MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

TO: Toxics Steering Group (TSG)

FROM: TSG Subcommittee for the Application of the Manganese Particulate Soil Inhalation Criteria in the Detroit Area (Subcommittee).
<u>Members</u>; Christina Bush, Department of Community Health; Divinia Ries, Remediation and Redevelopment Division; Kay Fritz, Waste and Hazardous Materials Division, Chair; Robert Sills, Air Quality Division
<u>Ad Hoc Members</u>; David Mason, Air Quality Division; David Slayton, Waste and Hazardous Materials Division; Deborah MacKenzie-Taylor, Waste and Hazardous Materials Division

DATE: May 22, 2009

SUBJECT: Final Report of the Subcommittee

ORGANIZATION OF THE FINAL REPORT

I. SUMMARY OF RECOMMENDATIONS FROM THE SUBCOMMITTEE

1. Revise the manganese (Mn) Particulate Soil Inhalation Criteria (PSIC) according to the best available information in the following manner:

   a. Reevaluate and update, if appropriate, the Department of Environmental Quality (DEQ) Mn Initial Threshold Screening Level (ITSL) (Completed March 2009).
   b. Generate the dispersion factor (Q/C) from the American Meteorologic Society (AMS)/EPA Regulatory Model Improvement Committee (AERMIC) dispersion model (AERMOD) program instead of Industrial Source Complex Short Term Model (ISCST3), using the most recent meteorological data set for (1) Midland/Bay City/Saginaw (MBS) for generic PSIC, and (2) Detroit Metro (DTW), Detroit City Airport (DET), or Grosse Ile (ONZ) for facility specific generic PSIC for facilities in the Detroit area (applicable for all PSIC).
   c. Incorporate source area size determination guidance into the DEQ, Remediation and Redevelopment Division (RRD) Operational Memorandum 1 – Attachment 7 (Completed July 2007). *(applicable for all PSIC)*
   d. Eliminate the particulate emission factor (PEF) two-fold adjustment factor (PEF/2) *(applicable for Mn PSIC only).*
   e. Use newer vehicle emission equations to calculate the vehicle emissions factor (Ev). *(applicable for all PSIC)*
   f. Evaluate the need for the addition of an appropriate relative source contribution factor (RSC) to the Mn PSIC algorithm for facilities in the Detroit area *(applicable for Mn PSIC in the Detroit area only; however, consideration of this factor is recommended for inclusion in the Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Act 451), Program Redesign for other hazardous substances also).*

2. Allow a 30 day review period for comments on this document from TSG members, after which the report will be revised and the final version sent to all TSG members (Completed May 2009).

3. Upon receipt of the final version of the Final Report by the TSG:

   a. Forward the Final Report to DEQ Administration, Air Quality Division (AQD), RRD, and Waste and Hazardous Materials Division (WHMD).
   b. Dissolve the TSG Subcommittee.

II. SUMMARY OF FINDINGS OF THE SUBCOMMITTEE

A. Recommendation Concerning the Mn ITSL and Particle Size

The AQD previous Mn ITSL was the same as the U.S. Environmental Protection Agency (EPA) Mn reference concentration (RfC), which was determined by the EPA in 1993. The

EPA has recently committed to reevaluate the Mn RfC; however, it may be several years before the reevaluation is complete. Meanwhile four other organizations have established or proposed health-based values for Mn air concentrations: World Health Organization (WHO) (2001); Health Canada (1994, 2008); California EPA (2000, 2008); and The Agency for Toxic Substances and Disease Registry (ATSDR) (2008). The Subcommittee identified key studies from the recent literature and recommended that the AQD use these in their reassessment of the Mn ITSL. A detailed discussion of this recommendation is in Section V.A of this report. The AQD completed its reevaluation of the Mn ITSL on March 2, 2009. The Mn ITSL will remain at 0.05 micrograms per cubic meter (µg/m^3), but will now have an annual averaging time (24-hour averaging time previously). The particle size issue is discussed in Section V.A this report and in the AQD Mn ITSL document.

B. Recommendation Concerning the Air Modeling Method

The AERMOD incorporates the most up-to-date science available and is the model required by the EPA and the AQD for dispersion modeling. Use of the AERMOD instead of the ISCST3 is recommended to generate Q/C values used to derive the PEF and, ultimately, the PSIC values. Recent (2002 to 2006) meteorological data sets have been evaluated for 15 Michigan locations, with MBS being selected as the average (median) location. Three locations in the Detroit area (DTW, DET, and ONZ) also have 2002 to 2006 meteorological data sets available. Facilities in the Detroit area may use these data sets to substitute facility-specific measurements for generic inputs per Part 201 and R 299.5726(7) of the Part 201 Rules. Therefore, it is recommended to use the MBS data set to calculate the generic PSIC using the AERMOD and data sets for Detroit locations to calculate facility-specific PSIC for facilities in the Detroit area. The use of the AERMOD model, together with the 2002 to 2006 meteorological data sets, will generate Q/C values that are more representative of actual conditions in Michigan. *This recommendation applies to the PSIC for all hazardous substances.* A detailed discussion of this recommendation is in Section V.B of this report. The effect of this recommendation on the generic Mn PSIC values is shown in **Attachment A** of this report.

C. Recommendation Concerning the Source Area Size Determination

Determination of a final PSIC value for Mn must include consideration for the areal extent of contamination (source size), which is accomplished by use of a source size modifier corresponding to a Q/C and source size. The RRD, with the assistance of the Subcommittee, has revised and expanded the guidance for selection of the appropriate source size modifier. This guidance has been incorporated into the updated RRD Operational Memorandum No. 1., Attachment 7 - Technical Support Document, Part 201 Generic Soil Inhalation Criteria (SIC) for Ambient Air, Part 213 Tier 1 Soil Inhalation Risk-Based Screening Levels for Ambient Air (DEQ TSD-SIC) (DEQ 2007). *This guidance applies to the PSIC for all hazardous substances.* A detailed discussion of this recommendation is in Section V.C of this report. The effects of several source size adjustments are shown in **Attachment A** of this report.

D. Recommendation Concerning the Two-Fold Adjustment Factor

Based on a review of the available toxicity information and health protection benchmarks, protection against the chronic neurological effects of exposure to Mn in airborne soil particulate appears to provide adequate protection from potential acute effects of Mn (assuming that peak 24-hour levels may be twice as high as annual average levels). Therefore, it is recommended that the current two-fold adjustment factor in the derivation of the Mn PSIC value should be eliminated on the basis that it does not appear to be necessary to ensure health protection for short-term peak levels relative to annual average levels. *This recommendation applies to the PSIC for Mn only.* A detailed discussion of this recommendation is in Section V.D of this report. The effect of this recommendation on the Mn PSIC values is shown in **Attachment A** of this report.

E. Recommendation Concerning Ev

Section 13.2.2, Fugitive Dust Sources – Unpaved Roads, of the EPA Compilation of Air Pollutant Emission Factors AP-42 1995 (AP-42) unpaved road equation presently used to calculate Ev for the PSIC has been updated. AP-42 now includes two newer (2003) unpaved road equations, plus it includes a new equation for paved roads. There are several options to update the Ev factor for the PSIC, four of which are presented in this report. It is recommended that the Ev be updated with this more recent information. *This recommendation applies to the PSIC for all hazardous substances.* A detailed discussion of this recommendation is in Section V.E of this report. Some potential effects of this recommendation on the Mn PSIC values are shown in **Attachment A** of this report.

F. Recommendation Concerning the RSC Factor

The purpose of adding an RSC factor to the Mn PSIC for facilities in the Detroit area would be to help avoid exceedences of the ITSL. Detroit area air monitoring data show Mn relatively elevated (in some cases exceeding the ITSL) in ambient air on a yearly basis in comparison to other state data. The addition of an RSC factor to the Mn PSIC algorithm would account for airborne Mn coming from sources other than soil. This may be necessary to adequately protect public health from the neurological effects of Mn toxicity from inhalation of ambient air. There was insufficient time and resources to evaluate this issue completely; therefore, the recommendation from the Subcommittee is for further evaluation of the addition of appropriate RSC(s) to the Mn PSIC for facilities in the Detroit area, both for present criteria development and also for inclusion in the Part 201 Program Redesign. *Presently this recommendation applies to the PSIC for Mn in the Detroit area only; however, the Subcommittee also recommends the RSC issue be included for consideration in the Part 201 Program Redesign for other hazardous substances.* A detailed discussion of this recommendation is in Section V.F of this report.

G. Comparison of Michigan's Mn PSIC with Other States and EPA Regions

All EPA, five neighboring states, and five distant states showed varying cleanup concentrations for soil Mn for the particulate inhalation exposure pathway. The Ev factor and PEF adjustment are unique to the Part 201 PSIC calculation, resulting in cleanup criteria more stringent than the EPA and other states' particulate inhalation exposure cleanup standards and/or screening levels for Mn. However, the Subcommittee determined that the calculation of the generic Part 201 PSIC should include all quantitative mechanisms to incorporate possible exposure conditions where emissions of soil contaminants could be increased (e.g., increased emissions generated by vehicular traffic on unpaved roads). Therefore, the Subcommittee concluded that the Ev factor and PEF adjustment were appropriately incorporated into the generic Part 201 PSIC algorithm to adequately protect human health. The modification of the Q/C, and consequently, the PSIC value based on source size, including the modification process, are also appropriate. A detailed discussion of this comparison is in Section V.G of this report.

III. INTRODUCTION TO THE SUBCOMMITTEE

The Subcommittee was initiated following a discussion at the April 2006 quarterly TSG meeting, which identified some challenges associated with the application of the Mn PSIC at several large facilities in the Detroit area. Specifically, many soil samples either on or adjacent to these facilities contained Mn concentrations exceeding the Part 201 Mn PSIC cleanup numbers, and the facilities were questioning several aspects of the Mn PSIC methodology. Selected surficial Mn soil concentrations are shown in **Attachment B** of this report. The Subcommittee started officially as a TSG Work Group (Work Group) in May 2006, with an aim to evaluate the derivation of the Mn PSIC values for application in Michigan, especially the Detroit area, to ascertain if those PSIC values are appropriate or if revisions may be justified. The first report of the Work Group, which included its rationale, purpose, and proposal, was presented at the July 2006 quarterly TSG meeting. At that meeting, the Work Group was changed to a Subcommittee. The Subcommittee for the application of the Mn PSIC in the Detroit Area met every one-to-two months and submitted its DRAFT Final Report to the TSG on February 25, 2009.

IV. SCOPE OF WORK FOR THE SUBCOMMITTEE

The overall goal of the Subcommittee was to evaluate the derivation of the Mn PSIC values for application in Michigan, especially the Detroit area, to ascertain if those PSIC values are appropriate or if revisions may be justified.

The Subcommittee was to summarize findings and recommendations in a document to be presented to the TSG, and determine if the findings support a "no further action," a briefing for upper management, a mechanism for stakeholder input, or other course of action. The Subcommittee decided to submit this Final Report to the TSG for approval, after which the TSG would forward the approved Final Report to the DEQ Administration, AQD, RRD, and WHMD, to act on the information as they deem necessary.

V. FINDINGS OF THE SUBCOMMITTEE

A. Recommendation Concerning the Mn ITSL and Particle Size

Contact Person: Christina Bush, Department of Community Health (DCH)

BACKGROUND

The AQD, Toxics Unit (TU), develops screening levels for the implementation of the Part 55, Air Pollution Control, or Act 451 rules pertaining to Air Toxics Rules (Rules 224-232). If the EPA has established a RfC for a chemical that is published in the EPA Integrated Risk Information System (IRIS), the ITSL is determined from the RfC. R 229(2)(b) allows for use of an alternative methodology for determining the ITSL, provided it is determined to be more appropriate, based on toxicological grounds, and supported by the scientific data (DEQ, AQD 2002).

The EPA RfC of 0.05 $\mu g/m^3$ for Mn is based on a study by Roels *et al.* (1992), in which occupational exposure to Mn dioxide resulted in impairment of neurobehavioral function (EPA 1993). The ATSDR also used this study in deriving their current chronic inhalation Minimal Risk Level (MRL) for Mn (ATSDR 2000). For purposes of this report, an ATSDR chronic inhalation MRL is equivalent in meaning to the EPA RfC.

In response to Docket ID No. EPA-HQ-ORD-2006-0950, which sought nominations of new assessments for the IRIS 2007 Program, the AQD, TU, requested that the EPA review the RfC for Mn (DEQ 2007). This request came about due to several issues:

1. There are more recent occupational studies, including a follow up to the key study used for the 1993 RfC determination that may provide information that will change the RfC.
2. Further clarification is desired for using the appropriate particle size when comparing ambient air levels to the RfC.
3. Research on fate and transport within the body suggests that there may be a more direct route to the brain (via the olfactory bulb) rather than absorption from the lungs and systemic transport.
4. More state-of-the-science dose calculations (i.e., benchmark dose modeling) may result in a refined RfC.

Although the EPA ultimately chose to include Mn in its IRIS 2007 program, the AQD-TU determined that an internal review of the Mn ITSL might be more timely and was warranted. Additionally, the Subcommittee determined that the toxicity information for Mn should be reviewed, and included this task in its scope of work (DEQ 2006).

DISCUSSION

Proposed Reference Values from Other Agencies

Several regulatory or health agencies have recently proposed updates to their inhalation reference values for Mn. The table below shows the agency, the agency's current reference value (in µg/m^3), the proposed change (in µg/m^3), and the key study used for the determination. The EPA RfC is included for comparison purposes.

Agency	Current (C) Value (Year)	Proposed (P) Value (Year)	Key Study
Health Canada	0.11 (1994)	0.05 (2008)	Lucchini *et al.* 1999 (P)
California EPA	0.09 (2008)	Not applicable	Roels *et al.* 1992 (C)
ATSDR	0.04 (2000)	0.3 (2008)	Roels *et al.* 1992 (P)
EPA	0.05 (1993)	None proposed	Roels *et al.* 1992 (C)

Additionally, the WHO established 0.15 µg/m^3 in 2001 as the air quality guideline for Mn in Europe. All current values are based on Roels *et al.* (1992). All proposed values also are based on Roels *et al.* (1992), except for Health Canada, which was based on Lucchini *et al.* (1999), and has the lowest proposed reference value. All proposed values were calculated using benchmark concentration analysis, modeling for either the 5 percent or 10 percent effect level. Uncertainty factor use varied between agencies. It should be noted that the proposed values, along with the WHO value, are within an order of magnitude of each other, suggesting the difference between the values is minimal.

The EPA definition of RfC is as follows (EPA 2008):

> An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL [no observed adverse effect level], LOAEL [lowest observed adverse effect level], or benchmark

concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in the EPA noncancer health assessments.

All of the current and proposed concentrations above are within an order of magnitude of the EPA 1993 Mn RfC, in the range of 0.04 to 0.3 µg/m^3. Thus, the current Mn ITSL, when considering the RfC definition – "within an order of magnitude" - seems to be fairly consistent with other proposed and final agency values.

Manganese ITSL Evaluation Process

Margaret Sadoff, former AQD toxicologist, conducted a literature search on Mn toxicity studies published more recently than those used by the EPA and ATSDR for their comparison values. She had compiled a list of papers of interest by late 2007 and shared the list with Christina Bush, toxicologist with the DCH. Ms. Bush is a member of the Subcommittee and is assisting the RRD by evaluating public health implications of soils that exceed the Mn PSIC in the cities of River Rouge and Ecorse.

The EPA released a "proposed key literature" list in April 2008 for their reevaluation of the Mn RfC. Upon reviewing this list, Ms. Sadoff and Ms. Bush added several articles to those already being reviewed. Each chose to read that which pertained more to her respective program (this resulted in some articles being read by both toxicologists). Although the inhalation of Mn oxides was of primary interest, the review also focused on other forms of Mn, other exposure routes, and investigation of other toxic endpoints. The entire list of documents reviewed by the Subcommittee and MDCH for this evaluation is included in **Attachment C**.

From the joint review, the following studies were selected as key studies in potentially updating the Mn ITSL:

1. Roels *et al.* 1999 - As discussed previously, the RfC for Mn is based on a study by Roels *et al.* (1992). The Roels group conducted a follow up longitudinal study on the cohort (Roels *et al.* 1999), conducting yearly evaluations from 1987 through 1995. The researchers investigated whether effects seen in the earlier study were reversible, since airborne Mn concentrations in the factory had decreased over the 8-year study period to about one-third their previous levels (790 to 250 µg/m^3). Results from the group for whom exposure had stopped suggested that the deficits seen in the earlier neurological tests were persistent, but may improve if the exposure had been low enough. The follow up study did not recruit new subjects, and the number of exposed and control subjects dropped from about 100 per group in the earlier study to about 35-40 per group (**Note**: a population below 100 in an epidemiological study can result in low statistical power). There were issues with the collection of personal air samples, possibly resulting in incomplete recovery of total dust. These issues should be taken into consideration if the follow up study is used to update the ITSL.

2. Crump and Rousseau 1999 - The EPA considered another study by Roels' group (Roels *et al.* 1987) when establishing the RfC, but the LOAEL for this study was greater than that for the 1992 study. The 1987 study also received follow up (Crump and Rousseau 1999). The researchers recruited additional workers and used blood and urine Mn levels as a dose indicator rather than conducting air sampling. Individual data from the earlier study were not available. The researchers concluded that, on a gross basis, there did not appear to be a trend toward poorer performance in Mn exposed workers over time. However, the average age increased by 5 years over the 11-year surveillance period, whereas average total exposure duration increased by 7 years, suggesting that the older work force may be

leaving. A younger incoming work force may be a healthier population, which could confound results. This should be taken into consideration if the follow up study is used to update the ITSL.

3. Bouchard *et al.* 2008 - Mergler *et al.* (1994) compared workers exposed to Mn dust and fumes to controls, sampling total and respirable dust, collecting blood and urine, and conducting an extensive battery of neurofunctional tests. Bouchard *et al.* (2008) conducted follow up on the cohort (71 of the original 74 matched pairs remained). The alloy plant where the exposed cohort had been employed had closed 14 years previous to the follow up. The researchers focused on the effect of exposure to Mn on symptoms reporting at each point in time, rather than the effect of exposure on the intra-individual change in symptoms reporting. Exposed workers in the highest tertile of Mn cumulative exposure index (CEI) reported the highest level of symptomatology. The median CEI was 19 milligrams (mg) Mn/m^3-yrs, and the mean numbers of years of exposure was 15.7.

4. Lucchini *et al.* 1999 - Lucchini *et al.* (1999) conducted follow up work on earlier studies which reported a significant dose-effect relationship between blood Mn and neurobehavioral changes and between blood Mn and serum prolactin levels. In the follow up, the researchers recruited additional workers and conducted more neurological tests. The overall results suggested that, while the exposed group performed more poorly than the control group, the neurobehavioral effects did not worsen since the previous study, but remained stable. The researchers used a LOAEL approach and determined that, according to the results, the average annual exposure to Mn as total dust for a worker should be lower than 100 µg/m^3. The authors also chose to use a CEI, rather than current air concentrations, because airborne Mn concentrations in the ferroalloy industry can vary substantially daily and weekly, even at the same location in the plant. Thus, a CEI would lessen or eliminate the effect of this fluctuation.

5. Gibbs *et al.* 1999 - Gibbs *et al.* (1999) used 30-day and 12-month exposure estimates in their study at a metal producing plant. They argued that these time frames would be more reliable than a CEI estimate “because of relatively steady process parameters over the preceding year and the relatively accurate estimate of hours worked.” Gibbs *et al.* reported that performance was negatively correlated with age, but was not affected by Mn concentrations. Airborne Mn levels were significantly lower in the study compared to other studies (0.18 mg/m^3 Mn total dust, 0.066 mg/m^3 respirable). This “negative” study, along with the Roels *et al*. 1992 study, was used by Clewell *et al.* (2003) in a benchmark dose calculation.

There were additional worker and non-worker studies conducted; however, the above studies provide a base on which to reevaluate the RfC.

<u>Consideration of Particulate Size</u>
Most of the occupational studies that were reviewed reported the Mn concentration in total suspended particulate (TSP), with some studies including the concentration in particulate matter equal to or less than 10 µm (PM10), as well. The inhalation reference values set by various regulatory or health agencies (discussed briefly earlier in this section) are based on PM10. The majority of air monitoring stations in Michigan that measure airborne metals report only TSP, which makes comparison to a reference value problematic: While TSP concentrations provide a conservative (protective) approach to determining ambient air impacts (i.e., if TSP is not exceeded, then a region is in compliance), PM10 data are the appropriate metric to use (at least

in the case of Mn). The AQD, therefore, currently uses TSP as a screen (and to compare to historical data).

In the derivation of the RfC, the EPA (1993) summarized the differential dose-response findings of the occupational exposure studies that quantified exposure to Mn in different particulate fractions. In the key study (Roels *et al*. 1992), the geometric mean Mn exposure for total dust was approximately 4.4-fold greater than the Mn exposure for respirable dust. The exposures were expressed as the occupational-lifetime integrated respirable or total dust (IRD or ITD). The LOAEL for the respirable dust fraction that was used for the RfC derivation was calculated by dividing the IRD by the average duration of worker exposure. By a similar calculation using the ITD, a LOAEL for the total dust exposure can be obtained. Thus, a benchmark for TSP exposures could be derived from the key study, resulting in a value that is approximately 4.4-fold higher than the current RfC. However, this should not be considered a default application for conversion of the PM10 benchmark to TSP, since research has shown that the proportion of PM10 TSP Mn ranges from 20 to 80 percent.

Uncertainty Factors

The EPA applied three uncertainty factors (UF) of 10 each (database limitations [less than chronic exposure, lack of developmental data, and uncertainties about the toxicity of different forms of Mn], LOAEL-to-no observed adverse effect level (NOAEL), and inter-individual) when deriving the RfC from Roels *et al.* (1992).

Database UF. The results of the follow up studies suggest that the database limitation UF may warrant a decrease in regard to the chronic exposure uncertainty.

Another database uncertainty issue, regarding particulate size and Mn form, pertains to whether the olfactory route is significant in humans. In rats, research has shown that inhaled Mn may travel directly to the brain through the olfactory bulb versus being absorbed systemically from the lung. Thus, larger particles that cannot enter the lower airway may, nonetheless, impact brain concentrations. It is unclear whether, and to what degree, the olfactory route is applicable in humans. The chemical form of Mn (insoluble versus soluble) may play a role in olfactory uptake. This should be considered when applying a database UF.

LOAEL-to-NOAEL UF. If a new RfC is calculated using benchmark dose analysis, the LOAEL-to-NOAEL UF will likely be eliminated.

Inter-individual UF. Some of the human data suggest that males may be more susceptible to the neurotoxic effects of Mn than females (Mergler 1999; Mergler *et al*. 1999; Beuter *et al.* 1999; Takser *et al.* 2003; Erikson *et al*. 2005). Both human and animal data suggest that older individuals may be more susceptible to neurotoxic effects of Mn (Crump and Rousseau 1999; Gibbs *et al.* 1999; Beuter *et al*. 1999; Erikson *et al.* 2005). Schneider *et al.* (2006) cited other research indicating a wide difference of individual susceptibility in humans exposed to Mn. Thus, the inter-individual UF would likely remain at 10.

Status of ITSL Review

The AQD, TU, which is charged with establishing new or revised ITSLs, evaluated the Subcommittee's preliminary review. The AQD completed the ITSL reevaluation on March 2, 2009. The Mn ITSL will remain at 0.05 $\mu g/m^3$, but will now have an annual (versus 24-hour) averaging time. The deliberative process for this determination has been documented by the AQD.

CONCLUSION AND RECOMMENDATION

The AQD's previous Mn ITSL was the same as the EPA Mn RfC, which was determined by the EPA in 1993. The EPA has recently committed to reevaluate the Mn RfC; however, it may take several years before the reevaluation is complete. Meanwhile four other organizations have established or proposed health based values for Mn air concentrations: WHO (2001), Health Canada (1994, 2008), the California EPA (2008), and ATSDR (2000, 2008). The Subcommittee identified key studies from the recent literature and recommended that the AQD use these in their reassessment of the Mn ITSL. The AQD completed its reevaluation of the Mn ITSL on March 2, 2009. The Mn ITSL will remain at 0.05 μg/m^3, but will now have an annual averaging time (Mn had a 24-hour averaging time previously). This report and the AQD Mn ITSL document also discuss the particle size issue.

B. Recommendation Concerning the Air Modeling Method

Contact Person: David Mason, AQD

BACKGROUND

The Part 201 PSIC algorithm incorporates a PEF which accounts for soil to air emissions of particulate contaminants due to wind erosion and vehicular traffic and subsequent dispersion of airborne contaminants represented by Q/C (DEQ 1998, DEQ, RRD 2007). The Q/C factor (ratio of emission rate to predicted concentration) represents dispersion of airborne contaminants from a square area source (e.g., one-half acre) expressed as grams per square meter per second (g/m^2-sec) per kilograms per cubic meter (kg/m^3) and derived using a dispersion model.

The EPA Soil Screening Guidance (SSG) (EPA 1996) presents nationally modeled regional Q/C values for 29 locations from selected states (e.g., Minneapolis, Minnesota; Cleveland, Ohio; and Chicago, IL) but did not include a Michigan location. Michigan generated its default Q/C values based on Michigan meteorological data but used the EPA Q/C modeling methods and assumptions as follows:

1. One-half acre source area size;
2. Zero receptor height, which is the recommended receptor height for air dispersion modeling according to the Source Receptor Analysis Branch, Office of Air Quality Planning Standards, of the EPA;
3. Uniform emission rate from a one-half acre source of 1.0 g/m^2-sec.
4. ISCST3 Model

The Michigan default Q/C values were derived using 1991 meteorological data from 15 Michigan locations. Briefly, the derivation involves imposing a Cartesian receptor grid on the one-half acre source area and estimating the annual average air concentration for each discrete receptor location using the ISCST3 model. The 90th percentile of the distribution of the average air concentrations for all receptor locations represents the Q/C value for each meteorological location. Using these results, three meteorological locations were selected and 5 years of meteorological data sets (1987-1991) for each location were modeled. The selection was based on location within an area of the state that is both agricultural and industrial, availability and analysis of 5 consecutive years of meteorological data, and "conservativeness" of the 1991 data. The 5-year analysis ensured that the year of data chosen to calculate the Q/C values was representative of general weather conditions for that area. One representative location was selected for conducting the air dispersion modeling to generate the default Q/C for various source sizes. This location represented roughly the 50th percentile of dispersion characteristics for the 15 Michigan meteorological monitoring locations originally modeled. See DEQ, RRD 2007 for additional details.

The original model used to generate Q/C values was the EPA ISCST3. This type of dispersion model is used primarily to support the EPA regulatory modeling programs (e.g., National Ambient Air Quality Standards, Prevention of Significant Deterioration). Due to various limitations and inadequacies of the ISCST3 model, the AMS and the EPA initiated a formal collaboration in 1991 with the designated goal of introducing recent advances in handling boundary layer conditions. As a result, the AERMIC formulated the AERMOD. The AERMOD is designed to model stationary sources of air pollution and is useful for modeling point, area, and volume sources. **Attachment D** of this report presents a comparison of the two dispersion models.

On November 9, 2005, the EPA published, in the Federal Register, a recommendation that AERMOD replace ISCST3 for dispersion modeling evaluations of criteria air pollutant and toxic air pollutant emissions from typical industrial facilities. This revision became effective December 9, 2005 (30-days after publication in the Federal Register), and a one-year transition period commenced with promulgation. During the transition period, both the EPA and the AQD accepted modeling performed with either the ISCST3 model or AERMOD. After the one-year period, beginning November 9, 2006, AERMOD was required to be used for federal regulatory applications and ISCST3 was no longer accepted. The AQD followed the same schedule and adopted the use of the AERMOD model pursuant to Part 55, Air Polution Control of Act 451, and its administrative rules, R 336.1240 *et seq.*

DISCUSSION

In order to update the PSIC Q/C values with the best available science, the modeling was conducted anew using the AERMOD dispersion model and meteorological data sets (2002 through 2006) from 15 Michigan locations. The procedure, described below, for selecting the representative meteorological data sets is essentially the same as the previous Q/C derivation with minor modifications.

A one-half acre source area size was used for modeling 15 sets of meteorological data routinely used in the AQD air dispersion modeling. The most recent year of available data for each location was chosen (2006). Maximum annual average concentrations were obtained using AERMOD assuming a standard emission rate of contaminant from soil of 0.001 g/m^2-sec. From these results, three meteorological locations with “median” predicted concentrations were selected. Therefore, these three locations do not represent “worst case” meteorological conditions for the state. The locations selected were MBS, Lansing, and DTW. These locations were then modeled with the most recent 5 years of data (2002-2006) to ensure that the data chosen to calculate the Q/C values was representative of general weather conditions for that area (i.e., the year did not represent unusual weather events). MBS was chosen as the location that best represents the 50th percentile of Q/C values for the 15 Michigan meteorological monitoring locations, and therefore, the proposed generic Part 201 PSIC Q/C is derived from the 2002-2006 data for MBS.

The three Detroit area locations with 2002-2006 data, DTW, DET, and ONZ, have slightly different meteorological data sets than MBS, and therefore, may be more representative of conditions in the Detroit area. Use of local data sets is allowed under R 299.5726(7), which states that facility-specific measurements may be substituted for the generic assumptions and still qualify the facility for a generic (facility-specific) closure. This Rule also allows local data to be used for the derivation of emission due to wind (Ew) and Q/C.

Q/C values were also generated for source sizes smaller and larger than one-half acre to develop the **Attachment E,** Source Size Modifier Table, of this report. The PSIC value for a one-half acre source size is adjusted using a modifier corresponding to the contamination source area size in order to establish the applicable PSIC value for that source size. The modifier is the ratio of the Q/C for a given source size to the Q/C for the one-half acre source size.

CONCLUSION AND RECOMMENDATION

AERMOD incorporates the most up-to-date science available and is the model required by the EPA and the AQD for dispersion modeling. Use of AERMOD instead of ISCST3 is recommended to generate Q/C values used to derive the PEF, and ultimately, the PSIC values. Recent (2002 to 2006) meteorological data have been evaluated for 15 Michigan locations, with MBS being selected as the average (median) location. Three locations in the Detroit area (DTW, DET, and ONZ) also have 2002 to 2006 meteorological data sets available. Facilities in the Detroit area may use these data sets to substitute facility-specific measurements for generic inputs per R 299.5726(7). Therefore, it is recommended that the MBS data set be used to calculate the generic PSIC using AERMOD, and data sets for Detroit locations to calculate facility-specific PSIC for facilities in the Detroit area. The use of the AERMOD model, together with the 2002 to 2006 meteorological data sets, will generate Q/C values that are more representative of actual conditions in Michigan. *This recommendation applies to the PSIC for all hazardous substances.* The effect of this recommendation on the Mn PSIC values is shown in **Attachment A**.

C. Recommendation Concerning the Source Area Size Determination

Contact Person: Divinia Ries, RRD

BACKGROUND

The SIC for volatiles (VSIC) and PSIC are derived using the series of equations for soil inhalation screening levels presented in the EPA SSG (EPA 1996). One of the inputs to the equation for calculating the volatilization or particulate emission factor is Q/C (DEQ 2007). The DEQ modeled Q/C values for different source sizes ranging from 400 square feet to 100 acres (R 299.5726(6)). The SIC values presented in the Part 201 criteria tables are calculated using a one-half acre source size Q/C of 82.33 g/m^2-s per kg/m^3. This Q/C value, derived using the ISCST3 dispersion model, is the current default only for the one-half acre source size-based PSIC. Applicable generic SIC values for other source sizes that are not one-half acre must be established for a facility by applying the appropriate source size modifier presented in the Source Size Modifier Table (R 299.5726(6)). To generate the applicable generic SIC, the one-half acre based PSIC value is multiplied by the modifier corresponding to the source size. When the source size falls between the sizes specified in R 299.5726(6), the modifier for the larger source size must be used. Additional Q/C values for 200 to 1,000 acres were later added for large contamination areas (DEQ 2007). A primary issue encountered when applying the modifier is determining how to establish the appropriate source size. Previously, an iterative process was used, but the iteration process (e.g., determining starting concentrations and when to end the iteration) and its application were confusing and greatly varied.

DISCUSSION

The Subcommittee assisted the RRD in defining the source size and the development of a method to establish source size in a consistent and efficient manner for a site or facility. This process involves the use of a screening level (SL) to identify the source of contamination areas. Briefly, a starting concentration for determining the contamination source area size, the SL is determined by adjusting the one-half acre residential source SIC value using the modifier for a 1,000 acre source, which is 0.35. The 1,000 acre-based SL value for Mn is 525 miligrams per kilogram (mg/kg), which is higher than the Mn statewide background concentration of 440 mg/kg. Next, the soil concentrations are compared to the SL to identify the source areas. The source area is defined as the contaminated area with soil concentration(s) exceeding the SL. The identified source areas are summed to determine the appropriate source area size. The modifier that corresponds to this source size, or the next higher source size, is used to modify the one-half acre Mn PSIC to establish the applicable generic Part 201 Mn PSIC for the site or facility. Refer to the SIC guidance document (DEQ 2007) for more source size application details and examples. A new Source Size Modifier Table using AERMOD model-based Q/Cs and more current meteorological data is also being proposed by the Subcommittee (see Section V.B.)

CONCLUSION AND RECOMMENDATION

Determination of the final applicable Mn PSIC value for a facility must include consideration for the areal extent of contamination, which is accomplished by use of a source size modifier. With the assistance of the Subcommittee, the RRD has revised and expanded the guidance for selection of the appropriate source size modifier. This modifier is applied directly to the PSIC to determine the final applicable PSIC for an individual facility. This guidance has been incorporated into the updated 2007 DEQ TSD-SIC guidance document. *This guidance applies to the PSIC for all hazardous substances.* The effects of several source size adjustments are shown in **Attachment A**.

D. Recommendation Concerning the 2-Fold Adjustment Factor

Contact Person: Robert Sills, AQD

BACKGROUND

The adjustment factor for peak particulate emissions and dispersion is discussed in the RRD TSD-SIC guidance document (DEQ 2007). An evaluation of the appropriateness of this adjustment factor in the Mn PSIC derivation is aided by a brief overview of the origin and basis for including this factor in the generic PSIC algorithm.

When the DEQ stakeholder workgroup originally developed the PSIC methodology in 1998 for application to a wide variety of substances, it was realized that there was an inconsistency regarding the averaging time for air impacts for some substances. While the vehicular erosion, wind erosion, and dispersion parameters of the methodology were designed to address long-term (annual) emissions and impacts, there were some health benchmark values for noncarcinogens (AQD ITSLs), which had short-term averaging times (1-hour, 8-hours, or 24-hours) rather than annual averaging times. The AQD utilizes averaging times, in association with the ITSL values, in evaluating the acceptability of emission impacts, establishing permitted emission limits, and interpreting air monitoring data. An inconsistency in the averaging times was problematic because the intention of the workgroup was to establish a methodology for deriving PSIC criteria which would be health protective, with the ITSLs (and their associated averaging times) serving as the basis for that level of protection for noncarcinogenic effects. A focus on only long-term (annual average) emissions and impacts raised the possibility that short-term peak impacts could exceed the ITSL concentration, even if the calculated annual average impact did not exceed the ITSL concentration. The workgroup considered various optional approaches to address this concern for short-term excursions above the annual average concentration. Most compelling were the available empirical data which indicated that monitored ambient air peak (90^{th} percentile) particulate (PM10) levels measured over 24-hour periods were roughly two-fold greater than annual average PM10 levels. Limited data also indicated that 1-hour and 8-hour peak levels were not substantially higher than 24-hour peak levels. Therefore, the workgroup incorporated into the generic methodology a two-fold adjustment factor. That adjustment to the particulate emission factor effectively reduced the PSIC values by one-half (50 percent). This adjustment was intended to be applied to all PSIC criteria for noncarcinogens with ITSLs with 1-hour, 8-hour, or 24-hour averaging times (DEQ 1998; RRD 2007). The purpose of the two-fold adjustment factor was to help ensure that annual average soil contaminant impacts to ambient air would not exceed ITSL concentrations which have short-term averaging times.

DISCUSSION

The AQD Mn ITSL of 0.05 μg/m^3 has a 24-hour averaging time. The ITSL is based on the RfC of the same value. The EPA assigns a daily dose-rate to reference doses (mg/kg-day), but they do not assign an averaging time to RfCs. Although the RfCs are intended to be protective for a lifetime of exposure, the EPA has not provided written guidance on assigning averaging times for various substances' RfCs. The Air Pollution Control Rules specify that ITSLs that are derived from RfCs and RfDs established by the EPA are assigned a 24-hour averaging time (R 336.1232(2)(b)). Therefore, air emission sources that are subject to the AQD, New Source Review permitting program, cannot cause incremental ambient air impacts exceeding the Mn ITSL of 0.05 μg/m^3 (24-hour average), for the emissions from a proposed *process*. The AQD, TU, has granted case-by-case exemptions from complying with the Mn ITSL (R 336.1226(d)) in cases where the *facility-wide* Mn emissions and impacts do not exceed 2 μg/m^3 (8-hour averaging time) or 0.05 μg/m^3 (annual averaging time). The value of 2 μg/m^3 was derived from the occupational exposure limit (200 μg/m^3, 8-hour time-weighted average) divided by an uncertainty factor of 100 (to account for intraspecies variability and differences in exposure duration). The purpose of that criterion (2 μg/m^3, 8-hour averaging time) is to help ensure protection of the general public from peak short-term exposures.

In practice, the EPA has directly compared RfCs to modeled annual average ambient air concentrations to evaluate their health significance, for Mn and other substances (e.g., National-Scale Air Toxics Assessment (NATA): http://www.epa.gov/ttn/atw/nata1999/). The EPA assessments of short-term ambient air impacts have generally utilized other health benchmarks intended for acute exposure scenarios (e.g., ATSDR acute MRLs or EPA Acute Exposure Guidance Limits (AEGLs)). Similarly, AQD (2005) directly compared annual average ambient air monitoring data for Mn to the ITSL (and RfC) value of 0.05 μg/m^3. For substances with California Relative Exposure Limits (RELs), ATSDR MRLs or EPA AEGL-1 values, the 24-hour monitoring results were compared to those short-term health protective benchmarks (DEQ, AQD 2005).

Consideration of the concern for environmental Mn exposures indicates that the critical (most sensitive) neurological effects have been associated with long-term exposure and chronic effects, rather than acute exposures (ATSDR 2000; EPA 1993). In order to compare the quantitative differences between the acute and chronic dose-response relationships, it would be desirable to compare health protective benchmark values for the different exposure durations. Unfortunately, there is no ATSDR acute MRL, California REL, or EPA AEGL for Mn. The U.S. Department of Energy has established a temporary emergency exposure limit (TEEL-0) of 0.4 mg/m^3 for Mn chloride, and 0.3 mg/m^3 for Mn dioxide; the TEEL-0 is the threshold concentration below which most people will experience no appreciable risk of health effects in emergency response scenarios. For occupational settings, the American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value – time weighted average (TLV-TWA) of 200 µg/m^3 for Mn and inorganic Mn compounds; National Institute for Occupational Safety and Health has set the REL-TWA at 1000 µg/m^3 and short-term exposure limit (15-minute TWA) at 3000 µg/m^3 for Mn compounds; and the Occupational Safety and Health Administration has established a permissible exposure ceiling limit at 5000 µg/m^3 for Mn compounds. These may be compared to the EPA RfC of 0.05 µg/m^3. As previously noted, the AQD has utilized a criterion of 2 µg/m^3 (8-hour averaging time) for determining the approvability of facility-wide Mn emissions and impacts, coupled with a criterion of 0.05 µg/m^3 (annual averaging time).

CONCLUSION AND RECOMMENDATION

Based on a review of the available toxicity information and health protection benchmarks, protection against the chronic neurological effects of exposure to Mn in airborne soil particulate appears to provide adequate protection from potential acute effects of Mn (assuming that peak 24-hour levels may be twice as high as annual average levels). Therefore, it is recommended that the current two-fold adjustment factor in the derivation of the Mn PSIC value should be eliminated on the basis that it does not appear to be necessary to ensure health protection for short-term peak levels relative to annual average levels. *This recommendation applies to the PSIC for Mn only.* The effect of this recommendation on the Mn PSIC values is shown in **Attachment A** of this report.

E. Recommendation Concerning Ev

Contact Person: Kay Fritz, WHMD

BACKGROUND

The PSIC is derived using the series of equations presented in the EPA SSG (EPA 1996). One of the factors that makes the DEQ PEF different from the PEF values for EPA regions and other states is the average annual emissions due to Ev. Calculation of the Ev is based on an equation found in Section 13.2.2, Fugitive Dust Sources – Unpaved Roads, EPA Compilation of Air Pollutant Emission Factors (AP-42). The Ev is derived using a size-specific emission factor for vehicle traffic on unpaved roads. The principal pollutant of interest is particulate matter no greater than 10 micrometers in aerodynamic diameter (PM10). Therefore the E10 is expressed as kilogram PM10 per vehicle-kilometer travel (VKT). The final Ev value is expressed as grams per meter squared-second, and is based on the E10 multiplied by the calculated residential and industrial VKT for a one-half acre source area size, passenger vehicle weight (2 Mg, about two tons), and 10 and 50 round trips, respectively.

Section 13.2.2 of AP-42 was updated in 2003; the update contains two equations, one for unpaved surfaces at industrial sites (Equation 1a), and one for publicly accessible unpaved roads dominated by light duty vehicles (Equation 1b). Additionally, a 2006 Paved Roads

Section (13.2.1) has been added in AP-42, which contains an emission equation for paved roads (Equation 1). The 1995 unpaved road equation, the 2003 unpaved road equations, and the paved road equation, are shown in **Attachment F**.

DISCUSSION

The present Ev values use the 1995 unpaved roads equation and the assumption that vehicles at the facility are two-ton passenger vehicles only. At facilities where trucks and other heavy equipment are expected to be present, the DEQ recommends that professional judgment be used for adjusting the Ev value for facilities where the generic assumptions (e.g., passenger vehicles and 50 round trips per day for industrial facilities) will not apply to the site-specific scenario. As an example, a site having contaminated roadways with heavy truck traffic would require a site-specific assessment of Ev and site-specific PSIC development to ensure protection of soil inhalation health effects.

Several different options for incorporating the new equations, or “best available information” (R 299.5701c), to the derivation of the Ev were explored by the Subcommittee:

1. The 2003 unpaved roads equations could be substituted for the present 1995 one: Equation 1b for residential scenarios, and Equation 1a for commercial and industrial scenarios. However, Equation 1a may not be suitable for the commercial scenario.

2. The 2003 unpaved roads equations could be substituted for the present 1995 one: Equation 1b for residential and commercial scenarios, and Equation 1a for industrial scenarios. This will require separating the commercial and industrial PSIC in the Part 201 criteria tables instead of combining them.

3. The 2003 unpaved equation, plus the new paved road equation, could be incorporated to calculate the E10. This would add more complexity, plus the commercial and industrial PSIC values would need to be separated in the Part 201 criteria tables instead of combined.

4. Generic residential PSIC only could be established and commercial and industrial sites could be evaluated using site-specific PSIC, based on a site-specific Ev. This option is consistent with the handling of this pathway by EPA Regions 3, 6, and 9 and Florida and Wisconsin. This option would add more complexity, plus all nonresidential cleanup criteria would be site-specific.

CONCLUSION AND RECOMMENDATION

The new AP-42 unpaved road equations and the new equation for paved roads should replace the present equations to ensure that the “best available information” (R 299.5701c) is used in deriving the ambient air inhalation criteria. Several options to update the Ev for the PSIC are presented. All of the presented options incorporate the best available information; however, these options have disadvantages also. It is recommended that one of the four options, a combination of two or more, and/or an option not listed, is chosen to update the Ev portion of the PSIC. *This recommendation applies to the PSIC for all hazardous substances.* The effect of this recommendation on the Mn PSIC values is shown in **Attachment A** of this report.

F. Recommendation Concerning the RSC Factor

Contact Person: Kay Fritz, WHMD

BACKGROUND

The RSC is defined in R 299.5703(d) as the portion of a person's total daily intake of a noncarcinogenic hazardous substance that comes from the medium being addressed by the cleanup criterion. Mn is a Class D human carcinogen ("not classifiable") (EPA 1993); however, for the purposes of developing Part 201 cleanup criteria Mn is categorized as a noncarcinogen, since the ITSL for Mn is based on its neurological effects (neurobehavioral function).

The potential need for an RSC for the Mn PSIC was identified by air monitoring data showing elevated levels of airborne Mn in the Detroit area: The cities of Dearborn, Detroit, and River Rouge have had detections of annual mean exceedances of the EPA RfC of 0.05 $\mu g/m^3$, and Allen Park has had detections of annual mean concentrations around 60 percent of the ITSL (**Attachments G and H** of this report).

DISCUSSION

Inclusion of an RSC in the Part 201 Mn PSIC algorithm would allow for consideration of the Mn already in air in this area from sources other than soil. The net effect would be a reduction in the total amount of Mn in air (airborne Mn plus Mn becoming airborne from soil), by reducing the allowable amount of airborne Mn coming from soil. The purpose of such a modification of the Mn PSIC would be to avoid exceedences of the ITSL.

Currently, an RSC is only included in the equations for drinking water and soil direct contact. It would be appropriate to include this factor in the other media pathway equations for noncarcinogenic effects for the following pathways: groundwater contact, groundwater volatilization to indoor air, soil volatilization to indoor air, soil volatilization to ambient air, and particulate soil inhalation. The RSC term is not in the EPA guidance equations since the EPA programs require multipathway risk analyses for risk assessment decisions. Part 201 had recognized the need to account for multipathway exposures in single pathway equations through the use of an RSC. However, for new pathways developed after the 1995 amendments, this need was overlooked, even though Section 20120a(4) states, in part:

> For the noncarcinogenic effects of a hazardous substance present in soils, the intake shall be assumed to be 100 percent of the protective level, unless compound and site-specific data are available to demonstrate that a different source contribution is appropriate.

Section 20120a(4) does not limit application of the RSC to only the soil direct contact pathway. The other soil pathways could include an RSC with a default of 100 percent or 1, with the option of substituting a different value when compound and site-specific data support using a more appropriate (lesser) RSC. Consideration of RSC additions to equations for other pathways is advised as part of the current Part 201 Program Redesign effort; however, authority to add this factor as needed already exists under the provisions of R 299.5532(9) and R 299.5706a(9)(a)(iv).

Additionally, pursuant to R 299.5736(2) and R 299.51005(2), the Part 55, Air Pollution Control, Rules are also relevant for management of hazardous substances. R 336.1228 allows consideration of requiring a lower air toxicant emission rate than that associated with the screening level, if needed, in order to ensure adequate protection of human health or the environment. Although the DEQ has not used this rule to actually require a lower emission rate, it has been used by the AQD as the authority to do multipathway risk assessments or cumulative risk assessments. Cumulative risk assessments may include accounting for background sources of exposure. Although, technically, it is not an RSC approach, it is a more inclusive exposure and risk assessment to better ensure that the risk characterization more fully accounts for total exposure and risk rather than focusing on just one compound at a time and just the specific emission source's (e.g., one stack) ambient air impact.

CONCLUSION AND RECOMMENDATION

The purpose of adding an RSC factor to the Mn PSIC for facilities in the Detroit area would be to avoid exceedences of the ITSL. Detroit area air monitoring data show Mn relatively elevated in comparison to other data (in some cases, exceeding the ITSL) in ambient air on a yearly basis. The addition of an RSC factor to the Mn PSIC algorithm for facilities in the Detroit area would account for airborne Mn coming from sources other than soil. This is necessary to adequately protect public health from the neurological effects of Mn toxicity from inhalation of ambient air. Thus, the recommendation from the Subcommittee is for further evaluation of the addition of appropriate RSC(s) to the Mn PSIC for facilities in the Detroit area, both for present criteria development and also for inclusion in the Part 201 Program Redesign. *Presently this recommendation applies to the PSIC for Mn in the Detroit area only; however, the Subcommittee also recommends the RSC issue be included for consideration in the Part 201 Program Redesign.*

G. Comparison of Michigan's Mn PSIC with Other States and EPA Regions

Contact Person: Divinia Ries, RRD

BACKGROUND

The Michigan generic soil to ambient air inhalation cleanup criteria for soil contaminants are established using algorithms presented in the EPA SSG (EPA 1996). Other states and the EPA regional agencies have, similarly, developed cleanup levels for screening soil contamination using the SSG equations. The Michigan generic PSIC value for Mn has been considered by some as being overly-stringent compared to cleanup levels generated by the EPA and other states. Therefore, a comparison of the Michigan generic PSIC to the soil to ambient air inhalation cleanup values developed by the EPA and other states is warranted.

The EPA Regions, neighboring states, and distant states were investigated to determine their contaminant cleanup values for the soil to ambient air inhalation pathway. Neighboring states were identified as Indiana, Illinois, Minnesota, Ohio, and Wisconsin. Distant states were California, Florida, New York, Texas, and West Virginia. EPA Regions 3, 6, and 9 were also included in this investigation. Information regarding the EPA and other agencies' SLs, plus their assumptions and inputs, for deriving Mn cleanup levels in soil are summarized in Tables 1 and 2 (Appendix A of **Attachment I** of this report**)**. Detailed explanations of the 1996 SSG algorithms and how the Michigan PSIC, other states' soil Mn values, and the EPA regional screening levels, were calculated and applied, are presented in **Attachment I** of this report.

DISCUSSION

<u>EPA Regional Cleanup Values</u>
EPA Regions 3, 6, and 9 recently (EPA 2008) agreed to update their separate cleanup tables into one shared by all three regions. The common cleanup levels are referred to as "Regional

Screening Levels for Chemical Contaminants at Superfund Sites" (The remaining EPA Regions do not have regional cleanup values). The Regional soil Mn cleanup value for residential land use is 1,800 mg/kg or parts per million (ppm), which is more stringent than Michigan's 3,300 ppm; however, the Regional cleanup value addresses soil direct contact (multipathway) exposures. The Regional Mn SL calculated for the residential inhalation pathway alone is 71,000 ppm. The Regional direct contact cleanup value for industrial land use is 23,000 ppm, and the inhalation pathway only SL is 300,000 ppm, while Michigan's is 1,500 ppm. The Regional soil Mn Inhalation cleanup values are clearly less stringent than Michigan's.

<u>Other States' Mn Cleanup Values</u>
The neighboring states, Illinois, Indiana, Ohio, Minnesota, and Wisconsin (Region 5) have different cleanup numbers than Regional and Michigan (see table below). Some inhalation cleanup values (e.g., Indiana) are estimated using the state's PEF and their algorithm for deriving the inhalation component of the cleanup number. The residential soil Mn cleanup values in these neighboring states range from 180 – 82,100 ppm. For industrial land use, the range of soil Mn cleanup values is 1,900 – 124,000 ppm. Ohio's cleanup levels of 180 and 1,900 ppm for residential and industrial, respectively are low since it used an adjusted pre-2008 EPA Region 9 preliminary remediation goals (PRGs). For non-carcinogens, Ohio divides the PRGs by 10 to consider effects from multi-contaminant exposures. Except for Ohio's low values, the soil Mn health risk cleanup levels of neighboring states are higher than Michigan.

The distant states reviewed, likewise, have varying cleanup numbers; however, these numbers address multi-route exposure; no value for the inhalation pathway alone was found on their Web sites. California, in Region 9, does not have a SL for soil Mn; California does have a provision to substitute naturally occurring Mn concentration on a site-specific basis. Florida's, in Region 4, soil cleanup target level for Mn is listed at 3,500 ppm for residential and 43,000 ppm for industrial. Florida recommends development of a site-specific PEF where dust emissions from traffic or mechanical disturbances are likely. The soil Mn multi-route cleanup levels for New York, Region 2, Texas, Region 6, and West Virginia, Region 3, are shown below. West Virginia's residential use cleanup concentration is identical to the Regional number; however, its concentration for industrial use is higher.

The differences between the Michigan, Regional, and states cleanup values for Mn arise mainly from the following:

1) The Regional and states cleanup levels use a higher PEF, which is calculated from a higher Q/C factor and a lower Ew factor and do not include emissions due to Ev and a PEF adjustment factor of 2. It must be noted, however, that the EPA and many of the states recommend modification of the PEF by changing the Q/C value for other (larger) source sizes, and that dust emissions from traffic or mechanical disturbances are recommended to be included for a site-specific PEF. These modifications would decrease the Mn cleanup number for industrial and/or residential land use.

2) The Regional and state derivations use different assumptions (e.g., lower target hazard quotient of 0.1 (Michigan is 1.0) and lower reference concentration) that can contribute to a lower cleanup value; however, their PEF value is so much higher than Michigan that the end result is still a cleanup value higher than Michigan's.

Mn Cleanup Values* in mg/kg

EPA and States	Inhalation pathway only		Multi-pathway	
	Residential	*Industrial*	*Residential*	*Industrial*
Michigan PSIC	**3,300**	**1,500**		
EPA Regions 3, 6 and 9 Screening Level (SL)	71,000[a]	300,000[a]	1,800[b]	23,000[b]
Illinois Soil Remediation Objective	69,000	91,000		
Indiana Closure Level	78,000 (est.)[c]		30,000 (est.)[c]	
Ohio (VAP)[d] standard	82,100 (est.)[d]	124,000 (est.)[d]		
Ohio (RRP)[e] Cleanup Level			180[e]	1,900[e]
Minnesota Soil Reference Value	12,000 (est.)[f]	8,430 (est.)[f]	1,400 (oral)[f]	5,600 (oral; inhalation)[f] (5-acre)*
Wisconsin Residual Contaminant Level	7,400[g]	52,000[g]		
California Human Health SL			No value for Mn	No value for Mn
Florida Soil Cleanup Target Levels			3,500	43,000
New York Soil Cleanup Objectives			2,000	10,000
Texas Protective Concentration Levels			3,700	36,000
West Virginia Uniform Risk Based Standards			1,800	47,000

* Values are intended for a one-half acre source area size unless indicated.
[a] Particulate Inhalation component of the Direct Contact SL algorithm
[b] Direct Contact SL – includes ingestion, dermal, and inhalation pathways
[c] IN does not have cleanup value for Mn. This estimate used the algorithm and assumptions for other non-carcinogen chemicals. IN calculates Direct Contact cleanup values, which cover oral, dermal, and inhalation pathways
[d] OH Voluntary Action Program (VAP) use Direct Contact standards; the standard for Mn is not available at this time. Estimate used algorithm and inputs required for the inhalation pathway only.
[e] OH Remedial Response Program (RRP) CL uses EPA Preliminary Remediation Goals (PRGs). The final CL for Mn is the PRG value divided by 10. The current industrial Mn SL reflects the pre-2008 EPA PRG for Mn.
[f] MN inhalation estimates used the EPA default assumptions and PEF for Mn. The oral (ingestion) pathway cleanup value is the driving cleanup level for residential sites.
[g] WI plugs its default assumptions into the EPA web calculator to derive its Mn RCL.

Modifying Factors

As noted above, several governmental entities have provisions for modifying the soil Mn cleanup numbers listed. EPA Regions 3, 6, and 9, and Illinois, Texas, and Wisconsin allow for source size adjustment using the Q/C factor. EPA Regions 3, 6, and 9, and Florida and Wisconsin recommend development of site-specific PEF for sites where dust emissions from traffic or mechanical disturbances are likely. In most cases these modifications will have a net effect of reducing the initial soil cleanup value.

CONCLUSION AND RECOMMENDATION

All of the EPA Regions, five neighboring states, and five distant states that were investigated showed varying cleanup concentrations for soil Mn for the particulate inhalation exposure pathway. The Michigan Ev factor and PEF adjustment contributed greatly to the lowering of the PSIC, making it more stringent than that of the EPA and other states. However, the generic PSIC should consider all possible exposure conditions where emissions of soil contaminants could be increased (e.g., increased emissions generated by vehicular traffic on unpaved roads) to adequately protect human health. Therefore, the Subcommittee recommends that the Ev factor remain in the generic PSIC algorithm and inputs to the Ev be studied further. The modification of the Q/C and consequently the PSIC value based on source size, including the modification process, are appropriate.

VI. REFERENCES *(additional references are listed in Attachment C)*

ATSDR. 2000. Toxicological Profile for Manganese.

ATSDR. Toxicological Profile for Manganese – Update (Draft). October 2008. http://stacks.cdc.gov/view/cdc/5167/

EPA (Environmental Protection Agency). 1993. Integrated Risk Information System – Manganese (CASRN 7439-96-5): Reference Concentration for Chronic Inhalation Exposure (RfC). Last revised 12/1/1993. http://www.epa.gov/ncea/iris/subst/0373.htm

EPA (Environmental Protection Agency), Office of Air Quality Planning and Standards. 1995. Compilation of Air Pollution Emission Factors. Volume I: Stationary Point and Area Sources. AP-42: Fifth Edition.

EPA (Environmental Protection Agency). 1996. Soil Screening Guidance.

EPA (Environmental Protection Agency. Accessed December 29, 2008. Integrated Risk Information System (IRIS), Glossary/Acronyms & Abbreviations. http://www.epa.gov/ncea/iris/help_gloss.htm

DEQ. August 31, 1998. Part 201 Generic Soil Inhalation Criteria for Ambient Air: Technical Support Document. Environmental Response Division.

DEQ. November 29, 2006. Toxics Steering Group Subcommittee for the Application of the Manganese Particulate Soil Inhalation Criteria in the Detroit Area: Scope of Work.

DEQ. January 19, 2007. Letter to OEI Docket, U.S. EPA, re Docket ID No. EPA-HQ-ORD-2006-0950.

DEQ-AQD. 2002. Procedures for Developing Screening Levels. http://www.michigan.gov/documents/deq/deq-aqd-toxics-slprocede_249641_7.pdf

DEQ-AQD. 2005. Detroit Air Toxics Initiative Risk Assessment Report.

DEQ-RRD. 2007. Operational Memorandum No. 1. Technical Support Document – Attachment 7, Part 201 Generic Soil Inhalation Criteria for Ambient Air, Part 213 Tier 1 Soil Inhalation Risk-Based Screening Levels for Ambient Air.

VII. ATTACHMENTS

ATTACHMENT A. Effect of the recommendations of the Subcommittee on the Mn PSIC values.

	Generic Mn PSIC for one-half acre source	Particulate Emission Factor of a one-half acre source	Dispersion Factor	Emission due to Wind erosion	Emission due to Vehicle traffic
Unpaved Residential*	**Mn PSIC ppm**	**PEF*** **	**Q/C**	**Ew**	**Ev**
Current	3,300	1.28E+08	82.33	5.50E-07	3.68E-07
Current with proposed Q/C and Ew	3,700	1.43E+08	62.27	1.37E-07	3.68E-07
Current with proposed Q/C and Ew, and proposed PEF not divided by 2	7,400	1.43E+08	62.27	1.37E-07	3.68E-07
Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, and unpaved public Ev equation	**8,600**	1.65E+08	62.27	1.37E-07	3.10E-07
Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved public Ev equation, and source area size of 100 sq. ft.)	**(36,000)**	1.65E+08	62.27	1.37E-07	3.10E-07
Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved public Ev equation, and source area size of 1,500 acres)	**(2,500)**	1.65E+08	62.27	1.37E-07	3.10E-07
Paved Residential*					
Paved public Ev equation (least silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	47,000	9.09E+08	62.27	1.37E-07	(zero)
Paved public Ev equation (mean silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	24,000	4.54E+08	62.27	1.37E-07	6.88E-08
Paved public Ev equation (most silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	18,000	3.53E+08	62.27	1.37E-07	1.08E-07
Unpaved Commercial*					
Current	1,500	3.95E+07	82.33	5.50E-07	1.81E-06
Current with proposed Q/C and Ew	1,200	3.31E+07	62.27	1.37E-07	1.81E-06
Current with proposed Q/C and Ew, and proposed PEF not divided by 2	2,500	3.31E+07	62.27	1.37E-07	1.81E-06
Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, and unpaved public Ev equation	**2,900**	3.90E+07	62.27	1.37E-07	1.53E-06
(Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved public Ev equation, and source area size of 100 sq. ft.)	**(12,000)**	3.90E+07	62.27	1.37E-07	1.53E-06
(Proposed with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved public Ev equation, and source area size of 1,500 acres)	**(840)**	3.90E+07	62.27	1.37E-07	1.53E-06

Paved Commercial*	Generic Mn PSIC for one-half acre source	Particulate Emission Factor of a one-half acre source	Dispersion Factor	Emission due to Wind erosion	Emission due to Vehicle traffic
Paved public Ev equation (least silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	68,000	9.09E+08	62.27	1.37E-07	(zero)
Paved public Ev equation (mean silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	11,000	1.52E+08	62.27	1.37E-07	3.40E-07
Paved public Ev equation (most silt loading) with proposed Q/C and Ew and proposed PEF not divided by 2	7,700	1.03E+08	62.27	1.37E-07	5.34E-07
Unpaved Industrial					
Current*	1,500	3.95E+07	82.33	5.50E-07	1.81E-06
Current* with proposed Q/C and Ew	1,200	3.31E+07	62.27	1.37E-07	1.81E-06
Current* with proposed Q/C and Ew, and proposed PEF not divided by 2	2,500	3.31E+07	62.27	1.37E-07	1.81E-06
Current* with proposed Q/C and Ew, proposed PEF not divided by 2, and unpaved industrial Ev equation	1,500	2.03E+07	62.27	1.37E-07	3.00E-06
Proposed** with proposed Q/C and Ew, proposed PEF not divided by 2, and unpaved industrial Ev equation	**220********	3.00E+06	62.27	1.37E-07	2.07E-05
(Proposed** with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved industrial Ev equation, and source area size of 100 sq. ft.)	**(930)**	3.00E+06	62.27	1.37E-07	2.07E-05
(Proposed** with proposed Q/C and Ew, proposed PEF not divided by 2, unpaved industrial Ev equation, and source area size of 1,500 acres)	**(64)********	3.00E+06	62.27	1.37E-07	2.07E-05

*The Ev value assumes that vehicles at the facility are passenger automobiles (2 tons).
**The Ev value assumes a mid-range vehicle weight for industrial sites (146 tons).
***PEF = (Q/C) x 1/[(Ew x (1-V)) + Ev]
****This criterion would default to background (440 ppm)

ATTACHMENT B. Some selected surficial Mn soil concentrations in the Detroit area. Blue dots represent areas where samples were below background Mn soil concentration. Green dots represent areas where samples were above background, but below industrial Mn soil concentration for one-half acre (1,500 ppm Mn). Yellow dots represent areas where samples were above industrial, but below residential Mn soil concentration for one-half acre (3,300 ppm Mn). Red dots represent areas where samples were above residential Mn soil concentration for one-half acre (3,300 ppm Mn).

ATTACHMENT C. Documents reviewed by MDEQ and MDCH for the ITSL evaluation.

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for manganese. Atlanta: US Department of Health and Human Services; 2000 Sept. (no longer available on-line)

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for manganese – draft update. Atlanta: US Department of Health and Human Services; 2008 Oct. http://stacks.cdc.gov/view/cdc/5167/

Alberta Environment. Assessment report on manganese for developing ambient air quality objectives. Prepared by WBK & Associaties, Inc. Pub. No. T/775. November 2004. http://environment.gov.ab.ca/info/library/6679.pdf

American Conference of Governmental Industrial Hygienists (ACGIH). 2001. Manganese and Inorganic Compounds. Threshold Limit Value – Time Weighted Average (TLV-TWA) document.

Andersen ME, JM Gearhart, and HJ Clewell III. 1999. Pharmacokinetic data needs to support risk assessments for inhaled and ingested manganese. Neurotoxicology 20(2-3):161-172.

Aschner M, Erikson KM, Dorman DC. 2005. Manganese dosimetry: species differences and implications for neurotoxicity. Critical Reviews in Toxicology 35:1-32.

Aschner M, Vrana KE, Zheng W. 1999. Manganese uptake and distribution in the central nervous system. Neurotoicology 20(2-3):173-180.

Baldwin M, Mergler D, Larribe F, Belanger S, Tardif R, Bilodeau L, Hudnell K. 1999. Bioindicator and exposure data for a population based study of manganese. Neurotoxicology 20(2-3): 343-354.

Bast-Pettersen R; Ellingsen DG; Hetland SM, Thomassen Y. 2004. Neuropsychological function in manganese alloy plant workers. Int Arch Occup Environ Health 77: 277-287.

Beuter A; Edwards R; DeGeoffroy A; Mergler D, Hudnell K. 1999. Quantification of neuromotor function for detection of the effects of manganese. Neurotoxicology 20(2-3): 355-366.

Boojar MMA, Goodarzi F. 2002. A longitudinal follow-up of pulmonary function and respiratory symptoms in workers exposed to manganese. J Occup Environ Med 44:282-290.

Bouchard M, Laforest F, Vandelac L, Bellinger D, Mergler D. 2006. Hair manganese and hyperactive behaviors: pilot study of school-age children exposed through tap water. Environ Health Perspect 115(1):122-127.

Bouchard M, Mergler D, Baldwin ME, Panisset M. 2008. Manganese cumulative exposure and symptoms: a follow-up study of alloy workers. Neurotoxicology (in press). doi:10.1016/j.neuro.2008.04.013

Bowler RM, Gysens S, Diamond E, Nakagawa S, Drazgic M, Roels HA. 2006. Manganese exposure: neuropsychological and neurological symptoms and effects in welders. Neurotoxicology 27:315-326.

Bowler RM, Mergler D, Sassine M-P, Larribe F, Hudnell K. 1999. Neuropsychiatric effects of manganese on mood. Neurotoxicology 20(2-3):367-368.

Bowler RM, Nakagawa S, Drezgic M, Roels HA, Park RM, Diamond E, Mergler D, Bouchard M, Bowler RP, Koller W. 2007. Sequelae of fume exposure in confined space welding: a neurological and neuropsychological case series. Neurotoxicology 28:298-311.

Bowler RM, Roels HA, Nakagawa S, Drezgic M, Diamond E, Park R, Koller W, Bowler RP, Mergler D, Bouchard M, Smith D, Gwiazda R, Doty RL. 2007. Dose-effect relationships between manganese exposure and neurological, neuropsychological and pulmonary function in confined space bridge welders. Occup Environ Med 64:167-177.

Brenneman KA, Wong BA, Buccellato MA, Costa ER, Gross EA, Dorman DC. 2000. Direct olfactory transport of inhaled manganese ($^{54}MnCl_2$) to the rat brain: toxicokinetic investigations in a unilateral nasal occlusion model. Toxicol Appl Pharmacol 169:238-248.

California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA). **Manganese and Compounds Reference Exposure Levels – Technical Support Document. December 2008.**

Chia SE, Foo SC, Gan SL, Jeyaratnam J, Tian CS. 1993. Neurobehavioral functions among workers exposed to manganese ore. Scand J Work Environ Health 19:264-70.

Clewell HJ, Lawrence GA, Calne DB, Crump KS. 2003. Determination of an occupational exposure guideline for manganese using the benchmark method. Risk Analysis 23(5): 1031-1046.

Crump KS, Rousseau P. 1999. Results from eleven years of neurological health surveillance at a manganese oxide and salt producing plant. Neurotoxicology 20(2-3): 273-286.

Davis JM. 1999. Inhalation health risks of manganese: an EPA perspective. Neurotoxicology 20(2-3): 511-518.

Deschamps JF, Guillaumot M, Raux S. 2001. Neurological effects in workers exposed to manganese. J Occup Environ Med 43(2):127-132.

Dorman DC, Brenneman KA, McElveen AM, Lynch SE, Roberts KC, Wong BA. 2002. Olfactory transport: a direct route of delivery of inhaled manganese phosphate to the rat brain. J. Toxicol. Environ. Health A. 65(20):1493-1511.

Dorman DC, McElveen AM, Marshall MW, Parkinson CU, James RA, Struve MF, Wong BA. 2004. Maternal-fetal distribution of manganese in the rat following inhalation exposure to manganese sulfate. Neurotoxicology 26:625-632.

Dorman DC, McElveen AM, Marshall MW, Parkinson CU, James RA, Struve MF, Wong BA. 2005. Tissue manganese concentrations in lactating rats and their offspring following combined *in utero* and lactation exposure to inhaled manganese sulfate. Toxicol Sciences 84:12-21.

Dorman DC, Struve MF, Clewell III HJ, Andersen ME. 2006. Application of pharmacokinetic data to the risk assessment of inhaled manganese. Neurotoxicology 27:752-764.

Dorman DC, Struve MF, Gross EA, Wong BA, Howroyd PC. 2005. Sub-chronic inhalation of high concentrations of manganese sulfate induces lower airway pathology in rhesus monkeys. Respiratory Research 6:121.

Dorman DC, Struve MF, James RA, Marshall MW, Parkinson CU, Wong BA. 2001. Influence of particle solubility on the delivery of inhaled manganese to the rat brain: manganese sulfate and manganese tetroxide pharmacokinetics followed repeated (14-day) exposure. Toxicol App Pharmacol 170:79-87.

Dorman DC, Struve MF, Wong BA. 2001. Pharmacolkinetic factors that influence manganese delivery to the brain. CIIT Activities 21(7-8): July-August.

Elder A, Gelein R, Silva V, Feikert T, Opanashuk L, Carter J, Potter R, Maynard A, Ito Y, Finkelstein J, Oberdöster G. 2006. Translocation of inhaled ultrafine manganese oxide particles to the central nervous system. Environ Health Perspect 114:1172-1178.

Elsner RJ, Spangler JG. 2005. Neurotoxicity of inhaled manganese: public health danger in the shower? Med Hypotheses 65(3):607-16.

EPA Toxicity and Exposure Assessment for Children's Health (TEACH). Chemical summary for manganese. Last revised 10/29/2007.

Erikson KM, Dorman DC, Lash LH, Aschner M. 2005. Persistent alterations in biomarkers of oxidative stress resulting from combined *in utero* and neonatal manganese inhalation. Biol Trace Element Res 104:151-163.

Erikson KM, Dorman DC, Lash LH, Ascher M. 2007. Manganese inhalation by Rhesus monkeys is associated with brain regional changes in biomarkers of neurotoxicity. Toxicol Sci 97(2):459-466.

Fechter LD. 1999. Distribution of manganese in development. Neurotoxicology 20(2-3): 197-202.

Fechter LD, Johnson DL, Lynch RA. 2002. The relationship of particle size to olfactory nerve uptake of a non-soluble form of manganese into brain. Neurotoxicology 23: 177-183.

Finley JW. 2004. Does environmental exposure to manganese pose a health risk to healthy adults? Nutrition Reviews 62(4): 148-153.

Gennart J-P, Buchet J-P, Roels H, Ghyselen P, Ceulemans E, Lauwerys R. 1992. Fertility of male workers epxosed to cadmium, lead, or manganeso. Amer J Epidemiol 135(11):1208-1219.

Gibbs, JP, Crump KS, Houck DP, Warren PA, Mosley WS. 1999. Focused medical surveillance: a search for subclinical movement disorders in a cohort of US workers exposed to low levels of manganese dust. Neurotoxicology 20(2-3):299-314.

Guilarte TR, Chen M-K, McGlothan JL, Verina T, Wong DF, Zhou Y, Alexander M, Rohde CA, Syversen T, Decamp E, Koser AJ, Fritz S, Gonczi H, Anderson DW, Schneider JS. 2006. Nigrostriatal dopamine system dysfunction and subtle motor deficits in manganese-exposed non-human primates. Experimental Neurology 202:381-390.

Guilarte TR, McGlothan JL, Degaonkar M, Chen M-K, Barrer PB, Syversen T, Schneider JS. 2006. Evidence for cortical dysfunction and widespread manganese accumulation in the nonhuman primate brain following chronic manganese exposure: a ^{1}H-MRS and MRI study. Toxicol Sciences 94(2):351-358.

Gwiazda R, Kern C, Smith D. 2005. Progression of neurochemical effects in different brain regions as a function of the magnitude and duration of manganese exposure. Toxicol Sci 84(1-S):122-123.

Gwiazda R, Lucchini R, Smith D. 2007. Adequacy and consistency of animal studies to evaluate the neurotoxicity of chronic low-level manganese exposure in humans. J Toxicol Environ Health, Part A, 70(7):594-605.

HaMai D, Rinderknecht AL, Guo-Sharman K, Kleinman MT, Bondy SC. 2006. Decreased expression of inflammation-related genes following inhalation exposure to manganese. Neurotoxicology 27:395-401.

He P, Liu D, Zhang G, Sun M. 1994. Effects of high-level manganese sewage irrigation on children's neurobehavior. Chinese J Prev Med 28(4):216-218.

Health Canada. Human health risk assessment for inhaled manganese: draft. Water, Air, and Climate Change Bureau. March 2008.

Heilig E, Molina R, Donaghey T, Brain JD, Wassling-Resnick M. 2005. Pharmacokinetics of pulmonary manganese absorption: evidence for increased susceptibility to manganese loading in irn-deficient rats. Am J Physiol Lung Cell Mol Physiol 288:L887-L893.

Henriksson J, Tallkvist J, Tjälve H. 1999. Transport of manganese via the olfactory pathway in rats: dosage dependency of the uptake and subcellular distribution of the metal in the olfactory epithelium and the brain. Toxicol Appl Pharmacol 156:119-128.

Henriksson J, Tjälve H. 2000. Manganese taken up into the CNS via the olfactory pathway in rats affects astrocytes. Toxicol Sciences 55:392-398.

Henry-Sam GA, Iszard MB. 2001. A comparative study of the reproductive toxicity of manganese in rats and mice. FASEB Journal 15(4):A585.

Hochberg F, Miller G, Valenzuela R, McNelis S, Crump KS, Covington T, Valdivia G, Hochberg B, Trustman JW. 1996. Late motor deficits of Chilean manganese miners: a blinded control study. Neurology 47:788-795.

Hudnell, HK. 1999. Effects from environmental Mn exposures: a review of the evidence from non-occupational exposure studies. Neurotoxicology 20(2-3): 379-398.

Institute for Environment and Health, Institute of Occupational Medicine. Occupational Exposure Limits: criteria document for manganese and inorganic manganese compounds. IEH Web Report W17. October 2004.

Iregren A. 1999. Manganese neurotoxicity in industrial exposures: proof of effects, critical exposure level, and sensitive tests. Neurotoxicology 20(2-3): 315-324.

Kusaka Y, Sato K, Suganuma N, Hosoda Y. 2001. Metal-induced lung disease: lessons from Japan's experience. J Occup Health 43:1-23.

Lauwerys R, Roels H, Genet P, Toussaint G, Bouckaert A, DeCooman S. 1985. Fertility in male workers exposed to mercury vapor or to manganese dust: a questionnaire study. Amer J Ind Med 7:171-176.

Leavens TL, Rao D, Andersen ME, Dorman DC. 2007. Evaluating transport of manganese from olfactory mucosa to striatum by pharmacokinetic modeling. Toxicol Sci 97(2):265-278.

Levy LS, Aitken R, Holmes P, Hughes J, Hurley F, Rumsby PC, Searl A, Shuker LK, Spurgeon A, Warren FC. 2004. The derivation of a health-based occupational exposure limit for manganese using human neurobehaviour/neurotoxicity data. Toxicology 202:133-134.

Lown BA, Morganti JB, D'Agostino R, Stineman CH, Massaro EJ. 1984. Effects on the postnatal development of the mouse of preconception, postconception and/or suckling exposure to manganese via maternal inhalation exposure to MnO_2 dust. Neurotoxicology 5(1):119-131.

Lucchini R, Apostoli P, Perrone C, Placidi D, Albini E, Migliorati P, Mergler D, Sassine M-P, Palmi S, Alessio L. 1999. Long term exposure to "low levels" of manganese oxides and neurofunctional changes in ferroalloy workers. Neurotoxicology 20(2-3):287-298.

Lucchini R, Selis L, Folli D, Apostoli P, Mutti A, Vanoni O, Iregren A, Alessio L. 1995. Neurobehavioral effects of manganese in workers from a ferroalloy plant after temporary cessation of exposure. Scand J Work Environ Health 21:143-149.

Mergler D. 1999. Neurotoxic effects of low level exposure to manganese in human populations. Environmental Research Section A 80: 99-102.

Mergler D, Baldwin M. 1997. Early manifestations of manganese neurotoxicity in humans: an update. Environmental Research 73: 92-100.

Mergler D, Baldwin M, Belanger S, Larribe F, Beuter A, Bowler R, Panisset M, Edwards R, DeGeoffroy A, Sassine M-P, Hudnell K. 1999. Manganese neurotoxicity, a continuum of dysfunction: results from a community based study. Neurotoxicology 20(2-3): 327-342.

Mergler D, Huel G, Bowler R, Iregren A, Belanger S, Baldwin M, Tardif R, Smargiassi A, Martin L. 1994. Nervous system dysfunction among workers with long-term exposure to manganese. Environmental Research 64: 151-180.

Myers JE, Thompson ML, Naik I, Theodorou P, Esswein E, Tassell H, Daya A, Renton K, Spies A, Paicker J, Young T, Jeebhay M, Ramushu S, London L, Rees DJ. 2003. The utility of biological monitoring for manganese in ferroalloy smelter workers in South Africa. Neurotoxicology 24: 875-883.

Myers JE, Thompson ML, Ramushu S, Young T, Jeebhay MF, London L, Esswein E, Renton K, Spies A, Boulle A, Naik I, Iregren A, Rees DJ. 2003. The nervous system effects of occupation exposure on workers in a South African manganese smelter. Neurotoxicology 24:885-894.

New York State Department of Environmental Conservation and New York State Department of Health. 2006. New York State Brownfield Cleanup Program. Development of Soil Cleanup Objectives. Technical Support Document. Available at http://www.dec.ny.gov/chemical/34189.html

Normandin L, Beaupré L, Salehi F, St.-Pierre A, Kennedy G, Mergler D, Butterworth RF, Philippe S, Zayed J. 2004. Manganese distribution in the brain and neurobehavioral changes following inhalation exposure of rats to three chemical forms of manganese. Neurotoxicology 25:433-441.

Normandin L, Carrier G, Gardiner PF, Kenndy G, Hazell AS, Mergler D, Butterworth RF, Philippe S, Zayed J. 2002. Assessment of bioaccumulation, neuropathology, and neurobehavior following subchronic (90 days) inhalation in Sprague-Dawley rats exposed to manganese phosphate. Toxicol Appl Pharmacol 183:135-145.

Normandin L, Panisset M, Zayed J. 2002. Manganese neurotoxicity: behavioral, pathological, and biochemical effects following various routes of exposure. Rev. Environ Health 17(3):189-217.

Ponnapakkam TP, Henry-Sam GA, Iszard MB. 2001. A comparative study of the reproductive toxicity of manganese in rats and mice. FASEB Journal 15(4):A585.

Reaney SH, Bench G, Smith DR. 2006. Brain accumulation and toxicity of Mn(II) and Mn(III) exposures. Toxicol Sciences 93(1):114-124.

Rindernecht A, McGregor J, Rouse-Ho A, Kleinman M. 2005. Environmental air pollution and *in utero* brain damage: maternal manganese (Mn) inhalation alters brain development and susceptibility to postnatal brain injury. Am J Obstet Gynecol 193(6(Suppl.)):S36.

Rodríguez-Agudelo Y, Riojas-Rodríguez H, Ríos C, Rosas I, Pedraza ES, Miranda J, Siebe C, Texcalac JL, Santos-Burgoa C. 2006. Motor alterations associated with exposure to manganese in the environment in Mexico. Science of the Total Environment 368:542-556.

Roels H, Lauwerys R, Buchet J-P, Genet P, Sarhan MJ, Hanotiau I, deFays M, Bernard A, Stanescu D. 1987. Epidemiological survey among workers exposed to manganese: effects on lung, central nervous system, and some biological indices. American Journal of Industrial Medicine 11: 307-327.

Roels HA, Ghyselen P, Buchet JP, Ceulemans E, Lauwerys RR. 1992. Assessment of the permissible exposure level to manganese in workers exposed to manganese dioxide dust. British Journal of Industrial Medicine 49: 25-34.

Roels HA, Ortega Eslava MI, Ceulemans E, Robert A, Lison D. 1999. Prospective study on the reversibility of neurobehavioral effects in workers exposed to manganese dioxide. Neurotoxicology 20(2-3): 255-272.

Roels HA, Meiers G, Delos M, Ortega I, Lauwerys R, Buchet JP, Lison D. 1997. Influence of the route of administration and the chemical form (MnCl2, MnO2) on the absorption and cerebral distribution of manganese in rats. Arch Toxicol 71:223-230.

Sahni V, Leger Y, Panaro L, Allen M, Giffin S, Fury D, Hamm N. 2007. Case report: a metabolic disorder presenting as paediatric mangansim. Environ Health Perspect 115:1776-1779.

Salehi F, Krewski D, Mergler D, Normandin L, Kennedy G, Philippe S, Zayed J. 2003. Bioaccumulation and locomotor effects of manganese phosphate/sulfate mixture in Sprague-Dawley rats following subchronic (90 days) inhalation exposure. Toxicol Appl Pharmacol 191:264-271.

Salehi F, Normandin L, Krewski D, Kennedy G, Philippe S, Zayed J. 2006. Neuropathology, tremor and electromyogram in rats exposed to manganese phosphate/sulfate mixture. J Appl Toxicol 26:419-426.

Santamaria AB, Cushing CA, Antonini JM, Finley BL, Mowat FS. 2007. State-of-the-science review: does manganese exposure during welding pose a neurological risk? J Toxicol Environ Health, Part B, 10:417-465.

Sassine M-P, Mergler D, Bowler R, Hudnell HK. 2002. Manganese accentuates adverse mental health effects associated with alcohol use disorders. Biol Psychiatry 51:909-921.

Schneider JS, Decamp E, Koser AM, Fritz S, Gonczi H, Syversen T, Guilarte TR. 2006. Effects of chronic manganese exposure on cognitive and motor functioning in non-human primates. Brain Res 1118(1):222-231.

Takser L, Lafond J, Bouchard M, St-Amour G, Mergler D. 2004. Manganese levels during pregnancy and at birth: relation to environmental factors and smoking in a southwest Quebec population. Environ Res 95:119-125.

Takser L, Mergler D, Hellier G, Sahuquillo J, Huel G. 2003. Manganese, monoamine metabolite levels at birth, and child psychomotor development. Neurotoxicology 24: 667-674.

Tapin D, Kennedy G, Lambert J, Zayed J. 2006. Bioaccumulation and locomotor effects of manganese sulfate in Sprague-Dawley rats following subchronic (90 days) inhalation exposure. Toxicol Appl Pharmacol 211:166-174.

Teeguarden JG, Dorman DC, Covington TR, Clewell III JH, Andersen ME. 2007. Pharmacokinetic modeling of manganese. I. Dose dependencies of uptake and elimination. J Toxicol Environ Health, Part A, 70(18):1493-1504.

Teeguarden JG, Dorman DC, Nong A, Covington TR, Clewell III HJ, Andersen ME. 2007. Pharmacokinetic modeling of manganese. II. Hepatic processing after ingestion and inhalation. J Toxicol Environ Health, Part A, 70(18):1505-1514.

Teeguarden JG, Gearhart J, Clewell III HJ, Covington TR, Nong A, Andersen ME. 2007. Pharmacokinetic modeling of manganese. III. Physiological approaches accounting for background and tracer kinetics. J Toxicol Environ Health, Part A, 70(18):1515-1526.

Tjalve H, Henriksson J. 1999. Uptake of metals in the brain via olfactory pathways. Neurotoxicology 20(2-3):181-196.

Torrente M, Colomina MT, Domingo JL. 2002. Effects of prenatal exposure to manganese on postnatal development and behavior in mice: influence of maternal restraint. Neurotoxicol Teratol 24:219-225.

U.S. Environmental Protection Agency (EPA). Integrated Risk Information System – Manganese (CASRN 7439-96-5): Reference Concentration for Chronic Inhalation Exposure (RfC). Last revised 12/1/1993.

Vitarella D, Wong BA, Moss OR, Dorman DC. 2000. Pharmacokinetics of inhaled manganese phosphate in male Sprague-Dawley rats following subacute (14-day) exposure. Toxicol Appl Pharmacol 163:279-285.

Weiss B. 1999. Manganese in the context of an integrated risk and decision process. Neurotoxicology 20(2-3):519-526.

Wirth JJ, Rossano MG, Daly DC, Paneth N, Puscheck E, Potter RC, Diamond MP. 2007. Ambient manganese exposure is negatively associated with human sperm motility and concentration. Epidemiology 18(2): 270-273.

Witholt R, Gwiazda RH, Smith DR. 2000. The neurobehavioral effects of subchronic manganese exposure in the presence and absence of pre-parkinsonism. Neurotoxicol Teratol 22:851-861.

Young T, Myers JE, Thompson ML. 2005. The nervous system effects of occupational exposure to manganese – measured as respirable dust – in a South African manganese smelter. Neurotoxicology 26:993-1000.

Yuan H, He S, He M, Niu Q, Wang L, Wang S. 2006. A comprehensive study on neurobehavior, neurotransmitters and lymphocyte subsets alteration of Chinese manganese welding workers. Life Sciences 78:1324-1328.

Zhang G, Liu D, He P. 1995. A preliminary study of the effect of manganese on learning abilities of primary school pupils. Chinese Journal of Preventive Medicine 29(3): 156-158.

ATTACHMENT D. Comparison of regulatory design concentrations – AERMOD vs. ISCST3, CTDMPLUS, ISC-PRIME.
USEPA Staff Report, Appendix A, June 2003. EPA_454/R_03_002

Table 1. Comparison of dispersion model features: AERMOD vs. ISCST3.

Feature	ISCST3	AERMOD (version 02222)	Comments
Types of sources modeled	sources	Same as ISCST3	Models are comparable
Plume Rise	Use Briggs equations with stack-top wind speed and vertical temperature gradient	In stable conditions, uses Briggs equations with winds and temperature gradient at stack top and half-way to final plume rise; in convective conditions, plume rise is superposed on the displacements by random convective velocities.	AERMOD is better because in stable conditions it factors in wind and temperature changes above stack top, and in unstable conditions it accounts for convective updrafts and downdrafts
Meteorological Data Input	One level of data accepted	An arbitrarily large number of data levels can be accommodated	AERMOD can adapt multiple levels of data to various stack and plume heights
Profiling Meteorological Data	Only wind speed is profiled	AERMOD creates profiles of wind, temperature, and turbulence, using all available measurement	AERMOD is much improved over ISCST3 in this area
Use of Meteorological Data in Plume Dispersion	Stack-top variables for all downwind distances	Variables measured throughout the plume depth (averaged from plume centerline to 2.15 sigma-z below centerline; changes with downwind distance)	AERMOD treatment is far more advanced than that of ISCST3; accounts for meteorological data throughout the plume
Plume Dispersion: General Treatment	Gaussian treatment in horizontal and vertical	Gaussian treatment in horizontal and in vertical for stable conditions; non-Gaussian probability density function in vertical for unstable conditions	AERMOD's unstable treatment of vertical dispersion is a more accurate portrayal of actual conditions
Urban Treatment	Urban option either on or off: no other specification available: all sources must be modeled either rural or urban	Population is specified, so treatment can consider a variety of urban conditions; sources can individually be modeled rural or urban	AERMOD provides variable urban treatment as a function of city population, and can selectively model sources as rural or urban
Characterization of Modeling Domain Surface Characteristics	Choice of rural or urban	Selection by direction and month of roughness length, albedo, and Bowen ratio, providing user flexibility to vary surface characteristics	AERMOD provides the user with considerably more options in the selection of the surface characteristics
Boundary Layer Parameters	Wind speed. mixing height, and stability class	Friction velocity, Monin-Obukhov length, convective velocity scale, mechanical and convective mixing height, sensible heat flux	AERMOD provides parameters required for use with up-to-date planetary boundary layer (PBL) parameterizations; ISCST3 does not
Mixed Layer Height	Holzworth scheme; uses interpolation based upon maximum afternoon mixing height.	Has convective and mechanical mixed layer height: convective height based upon hourly accumulation of sensible heat flux	AERMOD's formulation is significantly more advanced than that of ISCST3, includes a mechanical component, and in using hourly input data, provides a more realistic sequence of the diurnal mixing height changes

Feature	ISCST3	AERMOD (version 02222)	Comments
Terrain Depiction	Elevation at each receptor point	Controlling hill elevation and point elevation at each receptor, obtained from special terrain pre-processor (AERMAP) that uses digital elevation model (DEM) data	AERMOD's terrain pre-processor provides information for advanced critical dividing streamline height algorithms and uses digital data to obtain receptor elevations
Plume Dispersion: Plume Growth Rates	Based upon 6 discrete stability classes only: dispersion curves (Pasquill-Gifford) are based upon surface release experiments (e.g., Prairie Grass)	Uses profiles of vertical and horizontal turbulence (from measurements and/or PBL theory); variable with height; uses continuous growth functions rather than a discrete (stability-based) formulation	Use of turbulence-based plume growth with height dependence rather than that based upon stability class provides AERMOD with a substantial advancement over the ISCST3 treatment
Plume Interaction with Mixing Lid: convective conditions	If plume centerline is above lid, a zero ground-level concentration is assumed.	Three plume components are considered: a "direct" plume that is advected to the ground in a downdraft, an "indirect" plume caught in an updraft that reaches the lid and eventually is brought to the ground, and a plume that penetrates the mixing lid and disperses more slowly in the stable layer aloft (and which can re-enter the mixed layer and disperse to the ground)	The AERMOD treatment avoids potential underpredictions suffered by ISCST3 due to its "all or nothing" treatment of the plume; AERMOD's use of convective updrafts and downdrafts in a probability density function approach is a significant advancement over ISCST3
Plume Interaction with Mixing Lid: stable conditions	The mixing lid is ignored (assumed to be infinitely high)	A mechanically mixed layer near the ground is considered. Plume reflection from an elevated lid is considered.	AERMOD's use of a mechanically mixed layer is an advancement over the very simplistic ISCST3 approach
Building Downwash	Combination of Huber-Snyder and Scire-Schulman algorithms; many discontinuities	New PRIME downwash algorithm installed	AERMOD benefits from the technological advances offered by the PRIME model

ATTACHMENT E. Source size modifier table.

PSIC area source 90th percentile concentrations, Q/C's, and source size modifiers
AERMOD model
MidlandBayCitySaginaw (MBS) met data 2002-2006

Mean wind speed (m/s) @ 10.06 meters or 33 feet:

2002	4.39
2003	4.25
2004	4.25
2005	3.96
2006	3.96
average	**4.16**

source size	**90th percentile concentra-tion: C**	**Q**	**Q/C**	**modifier**
(sq. ft. or acres)	(ug/m3)	($0.001*10^9$)	(g/m^2-s kg/m^3)	
100 sq ft	2276.77	1000000	439.22	4.23
400 sq ft	5382.24	1000000	185.80	2.98
1000 sq ft	7900.83	1000000	126.57	2.03
2000 sq ft	9634.81	1000000	103.79	1.67
1/2 acre	16058.02	1000000	62.27	1.00
1 acre	18170.45	1000000	55.03	0.88
5 acres	23859.40	1000000	41.91	0.67
10 acres	26289.45	1000000	38.04	0.61
32 acres	31364.84	1000000	31.88	0.51
100 acres	37032.40	1000000	27.00	0.43
200 acres	40847.42	1000000	24.48	0.39
300 acres	43183.64	1000000	23.16	0.37
500 acres	46297.16	1000000	21.60	0.35
1000 acres	51319.68	1000000	19.49	0.31
1500 acres	54528.26	1000000	18.34	0.29

ATTACHMENT F. Unpaved and Paved Road Equations from AP-42.

1995 Equation :
(DEQ-RRD 2007)

$$E_{10} = k \times 1.7 \times (s/12) \times (S/48) \times (W/2.7)^{0.7} \times (w/4)^{0.5} \times ((365-p)/365)$$

where,

E_{10} = PM_{10} emissions per vehicle-kilometer of travel (VKT)
k = Particle size multiplier
s = Silt content of road surface material
S = Mean vehicle speed, (km/hr)
W = Mean vehicle weight (tons)
w = Mean number of wheels
p = Number of days with at least 0.254 mm (0.01 inch) of precipitation per year

....

2003 Equations: For vehicles traveling on unpaved surfaces at industrial sites:
(EPA 1995):

$$E = k \times (s/12)^a \times (W/3)^b \qquad (1a)$$

For vehicles traveling on publicly accessible roads, dominated by light duty vehicles:

$$E = \frac{k \times (s/12)^a \times (S/30)^d}{(M/0.5)^c} - C \qquad (1b)$$

where,

E = Emissions per vehicle-mile of travel (lb/VMT)

$k, a, b, c,$ and d = Empirical constants (Reference 6 in EPA 1995)
s = Silt content of road surface material (%)
S = Mean vehicle speed (mph)
W = Mean vehicle weight (tons)
M = Surface material moisture content (%)
C = Emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear

....

2006 Equation:
(EPA 1995)

The quantity of particulate emissions from resuspension of loose material on the road surface due to vehicle travel on a dry paved road: (1)

$$E = k\left(\frac{sL}{2}\right)^{0.65} \times \left(\frac{W}{3}\right)^{1.5} - C$$

where,

E = Particulate emission factor (having units matching the units of k)
k = Particle size multiplier for particle size range and units of interest
sL = Road surface silt loading (grams per square meter) (g/m2)
W = Average weight (tons) of the vehicles traveling the road
C = Emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear

ATTACHMENT G. Detroit area Mn air concentrations, based on EPA estimates (NATA; National-scale Air Toxics Assessment) and 2004-2005 monitoring data.

Data type	Data source	Location	Annual Mean [Mn] (ug/m3)	Maximum 24 hr level (ug/m3)
Emission inventory and modeling, 1999	USEPA NATA 1999 study	Wayne County	0.0045	N/A
Emission inventory and modeling, 1999	USEPA NATA 1999 study	Census tracts in Wayne County, 5th and 95th percentiles	0.0007 0.0098	N/A
Monitoring, 2004	AQD 2004 Annual Air Quality Report	Allen Park (TSP and PM2.5))	0.0334 (in TSP) 0.003 (in PM2.5)	0.18 (in TSP) 0.0149 (in PM2.5)
Monitoring, 2004	AQD 2004 Annual Air Quality Report	River Rouge (TSP)	**0.0728**	0.228
Monitoring, 2004	AQD 2004 Annual Air Quality Report	Detroit, W. Fort St. (SWHS; N. Delray)(TSP)	**0.098**	0.554
Monitoring, 2004	AQD 2004 Annual Air Quality Report	Detroit, E. 7 Mile (N.E. Detroit) (TSP)	0.0353	0.241
Monitoring, 2004	AQD 2004 Annual Air Quality Report	Dearborn (TSP, PM10 and PM2.5)	**0.139** (in TSP) **0.0846** (in PM10) 0.030 (in PM2.5)	0.677 (in TSP) 0.412 (in PM10) 0.226 (in PM2.5)
Monitoring, 2005	AQD data	Allen Park (TSP, PM2.5)	0.0284 (in TSP) 0.0036 (in PM2.5)	0.104 (in TSP) 0.0146 (in PM2.5)
Monitoring, 2005	AQD data	River Rouge (TSP)	**0.072**	0.285
Monitoring, 2005	AQD data	Detroit, W. Fort St. (SWHS; N. Delray)(TSP)	**0.163**	3.61
Monitoring, 2005	AQD data	Detroit, E. 7 Mile (N.E. Detroit)(TSP)	0.0292	0.106
Monitoring, 2005	AQD data	Dearborn (TSP, PM2.5)	**0.144** (in TSP) 0.03 (in PM2.5)	0.631 (in TSP) 0.16 (in PM2.5)
Monitoring, 2005	AQD data	Yellow Freight (S. Delray) (TSP)	**0.175**	0.896

[1] Annual arithmetic mean values in **bold** exceed the ITSL of 0.05 ug/m^3.

ATTACHMENT H. Detroit area Mn monitoring data, 2001-2002 (Detroit Pilot Project and Detroit Air Toxics Initiative (DATI)(DEQ-AQD 2005)).

Data type	Data source	Location	2001-2002 Mean [Mn] (ug/m3)[1]	Maximum 24 hr level (ug/m3)
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Allen Park (TSP)	0.0299	0.107
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	River Rouge (TSP)	**0.075**	0.269
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Detroit, W. Fort St. (SWHS; N. Delray)(TSP)	**0.093**	0.188
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Detroit, E. 7 Mile (N.E. Detroit)(TSP)	0.0261	0.0806
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Dearborn (TSP)	**0.198**	1.19
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Yellow Freight (S. Delray) (TSP)	**0.274**	1.94
Monitoring, 2001-2002	DATI Risk Assessment Report, 2005	Southfield (696/Lodge) (TSP)	0.0162	0.0488

[1] Annual arithmetic mean values in **bold** exceed the ITSL of 0.05 ug/m^3

ATTACHMENT I. Michigan Mn PSIC Comparison to EPA and Other States Cleanup Values

EXECUTIVE SUMMARY

The Subcommittee has been tasked with the evaluation of the derivation of the Mn PSIC for application in the Detroit area. In line with this goal, the Subcommittee compared the development of the DEQ generic soil to ambient air PSIC for soil contaminants to the EPA Regional SLs and other states cleanup levels for screening soil contamination to determine how the DEQ soil criteria for Mn differ to those used by the EPA and other states. The examination of these differences and their rationale helped determine whether the DEQ criteria are overly-stringent compared to other cleanup values.

The soil inhalation cleanup values by the DEQ, EPA Regions 3, 6, and 9, and Region 5 states are established using the basic algorithm for developing the soil to ambient air inhalation cleanup levels presented in the 1996 EPA SSG. The incorporation of the emissions due to Ev to the basic soil inhalation algorithm by the DEQ produces a more conservative value compared to the EPA and other states. This modification is prescribed in the SSG document and required by Minnesota, Wisconsin, and Illinois for sites where there are high dust emissions due to vehicle traffic on unpaved roads to ensure that the clean value is protective of this additional source of emission. The two-fold adjustment of PEF for noncarcinogens, PEF/2, further contributes to the lowering of the PSIC value. In addition, the Q/C used by Michigan is slightly lower than those used by the EPA and other states. Other factors, such as exposure duration and target hazard quotient (HQ), also contributed to the variation in values among the states.

The DEQ translated and simplified the SSG concept of source size for Q/C by generating Q/C values and modifiers for source sizes other than one-half acre. Minnesota, Illinois, and Wisconsin also apply the source size requirement; however, their process for determining source size is not clear.

The Ev factor and the two-fold adjustment to the PEF contribute greatly to the lowering of the PSIC. However, the generic PSIC should consider all possible conditions where emissions of soil contaminants could be increased to ensure protection of human health. Therefore, it is recommended that the Ev factor remain in the generic PSIC algorithm to ensure the protectiveness of the criteria. The two-fold adjustment factor evaluation and recommendation is discussed in Section V.D of this report.

INTRODUCTION

The Subcommittee prepared this report to respond to the questions presented to the DEQ, RRD, and WHMD by property owners and people living in communities in or around areas where Mn concentrations in soil exceed the Michigan generic PSIC. One of the questions relates to how the DEQ Mn soil criteria values compare to ones used by the EPA and other states and whether the DEQ criteria are truly more stringent in comparison.

The Michigan generic PSIC for soil contaminants are established using algorithms presented in the EPA SSG (EPA 1996). Other states and the EPA regional agencies have similarly developed cleanup levels for screening soil contamination using the SSG algorithms. Many states use the cleanup levels for screening, whereas Michigan and some states (Illinois and Wisconsin) use these cleanup levels as ultimate remediation goals or criteria.

The Michigan generic PSIC values for Mn have been considered by the regulated community as being overly stringent compared to cleanup levels generated by EPA and other states. The PSIC and its input parameters are compared to EPA and other states' cleanup levels and their default parameters to determine the underlying reasons for the differences in the clean up values and derivation procedures. These differences are analyzed using the EPA SSG algorithms and guidance on soil-ambient air inhalation as background (below). Comparison of EPA regions and other states' Mn cleanup value derivation to the Michigan PSIC algorithms and assumptions is made by presenting and analyzing their program, equations, assumptions and application (Section III-V). The cleanup values and inputs for Michigan, EPA, and states are summarized in Table 1 and 2 (Attachment I - Appendix A, below).

1996 EPA-SSG SOIL PARTICULATE SCREENING LEVEL (SL) ALGORITHMS

The SSG algorithms used to derive the soil to ambient air inhalation SL or cleanup values for chemicals that are non-carcinogens consisted of four main components:
1. HQ for noncarcinogens,
2. Exposure assumptions (exposure frequency (EF) and duration (ED)),
3. Dust PEF, and
4. Chronic inhalation RfC.

The RfCs are chemical-specific whereas the PEF is influenced mainly by meteorological characteristics, and to a small extent, by surface soil characteristics (i.e., silt loading and surface roughness). The default values for industrial contaminated sites are presented in the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (SG-SSL) (EPA, 2002).

$$\text{Particulate Screening Level (mg/kg)} = \frac{\text{THQ} \times \text{AT} \times 365\ \text{d/yr}}{\text{EF} \times \text{ED} \times \left(\frac{1}{\text{RfC}} \times \frac{1}{\text{PEF}}\right)}$$

where:

SL	Screening Level (mg/kg)	Residential – 1.8E+3 Industrial – 2.3E+4
THQ	Target Hazard quotient	1
AT	Averaging time (years)	Residential – 30 **Industrial – 25**
EF	Exposure frequency (days/year)	Residential – 350 **Industrial – 225**
ED	Exposure duration (years)	Residential – 30 **Industrial – 25**
RfC	Inhalation reference concentration (ug/m^3)	Chemical-specific (Mn – 5.0E-5 mg/kg-day)
PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	Residential – 1.32E+9 **Industrial – 1.36E+9**

The PEF equation relates the contaminant concentration in soil with the concentration of particulates in the air due to fugitive dust emissions from contaminated soils. The soil is an open source (i.e., emissions are fugitive since the discharge into the ambient air is not in a "confined flow stream").

$$PEF\ (m^3/kg) = Q/C \times \frac{3{,}600\ s/h}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

where:

PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	Residential – 1.32E+9 **Industrial – 1.36E+9**
Q/C	Dispersion factor for 0.5 acre source size (g/m^2-second per kg/m^3)	Residential – 90.8 **Industrial – 93.77**
V	Vegetative cover (unitless)	0.5 (50%)
U m	Mean annual wind speed at 7 m (m/s)	4.69
Ut	Equivalent threshold value of wind speed at 7 m (m/s)	11.32
F(x)	Function dependent on derived Um/Ut using Cowherd	0.194

The PEF equation presented in the SSG contains 3 main inputs:

1. Q/C for Ew – Q/C is generated, using dispersion modeling and meteorological data for different source sizes (EPA 2002). The Q/C is the inverse of the mean concentration at the center of a one-half acre contamination source (area). The default Q/C value of 90.80 g/m2-s per kg/m^3 was generated using Minneapolis, Minnesota, meteorological conditions and a source size of one-half acre. Regional default Q/C equation constants have also been derived for 28 other cities or climatic zones using a one-half acre source size; therefore, the EPA generated an equation and a look up table that can be used in generating Q/C values for different source sizes (one-half up to 500 acres) for different climatic zones (Appendix D, EPA 2002). The Q/C for source sizes other than one-half acre is then used to develop site-specific PEF (EPA 2002). None of the regional default Q/Cs included a Michigan-based climatic zone.

2. Emissions factor due to Ew - The equation is based on the "unlimited reservoir" model of Cowherd *et al.* (EPA 1985). The "[3,600 / (0.036 x (1-V) x $(U_m/U_t)^3$ x F(*x*))"] portion of the SSG equation for the default PEF equation is similar to the emissions due to Ew emission factor in the Michigan PEF equation without the (1-V) correction. The conversion factor of 3,600 sec/hr converts the empirical constant 0.036 $gm^{-2}\ hr^{-1}$ to $gm^{-2}\ s^{-1}$. The corrected threshold friction velocity (U_t), 11.32 m/s at 7 m height, is related to the mode of the soil aggregate particle size distribution at the surface and derived by Cowherd *et al.* (1985); it assumed a mode aggregate size of 500 µm and an uncorrected U_t of 0.5 m/s. A default correction of 1.25 is applied to derive a final U_t of 0.625 m/s (see equation below), which provides an equivalent wind speed of 11.32 m/s after adjusting to 7 m. The F(x) term is an empirically based function dependent on U_m and U_t. The EPA refers to Cowherd *et al.* (1985) for the derivation of this parameter.

$$U_t = \frac{u_*}{0.4} \ln\left(\frac{z}{z_o}\right)$$

3. Fraction of vegetation cover (1 V) - The emission factor due to Ew is affected by vegetation cover (V), and is therefore adjusted by applying the (1 V) fraction; the default value for V is 0.5 or 50 percent.

The EPA SSG and the SG-SSL do not incorporate in their residential or industrial/commercial PEF equations an Ev (i.e., emission factor due to fugitive dust generated by vehicle traffic on unpaved roads). However, under the section discussing the application of the particulate SL (Section 4-16), the SSG enumerated conditions and activities where the SLs may not be valid (protective) and where Ev may need to be considered due to high generation of dusts. These conditions include:

1. Dry soils (i.e., moisture content is less than 8 percent);
2. Finely divided or dusty soils (high silt or clay content);
3. High average annual wind speeds (greater than 5.3 m/s);
4. Less than 50 percent vegetation; and
5. Activities that will generate high dust levels due to heavy truck traffic on unpaved roads and construction-related activities.

DEQ PSIC DERIVATION

The DEQ algorithms used to establish the DEQ generic PSIC values adopted the EPA SSG equations with modifications. The DEQ PEF equation includes an Ev factor (DEQ 2007). The algorithms, default assumptions, and the calculated generic criteria values are promulgated in the Part 201 administrative rules (R 299.5726, R 299.5746 and R 299.5748). The PSIC equations presented in the Part 201 Rules inadvertently omitted the adjustment of 2 to the PEF value (PEF/2); but the PSIC values presented in the promulgated criteria tables (R 299.5746 and R 299.5748) were calculated using one-half of the PEF as shown in the equation below to account for short-term peak particulate levels.

$$\text{PSIC} = \frac{THQ \times AT}{EF \times ED \times (1/ITSL) \times (1/(PEF/2))}$$

where:

PSIC	Particulate Soil Inhalation Criteria (mg/kg)	Residential – 3.3E+3 **Industrial – 1.5E+3**
THQ	Target Hazard quotient	1
AT	Averaging time (years), (ED x 365 days/year)	Residential – 10,950 **Industrial – 7,665**
EF	Exposure frequency (days/year)	Residential – 350 **Industrial – 245**
ED	Exposure duration (years)	Residential – 30 **Industrial – 21**
ITSL	Initial Threshold Screening Level (an Inhalation reference concentration) (ug/m^3)	Chemical-specific (Mn – 5.0E-5 mg/kg-day)
PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	Residential – 1.28E+8 **Industrial – 3.95E+7**
PEF/2	Adjusted PEF	Residential – 6.4E+9 **Industrial – 1.97E+7**

Michigan Q/C values for different source sizes are developed employing the ISCST3 dispersion model that EPA used for developing the SSG default Q/C constants. In contrast to other states, Michigan considered 5-year meteorological data sets from Michigan air monitoring stations as inputs to the model.

$$PEF = (Q/C)*[1/Ew((1-V)) + Ev]$$

Where:

PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	Residential – 1.28E+8 Industrial – 3.95E+7
Q/C	Dispersion factor for 0.5 acre source size (g/m^2-sec per kg/m^3)	Residential – 82.33 Industrial – 82.33
V	Vegetative cover (unitless)	0.5
Ew	Emission due to wind at height 7 m (g/m^2-sec)	5.50 E-7
Ev	Emission due to vehicle traffic (g/m^2- sec)	Residential – 3.68 E-7 Industrial – 1.81 E-6

The PSIC values presented in the Criteria Tables are only for a one-half acre contamination source size. For sites with source-sizes other than one-half acre, a table of Q/C values for various source sizes and their corresponding modifiers was generated (R299.5726(6)). The modifier must be used as multiplier of the one-half acre PSIC value to generate the applicable PSIC. For example, the applicable industrial PSIC value for Mn for a one acre source size is 1,305 mg/kg (1,500 mg/kg x 0.87).

The Ew factor derivation is similar to the EPA SSG without the vegetative cover fraction. The Ew is derived by a series of calculations shown below:

1. $Ew = 0.036(U_m/Ut_{adj})^3 \times F(x)/3600$
2. $Um = Um_{(z)}*(7/z)^{0.15}$
3. $Utadj = ((U^*t*CF)/0.4)*(\ln(7.0/z_0)$
4. $x = 0.886*(Utadj/Um)$
5. Function dependent on Cowherd derived *x* (F(*x*))

where:

Emissions due to wind erosion (Ew)	=	**5.51E-07**	g/m^2-s
Respirable fraction emission rate	=	0.036	
Adjusted mean annual wind speed to ht. of 7 m (Um)	=	4.62	m/s
Mean annual windspeed at height z ($Um_{(z)}$)	=	4.56	m/s
Wind speed measurement height (z)	=	6.4	m
Surface soil mode aggregate size (As)	=	0.35	mm
Equivalent threshold friction velocity for As of 0.35 (U^*t)	=	0.42	m/s
Correction factor for non-erodible elements (CF)	=	1.25	unitless
Roughness height (z_0)	=	0.005	m
Equivalent threshold friction velocity at ht. 7 m (Ut)	=	7.61	m/s
Cowherd derived *x* *(x)*	=	1.823	unitless
Function dependent on Cowherd derived *x* (F(*x*))	=	**0.480**	unitless

As mentioned above, Michigan included, in its PEF derivation, the contribution of dust emissions due to fugitive particulates generated from vehicular traffic on unpaved roads. The Ev factor is calculated for a one-half acre source size and added to the Ew value. The Ev factor values for residential and industrial sites are 3.68E-7 and 1.81E-6, respectively. The Ev factor contributes to the lowering of the PEF values and explains why the industrial PSIC value is more stringent (lower) than the residential PSIC value.

EPA AND STATES DERIVATION AND CLEANUP LEVELS

The cleanup values, derivation specific including inputs to the equation of EPA and the states examined are summarized in Attachment I - Appendix A.

EPA Regional Screening Levels

The new 2008 revised Regional SLs for Chemical Contaminants at Superfund Sites (May 2008) or Regional soil cleanup values replaced the PRGs used by the EPA, Regions 3, 6, and 9. The SLs determine whether additional investigation and site cleanups will be required. They are used like the PRGs for scoping and baseline screening purposes and are applied as final cleanup PRGs for site-specific risks if site-specific data are used. The final SL for a chemical is the direct contact SL, a multipathway or multiroute value that includes accidental ingestion, dermal contact, and inhalation of contaminated dust, or air containing chemical vapors emitted from soil, and is derived using the equation:

$$\text{Direct Contact SL} = 1/[(1/SL_{ingestion}) + (1/SL_{dermal}) + (1/SL_{inhalation})]$$

SLs for individual pathways are also calculated. The SL for inhalation of particulates emitted from soil is derived using the EPA SSG equation but without consideration of the Ev factor. Unlike the SSG SL and the PSIC, the Regional SL includes exposure time (ET), which is 24 hours/day for residential; but this can vary for industrial exposures, e.g. 8 work-hours/day. This input was not explicit in the 1996 SSG. The EPA algorithm for non-carcinogens considers children exposure only and therefore 6 years is used for exposure duration (EDc). At the time of this report, the EPA inhalation reference concentration (RfC) for Mn remains at 0.05 µg/m^3 or 5.0 E-05 mg/m^3.

In contrast to the MDEQ inhalation criteria where separate values for particulates (PSIC) and volatiles (VSIC) are determined, the EPA generic inhalation SL algorithm sums the volatilization (VF) and particulate emission factors (PEF) of the chemical. For Mn however, the VF is not an applicable emission factor.

inhalation of particulates emitted from soil,

$$SL_{res\text{-}sol\text{-}nc\text{-}inh}\,(mg/kg) = \frac{THQ \times AT_r\left(\frac{365\ \text{days}}{\text{year}} \times ED_c\,(6\ \text{years})\right)}{EF_r\left(\frac{350\ \text{days}}{\text{year}}\right) \times ED_c\,(6\ \text{year}) \times ET_{rs}\left(\frac{24\ \text{hours}}{\text{day}}\right) \times \left(\frac{1\ \text{day}}{24\ \text{hours}}\right) \times \frac{1}{RfC\left(\frac{mg}{m^3}\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{Kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{Kg}\right)}\right)}$$

$$PEF_w = \frac{Q}{C_w} \times \frac{3{,}600}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}$$

where

$$\frac{Q}{C_w} = A \times \exp\left[\frac{(\ln A_s - B)^2}{C}\right]$$

Particulate Emission Factor Variables			
PEF	Particulate Emission Factor - Minneapolis (m^3/kg)	1.36×10^9(region-specific)	Determined in this calculator
Q/C	Inverse of the Mean Concentration at the Center of a 0.5-Acre-Square Source (g/m^2-s per kg/m^3)	93.77 (region-specific)	Determined in this calculator
V	Fraction of Vegetative Cover (unitless)	0.5	U.S. EPA 1996a (pg. 23)
U_m	Mean Annual Wind Speed (m/s)	4.69	U.S. EPA 1996a (pg. 23)
U_t	Equivalent Threshold Value of Wind Speed at 7m (m/s)	11.32	U.S. EPA 1996a (pg. 23)
F(x)	Function Dependent on U_m /U_t (unitless)	0.194	U.S. EPA 1996a (pg. 23)
A	Dispersion constant unitless	PEF and region-specific	U.S. EPA 2002 (pg. D-6 to D-8)
A_s	Areal extent of the site or contamination (acres)	0.5 (range 0.5 to 500)	U.S. EPA 2002 (pg. D-2)
B	Dispersion constant unitless	PEF and region-specific	U.S. EPA 2002 (pg. D-6 to D-8)
C	Dispersion constant unitless	PEF and region-specific	U.S. EPA 2002 (pg. D-6 to D-8)

The EPA default PEF uses a Q/C value of 93.77; this value is based on Minneapolis meteorological conditions. The Q/C is modeled using a one-half acre source size. The SL guidance document indicates that regional Q/Cs may be determined using the regional default Q/C inputs presented in the 1996 SSG, which allows manipulation for source sizes larger than one-half acre.

Compared to the Michigan PEF, the EPA default PEF value of 1.316E+9 is not corrected nor adjusted for Mn and other non-carcinogens because EPA uses the reference concentration (RfC) for inhalation, which does not have "averaging times" assigned to it unlike the Michigan ITSL. Previous EPA PRG derivation used the reference dose for inhalation (RfDi), instead of RfC (5.0E-5 mg/m^3); the RfDi for Mn is 1.4E-5 mg/kg-day. The RfDi is the RfC (5.0E-5 mg/m^3) multiplied by the inhalation rate (20 m^3/day) and divided by body weight of 70 kg.

The EPA SLs are derived using a wind erosion emission factor (equivalent to the Michigan Ew) that is based on the mean Minneapolis wind speed of 4.69 m/s at 7 meters height. The equivalent threshold value of wind speed at 7 m is 11.32. These defaults and their derivation are similar to the ones presented in the EPA-SSG (1996).

Although generic PEF calculation did not include the Ev factor; the SL guidance document states that *"the generic soil PEF evaluates wind-borne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here"* and therefore the user is advised to account for specific vehicular traffic or mechanical disturbance in developing their site-specific PRGs for remediation sites.

The new EPA Region 9 inhalation SLs for Mn for a one-half acre source size for residential exposure and indoor and outdoor worker (industrial) are 1,800 and 23,000 mg/kg, respectively.

<u>Neighboring States (Region 5) Derivation and Cleanup Levels</u>

The neighboring states, or Region 5 states, consists of Indiana, Illinois, Ohio, Minnesota and Wisconsin. The derivation and application of cleanup values are discussed in detail to provide a clear explanation of the cause for the different values. Where cleanup values are presented as direct contact or multi-pathway values, the cleanup value for the inhalation pathway is estimated using the inhalation pathway algorithm and the state default parameters to enable appropriate comparison with the Michigan PSIC.

Indiana Closure Levels. The Indiana default soil cleanup levels are developed under the Department of Environmental Management (IDEM) Risk Integrated System of Closure (RISC) and are called Closure Levels (CLs). The CLs provide a default approach to cleanup of sites and are determined for residential and commercial/ industrial use sites (IDEM, 2006). The default soil CL for a given chemical is the lowest of the values for soil saturation (Csat), soil attenuation capacity, calculated direct exposure level, or migration to ground water. CLs for direct exposures (ingestion, dermal absorption, and inhalation) are calculated by summing up the intake from the individual exposure pathways (see equation below). The residential surface soil values are generated using a “weighted approach”, i.e. the body weight, exposure duration, and inhalation rates are age-adjusted or “weighted” for each exposure route.

Residential Direct Contact (Non-carcinogens)	$C_{ssrn} = \dfrac{THQ \times AT_n \times 365\ {}^{days}\!/_{year}}{EF_{rs}\left[\left(\dfrac{IngF_{adj} + \left(SFS_{adj} \times ABS\right)}{RFD_o \times 10^6\ {}^{mg}\!/_{kg}}\right) + \dfrac{InhF_{adj}}{RFD_i}\left(\dfrac{1}{VF} + \dfrac{1}{PEF}\right)\right]}$

where:

C_{ssrn}	=	Residential Direct Contact CL for non-carcinogens	
THQ	=	Target Hazard quotient	1
AT	=	Averaging time (yrs)	30
$IngF_{adj}$	=	Oral intake factor	Not listed for Mn
SFS_{adj}	=	Dermal factor	Not listed for Mn
$InhF_{adj}$	=	Inhalation factor age adjusted (m^3-yr/kg-day)	10.9
EF_{rs}	=	Exposure Frequency, residential soil (days/year)	250
RfD_o	=	Oral reference dose (mg/kg-day)	Not listed for Mn
RfD_i	=	Inhalation reference dose (mg/kg-day)	Not listed for Mn
VF	=	Volatilization factor	Not applicable for Mn
PEF	=	Particulate emission factor (default) (m^3/kg)	1.316E+09

$$\text{InhF}_{\text{adj}} = \left[\frac{ED_{ch} \times IR_{ch}}{BW_{ch}} + \frac{(ED_{raas} - ED_{ch}) \times IR_{raas}}{BW_a}\right]$$

where:

$InhF_{adj}$	=	Inhalation factor age adjusted (m^3-yr/kg-day)	10.9
ED_{ch}	=	Exposure duration, child (days/year)	6
ED_{raas}	=	Exposure duration, residential, adult (days/year)	30
IR_{raas}		Inhalation rate (m^3/day)	10
IR_{ch}		Inhalation rate residential, adult (m^3/day)	20
BW_{ch}	=	Body weight child (kg)	15
BW_a	=	Body weight adult (kg)	70

The inhalation component of the Indiana direct exposure CL algorithm uses equations and PEF default inputs presented in the 1996 SSG. The PEF parameters are based on Minneapolis meteorological data and a one-half acre source size. No guidance on source size requirement or adjustment was presented on the IDEM web site.

Particulate Emission Factor Equation	$PEF = Q/C_p \times \left[\frac{3{,}600\ s/h}{0.036 \times (1-V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x)} \right]$

where:

PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	1.316E+9 (EPA, 1996)
Q/C	Dispersion factor for 0.5 acre source size (g/m2-s per kg/m3)	90.80
V	Vegetative cover (unitless)	0.5 (50%)
U m	Mean annual wind speed at 7 m (m/s)	4.69
Ut	Equivalent threshold value of wind speed at 7 m (m/s)	11.32
F(x)	Function dependent on derived Um/Ut using Cowherd	0.194 (assumed for IDEM)

Mn is not listed in the Default Closure Tables (Appendix 1 Table A). However, site-specific CL for Mn could be calculated when necessary (IDEM Communication, 2007). Using the IDEM inhalation algorithms, default assumptions and variables for non-carcinogenic chemicals (residential EF - 250 days, PEF - 1.32E+9 m^3/kg, and weighted inhalation factor - 10.9 m3-yr/kg-day) and the current EPA-IRIS RfC value for Mn (5E-05 mg/m^3) converted to RfDi of 1.4E-5 mg/kg-day, the *estimated residential soil CL for Mn* for a one-half acre source size is 7.85E+04 mg/kg. This estimate is ten fold higher than the Michigan one-half acre residential PSIC for Mn due to the following:

1. Use of RfDi, which is higher than the RfC,
2. Use of age-adjusted inhalation factor,
3. Higher PEF value since Ev and PEF adjustment for non-carcinogens are not considered, and Q/C and Ew values are higher than the Michigan-based defaults.

Illinois Soil Remediation Objectives. The Illinois EPA health risk-based method for developing remediation objectives for contaminated soil and groundwater is the Tiered Approach to Corrective Action Objectives (TACO). There are three tiers for selecting remediation objectives. The selected tier or tiers used for developing the remediation objectives depends on the site-specific conditions and the site owner's or operator's remediation goals. (**http://www.epa.state.il.us/land/taco/fact-sheet.html**)

In Tier 1, site sample analytical results are compared to baseline remediation objectives presented in Section 742.Table A and B: Tier 1 Soil Remediation Objectives (SROs) "look-up" tables for inhalation, ingestion, and migration. The most restrictive value among the SROs becomes the site's residential or industrial/commercial land use SRO. Tier 2 allows for calculation of site-specific remediation objectives while Tier 3 addresses situations which cannot be handled under the first two tiers.

The SROs for the inhalation exposure to fugitive dusts are derived using the EPA SSG equations and parameters shown below (taken from Section 742, Appendix C, Table A: SSL

Equations and Table B:SSL Parameters). The construction worker PEF is generated by dividing the industrial/commercial PEF value is divided by 10 to generate the construction worker PEF.

$$\text{SSL} = \frac{HQ \times AT \times 365}{EF \times ED \times (1/RfC \times 1/PEF)}$$

and,

$$PEF = (Q/C) \times 3600 \times 1/\left[(0.036(1-V)) \times (Um/Ut)^3 \times F(x)\right]$$

where:

SRO	Soil Remediation Objective (mg/kg)	Residential – 69,000 Industrial – 91,000 Construction – 8,700
HQ	Hazard quotient	1
AT	Averaging time (years)	Residential – 30 Industrial – 25 Construction W – 0.115 (42 days)
EF	Exposure frequency (days/year)	Residential – 350 Industrial – 250
ED	Exposure duration (years)	Residential – 30 Industrial – 25 Construction W – 1
RfC	Inhalation reference concentration (mg/m^3)	5.0E-5
PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	Residential – 1.32E+9 (same as EPA derivation) Industrial – 1.24E+9 Construction W – 1.24E+8
Q/C	Dispersion factor for 0.5 acre source size (Q/C values for other sizes are determined using a per source area table) below)	Residential – 90.8 Industrial – 85.81

Varying Q/C values can be determined depending on the source size as shown below. The derivation of the Ew factor including inputs (e.g.. mean wind speed) is not shown on the web site but it is assumed that the EPA-SSG derivation was used since the SRO residential PEF value is similar to the EPA value.

Q/C by source area (Section 742 Table H)

Source (acres)	Q/C value(g/m2-s per kg/m3)
0.5	97.78
1	85.81
2	76.08
5	65.75
10	59.16
30	50.60

The Mn RfDi used in the SRO derivation is 1.4E-05 mg/kg, which is based on the IRIS RfC (5.0E-05 mg/m^3) (http://www.epa.state.il.us/land/taco/toxicity-values.xls).

The default residential and industrial Mn inhalation SROs are 69,000 mg/kg for a one-half acre source size and 91,000 mg/kg for a one (1) acre source size, respectively. These values are higher than the Michigan PSIC for residential (3,300 mg/kg for one-half acre) and industrial (1,305 mg/kg for 1 acre) because the SRO derivation:

1. Did not consider application of averaging time to RfC and therefore PEF adjustment is not required
2. Does not include an Ev parameterUsed RfDi value instead of RfC, and
3. Used EPA-SSG default values for its residential Q/C and Ew while industrial PEF used Chicago based Q/C and Ew values.

Ohio Voluntary Action Program and Remedial Response Program. Ohio has 2 main programs addressing contaminated sites under the Division of Emergency and Remedial Response. One is the Voluntary Action Program (VAP), which allows companies to investigate possible environmental contamination, clean it and receive a promise from the State of Ohio that no more cleanup is needed. If the cleanup meets OH environmental standards without direct oversight from Ohio EPA, Ohio EPA can release the owner from the responsibility of doing further investigation and cleanup (OH-EPA, 2008). Concentrations of contaminated soils are compared to generic numerical standards, which were developed using the Monte Carlo Simulation probabilistic approach. The generic soil direct contact standards or target cleanup concentrations (TC) incorporate multi-pathway exposures: dermal contact, inhalation and ingestion (as shown in the equation below), for every standard developed for a particular land use (residential, commercial and industrial) (OH-EPA, 2002).

$$\mathrm{TC} = \frac{HQ}{\left(\frac{IF_{oral}}{RfD_{oral}}\right) + \left(\frac{IF_{derm}}{RfD_{derm}}\right) + \left(\frac{IF_{inh}}{RfD_{inh}}\right)}$$

where:

TC	=	Target Cleanup concentration
HQ	=	Hazard quotient
IF_{oral}	=	Oral intake factor
IF_{demal}	=	Dermal intake factor
IF_{inh}	=	Inhalation intake factor
RfD_{oral}	=	Oral reference dose
RfD_{demal}	=	Dermal reference dose
RfD_{inh}	=	Inhalation reference dose

$$\mathrm{IFinh} = \frac{IR \times EF \times ED \times ET \times Finh \times AT \times \left(\frac{1}{PEF} + \frac{1}{VF}\right)}{BW \times AT}$$

where:

IFinh	Inhalation-specific intake factor (mg/kg-day)	
IR	Inhalation rate (m^3/hr)	Residential – 0.9 (adult); 0.66 (child) Industrial – 1.0
ED	Exposure duration (years)	Residential – 30 (adult); 6 (child) – 25

EF	Exposure frequency (days/year)	Residential – 350 (adult and child) Industrial – 250
ET	Exposure Time (hrs/day)	Residential – 24 (adult and child) Industrial – 8
Finh	Fractional inhalation intake from contaminated source (unitless)	1
AT	Averaging time, non-cancer (days)	Residential –10,950 (adult); 2,190 (child) Industrial – 9,125
BW	Body weight (kg)	70 (adult); 15 child)
VF	Volatilization factor (not applicable to metal particulates)	Not applicable to Mn
PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	1.7E+9 (for all land uses)

The PEF is calculated using the EPA SSG equation with Q/C dispersion factor and wind speed values based on Cleveland data. Note that the equivalent threshold value (Ut) and the function dependent on derived Um/Ut using Cowherd (Fx) is the same as the EPA default value, which used Minnesota based Q/C and Ew defaults. No guidance on source area sizes other than one-half acre was noted in the guidance document.

$$PEF = (Q/C) \times 3600 \times 1 / \left[(0.036(1-V)) \times (Um/Ut)^3 \times F(x)\right]$$

where:

PEF	Particulate emission factor for 0.5 acre source size (m^3/kg)	1.7E+9 (residential and industrial)
Q/C	Dispersion factor for 0.5 acre source size (g/m2-s per kg/m3)	83.22
V	Vegetative cover (unitless)	0.5
Um	Mean annual wind speed at 7 m (m/s)	4.2
Ut	Equivalent threshold value of wind speed at 7 m (m/s)	11.32
F(x)	Function dependent on derived Um/Ut using Cowherd	0.194

A soil standard for Mn is not available at this time (OH-EPA Communication). However, using the VAP algorithms and default assumptions listed above, the estimated inhalation one-half acre based TCs for Mn can be calculated. The estimated one-half acre soil TCs are **8.21E+04 and 1.24E+05 mg/kg** for residential and industrial land use, respectively. These estimates are higher than the MDEQ PSIC for the same reasons cited for the EPA SLs and IEPA SROs.

Another Ohio program that addresses contamination is the Remedial Response Program (RRP). This program requires the Ohio EPA through the Ohio Revised Code to investigate the nature and extent of historical hazardous waste releases, determine whether contaminated sites represent a risk to human health or the environment, identify the preferred remedial actions and oversee the cleanup. The RRP uses the EPA Region 9 Preliminary Remediation Goals (PRGs) values as the basis for their generic cleanup values. The Region 9 PRGs, which have been replaced by the 2008 EPA SLs, were derived using SSG equations and default values and are higher than the MDEQ PSIC. The RRP final cleanup values for noncarcinogens are generated by dividing the Region 9 PRGs by 10 to account for effects from exposure to multiple contaminants (OH-EPA, 2005).

The Ohio RRP Cleanup Level for Mn is 1.8E+2 mg/kg-day, an order of magnitude lower than the EPA PRG of 1.8E+3 mg/kg-day and lower than the residential PSIC value of 3.3E+3 mg/kg but higher than the industrial PSIC of 1,500 mg/kg.

Minnesota Soil Reference Values. The Minnesota Pollution Control Agency (MPCA) Agency's Site Remediation Section (SRS) established Soil Reference Values (SRVs) to evaluate human exposure to contaminated soil (MN, 2006). Risk evaluation is based on a tiered approach. Contaminant concentrations that exceed the generic residential Tier 1 SRVs are further evaluated using Tier 2 or simple site-specific risk characterization. Sites that have exposure pathways or conditions that can not be assessed by a Tier 1 or 2 risk characterization are evaluated under Tier 3 (detailed site-specific).

Table A1.7 Residential - Chronic Inhalation of Vapors or Particulate from Soil

$$\text{LADC or ADC}_{air} = \frac{Cair \times EF \times ED \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{air}	Average daily concentration in air (mg/m^3 or ug/m^3).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) = C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg		Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period (days/year).	350	C	1/PEF and 1/VF are based on annual estimates.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr LADC calculation AT = 70 yrs x 365 days/yr

C = Central Tendency Value

The generic residential Tier 1 SRVs used to evaluate inhalation exposures to resuspended particulates are expressed as air contaminant concentration or Average Daily Concentration (ADCair). The ADCair depends upon the frequency and duration of the assumed exposures. The SRV guidance document indicates that the equation is a simple adjustment of the exposure point concentration to account for the time spent in the contaminated area (MN, 2006). To calculate the airborne contaminant concentration, the ADCair value is multiplied by the inverse of the PEF (i.e., 1.3E-3 mg/m3).

The default source size for PEF calculation is 5 acre leading to a Tier 1 SRV value of 1.3E-3 mg/m^3 for Mn. Applying the EPA-SSG equations and default Q/C, Um, Ut and f(x) values shown above, the estimated PEF is 7.7E+8 mg/m^3 for a five acre source size. The guidance specifies that Q/C should be adjusted if site-specific value is available. The inhalation SRVs do not consider Ev or other conditions that may cause higher emissions due to mechanical disturbances. However, the guidance document provides a statement that the presence of these conditions on the site indicate that the Tier 1 SRV may not be adequately protective.

Table A1.8 Residential - Calculation of Chronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600\, s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	7.7E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0.5	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.92	Based on climatic data for Minneapolis/St. Paul metropolitan area (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

*Chronic industrial exposure***.** Contaminants inhaled by the receptor at or near an industrial site are evaluated using the calculated ADCair for industrial workers and a PEF (1/PEF) of 2.3 E-9 kg/m^3 (2.3 $\mu g/m^3$). The particulate air concentration utilized for industrial use is 5 $\mu g/m^3$. The calculated particulate air concentration is multiplied by a factor of two to include emissions from other sources of soil disturbance (e.g., vehicle traffic) since the equation only considered wind erosion of soil. This adjustment is applied to the default PEF to be protective of greater and frequent disturbance of soil that may occur in industrial areas. If industrial site activities are likely to produce physical disturbance of the contaminated soil (e.g. grading, excavation, vehicle traffic), and if these activities are expected to frequently occur, the SRV guidance indicates that the default PEF may not be protective in these instances. Requirement for site-specific PEF is, however, not clearly stated in the guidance document.

Table A1.27 Industrial Worker - Calculation of Chronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600 s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	3.8E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m²-s per kg/m³)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.9	Based on climatic data for Minneapolis/St. Paul metropolitan area. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

Table A1.26 Industrial Worker - Chronic Inhalation of Vapors or Particulate

$$\text{LADC or ADC}_{air} = \frac{Cair \times EF \times ED \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{air}	Average daily concentration in air (mg/m³ or ug/m³).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m³ or ug/m³) = C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 μg/mg		Utilized for LADC calculation since toxicity values are in ug/m³
EF	Number of exposure days during the exposure period (days/year).	250	C	PEF and VF values are based on annual estimates.
ED	Duration of the exposure period (years).	25	U	95th percentile worker tenure. (Maguire 1993)
BW	Body weight of the receptor (kg).	70	C	EPA, 1997
AT	Averaging Time (days)	9125 25550		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

C = Central Tendency Value
U = Upper Tendency Value

The EPA SSG Q/C value for five-acre source size for the city of Minneapolis was the default Q/C for generating the PEF. Using the linear inverse relationship between the log of the source size and the log of the Q/C, Minnesota developed Q/C values for other source sizes not included in the EPA SSG. The industrial Ew assumed a zero vegetation.

The residential inhalation cleanup value equivalent to the PSIC was calculated using Minnesota's default exposure values, PEF value, and a THQ of 1. The resulting estimate of 12,000 mg/kg is much higher than the MI PSIC due to the following:

1. No PEF adjustment is applied.
2. PEF (1.14E+9 m^3/kg) is ten-fold higher than MI's PEF because:
    a. PEF does not include an Ev factor, and
    b. Q/C value (90.8 g/m^2-s per m^3/kg) is higher than MI's Q/C.
3. The Mn RfC value (0.2 $\mu g/m^3$) is higher.

Wisconsin Residual Contaminant Levels. The Wisconsin Department of Natural Resources (DNR) Remediation and Redevelopment (RR) Program oversees the investigation, cleanup and redevelopment of contaminated properties. The RR Program has a One Cleanup Program Memorandum of Agreement with the U.S. EPA Region 5 that addresses cleanup requirements across several environmental media. The RR guidance document "Determining Residual Contaminant Levels (RCLs) Using the EPA Soil Screening Level Web Site" outlines the use of the EPA web site to generate RCLs for use in the cleanup of soil contamination. Even though the generic RCLs are generated using the EPA web calculator, Wisconsin requires that the derivation must follow the soil clean up code (NR 720, Wis. Adm. Code). For example, the calculated site-specific generic RCLs must use the default target hazard quotient (THQ ≤1), hazard index (ΣTHQ = HI ≤1) and cancer risk (TCR ≤ 10^{-5}). Generic residential RCLs must be developed using the THQ and TCR of 0.2 and 10-7, respectively.

The RCLs for inhalation of fugitive dust or soil particulates are generated by plugging Wisconsin default parameters into the EPA web calculator (http://rais.ornl.gov/epa/ssl1.htm) but with stated limitations and required assumptions, including:

1. Applicable site is one-half acres or less in area. A contaminated area of no more than one-half acre is assumed in the generic calculator. Wisconsin requires the adjustment of the generic RCL for sites with sizes greater than one-half acre. The guidance presented this example: The generic RCL for hexavalent chromium at a one-half acre residential site is 14 mg/kg. If this concentration is considered at a 10-acre site, Wisconsin contends that "the highly contaminated soil can be diluted by spreading it over a larger area. Diluting the contamination is not only an inappropriate remedy, but the redistribution could prove more detrimental to human health than containing the contaminants in a smaller area".
2. The contaminant is not a mixture of compounds. Evaluation of additional factors is required when multiple contaminants are involved. Both the TTHQ and CR requirements in NR 720 must be applied.
3. Site does not pose any ecological risk.
4. Site does not pose any safety risk.
5. Indoor-air pathway is not a consideration.
6. Site does not pose a dermal-contact risk.
7. The NR 140 ES (enforcement standard) is the same as the federal drinking water MCL (maximum contaminant level).

The EPA web calculator uses the SSG algorithms for deriving the particulate inhalation cleanup level. The PEF value and the required default parameter inputs to the generic particulate inhalation RCL equation are presented in the figure below.

Wisconsin Rules (NR 720.19(5)(c)) define the PEF as the concentration of 1.4 µg/m^3 (1.4 E-9 kg/m^3) contaminated soil particles with diameter of less than 10 µm. This value is actually 1/PEF, i.e. the PEF is 7.14E+08 m^3/kg. Other inputs (Um, Ut, and F(x)) are adjusted to arrive at this value (see below).

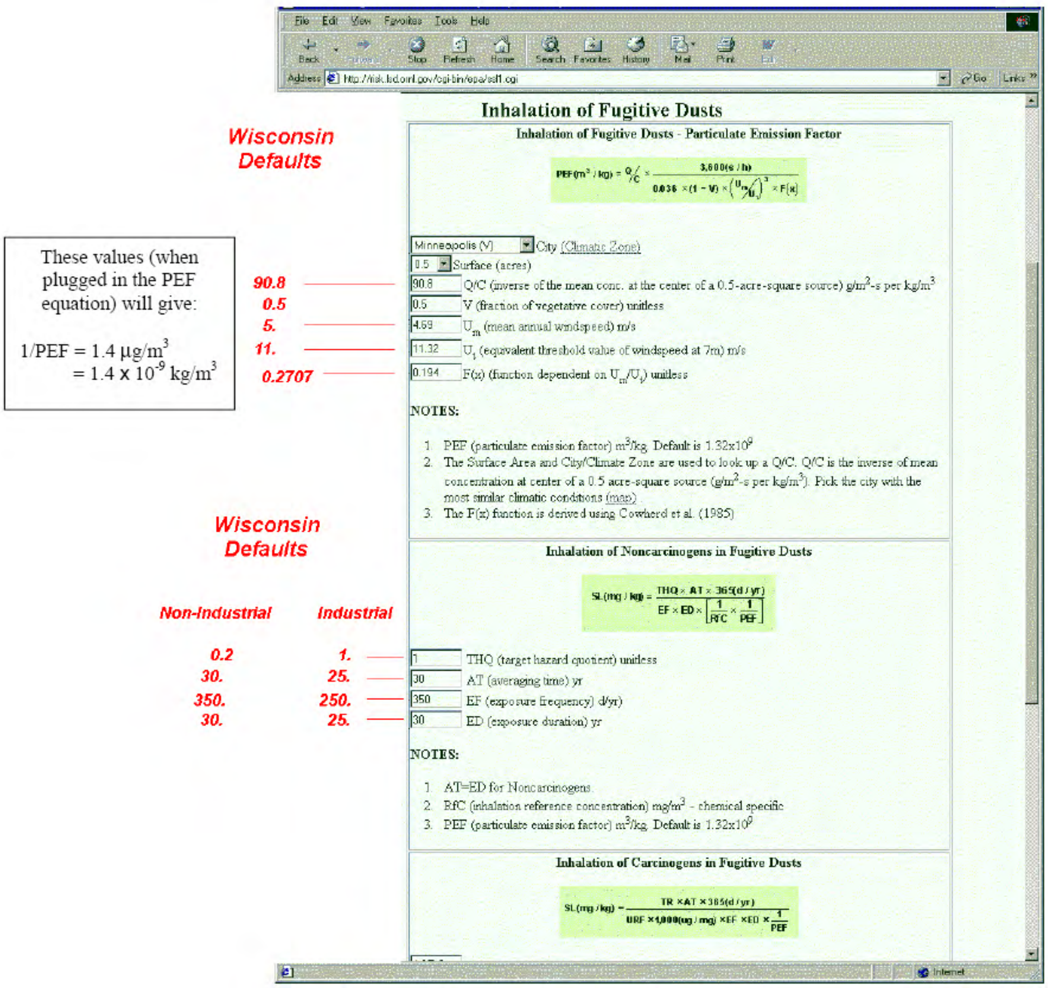
The generic RCLs for Mn residential and industrial particulate inhalation using the calculator web page are **7.44E+3** and **5.21E+4**, respectively. The residential RCL is slightly higher than the residential PSIC while the industrial RCL value is ten fold higher than the corresponding PSIC due to:

1. Lower HQ (0.2) for residential
2. Lower ED, EF, and AT values, and

3. No Ev and no PEF adjustment are applied.

The Wisconsin RCL Calculator Web Page.

Default Parameters to Use in Calculating Generic **Particulate**[2] **Inhalation** RCL



<u>Other States (California, Florida, New York, Texas, and West Virginia).</u>
Distant states whose information was accessible on the internet were identified as California, Florida, New York, Texas, and West Virginia. These states derive multi-route soil cleanup values or screening levels which are equivalent to the EPA PRGs. The equations for these cleanup values consider the sum of the risks from ingestion, dermal contact and inhalation (outdoor or ambient); they do not consider vapor intrusion (indoor air). All 3 exposure routes are referred to as “direct contact”. The use of the multi-route cleanup value does not preclude the use of route specific cleanup levels especially for a chemical with toxicity that is unique or specific to that route.

Michigan's Direct Contact Criteria (DCC) includes ingestion and dermal contact only; a separate cleanup value represents inhalation of particulates (PSIC) or volatiles (VSIC) present in soil. An estimate of the Michigan multi-route cleanup value for Mn, i.e. direct contact and particulate inhalation, was calculated to enable a comparison with these states. The Mn residential and industrial cleanup values of these states ranges from 1,800 to 3,700 and 10,000 to 43,000 mg/kg, respectively. Combining the Michigan DCC (25,000 and 90,000 for residential and industrial, respectively) and the PSIC (3,300 and 1,500 for residential and industrial, respectively) resulted in a multi-route cleanup value of 2,920 and 48,000 mg/kg for residential and industrial use properties, respectively.

Studies have indicated, however, that the most sensitive route of exposure for Mn is inhalation compared to ingestion and dermal contact. The human body is able to maintain homeostatic control over ingested Mn and unlike lead, the dermal route is not a concern (ATSDR 2000). The neurotoxicity of inhaled Mn has caused its inhalation toxicity value to be much lower than that of other metals. For Mn, the risks from dermal and ingestion exposures do not contribute to an increased toxicity and accounting for the risk due to inhalation exposure, i.e. using PSIC only, would not lead to an underestimation of the risk. Therefore, the use of multi-route exposure is not necessary in the case of Mn.

Table 2: Comparison of Michigan Mn Criteria to Distant States (Appendix A) presents details on the derivation of the inhalation component of the states' cleanup levels including assumptions and parameters used in establishing the PEF.

CONCLUSION AND RECOMMENDATION

The Michigan generic PSIC for Mn and its development is evaluated by comparing them to the cleanup levels generated by the EPA Regions and other states. Analysis of the development of soil inhalation cleanup values by the EPA, Regions 3, 6, and 9, and EPA, Region 5, states showed that the basic algorithm for developing the cleanup value are similar. However, the incorporation of the Ev to the basic algorithm by the MDEQ led to a more conservative value. This modification is prescribed in the EPA SSG document and required by Minnesota, Wisconsin, and Illinois for sites where the clean value using the basic algorithm is deemed not sufficiently protective due to high dust emissions resulting from vehicle traffic or mechanical disturbances. For the generic PSIC to be protective of all scenarios, the MDEQ deemed it appropriate to include Ev in generating the PSIC.

The two-fold adjustment of PEF for noncarcinogens by dividing the PEF value by two further contributed to the lowering of the PSIC value. The use of the Michigan-based Q/C and meteorological data are scientific and more appropriate than the default Q/Cs presented by the EPA SSG. The MDEQ translated and simplified the EPA SSG concept of source size for Q/C and its application in generating the appropriate PSIC value by generating Q/C values and corresponding modifiers for source sizes other than one-half acre. Minnesota, Illinois, and Wisconsin also apply the source size modification requirement even though EPA SSG default Q/C values were used.

Based on this analysis, the Subcommittee concludes that the Ev factor and the PEF adjustment contributed greatly to the lowering of the PSIC. However, the generic PSIC should consider all possible conditions where emissions of soil contaminants could be increased to adequately protect human health. The current MDEQ criteria are designed for single pathway, single chemical application and do not address cumulative effects, multi-exposure effects, and susceptible populations (e.g. children, pregnant women, aged). It is therefore prudent for MDEQ to consider all exposure possibilities and conditions that could increase exposure to the inhalation of soil contaminants such as that generated by vehicular traffic on unpaved roads. MDEQ allows facility and site-specific PSIC development where inputs can be modified in relation to the site and these options are available if preferred.

Therefore, the Committee recommends that the Ev factor remain in the generic PSIC development to ensure the protectiveness of the criteria. Regarding the modification of the Q/C based on source size to generate the applicable generic PSIC, the MDEQ proposed method in the recently revised TSD is deemed reasonable and appropriate unless another method is shown to be better scientifically.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological profile for manganese. Atlanta: US Department of Health and Human Services.

CAL-EPA and Office of Environmental Hazards. Soil Screening Values, Human-Exposure-Based Screening Numbers Developed to Aid Estimation of Cleanup Costs for Contaminated Soil (January 2005 Revision). http://www.oehha.ca.gov/soil.html and http://www.oehha.ca.gov/risk/pdf/screenreport010405.pdf

Cowherd, C., G. Muleski, P. Engelhart, and D. Gillete. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination. EPA/600/8-85/002. Prepared for EPA Office of Health and Environmental Assessment, Washington, D.C.

Florida Department of Environmental Protection. Hazardous Waste Cleanup Section. and http://www.dep.state.fl.us/waste/quick_topics/publications/wc/FinalGuidanceDocumentsFlowCharts_April2005/TechnicalReport2FinalFeb2005(Final3-28-05).pdf

Illinois Environmental Protection Agency Bureau of Land, Tiered Approach to Corrective Action Objectives (TACO). http://www.epa.state.il.us/land/cleanup-programs/index.html and http://www.epa.state.il.us/land/taco/

Indiana Department of Environmental Management (IDEM) Risk Integrated System of Closure (RISC) Technical Resource Guidance Document 2001 http://www.in.gov/idem/files/risctechguidance.pdf (9/09/2008)

Indiana Department of Environmental Management (IDEM) Risk Integrated System of Closure (RISC) Technical Resource Guidance Document, Appendix 1 Default Closure Tables (January 2006) (http://www.in.gov/idem/files/risctech_appendix1_2006.pdf) (9/09/2008)

Minnesota Pollution Control Agency (MPCA) Site Draft Guidelines: Risk-Based Guidance for the Soil - Human Health Pathway, Volume 2, Technical Support Document (January 1999)

Minnesota Tier 1 Soil Reference Value (SRV) Spreadsheet (May 2007) (9/09/2008)

Minnesota Tier 2 Soil Reference Value (SRV) Spreadsheet (May 2007)
(9/09/2008)

New York Department of Environmental Conservation. Environmental Cleanup Policy and Guidance and Remedial Soil Cleanup Objectives, and Remediation Guidance and Policy Documents - NYS Dept. of Environmental Conservation

Ohio Division of Emergency and Remedial Response (DERR),. Use of Risk-Based Numbers in the Remedial Response Process Overview Paper. DERR-00-RR-038 (June 2005) http://www.epa.state.oh.us/derr/rules/RR-038.pdf (9/09/2008)

Ohio Division of Emergency and Remedial Response (DERR). Voluntary Action Program (VAP) Generic Direct-Contact Soil Standards Summary. OAC 3745-300-08 (B) and (C) (October, 2002). (9/10/2008)

Ohio Division of Emergency and Remedial Response (DERR). Voluntary Action Program (VAP) Support Document for the Development of Generic Numerical Standards and Risk Assessment Procedures (February, 2002) http://www.epa.state.oh.us/Portals/30/rules/2014/Risk%20Support%20Document.pdf (9/10/2008)

Personal communication with Ohio-EPA DERR staff (Ms. Audrey Rush)

Personal communication with Indiana IDEM staff (Mr. Eric Bailey)

Personal communication with Wisconsin RRD Staff (Mr. Resty Pelayo).

Personal communication with Minnesota MPCA Staff (Ms. Emily Hansen).

Texas Commission on Environmental Quality. Texas Risk Reduction Program Protective Concentration Levels (PCLs). http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html

United States Environmental Protection Agency. 1996. Soil Screening Guidance: User's Guide. Publication 9355.4-23. Office of Solid Waste and Emergency Response, Washington, D.C.

West Virginia department of Environmental Protection Office of Environmental Remediation, and http://www.wvdep.org/Docs/15435_60CSR3_July%2008%20vs%20previous%20De%20Minimis%20Values.pdf

Wisconsin Department of Natural Resources, Guidance on "Determining Residual Contaminant Levels Using The EPA Soil Screening Level Web Site" (January 2002). (9/09/2008) Resources for environmental professionals - Wisconsin DNR (9/09/2008)

APPENDIX A. COMPARISON TABLES

Table 1. Comparison of Michigan Mn Inhalation Criteria to Neighboring States and EPA Regions

State/region	Michigan	Indiana	Illinois	Ohio		Wisconsin	Minnesota	EPA Regions 3, 6 and 9
Soil Clean-up Level/Screening Level (SL) Name/Description	Particulate Soil Inhalation Criteria (PSIC)	Soil Direct Contact Closure Levels (CL) (includes ingestion, inhalation, and dermal pathways)	Tier 1 Soil Remediation Objectives (SRO)	Voluntary Action Program (VAP) standards (2002)	Remedial Response Program (RRP) Screening Values (SVs) -	Residual Contaminant Levels (RCLs)	Soil Reference Values (SRV)	Revised Screening levels (SLs); Preliminary Remediation Goals (PRG) are used for site-specific risks.
Latest revision/guidance and clean-up levels update	(2007)	(2007)	(2002)	(VAP - 2002)	(RRP - 2005)	(2002)	1999 (guidance), 2007 (SRV table update)	(2008)
Manganese soil particulate inhalation criteria or screening levels (mg/kg unless indicated)	Residential – 3,300 Industrial - 1,500	Mn CL is not listed Residential direct contact estimate [1] – 30,000 Residential inhalation only estimate [2] – 78,000	Residential – 69,000 Industrial – 91,000 Construction worker – 8,700	Residential estimate [2] – 82,100 (adult)	Direct contact: Residential PRG – 1.8E+2 Industrial PRG – 1.9E+3 Inhalation only estimate:[2] Residential – 12,000 Industrial – 8,430	Residential – 7,400 Industrial – 52,000	Tier 1 Residential – 1,400 (oral) Tier 2 Industrial – 5,600 (oral, inh; 5 acre) 1/2 acre inhalation estimate:[3] Tier 1 Residential	Direct contact: [3] Residential – 1,800 ppm Industrial – 23,000 ppm Inhalation only: Residential – 71,000 Industrial – 300,000
Source Size used for Clean-up value	1/2 acre	1/2 acre	1/2 acre (residential (R)), 1 acre (industrial (I))	1/2 acre		1/2 acre	5 acre	1/2 acre
Is the calculation of the inhalation clean-up values or inhalation component based on the EPA 1996 Soil Soil Screening Guidance (SSG) equations?	Yes	Yes	Yes	No; the emission factor represents the sum of the volatilzation factor (VF) and PEF (1/PEF + 1/VF).		Yes	No; the SRV is calculated for average daily concentration (ADC), which does not include THQ and RfC.	No; the emission factor represents the sum of the volatilzation factor (VF) and PEF (1/PEF + 1/VF).
Are clean-up numbers based on single or multiple pathway assessment?	Inhalation pathway only.	Multi-pathway	Inhalation pathway only.	Multi-pathway	Multi-pathway	Inhalation pathway only.	Clean-up value is the lowest calculated for each pathway; For Mn, the driving pathway is oral for residential and both oral and inhalation for industrial sites.	Individual and Multi-pathway.
Is the Mn toxicity concentration based on the 1993 EPA IRIS reference concentration (RfC) value of 0.05 $\mu g/m^3$?	Yes	Not applicable for Mn; inhalation toxicity values are expressed as RfDi.	Yes	Yes, the IRIS RfC for Mn is used to derive an inhalation dose (RfDi) of 1.43E-2 μg/kg-day.		Yes	0.2 $\mu g/m^3$ (modified IRIS RfC value).	Yes
Is the PEF adjusted for averaging time assigned to the reference concentration or ambient air screening levels?	Yes, the PEF is divided by 2 when the Initial Threshold screening Level (ITSL) is assigned a 24 hour averaging time (Air Toxics Rules). The ITSL for Mn adopted the EPA IRIS RfC value.	No	No	No.		No. The air SL for Mn is 4.8 $\mu g/m^3$ (NR445 - Control of Hazardous Air Pollutants) based on 8-hr TWA of 200 ug/m3; 24-hour averaging time. Wisconsin does not adopt IRIS RfC values with uncertainty factors greater than 300.	No.	No.
Derivation Input Parameters:	PSIC Inputs:	Inputs different from PSIC:	Inputs different from PSIC:	Inputs different from PSIC: VAP standard:	RRP -SVs:	Inputs different from PSIC:	Inputs different from PSIC:	Inputs different from PSIC:
Hazard Quotient (HQ)	1				0.1 (R); 1.0 (I)	0.2 (R); 1.0 (I)	0.2	0.1 (R); 1.0 (I)
Averaging time (AT) (ED x 365 days/yr), days	10,950 (R), 9,125 (I)							2,190 (R-child), 9,125 (I)
Exposure frequency, days/year (EF)	350 (R); 245 (I)	250 (R)	350 (R); 250 (I)	350 (R); 250 (I)	350 (R-adult), 250 (I)	350 (non-I), 250 (I)	350 (non-I), 250 (I)	350 (R-adult), 250 (I)
Exposure Duration, years (ED)	30 (R); 25 (I)	30 (adult); 6 (child)		30, 6 (R-adult, child); 25 (I)	6 (R); 25 (I)		33 (R); 25 (I)	6 (R); 25 (I)

Table 1. Comparison of Michigan Mn Inhalation Criteria to Neighboring States and EPA Regions

State/region	Michigan	Indiana	Illinois	Ohio		Wisconsin	Minnesota	EPA Regions 3, 6 and 9
Particulate Emission Factor, m3/kg (PEF)	1.28E+8 (R); 3.95E+7 (I)	1.32E+09	1.32E+9 (R) (1/2 acre); 1.24E+9 (I) (1 acre)	1.70E+09	1.32E+09	7.14E+08	For 5 acre - 7.7E+8 (R), 3.8E+8 (I) For 1/2 acre - 1.14E+9 (R), 5.8E+8 (I) estimate [3]	1.36E+09
PEF Inputs:								
Dispersion Factor, g/m2-s per m3/kg (Q/C)	Q/C - 82.33 (0.5 acre)	Q/C - 90.8 (0.5 acre)	97.78 (0.5 acre); 85.81 (1 acre)	83.22 (0.5 acre)	90.8 (0.5 acre)	90.8 (0.5 acre)	61.03 (5 acre); 90.8 (0.5 acre)	93.77 (0.5 acre)
Emissions due to wind, g/m2-sec (Ew)	Ew - 5.5E-7	Ew - 1.4E-7 (estimated value)[4]	Ew - 1.4E-7 (estimated value)[4]	9.9E-8 (estimated value)[4]	1.4E-7 (estimated value [4]	2.5E-7 (estimated value)[4]	1.6E-7 (estimated value)[4]	1.4E-7 (estimated value [4]
Vegetative Cover, % (V)	V - 50% (0.5)							
Emissions due to vehicle, g/m2-sec (Ev)	Ev - 3.68E-7 (R); 1.81E-6 (I)	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.
Others:		Age-adjusted Inhalation factor (InhF)10.9 m3-yr/kg-day		Finh (inhalation intake factor (kg/kg-day)				
		Inhalation rate (IR) m3/day - 20 (adults); 10 (child)						
Basis for Dispersion Factor (Q/C)	Michigan-based climatic data for 1/2 acre-source size; Q/C for other source sizes up to 1,000 acres are listed.	Minneapolis climatic data for 1/2 acre; No guidance for other source sizes.	Residential PEF uses EPA Q/C value for Minneapolis for 1/2 acre-source size; Industrial PEFuses Q/C for Chicago for 1 acre; Q/C for other source sizes up to 30 acres are listed.	EPA's Q/C value for Cleveland for 1/2- acre source size. No guidance for other source sizes.	EPA's Q/C value for Minneapolis for 5 acre-source size. Guidance for Q/C for other source sizes refers to the SSG.	EPA's Q/C value for Minneapolis. Adjustment of RCL value for source sizes greater than 1/2 acre is required.	EPA's Q/C value for Minneapolis for 5 acre-source size.	EPA's Q/C value for Minneapolis for 1/2 acre-source size. Guidance for Q/C for other source sizes refers to the SSG.
Emissions due to wind input:								
Mean annual windspeed (Um) at 7 meters	Um - 6.4	Um - 4.69	Um - 4.69	Um - 4.69	Um - 4.69	Um - 5.0	Um - 4.69	Um - 4.69
Equivalent threshold value of wind speed (Ut) at 7 meters height	Ut - 11.32	Ut - 11.32	Ut - 11.32	Ut - 11.32	Ut - 11.32	Ut - 11.00	Ut - 11.32	Ut - 11.32
Function of X derived from Cowherd	F(x) - 0.194	F(x) - 0.194	F(x) - 0.194	F(x) - 0.194	F(x) - 0.194	F(x) - 0.2707	F(x) - 0.194	F(x) - 0.194
Emissions due to vehicle traffic (Ev)	Included in the PEF derivation; derived for residential and industrial sites using the 1985 AP-42 equation for dust emissions of unpaved roads.	Not considered in the PEF derivation.	Not included in the PEF equation.	Not included in the PEF equation.		Not included, however, for sites with dust emissions from traffic or mechanical disturbances, site-specific PEF is recommended	Not included in the PEF equation.	Not included, however, for sites with dust emissions from traffic or mechanical disturbances, site-specific PEF is recommended
Source size-based adjustment of clean up value	Q/C for source sizes other than 01/2 acre up to 1,000 acres have been developed and are required to develop the applicable source-size modified clean-up value.	No program direction relating to source sizes different from 1/2 acre	Q/C for source sizes other than 01/2 acre up to 30 acres have been developed and are required to develop the applicable source-size modified clean-up value for industrial sites.	No program direction relating to source sizes different from 1/2 acre		No source size adjustment.		Q/C for source sizes other than 01/2 acre up to 32 acres can be developed using the 1996 SSG and Supplemental Guidance.
Clean-up categories	residential and industrial/commercial land use; generic, facility-specific and site-specific clean-up categories.	residential and industrial/commercial land use; generic and site-specific clean-up categories.	residential and industrial/commercial land use; tiered SROs: Tier 1 (generic) and Tier 2 and 3 (site-specific clean-up categories)	Value is 1/10 of the EPA residential PRGs for Mn: Direct Contact – 1.8E+3 (R) 1.9E+4 (I) Soil inhalation PRG - 2,900 [4]		Non-industrial and industrial; generic assumptions for screening level	Guidance for Q/C for other source sizes refers to the SSG.	residential, industrial (outdoor/indoor worker), and recreational screening levels

Table 1. Comparison of Michigan Mn Inhalation Criteria to Neighboring States and EPA Regions

State/region	Michigan	Indiana	Illinois	Ohio		Wisconsin	Minnesota	EPA Regions 3, 6 and 9
Additional Comments:				VAP: Rule revision (Spring, 2008) will use RfC; current rule converts RfC values to RfDi.		RCLs are generated using the EPA web calculator which uses toxicity value from IRIS; NRF Ruies (0 1/PEF value - 1.4 ug/m3)		
Source/Web link	http://www.deq.state.mi.us/documents/deq-rrd-Op_Memo1_Attach7-SoilInhalationCleanupCriteria-TSD.pdf	http://www.in.gov/idem/files/risctech_appendix1_2006.pdf	http://www.epa.state.il.us/land/taco/fact-sheet.html	http://www.epa.state.oh.us/derr/vap/docs/GNS_SoilQuickRef.pdf	http://www.epa.state.oh.us/derr/rules/RR-038.pdf	http://www.dnr.state.wi.us/org/aw/rr/archives/pub_index.html#TECHNICAL-GE	http://www.pca.state.mn.us/cleanup/pubs/srv3_99.pdf	http://epa-prgs.ornl.gov/chemicals/index.shtml

[1] Estimate was calculated by IDEM staff
[2] Estimate was calculated using the equation and inputs/values presented in the guidance documents.
[3] Estimate was calculated using the equation, 1/2 acre source size Q/C and other inputs and values presented in the guidance document.
[4] Ew estimate used the portion of the PEF equation less the Q/C and vegetation factors.

Abbreviations: R - residential
I - industrial

Table 2. Comparison of Michigan Mn Inhalation Criteria to Distant States

State/region	Michigan	California	Florida	New York	Texas	West Virginia
Soil Clean-up Level/Screening Level (SL) Name/Description	Particulate Soil Inhalation Criteria (PSIC)	California Human Health Screening Levels (CHHSLs)		Soil Cleanup Objectives (SCO)	Protective Concentration Levels (PCLs)	Uniform Risk-Based Standards
Latest revision/guidance and clean-up levels update	(2007)	(2005)	(2005)	(2006)	(2008)	(1997)
Manganese soil particulate inhalation criteria or screening levels (mg/kg unless indicated)	Inhalation pathway only: Residential – 3,300 Industrial – 1,500 Multi-pathway estimate: Residential – 2,920 Industrial – 48,000	None for Mn	Multi-pathway: Residential – 3,500 Industrial – 43,000	Multi-pathway: Residential – 2,000 Industrial – 10,000	Multi-pathway: Residential - 3,700 Industrial - 36,000	Multi-pathway: Residential – 1,800 ppm Industrial - 23,000 ppm
Source Size used for Clean-up value	1/2 acre	1/2 acre	1/2 acre	1/2 acre	1/2 acre	1/2 acre
Is the calculation of the inhalation clean-up values or inhalation component based on the EPA 1996 Soil Soil Screening Guidance (SSG) equations?	Yes	Yes	Yes	Yes	Yes	Yes
Are clean-up numbers based on single or multiple pathway assessment?	Individual pathway	Multi-pathway	Multi-pathway (ingestion, dermal contact, and inhalation)	Multi-pathway (ingestion, dermal contact, and inhalation)	Multi-pathway (ingestion, dermal contact, and inhalation)	Multi-pathway (ingestion, dermal contact, and inhalation)
Is the Mn toxicity concentration based on the 1993 EPA IRIS reference concentration (RfC) value of 0.05 µg/m^3?	Yes	No Mn information.	Yes	0.15 µg/m3	Yes	Yes, the IRIS RfC for Mn is used to derive the RfDi (1.43E-2 µg/kg-day).
Is the PEF adjusted for averaging time assigned to the reference concentration or ambient air screening levels?	Yes, the PEF is divided by 2 when the Initial Threshold screening Level (ITSL) is assigned a 24 hour averaging time (Air Toxics Rules). The ITSL for Mn adopted the EPA IRIS RfC value.	Not applicable.	No	No	No.	No.
Derivation Input Parameters:	Generic PSIC Inputs:	Inputs different from PSIC:	Inputs different from PSIC:	Inputs different from PSIC:	Inputs different from PSIC:	Inputs different from PSIC:
Hazard Quotient (HQ)	1	Not available				
Averaging time (AT), (ED x 365 days/yr), days	10,950 (R), 9,125 (I)	Not available	Age adjusted: 12,045 (R), 9,125 (I)	Age adjusted: 25,550 (R), 9,125 (I)		Age adjusted: 2,190 (R), 9,125 (I)
Exposure frequency, days/year (EF)	350 (R); 245 (I)	Not available	350 (R); 250 (I)	35 (R), 31 (I)	350 (R), 250 (I)	350 (R and I)
Exposure Duration, years (ED)	30; 25 (I)	Not available	6 (R); 25 (I)	70 (R); 25 (I)	30 (R); 25 (I)	6 (R); 25 (I)

Table 2. Comparison of Michigan Mn Inhalation Criteria to Distant States

State/region	Michigan	California	Florida	New York	Texas	West Virginia
Particulate Emission Factor, m3/kg (PEF)	1.28E+8 (R); 3.95E+7 (I)	Not available	1.24E+9	1.21E+9	1.08E+9	1.32E+09
PEF Inputs:						
Dispersion Factor, g/m2-s per m3/kg (Q/C)	82.33 (0.5 acre)	Not available	85.61 (0.5 acre)	83.53 (0.5 acre)	79.25 (0.5 acre)	90.8 (0.5 acre)
Emissions due to wind, g/m2-sec (Ew)	Ew - 5.5E-7	Not available	1.4E-7 (estimated value)[5]	1.4E-7 (estimated value)[5]	8.5E-8 (estimated value)[5]	6.9E-8 (estimated value [5]
Vegetative Cover, % (V)	50% (0.5)	Not available				
Emissions due to vehicle, g/m2-sec (Ev)	Ev - 3.68E-7 (R); 1.81E-6 (I)	Not available	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.
Basis for Dispersion Factor (Q/C)	Michigan-based climatic data for 1/2 acre-source size; Q/C for other source sizes up to 1,000 acres are listed.	Not available	EPA's Q/C value for Miami, FL	EPA's Q/C values for Cleveland, Harrisburg, Hartford, and Philadelphia were averaged to represent possible meteorological conditions in NY state.	EPA's Q/C value for Houston; Q/C given for 0.5 acre and 30 acre sources, other source area acreage may be used in the equation.	Minneapolis climatic data for 1/2- acre source size.
Emissions due to wind input:						
Mean annual windspeed (Um) at 7 meters	Um - 6.4		Um - 4.69	Um - 4.69	Um - 4.8	Um - 4.69
Equivalent threshold value of wind speed (Ut) at 7 meters height	Ut - 11.32		Ut - 11.32	Ut - 11.32	Ut - 11.32	Ut - 11.32
Function of X derived from Cowherd	F(x) - 0.194		F(x) - 0.194	F(x) - 0.194	F(x) - 0.224	F(x) - 0.194
Emissions due to vehicle traffic (Ev)	Included in the PEF derivation; derived for residential and industrial sites using the 1985 AP 42 equation for dust emissions for unpaved roads.	Not included in PEF equation.	Not included; however, for sites with dust emissions from traffic or mechanical disturbances, a site specific PEF is recommended.	Not included in PEF equation.	Not included in PEF equation.	Not included in PEF equation.
Source/Web link		http://www.calepa.ca.gov/brownfields/documents/2005/CHHSLsGuide.pdf	http://www.dep.state.fl.us/waste/quick_topics/publications/wc/FinalGuidanceDocumentsFlowCharts_April2005/TechnicalReport2FinalFeb2005(Final3-28-05).pdf	http://www.dec.ny.gov/regulations/2612.html	http://www.tceq.state.tx.us/assets/public/legal/rules/rules/pdflib/350d.pdf and http://www.tceq.state.tx.us/remediation/trrp/trrppcls.html	http://www.wvdep.org/Docs/3200_RemediationGuidanceVersion2-1.pdf

[5] Estimate was calculated using the equation and inputs/values presented in the guidance documents.