPENDIX B

DETAILED SA CALCULATIONS

[Appendix B_Detailed SA Calculations.xlsx]

Appendix B. Detailed SA Calculations

Age Group	Ages (Months)	# of months	Mean Surface Area by Body Part (m^2)*									Product of SA and number of months (m^2)				
			Head	Trunk	Arms	Forearms	Hands	Legs	Lower Legs	Feet	Total***	Head	Hands	Forearms	Lower Legs	Feet
Birth to <1 month	0-1	1	0.053	0.104	0.04	0.018	0.015	0.06	0.024	0.019	0.29	0.05	0.02	0.02	0.02	0.019
1 to <3 months	1-3	2	0.06	0.118	0.045	0.020	0.017	0.068	0.027	0.021	0.33	0.12	0.03	0.04	0.05	0.042
3 to <6 months	3-6	3	0.069	0.136	0.052	0.023	0.02	0.078	0.031	0.025	0.38	0.21	0.06	0.07	0.09	0.075
6 to <12 months	6-12	6	0.082	0.161	0.062	0.028	0.024	0.093	0.037	0.029	0.45	0.49	0.14	0.17	0.22	0.174
1 to <2 years	12-24	12	0.087	0.188	0.069	0.031	0.03	0.122	0.049	0.033	0.53	1.04	0.36	0.37	0.59	0.396
2 to <3 years	24-36	12	0.051	0.25	0.088	0.040	0.028	0.154	0.062	0.038	0.61	0.61	0.34	0.48	0.74	0.456
3 to <6 years	36-72	36	0.061	0.313	0.106	0.048	0.037	0.195	0.078	0.049	0.76	2.20	1.33	1.72	2.81	1.764
6 to <11 years	72-132	60	0.066	0.428	0.151	0.068	0.051	0.311	0.124	0.073	1.08	3.96	3.06	4.08	7.46	
11 to <16 years	132-192	60	0.073	0.63	0.227	0.102	0.072	0.483	0.193	0.105	1.59	4.38	4.32	6.13	11.59	
16 to <21 years	192-252	60	0.075	0.759	0.269	0.121	0.083	0.543	0.217	0.112	1.84	4.50	4.98	7.26	13.03	
Adult Male 21+		132	0.136	0.827	0.314	0.148	0.107	0.682	0.268	0.137	2.09	17.95	14.12	19.54	35.38	
Adult Female 21+		132	0.114	0.654	0.237	0.112	0.089	0.598	0.233	0.122	1.85	15.05	11.75	14.75	30.76	
Average Adult 21+**		132	0.125	0.741	0.276	0.130	0.098	0.64	0.251	0.130	1.97	16.50	12.94	17.14	33.07	

Source: U.S. EPA (2011). U.S. EPA Analysis of NHANES 1999-2006 data, U.S. EPA, 1985, and Boniol et al., 2008. Values shown are means based on Tables 7-1 (Total Body Surface Area by age and sex) and 7-2 (Surface Area of Body Parts).
Forearm-to-arm ratio =0.45; lower leg-to-leg ratio = 0.4.
* Calculated as mean percentage of body part times mean total body surface area.
** Average of adult male and adult female.
***Total SAs for adult groups based on TWA for data from Table 7-1 for ages 21+.

Ages (years)	Time Weighted Average SA by Age Group and Exposed Body Part (m^2)								Time Weighted Average SA by Age Group and Exposed Body Part (cm^2)							
	Head	Hands	Forearms	Lower Legs	Feet	Head, Forearms, Lower Legs, Hands, and Feet	Head, Forearms, Lower Legs, and Hands	Head, hands, and forearms	Head	Hands	Forearms	Lower Legs	Feet	Head, Forearms, Lower Legs, Hands, and Feet	Head, Forearms, Lower Legs, and Hands	Head, hands, and forearms
0-<2	0.0798	0.0255	0.0279	0.0409	0.0294	0.2035			798	255	279	409	294	2035		
2-<6	0.0585	0.0348	0.0457	0.0739	0.0463	0.2591			585	348	457	739	463	2592		
0-6	0.0656	0.0317	0.0397	0.0629	0.0406	0.2406			656	317	397	629	406	2405		
6-<32	0.0940	0.0811	0.1109	0.2088			0.4949		940	811	1109	2088			4948	
16-<32	0.1094	0.0933	0.1271	0.2401			0.5699		1094	933	1271	2401			5699	
6-<16	0.0695	0.0615	0.0851	0.1588			0.3749		695	615	851	1588			3749	
Male Adult/ 21+	0.1360	0.1070	0.1480	0.2680			0.6590		1360	1070	1480	2680			6590	
Female Adult/21+	0.1140	0.0890	0.1117	0.2330			0.5477		1140	890	1117	2330			5477	
Adult/21+	0.1250	0.0980	0.1299	0.2505			0.6034		1250	980	1299	2505			6034	
Nonresidential								0.3529								3529
Pregnant worker								0.3147								3147