September 2015

ATTACHMENT H

Part 201 Generic Exposure Assumption Values Update

TECHNICAL SUPPORT DOCUMENT

SUBJECT: SOIL DIRECT CONTACT EXPOSURE FREQUENCY (EF)

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 in 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 (Resource Materials) Section 4.3.

The exposure of pregnant receptors (residents and workers) to developmental and reproductive (DR) toxicants is classified into either a single event exposure (SE) or a full-term exposure (FT). The SRC recommended values are appropriate to those categorized as SE. For hazardous substances categorized as a FT DR toxicant, MDEQ assumes the exposure to occur over the full duration of the pregnancy; therefore, the residential and nonresidential exposure frequency for FT DR toxicants is 268.5 and 183 days/year, respectively. Refer to Resource Materials Section 3.2.5 and Attachment F.

Background

This Technical Support Document (TSD) describes the process used to update generic exposure assumption values for the soil direct contact exposure frequency (EF) 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 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 current Part 201 generic exposure assumptions (MDEQ, 2005) 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 EF presented in this TSD are based on upper percentiles.

Introduction

EF represents the number of days per year that individuals may be exposed to contaminants in soil through ingestion (EFi) and dermal contact (EFd) at their residences or workplaces. This TSD is organized into three sections (1) residential exposure frequency (EFir and EFdr), (2) nonresidential exposure scenarios (EFin and EFdn), including pregnant workers (EFndev) and (3) a summary of 2015 updated values. Below is a comparison of the MDEQ (2005) and 2015 updated values for EFs.

Table 1. Summary of 2005 and 2015 Updated MDEQ Values for Soil Direct Contact Exposure Frequency

Exposure Parameter	2005 MDEQ Value (days/year)	2015 Updated Value (days/year)
EFir = Exposure frequency for ingestion (residential)	350	350
EFdr = Exposure frequency for dermal contact (residential)	245	275
EFin = Exposure frequency for ingestion (nonresidential)	245	238
EFdn = Exposure frequency for dermal contact (nonresidential)	160	188
EFndev = Exposure frequency for pregnant workers	ND	1

ND: No data

Section 1. Residential Soil Direct Contact Exposure Frequency (EF)

1.1 Introduction

For residential exposure scenarios, MDEQ uses an EFir and EFdr that are intended to represent the number of days per year that a homeowner spends in contact with unfrozen soil while at their residence. In accordance with MDEQ's selection of a high-end value for EF, this TSD focuses on high-end estimates where available.

1.2. MDEQ 2005 Value

1.2.1 Description of MDEQ (2005) Value

MDEQ (2005) recommended an EFir of 350 days per year for adults and children. This value was based on U.S. EPA's recommended EFir of 350 days per year for evaluating reasonable maximum exposures (U.S. EPA, 1991). The EFir in U.S. EPA (1991) was based on the common assumption that Americans are away from their homes (i.e., on vacation) for 15 days per year. This assumption was considered to represent "constant, year-round exposure" to soil, water, and air (U.S. EPA, 1991). MDEQ (2005) did not adjust this exposure frequency to account for reduced exposure to soil during the winter because dust exposure can continue during winter, and soil ingestion rates available at the time included both soil and dust.

MDEQ (2005) recommended an EFdr of 245 days per year. This value is based on 1) U.S. EPA's (1991) recommendation to consider local weather conditions[1] when determining an EFdr, and 2) the assumption that dermal contact with soil is limited or nonexistent during an estimated 120 days of winter (i.e., four months), when the ground is either frozen or covered with snow (MDEQ, 2005). This EF implicitly assumes that vacation time away from home occurs only during the winter (i.e., no vacation days are subtracted from the days when contact with soil is not limited due to weather).

1.2.2 Evaluation of Data Quality Objectives

The EFir and EFdr 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). The EFir and EFdr recommended by MDEQ (2005) are based on the EFir value cited by U.S. EPA (1991) and an EFdr value that accounts for Michigan winters. The assumption by U.S. EPA (1991) that people are away from their homes for 15 days per year is undocumented, but is intended to yield an upper bound estimate of EFir. The assumption that Michigan winters render soil inaccessible for dermal contact for 120 days per year is also undocumented, but is assumed to be based on local knowledge of weather. Finally, the implicit assumption that vacation time away from home occurs only in the winter is unlikely to reflect vacation patterns in Michigan, where summer travel may also be popular. Whether the assumptions made in deriving EFir or EFdr reflect current conditions is not known. Rating: Medium.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). The basis for the EFir value is clearly described in U.S. EPA (1991). No information is presented in U.S. EPA (1991) regarding the nature of the search for data relevant to EFir. MDEQ (2005) explains adjusting the EFdr using the duration of winter, but does not cite sources of data. Rating: Low.

Soundness and credibility (*adequacy of approach; intrinsic sources of bias; sample size*). The EF parameters recommended by MDEQ are based on reasonable assumptions regarding the average duration of time spent away from home, and the average duration of time when there is limited access to dermal contact with soil. The approach of adjusting EF by local or regional climatic conditions was discussed by U.S. EPA (1991) and is considered appropriate. However, no data are provided to support the assumptions. Rating: Low.

Transparency and objectivity (availability of supporting data; funding source; peer-review). U.S. EPA (1991) did not provide any documentation to justify the assumption regarding an EFir of 350 days per year. Likewise, MDEQ (2005) did not provide data or references to support the assumption that winter lasts on average 120 days each year. Rating: Low.

[1]U.S. EPA (1991) did not provide specific adjustments for different geographical areas.

Certainty (number and agreement of studies). Given that EFir and EFdr for exposure to soil are based on assumptions, the uncertainty associated with these parameters is high. Rating: Low.

1.3. Evaluation of New Information Using Decision Framework

1.3.1 Michigan-Specific Data

1.3.1.1 Summary of Search Results

The MDEQ Remediation and Redevelopment Division (RRD) was contacted by email and phone to determine if the Department was aware of research or could provide data pertinent to the frequency of direct contact with soil in Michigan; however, the Agency was not aware of research or data relevant to this exposure parameter. The following research universities were contacted by email and phone to determine if each was aware of research or could provide data pertinent to frequency of exposure to soil among residents in Michigan: University of Michigan, Michigan State University, Western Michigan University, and Michigan Technological University.

The two primary assumptions made by U.S. EPA and MDEQ regarding EF are the amount of time people spend away from their homes each year (i.e., vacation time) and the length of time soil is frozen or snow-covered. Michigan State University (MSU) offered data relevant to the latter assumption.

MSU Extension collects daily minimum and maximum air temperature, as well as soil temperature at two inches and four inches below the surface, from more than 80 weather stations across the state. This program is managed by Dr. Jeff Andresen, Associate Professor of Meteorology/Climatology in the Department of Geography and State Climatologist for Michigan. Dr. Andresen was contacted and asked whether these data could be used to estimate a state-wide estimate of the annual average number of days with air or soil temperature ≤ 32 degrees Fahrenheit (ºF) as an estimate of the number of days that soil is frozen or snow-covered.

Dr. Andresen selected twenty[2] of the 80+ possible weather stations as those that would best provide a reliable representation of annual air and soil temperature conditions state-wide, and recommended that at least 10 years of data be used. For the 20 stations selected by Dr. Andresen, data from the last 10 full years (e.g., 2005 through 2014 inclusive) were downloaded from the Enviro-weather database and analyzed to obtain an estimate of the number of days each year when air or soil temperature was at or below freezing (32ºF). Specifically, maximum air temperature and maximum soil temperature at two inches below grade were downloaded for each day and station from January 1, 2005 through December 31, 2014. The resulting data contained 365 days per year of data for 10 years for each of 20 monitoring stations (a total of 73,000 possible data points, and 200 station-year datasets).

[2] Stations at the following locations were selected: Albion, Bear Lake, Benton Harbor, Chatham, Dundee, East Lansing, Eastport, Escanaba, Fairgrove, Fremont, Hart, Hawks, Ithaca, Kawkawlin, Lakeview, Mendon, Sandusky, Sparta, Stephenson, and Traverse City. Station locations and data are provided online at: http://www.agweather.geo.msu.edu/mawn/.

The data were analyzed as follows. Some datasets for individual station-year combinations were missing temperature measurements for a few scattered days each year, while others were missing several to many consecutive days of measurements. Because the metric of interest for EF is number of days per year when air or soil temperature was at or below freezing, missing data may have a big impact (e.g., if data for a given station-year were primarily missing from months when freezing temperatures were possible and/or likely). One option to address the issue of missing data would be to omit any station-year dataset with less than 365 days of data. However, using this approach would result in the omission of many datasets (81/200 datasets had <365 measurements per year for soil temperature; 78/200 datasets had <365 measurements for air temperature). To avoid losing this much data, selected missing data points were interpolated from the measurements the day before and the day after the days with missing data. Specifically, for periods of 5 or fewer consecutive missing days of temperature data, the average of the temperatures on the dates bounding the missing data was assigned to all intervening days. For example, if the maximum soil temperature on April 4, 2009 was 40ºF, there were no soil temperature data for April 5, 6, and 7, and the maximum soil temperature on April 8 was 44ºF, a maximum soil temperature of 42 ºF would be assigned for April 5, 6, and 7. When there were 6 or more consecutive days with missing maximum temperature data, that station-year dataset would be omitted from the overall analysis except under the following circumstance. If the missing temperature were from dates in June, July, or August, the dataset was retained, because the absence of these data would not influence the estimated number of days with air or soil temperature less than or equal to 32 ºF.

After eliminating the station-year combinations with 6 or more consecutive days missing in months other than June, July, or August, the number of days each year with maximum air or maximum soil temperature less than or equal to 32 ºF was calculated for each year and each station. Then, the average number of days per year with temperature ≤ 32 ºF was calculated across all years for each station. In addition, the average across all stations for each year was calculated separately. The mean, standard deviation, and count by station and by year are shown in Tables 2 and 3, respectively. The final data were examined three ways: first, the mean across years for each station was averaged across stations, yielding an overall mean of 77 days per year for 20 stations. Second, the mean across stations for each year was averaged, yielding an overall mean of 80 days per year for 10 years of data. Finally, the average across the pooled data (166 observations) was calculated, yielding a value of 78 days per year. For comparison, the average across the raw datasets (including those with 6 or more consecutive days of missing data during months other than June, July, and August and with no interpolated values) was also 78 days per year. Table 4 compares the results from the four different analyses. As the table shows, the final results vary by ±2 days using the four approaches; thus, the data are not very sensitive to alternative analyses. This analysis suggests that 78 days per year is a reasonable estimate of the number of days per year with maximum air or soil temperature below 32ºF across the state of Michigan.

Table 2. Number of days per year with maximum air or maximum soil temperature ≤ 32ºF, by station, including interpolated data

	Albion	Bear Lake	Benton Harbor	Chatham	Dundee	East Lansing	Eastport	Escanaba	Fairgrove	Fremont
No. of full years	8	8	8	6	8	8	5	10	9	9
Mean days/year	70	54	58	77	71	66	74	117	89	77
SD	17	15	25	14	27	22	27	30	16	24
	Hart	Hawks	Ithaca	Kawkawlin	Lakeview	Mendon	Sandusky	Sparta	Stephenson	Traverse City
No. of full years	8	8	9	10	10	9	8	10	7	9
Mean days/year	68	73	77	86	89	59	81	64	103	90
SD	35	23	22	24	23	23	26	22	35	24

Table 3. Number of days per year with maximum air or maximum soil temperature ≤ 32ºF, by year, including interpolated data

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
No. of Cities	18	19	18	16	16	17	16	15	15	17
Mean days/year	95	42	77	87	79	78	73	43	97	107
SD	16	10	10	19	11	16	23	25	26	27

Table 4. Sensitivity analysis: Overall mean days per year with maximum air or maximum soil temperature ≤ 32ºF

Data and analysis	City-year datasets included	Interpolated data included	Days per year
Overall mean of pooled data	All datasets	No	78
Overall mean of pooled data	Only datasets with 5 or fewer consecutive days of missing data in months other than June, July, or August	Yes	78
Mean of average by city across all years	Only datasets with 5 or fewer consecutive days of missing data in months other than June, July, or August	Yes	77
Mean of average by year across all cities	Only datasets with 5 or fewer consecutive days of missing data in months other than June, July, or August	Yes	80

1.3.1.2 Evaluation of Data Quality Objectives

The data obtained from MSU were evaluated using the Part 201 DQOs. A summary of the evaluation follows.

Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness). MSU provided daily soil and air temperatures between January 1, 2005 and December 31, 2014 for 20 monitoring stations in Michigan. The stations were selected by State Meteorologist Dr. Jeff Andresen to provide data representative of the entire state. These data are both current and specific to Michigan. Rating: High.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). Data provided by MSU were not complete, with missing data points for several stations and years. The influence of the missing data on the final outcome is uncertain. However, the available data provide good coverage across the state (stations were selected by the State Climatologist to provide representation of state-wide averages) and 10 years of recent data. Rating: Low-Medium.

Soundness and credibility (*adequacy of approach; intrinsic sources of bias; sample size*). According to Dr. Andresen, the methods for data collection employed by MSU are modeled after those of the National Oceanic and Atmospheric Administration (NOAA). The sample size (200 station-year combinations) was recommended by Dr. Andresen and is deemed adequate to the purpose. A potential source of bias is the approach used to interpolate missing data; however, as the sensitivity analysis suggested that the final result using interpolated data did not differ from the result of analyzing the raw data, this bias is expected to be minimal. The data used for this analysis reflected days per year when the maximum air or soil (2 inches belowgrade) temperature was ≤ 32 ºF; no data on the number of days when soil is snow-covered were available. However, air temperature is believed to be a reasonable surrogate for the latter, as precipitation on the ground at that air temperature is likely to be snow. In addition, at an air temperature of 32 ºF or lower, exposure to soil would also be limited by winter clothing and gloves/mittens. Rating: Medium-High.

Transparency and objectivity (availability of supporting data; funding source; peer-review). The data collected by MSU were collected to provide weather information for agricultural and natural resource management purposes in Michigan. Based on the limited information available on the website, funding for the data collection is provided by MSU and support from contributions. The MSU data and analysis described above have not undergone peer review. Rating: Medium.
Certainty (number and agreement of studies). No other studies were available to compare with the data from MSU. Rating: Low.

1.3.2 Most Recent EPA Recommended Value(s)

U.S. EPA (2011) Exposure Factors Handbook does not provide EFir or EFdr values. U.S. EPA (2014) OSWER Directive 9200.1-120 recommends an overall EF (e.g., relevant to drinking water intake, soil ingestion, dermal contact with soil or water, inhalation of contaminants originating in soil or water) for residential exposure of 350 days per year, citing U.S. EPA (1991)

as the source. Because the U.S. EPA (2014) value is based on the same document (U.S. EPA, 1991) and assumptions as the MDEQ (2005) value, no further evaluation of DQOs for the EF from U.S. EPA (2014) was conducted.

1.3.3 New Scientific Literature

A search of the open scientific literature (PubMed and ToxLine) for data on EFir and EFdr published since 2009 was conducted. Literature regarding the number of days people spend away from home each year was not located.

Schaetzl and Tomczak (2001) studied soil temperatures in Michigan's Saginaw Valley between December 4th 1996 and May 31st 1997 (i.e., winter). The study reported that the Saginaw FAA Airport and St. Charles weather stations had measurable, relatively continuous snowpack for 109 days; however, it did not account for days when the ground is frozen but not covered by snow. A more recent publication by Schaetzl and colleagues (Isard et al., 2008) included an analysis of changes in soil temperature between 1976 and 2000; however, data were reported in terms of soil temperature change (rather than absolute temperature). Thus, no further evaluation of these studies was conducted.

1.3.4 New Federal Data Sources

1.3.4.1 Summary of Search Results

A search of federal sources of data on soil temperature and time away from home was conducted. The search included evaluating publicly available databases, reports, data briefs, and publications from federal agencies including the National Oceanic and Atmospheric Administration (NOAA), the U.S. Bureau of Labor Statistics (BLS), and the U.S. Department of Transportation. In addition, the relevant data reported by the Society for Human Resource Management (SHRM) were evaluated.

Based on data collected in nine cities throughout Michigan[3] over 34 to 71 years, NOAA (2012) reported that minimum air temperatures of 32 ^{o}F or less were recorded on average 156 days per year (range 130-191). However, the minimum temperature on any given day is more likely to occur at night than during the day (when soil contact would occur); further, it is likely that the number of days with a minimum air temperature below 32 ^{o}F is much larger than the number of days that ground in Michigan is frozen or snow-covered. Thus, these data were not considered further.

The National Household Travel Survey, administered by the U.S. Department of Transportation, Federal Highway Administration includes data on the length of travel for various purposes; however, searches of the website[4] did not yield reports or readily accessible statistical analyses of these data.

[3] Alpena, Detroit, Flint, Grand Rapids, Houghton Lake, Lansing, Marquette, Muskegon, and Sault Ste. Marie.
[4] http://nhts.ornl.gov/index.shtml

The U.S. BLS collects and reports data on paid leave among workers in the U.S. The most recent data located on the U.S. BLS website (2014) reported mean number of days of vacation and holiday for civilian and private industry workers. For workers with one year of service, the mean numbers of paid vacation and holidays were ten and eight days, respectively, during the years 2010 to 2014 for both civilian and private industry[5] workers (Table 5). As shown in Table 5, workers with five years of service were given a mean of 14 days paid vacation and 8 holidays.

According to a survey conducted by SHRM (2009), the average number of paid vacation days in the U.S. in 2009 was 10 days per year for one year of service, 15 days per year with five years of service, and 16 days per year with 10 years of service (Table 5). The survey was completed by human resource officers in 494 organizations across the U.S., and included a range of sectors, staff sizes, and industries. SHRM (2009) did not report holiday time.

Table 5. Summary of Occupational Leave (days) from Key Studies

Years of Service	U.S. BLS (2014)[a]	SHRM (2009)[b]
Vacation Days Offered		
1	10	10
5	14	15
10	ND	16
Holidays Offered		
1	8	ND
5	8	
10	ND	

[a]Values are based on data collected from 2010 to 2014.
[b]Values are based on data collected in 2009.
ND = No data.

1.3.4.2 Evaluation of Data Quality Objectives

The data obtained from U.S. BLS (2014), and SHRM (2009) were evaluated using the Part 201 DQOs. A summary of the evaluation follows.

Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness). U.S. BLS (2014) and SHRM (2009) reported national averages that included data collected in Michigan for the number of paid days away from work (e.g., vacation). There is no basis upon which to conclude that the numbers of vacation days, holidays, or paid days off from work would differ substantially between the U.S. as a whole and Michigan. Rating: Medium.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). U.S. BLS (2014) did not provide a detailed report of its methods for data collection and curation. SHRM (2009) provided a brief summary of survey methods, but did not report holiday time. Rating: Low.

[5]During 2010, the mean number of paid vacation days for private industry workers with one year of service was nine, not 10 days; from 2011 to 2014 the number remained constant at 10.

Soundness and credibility (*adequacy of approach; intrinsic sources of bias; sample size*). U.S. BLS (2014) did not provide a detailed report of its methods for data collection and curation; however, it is reasonable to assume that the agency used well-established survey and analysis methods. U.S. BLS (2014) also did not report the number of organizations surveyed to obtain the data. The approach used by SHRM (2009) appears to be reasonable based on the information provided; in addition, this organization has conducted similar surveys for a number of years. A total of 494 organizations were surveyed by SHRM (2009) to obtain the information on paid days off. Rating: High.

Transparency and objectivity (availability of supporting data; funding source; peer-review). The data collected by U.S. BLS (2014) underwent federal review; it is uncertain whether these data received peer-review. U.S. BLS is a U.S. government organization and is expected to provide objective data and analysis. SHRM (2009) was published on the internet and openly available; however, the data were not subjected to formal peer-review. Rating: Medium-High.

Certainty (number and agreement of studies). Both U.S. BLS (2014) and SHRM (2009) provided similar results for number of vacation days per year (10 for one year of service and 14-15 for five years of service). SHRM did not report average number of holidays. Rating: Medium.

1.3.5 Other State and/or International Searches

1.3.5.1 Summary of Search Results

State and international agencies listed in the introduction to this TSD were searched for recommended EFir values. Table 6 below summarizes the recommended EFir values identified in the searches. As shown in the table, values for EFs, with a few exceptions, are generally based on the value reported by U.S. EPA (1991, 2014). The states of Massachusetts (MCP, 2015) and Indiana (IDEM, 2012) use an EFir of 250 days per year, based on an EF of five days per week for 50 weeks (April through October). The state of Washington (WAC, 2001) uses an EFir and EFdr of 365 days per year (i.e., there is no adjustment for time away from home). The state of Minnesota (MPCA, 2015) specifies an EFir of 350 days per year for nonvolatile organic compounds, an EFir of 250 days per year for volatile organic compounds (VOCs), and an EFdr of 250 days per year for nonvolatile organic compounds only (EFdr is 0 for VOCs). The reduced EFin for VOCs reflects the assumption that VOCs will not be present in indoor dust due to their volatile nature; the EFdr of 0 reflects the assumption that dermal contact will not be a significant exposure route for VOCs.

The Ontario Ministry of the Environment and Climate Change (MOE, 2011) derived an EFir for residents of seven days per week for 39 weeks (273 days per year). Because the state and international values were based on assumptions specific to the location, further evaluation of DQOs for these values was not conducted.

Table 6. Comparison of default state and international EF values.

Exposure parameter	MI	IL	CA	MA	MN	WA	WI	IN	OH	OR	TX	Ontario, CA	EU JRC	EU ECETPC
EFir (days/years)	350	350	350	250	250 350	365[c]	350	250	350	350[a]	350	273[b]	ND	ND
EFdr (days/year)	245	350	350	250	250	365[c]	ND	ND	ND	ND	ND	273[b]	ND	ND

ND = No data;
[a]Oregon also specifies an urban residential EF of 175 days per year (ODEQ, 2010).
[b]EFir for residents assumes seven days per week for 39 weeks (273 days per year).
[c]Reported as fraction (1.0) of year (WAC, 2001).

1.4 Comparison of Results of DQO Evaluations

Table 7 provides a comparison of the DQO evaluations for the MDEQ (2005) EFir and EFdr and the alternate estimates from key studies considered in this review. For each DQO, the assessments have been compiled and rated from low to high.

Table 7. Summary of DQO evaluation for Residential EF.

Parameter	MDEQ (2005) value	New Michigan data	U.S. EPA (2011)	U.S. EPA (1991, 2014)	New scientific literature	U.S. BLS (2014) SHRM (2009)
EFir (days/year)	350[a]	ND		350[a]	ND	347[d]
EFdr (days/year)	245[b]	287[c]	ND	ND		ND
Data Quality Objective Scoring						
Relevance and applicability to Michigan	M	H	NA	M	NA	M
Clarity and comprehensiveness	L	L-M		L		L
Soundness and credibility	L	M-H		L		H
Transparency and objectivity	L	M		L		M-H
Certainty	L	L		L		M

ND = No data; H = high; M = medium; L = low; M-H = Medium to High; L-M = Low to Medium.
[a]Based on 15 days per year away from the residence.
[b]Based on 120 days of winter (including 15 days per year away from the residence during winter).
[c]Based on days per year when maximum air and soil temperature is more than 32° F (calculated as 365 minus the average number of days (78) when maximum temperature is at or below 32° F)
[d]Based on 10 paid vacation days per year (conservative estimate) and eight paid holidays.

1.5. Conclusion

MDEQ (2005) value for EFir (350 days/year) based on an assumption regarding the number of days people are away from their homes each year (15 days) is generally supported by data reported by U.S. BLS (2014) and SHRM (2009). While U.S. BLS (2014) and SHRM (2009) show that the average worker receives at least 10 days of vacation and 8 holidays, some of the vacation and holidays may be spent at the residence; thus, the previous estimate of 15 days away from home remains a reasonable assumption. The most appropriate data to inform this

parameter would be average number of full days spent away from home each year; a reliable and readily accessible source for these data was not located among the resources consulted. MDEQ (2005) also considered the potential for year-round exposure to dust in setting the EFir at 350 days/year. However, this leads to the incompatible assumption that dermal contact with soil occurs only when the ground is not frozen or snow covered, while ingestion of soil occurs year-round. Estimates of both dust and soil intake rates are now available (see TSD for soil ingestion). To retain the same algorithm structure used previously, the EFir will remain the same at 350 days/year, and the soil and dust intake rate for residents will be calculated using the intake rate for soil and dust for the fraction of the year when the ground is not frozen or snow-covered (e.g., EFdr), and the intake rate for dust for the remainder of the year (e.g., EFir – EFdr).

The MDEQ (2005) value for EFdr is obtained by subtracting the number of days when the ground is expected to be frozen or snow-covered in Michigan from the number of days in a year (365 days/year). The average number of days when the maximum air or soil temperature is ≤32ºF based on MSU data (78 days) provides an empirical value for the assumption of number of days when exposure to soil will be limited or nonexistent. Subtracting this number from 365 yields an estimate of 287 days per year when dermal exposure to soil may occur; however, this calculation does not account for time away from home. Because EFir assumes that residents are away from home for 15 days per year, it would be appropriate to make a similar assumption in the calculation of EFdr. Prorating the total days away from home equally over the year would suggest that 12 of the 15 days away from home occur during the fraction of the year when the ground is not frozen or snow-covered (15 x 287/365= 12 days). Therefore, it is recommended that a value of 275 days per year (287 days when temperature is >32 minus 12 days away from home during that time) be used for EFdr.

Section 2. EF for Nonresidential Exposure Pathways

2.1. Introduction

For nonresidential exposure scenarios, MDEQ uses an EFin and EFdn that are intended to represent the number of days per year that a worker spends in contact with unfrozen soil while at their workplace. In accordance with MDEQ's selection of a high-end value for EF, this TSD focuses on high-end estimates where available.

2.2 Current (MDEQ 2005) Value

2.2.1 Description of Current Value

MDEQ (2005) recommended an EFin of 245 days per year for nonresidential workers. This value represents the number of days per year that a person is exposed to soil at the workplace. The value is based on U.S. EPA's (1991) recommendation of 250 days per year for nonresidential exposure scenarios, which assumes that people are at work five days per week, 50 weeks per year (with two weeks of vacation, holiday, sick, or other leave time per year).

MDEQ (2005) then subtracts an additional five days of sick leave or vacation time away from the workplace, for a final EFin of 245 days per year. EFin is intended to account for both soil and dust ingestion which can occur year-round.

MDEQ (2005) recommended an EFdn of 160 days per year. This value is based on an assumption of 120 days (4 months) in which snow cover or frozen ground make soil unavailable for contact; 21 days (representing 15 work days of vacation, holiday, and sick or other leave); and an adjustment for exposure on only five of seven days in a typical work week. MDEQ (2005) gives the following equation for EFdn:

$$(365 - 120 - 21) \times {}^{5}/_{7} = 160$$

This calculation implicitly assumes that all time away from work occurs during the fraction of the year when the ground is not frozen or snow-covered.

The assumption regarding days per year when the ground in Michigan is frozen or covered by snow was evaluated earlier for the residential soil contact EF parameters above, and DQO assessment of this assumption is not repeated.

2.2.2 Evaluation of Data Quality Objectives

MDEQ (2005) EFin and EFdn values were evaluated using the Part 201 DQOs. A summary of the evaluation follows.

Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness). The assumption that people are away from work for three weeks per year is based on professional judgment; no data were cited to support it. The implicit assumption that vacation time away from home occurs only in the summer may not reflect vacation patterns in Michigan, where winter holiday and vacation travel may also be popular. The assumption that people work on average five days per week is not cited to a particular source but is a generally accepted norm in the U.S. workplace and is expected to be relevant to Michigan. The temporal representativeness of these assumptions is unknown as data are not provided to support them. Rating: Medium.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search). The EFin value of 245 days/year used by MDEQ (2005) was explained by MDEQ (2005), but no sources are cited. Rating: Low.

Soundness and credibility (*adequacy of approach; intrinsic sources of bias; sample size*). The EF parameters recommended by MDEQ are based on reasonable assumptions regarding the average duration of time spent away from work and the average duration of time when there is limited access to dermal contact with soil. The approach of adjusting EF by local or regional climatic conditions was discussed by U.S. EPA (1991) and is considered appropriate. However, no data are provided to support the assumptions. Rating: Low.

Transparency and objectivity (availability of supporting data; funding source; peer-review). MDEQ (2005) did not cite data to support their assumptions of 120 days when soil is inaccessible or three weeks (15 workdays) away from the workplace. Rating: Low.

Certainty (number and agreement of studies). Given that EFin and EFdn values from MDEQ (2005) are based on assumptions, the uncertainty associated with these parameters is high. Rating: Low.

2.3. Evaluation of New Information Using Decision Framework

2.3.1 Michigan-Specific Data

2.3.1.1 Summary of Search Results

The two primary assumptions made by U.S. EPA and MDEQ to estimate EFin and EFdn are the amount of time people spend away from their workplace each year (i.e., vacation time) and the length of time soil is frozen or snow-covered. The MDEQ RRD was contacted by email and phone to determine if the Department was aware of research or could provide data pertinent to the frequency of direct contact to soil in Michigan; however, the Agency was not aware of research or data relevant to this exposure parameter. Likewise, Michigan's Occupational Safety and Health Agency (MIOSHA) was contacted to attempt to obtain information on time spent away from work; no information was provided in the time frame required for this TSD. The following research universities were contacted by email and phone to determine if each was aware of research or could provide data pertinent to frequency of exposure to soil among nonresidential workers in Michigan: University of Michigan, MSU, Western Michigan University, and Michigan Technological University.

As described earlier in Section 1.3.1, data relevant to the estimation of number of days per year when contact with soil is limited were provided by MSU Extension. The data and analysis were described in that section, and DQO evaluation for the data was provided in Section 1.3.1.2.

2.3.2 Most Recent EPA Recommended Value(s)

2.3.2.1 Summary of Search Results

U.S. EPA (2011) does not provide EFin or EFdn data or values. U.S. EPA (2014) recommended an EF for worker exposure of 250 days per year (5 days per week for 50 weeks per year) for both a generic worker and for an indoor worker based on recommendations presented in U.S. EPA (1991). The values presented in U.S. EPA (1991) are based on the assumptions that workers receive two weeks off per year, and that work weeks are 5 days long.

U.S. EPA (2014) also reports an EF for outdoor workers of 225 days/year, citing U.S. EPA (2002). This value is based on the U.S. Census Bureau's 1990 Earnings by Occupation and Education Survey which collected data on the average number of days worked per years by male and female workers in occupational categories likely to be similar to those of an outdoor worker scenario (e.g., groundskeepers and gardeners, mechanics and repairers, painters, and construction and maintenance; U.S. EPA, 2002).

Because the U.S. EPA (2014) value for the worker is based on the same document (U.S. EPA, 1991) and general assumptions as the MDEQ (2005) value, no further evaluation of DQO for the EF from U.S. EPA (2014) was conducted.

2.3.3. New Scientific Literature

2.3.3.1 Summary of Search Results

A search of the open scientific literature (PubMed and ToxLine) for data on EFin and EFdn published since 2009 was conducted. The results of literature search are provided in Section 1.3.3.

2.3.3.2 Evaluation of Data Quality Objectives: Not relevant

2.3.4 New Federal Data Sources

2.3.4.1 Summary of Search Results

A search of federal sources of data on soil temperature and time away from home was conducted. The search included evaluating publicly available databases, reports, data briefs, and publications from federal agencies including NOAA, U.S. BLS, and the U.S. Department of Transportation. In addition, the relevant data reported by the SHRM (2009) were evaluated. The results of the search are reported in Section 1.3.4.1 (see also Table 5), with the exception of sick days taken by worker. Based on data obtained from 2010 to 2014, U.S. BLS (2014) reported that workers with either one or five years of service, the mean numbers of paid sick days offered were 7 - 8 days for both civilian and private industry workers. In an earlier report, U.S. BLS (2012) reported that full-time workers in most private industries (other than leisure and hospitality industries, which used on average two days per year) used on average four days of sick leave per year. Additional research or relevant data were not located.

2.3.4.2 Evaluation of Data Quality Objectives. The DQOs for U.S. BLS (2014) and SHRM (2009) were evaluated previously in Section 1.3.4. DQO ratings for U.S. BLS (2014) would also apply to U.S. BLS (2012).

2.3.5. State and International Searches

2.3.5.1 Summary of Search Results

State and international agencies listed in the Background section of this TSD were searched for recommended EF values. Table 8 below summarizes the recommended EF values identified in the searches. As shown in the table, values for EFs, with a few exceptions, are generally based on the value reported by U.S. EPA (1991, 2014). The state of Minnesota recommends an EFin for non VOCs of 250 days per year, and an EFin for VOCs of 180 days per year (MPCA, 2015). The reduced EFin for VOCs reflects the understanding that VOCs will not be present in indoor dust due to their volatile nature. For dermal contact, MPCA assumed that dermal contact with VOCs would be negligible, and that dermal contact with non-VOCs would only be significant when the ground is not frozen or snow cover is less than one inch. The state of Washington (WAC, 2001) reports EF as a fraction of a year, and gives values of 0.4 to 0.7 (equivalent to 146 to 246 days/year) depending on the method used to obtain cleanup levels; the basis for these values was not reported. The Ontario Ministry of the Environment and Climate Change (MOE,

2011) assumed that exposure to soil was limited during months (i.e., 3 months) when daily temperatures are equal or less than 0 ^{o}C, or months when at least seven days of snow depth equal to or greater than five cm occurs. MOE (2011) also reported an EF for pregnant adult females aged 20-59 years as seven days per week for 52 weeks (365 days per year) (Richardson, 1997). Because the values used by other states and Canada were either based on the same sources as MDEQ (2005) value or state- or Canadian-specific assumptions, further evaluation of DQOs for these values was not conducted.

Table 8. Comparison of default state and international EF values (nonresidential).

Exposure parameter	MI	IL	CA	MA	MN	WA	WI	IN	OH	OR	TX	Ontario, CA	EU JRC	EU ECETPC
EFin (days/years)	245	250	250	245	180 250[a]	146 to 256[c]	250	250	250	250	250	195[d]	ND	ND
EFdn (days/year)	160	250	250	ND	180 0[b]	146 to 256[c]	ND	ND	ND	ND	ND	195[d]	ND	ND

ND = No data
[a] 250 days per year for non-VOCs and 180 days per year for VOCs (MPCA, 2015).
[b] 180 days per year for non-VOCs and 0 days per year for VOCs (MPCA, 2015).
[c] Reported as fraction (0.4-0.7) of year (WAC 2001); basis was not reported.
[d] Assumes 39 weeks of exposure, 5 days per week.

2.4 Comparison of Results of DQO Evaluations.

Table 9 provides a comparison of the DQO evaluations for the MDEQ (2005) EFir and EFdr and the alternate estimates from key studies in this review. For each DQO, the assessments have been compiled and rated from low to high.

Table 9. Summary of DQO evaluation for EF.

Parameter	MDEQ (2005) value	New Michigan data	U.S. EPA (2011)	U.S. EPA (2014)	New scientific literature	U.S. BLS (2014) SHRM (2009)
EFin (days/year)	245[a]	ND	ND	250[d]	ND	238[e]
EFdn (days/year)	160[b]	188[c]		ND		ND
Data Quality Objective Scoring						
Relevance and applicability to Michigan	M	H	ND	M	ND	M
Clarity and comprehensiveness	L	L-M		L		L
Soundness and credibility	L	M-H		L		H
Transparency and objectivity	L	M		L		M-H
Certainty	L	L		L		H

ND = No data; H = high; M = medium; L = low; M-H = Medium to High; L-M = Low to Medium.
[a] Based on 5 days per week for 49 weeks.
[b] Based on 120 days of winter, 21 days of paid leave, and a 5-day work week.
[c] Based on days per year when minimum air and soil temperature is more than 32° F (calculated as 365 minus the mean number of days (78) when maximum air or maximum air temperature is below 32° F (365 – 78= 287 days), adjusted for 5 work days/week (287 x 5/7 = 205 days) minus 17 of 22 possible days off (22 x 287/365 = 17 days) assumed to occur during the time when maximum temperature is above 32° F).
[d] Based on 5 days per week for 50 weeks.
[e] Calculated as total possible work days (5 days/week x 52 weeks = 260 days) minus total days off (22 days, assuming 10 vacation days, 8 holidays and 4 sick days used per year).

2.5. Conclusion

MDEQ (2005) values for EFin are based on assumptions regarding the number of days people are away from the workplace each year (i.e., annual vacation, holiday, and/or sick time and length of work week). Using data provided by U.S. BLS (2014, 2012), and the assumption that most workers use all of their offered vacation (a minimum of 10 days) and holiday (8 days) time, as well as on average four sick days per year, it can be estimated that the average worker takes 22 days off. Based on this assumption, it can be calculated that the average worker is at his or her workplace (where exposure is assumed to occur) for 238 days per year (365 x 5/7 - 22).

The other factor considered by MDEQ (2005) in selecting the nonresidential EFin was the need to coordinate this factor with the available data for soil ingestion rate, which did not distinguish between intake of soil and dust; thus, EFin had to account for potential year-round exposure to dust. However, this leads to the incompatible assumption that dermal contact with soil occurs only when the ground is not frozen or snow covered, while ingestion of soil occurs year-round. Because data distinguishing dust and soil intake rates are now available (see TSD for soil ingestion), and the soil and dust intake rate for nonresidents be calculated using the intake rate for soil +dust for the fraction of the year when the ground is not frozen or snow-covered ([365-78]/365 or 79% of the year) and the intake rate for dust for the remainder of the year (78/365 or 21% of the year). The EFin would remain at 238 days per year and would not be adjusted for climate because it would account for year-round intake.

The (MDEQ 2005) value for EFdn is obtained by subtracting the number of days when the ground is expected to be frozen or snow-covered in Michigan (120 days) and 21 days off, and adjusting the balance for a 5/7 day work week. The average number of days when the maximum air or soil temperature is ≤32ºF based on MSU data (78 days) provides an empirical value for the assumption of number of days when exposure to soil will be limited or nonexistent. The calculation used by MDEQ (2005) to obtain EFdn implicitly assumed that all days off occur during the fraction of the year when the ground is not frozen or snow-covered. Using the updated assumption of 22 days off from work per year and prorating these days equally over the year would suggest that 15 of the 22 days off occur during the fraction of the year when the ground is not frozen or snow-covered (22 x 287/365 = 17 days). This calculation yields a final EFdn value of ([{365 – 78} x 5/7]-17 = 188 days).

Assessment of pregnant worker exposure to developmental toxicants represents a special case, for which the recommended EFin and EFdn would not apply. Because developmental toxicants may exert permanent effects on the fetus after only a very brief gestational exposure during a critical window of susceptibility (U.S. EPA 1996), the dose metric of interest is the peak dose occurring at any time during pregnancy (i.e., not averaged over 5/7 days or over a fraction of the year). Use of this dose metric would be protective for developmental toxicants with a narrow critical window of susceptibility (five days or less). Thus, the exposure frequency recommended for use in evaluating developmental toxicity in pregnant workers is 1 day/year.

Section 3. Summary of Recommendations

The table below summarizes the recommended EF values for residential and nonresidential direct contact with soil via ingestion and dermal contact based on the DQO evaluation described in this TSD.

Table 10. Summary of Updated MDEQ Soil Direct Contact Exposure Frequency Values

Exposure Parameter	2015 Updated Value (days/year)
EFir = Exposure frequency for ingestion (residential)	350
EFdr = Exposure frequency for dermal contact (residential)	275
EFin = Exposure frequency for ingestion (nonresidential)	238
EFdn = Exposure frequency for dermal contact (nonresidential)	188
EFndev = Exposure frequency for pregnant workers	1

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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.

2.2.3 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).

2.2.4 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.

2.2.5 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.