Charter Steel Slag Health Assessment

Adam Streiffer, MSPH
Robert Thiboldeaux, PhD

Wisconsin
Department of Health Services

Division of Public Health
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At the request of the Department of Natural Resources (DNR), the Wisconsin Department of Health Services (DHS) assessed human health risks from the beneficial use of electric arc furnace (EAF) slag, ladle slag, and the mixture of EAF and ladle (mixed) slags from Charter Steel's steel-production processes for unconfined uses in southeast Wisconsin. DHS makes the following conclusions:

1) **Incidental Ingestion Exposure Pathway**
Using various exposure scenarios, based on current U.S. Environmental Protection Agency (EPA) health-based exposure guidance, DHS concludes that unhealthy exposures to children via direct contact may reasonably result from use of slag on residential or daycare properties. **DHS recommends that use of unconfined Charter Steel EAF and mixed slags in residential (i.e., non-commercial and non-industrial) settings be restricted.**

2) **Dust Inhalation Exposure Pathway**
A worst-case exposure analysis of modeled ambient PM10 concentrations produced by traffic on roads, shoulders, and parking lots constructed of unbonded Charter Steel EAF, ladle, and mixed slag failed to indicate health hazards from constituents of the slag in the PM10 dust. **DHS recommends no restrictions on the use of unconfined Charter Steel slags in road, shoulder, and parking lot construction, except in settings as noted above.**

3) **Drinking Water Pathway**
The potential exists for ground and surface water contamination resulting from leaching of metals and other constituents from unconfined use of EAF, ladle, or mixed slags exposed to precipitation. However, insufficient information is available to determine what volumes of EAF, ladle, or mixed slag would be necessary in constructed surface applications to cause ground or surface water contamination at levels that may impact human health. **DHS recommends further review of this pathway as environmental data becomes available.**

BACKGROUND

Charter Steel Company (Charter Steel) owns and operates a steel mill facility located at 1658 Cold Springs Road in Saukville, Wisconsin. This facility utilizes an electric arc furnace (EAF) to melt feedstock of steel scrap and non-scrap iron. As the feedstock melts, carbon is injected into the furnace, along with natural gas, oxygen and lime. The molten lime forms a slag, which floats to the top of the steel bath. This slag is known as EAF slag. As oxygen is injected into the furnace, it combines with carbon to form carbon monoxide gas. As the gas floats to the top of the furnace, less dense impurities are pulled out of the steel (many in the form of oxides), and are trapped in the floating slag layer. The slag is decanted from the furnace into a slag pot prior to the removal of the steel from the furnace.[1]

After completion of the primary steelmaking process, the liquid metal is further refined by utilizing a combined ladle metallurgical furnace with a degasser unit; this system is referred to as a vacuum arc degasser (VAD). Depending on the grade of steel being produced, alloys such as chromium, molybdenum, nickel, silicon, boron, or manganese may be added during the refining process along with lime. Slag produced in this process is referred to as ladle slag.

Both EAF and ladle slags are primarily composed of "oxides of calcium, iron, silicon, aluminum, magnesium, and manganese, in complexes of calcium silicates, aluminosilicates, and aluminoferrite."[2] Slag also contains waste metals and other impurities which vary by batch, scrap metal source, and by milling process (i.e., EAF or VAD).

Currently, prior to sale and distribution, both the EAF and ladle slags are cooled, combined, and then screened into three different sizes of 8-inch, 4-inch, and ¾-inch and smaller material. In general, EAF slag is a larger aggregate and ladle slag is a finer particle size. The sorted, mixed slags are stored in large, open air piles in the slag processing area at Charter Steel while they await sale and distribution. Tube City IMS operates the slag processing facility on Charter Steel's Saukville property. In 2014, Charter Steel in Saukville, Wisconsin, produced approximately 65,850 tons of steel slag, of which approximately 49,324 tons were beneficially used (28,355 tons of less than ¾-inch mixed slag, 18,307 tons of ¾-inch to 4-inch mixed slag, 1,662 tons of ¾-inch to 4-inch EAF slag, and 1,000 tons of greater than 4-inch mixed slag).[3]

Slag generated at Charter Steel has previously been sold for use in construction of residential driveways, parking lots, and rural roads in southeastern Wisconsin. In 2008, in response to citizen and local health officials' concerns, DHS evaluated[4] the health impacts of unconfined mixed slag when used in residential settings. DHS concluded that restrictions against residential use of slag were advised. That evaluation served as a basis for use restrictions imposed on Charter Steel by DNR beginning with their conditional Grant of Exemption for the Beneficial Use of Charter Steel Slag dated July 24, 2009.

In May 2014, as part of the renewal process for Charter Steel's conditional approval to beneficially use the steel slags, DNR requested that DHS re-evaluate the potential human health risks from unconfined use of Charter Steel EAF, ladle, and mixed slags, and expand the scope of the assessment to include other exposure scenarios including typical Wisconsin winter snow cover and bioavailability of metals. This document summarizes our evaluation of residential (non-occupational) exposure to Charter Steel EAF, ladle, and mixed slags via both soil ingestion and inhalation. Ingestion of slag-contaminated ground or surface water was not evaluated, as sufficient data was not available.

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[1] Email correspondence between Ruth O'Donnell, Wisconsin Department of Natural Resources, and Charter Steel on February 16, 2015.

[2] *Human Health Risk Assessment for Iron and Steel Slag*. December 2011. ToxStrategies, Inc.

[3] *2014 Charter Steel Annual Slag Report.* Prepared by Tube City IMS for Charter Steel Company. Document dated March 27, 2015.

[4] Knobeloch, Lynda. August 2008. *Evaluation of Childhood Exposures to Steel-making Slag used in Residential Settings*. Wisconsin Department of Health and Family Services.

RISK ASSESSMENT

Screening

Laboratory analytical data of Charter Steel slags (EAF, ladle, and mixed slags) dating as far back as 1994 was provided to DHS by DNR. Laboratory reports include samples collected and analyzed by Charter Steel and submitted to DNR as a condition of its beneficial use Grant of Exemption reporting requirements, as well as samples collected and analyzed by DNR for independent verification. DHS tabulated the analytical data, and calculated maximum and average values for each constituent both including and excluding the DNR-funded analyses. Both maximum and average values were then compared to EPA residential soil screening values for incidental ingestion. This data is presented in **Table 1**. Slag constituents that exceeded EPA screening values were further evaluated in several ingestion and inhalation scenarios.

Ingestion Exposure Route

In this exposure route, children, in particular young children, may have direct contact (via hand-to-mouth incidental ingestion) with slag when it is used as unbonded surface course for an (un-paved) residential driveway. This exposure may occur during outdoor play activities by directly handling the slag, or coming into contact with it from play with toys that have been in contact with slag. Fine particulates in slag can be picked up on clothing, shoes, vehicles, and domestic animals and carried into homes, car interiors, and garages, increasing the potential for exposure.

This assessment looks at children as a sensitive population more susceptible to direct contact and assumes the following:

- Up to half of the soil ingested by a child could be slag-related particulates (EF = 50%).
- Bodyweight of 16 kg (child).[5]
- Estimates only consider exposure to constituents via soil ingestion and do not take into consideration dietary or other environmental exposures.
- Separate calculations were run and assessed for EAF, ladle, and mixed slag concentrations.
- Both maximum and average concentrations were evaluated for all scenarios.

The following direct-contact exposure scenarios were evaluated:

1) **Child Incidental Soil Ingestion Scenario 1 (Table 2)**
   Intake Rate: 200 mg/day intake of contaminated soil[6]
   Concentrations: Maximum and average concentrations include DNR data
   Bioavailability: 100% bioavailability of metals was assumed

2) **Child Incidental Soil Ingestion Scenario 2 (Table 3)**
   Intake Rate: 133 mg/day intake of contaminated soil[7]
   Concentrations: Maximum and average concentrations include DNR data
   Bioavailability: 100% bioavailability of metals was assumed

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[5] Bodyweight for children 1 - 6 years old (50th percentile); Public Health Assessment Guidance Manual, App G. Agency for Toxic Substance and Disease Registry (ATSDR), 2005 Update. http://www.atsdr.cdc.gov/hac/PHAManual/appg.html

[6] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child, assuming 365 days of exposure per year. Public Health Assessment Guidance Manual, App G. ATSDR, 2005 Update.

[7] Standard ingestion rate of 200 mg/day x 8/12 months, to account for an assumed four months of ice and snow cover during the year.

3) **Child Incidental Soil Ingestion Scenario 3 (Table 4)**
Intake Rate: 200 mg/day intake of contaminated soil
Concentrations: Maximum and average concentrations exclude DNR data
Bioavailability: 100% bioavailability of metals was assumed

4) **Child Incidental Soil Ingestion Scenario 4 (Table 5)**
Intake Rate: 133 mg/day intake of contaminated soil
Concentrations: Maximum and average concentrations exclude DNR data
Bioavailability: 100% bioavailability of metals was assumed

5) **Child Incidental Soil Ingestion Scenario 5 (Table 6)**
Intake Rate: 200 mg/day intake of contaminated soil
Concentrations: Maximum and average concentrations exclude DNR data
Bioavailability factor: 25% bioavailability of metals assumed

6) **Child Incidental Soil Ingestion Scenario 6 (Table 7)**
Intake Rate: 133 mg/day intake of contaminated soil
Concentrations: Maximum and average concentrations exclude DNR data
Bioavailability factor: 25% bioavailability of metals assumed

<u>Example Calculation</u>
(Soil Ingestion Scenario 1, Manganese, average concentration, mixed slag)

D = (C X IR X EF X CF X BF) / BW

D = Exposure Dose	
C = Contaminant Concentration	[28,552 mg/kg]
IR = Intake Rate of soil	[200 mg/day]
EF = Exposure Factor	[50%]
CF = Conversion Factor	[10^{-6} kg/mg]
BW = Body Weight	[16 kg]
BF = Bioavailability Factor	[100%]

D = (28,552 mg/kg x 200 mg/day x 50% x 10^{-6} kg/mg) / 16 kg

D = 0.178 mg/kg/day

Reference Dose (RfD) = 0.024 mg/kg/day

Hazard Quotient (HQ) = D/RfD
= 0.178/0.024
= 7.4 (HQ > 1 constitutes health risk)

A HQ > 1 constitutes health risk. In short, a HQ > 1 means that the calculated dose (D) is greater than the reference dose (RfD). Since the RfD is the exposure point below which appreciable risk is not likely to occur, any dose over this RfD indicates a health risk. These two numbers are normalized as a ratio using the Hazard Quotient. Excel workbooks of the full calculations are attached as **Tables**.

Inhalation

In this exposure route, children living near unpaved roads or parking lots constructed with unbonded Charter Steel slags may inhale dust containing constituents of concern resulting from the normal use of that infrastructure. In order to assess this pathway, DHS solicited the assistance of air modelers within the DNR Air Management Bureau to model annual PM10 dispersion amounts. The DNR Modelers chose the following five modeled scenarios to determine an annual average PM10 concentration at various distances from the road or parking lot of concern. A complete write-up of the modeling exercise is included as **Appendix 1**.

In brief, the modeled scenarios were as follows:

1) Unpaved Slag-Constructed Farm Lane Road 1
2) Unpaved Slag-Constructed Farm Lane Road 2
3) Unpaved Slag-Constructed Road Shoulder
4) Unpaved Slag-Constructed Industrial Parking Lot 1
5) Unpaved Slag-Constructed Industrial Parking Lot 2

This assessment looks at children as a sensitive population more susceptible to inhalation risk and makes the following assumptions:

- Intake rate and body weight were chosen based on published air intake rates (IR) and body weights (BW).[8] A worst-case scenario was utilized, and determined by calculating ratios of IR to BW for all child age groups. The highest ratio was deemed worst case as such ratio corresponds to the highest exposure per body weight. The birth to one month age group represents the highest IR/BW ratio.
- A worst-case exposure factor of 100% was used, meaning that 12 months per year (365 days per year) of exposure were assumed.
- The worst-case modeled PM10 scenario was used as a starting point for evaluation in both scenarios.
- Estimates only consider exposure to these constituents via inhalation and do not take into consideration dietary or other environmental exposures.
- Separate calculations were run and assessed for EAF, ladle, and mixed slag concentrations.
- Both maximum and average concentrations were evaluated for both scenarios.
- Maximum and average concentrations include DNR data for both scenarios.
- 100% bioavailability of metals was assumed for both scenarios.

Empirical data indicates that approximately 90% of PM10-sized particles impact and are trapped by the nasopharynx.[9] This assessment assumes that impacted material is then swallowed, amounting to an ingestion route of exposure, while smaller dust particles, corresponding to PM2.5, are assumed to be respired into the deep lungs.[10] As such, two exposure scenarios were evaluated via the inhalation pathway:

[8] Exposure Factors Handbook, chapter 6. September 2011. US Environmental Protection Agency (EPA).

[9] Derelanko MJ, Hollinger MA (*eds*.). 2002. *Handbook of Toxicology, 2nd ed.* CRC Press.

[10] Thiboldeaux, R. 2007. *Amery-Dresser Trail Health Consultation*. US Department of Health and Human Services, Public Health Service. Agency for Toxic Substance and Disease Registry.

1) **Child Inhalation Scenario 1, PM10 Nasopharyngeal Swallow (Table 8)**
   Nasopharyngeal impaction of PM10 has been demonstrated to be followed by swallowing, amounting to an ingestion route of exposure. Thus this route was evaluated using soil ingestion reference doses.

2) **Child Inhalation Scenario 2, PM2.5 Respirable Fraction (Table 9)**
   For this scenario, we assumed that all PM10 was composed of PM2.5 (respirable fraction) as a worst-case starting point for evaluation. This route was evaluated using inhalation reference concentrations.

Exposure via ground or surface water

Groundwater monitoring results[11] from Charter Steel's Saukville facility demonstrate that the potential exists for groundwater and surface water impacts due to leaching of metals and other constituents from EAF, ladle, or mixed slags. Insufficient information is available to determine what volumes of slags in a slag-constructed surface application would cause impacts to ground or surface water at levels that may impact human health.

DISCUSSION AND CONCLUSIONS

1. The calculated exposure estimate for incidental hand-to-mouth ingestion of Charter Steel slag reasonably predicts exposure in excess of public health risk levels (**Tables 2-7**). Risk levels were exceeded for all calculated scenarios for both EAF and mixed slag, as well as for 6 of the 12 scenarios for ladle slag. A summary table of these scenarios and conclusions is below.

2. In contrast, no excess risk was predicted using modeled estimates of slag particulates generated from road surfaces and parking lots (**Tables 8-9**).

Incidental Ingestion Hazard Quotient Exceedance Summary Table

	Child Incidental Soil Ingestion Scenario 1 (Table 2)		**Child Incidental Soil Ingestion Scenario 2 (Table 3)**		**Child Incidental Soil Ingestion Scenario 3 (Table 4)**		**Child Incidental Soil Ingestion Scenario 4 (Table 5)**		**Child Incidental Soil Ingestion Scenario 5 (Table 6)**		**Child Incidental Soil Ingestion Scenario 6 (Table 7)**	
	Max	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**	**Max**	**Avg**
Mixed Slag	Sb, Fe, Mn, Tl, V	Fe, Mn, Tl	Sb, Fe, Mn, Tl	Fe, Mn, Tl	Fe, Mn, Tl, V	Fe, Mn, Tl	Fe, Mn, Tl	Fe, Mn, Tl	Mn, Tl	Mn	Mn, Tl	Mn
EAF Slag	Sb, Fe, Mn, Tl, V	Fe, Mn, Tl	Sb, Fe, Mn, Tl	Fe, Mn, Tl	Fe, Mn, Tl, V	Fe, Mn, Tl	Fe, Mn, Tl	Mn, Tl	Mn, Tl	Mn	Mn, Tl	Mn
Ladle Slag	Tl	Tl	Tl	Tl	Tl	None	Tl	None	None	None	None	None

Notes:
This table summarizes the constituents that exceed hazard quotient of 1 under the various scenarios evaluated.
Sb – Antimony Fe – Iron
Mn – Manganese Tl – Thallium
V – Vanadium

[11] Groundwater Monitoring Results and Request for Closure, IMS at Charter Steel. May 16, 2012. Stantec Consulting Services, Inc.

It should be noted that cumulative exposures were not formally calculated as part of our risk assessment. However, preliminary calculations suggest that such cumulative exposure would not alter the risk conclusions and recommendations of the individual inhalation and incidental ingestion pathways (namely to restrict use of slag by-products for residential application, but not in road construction applications). In addition, it should be noted that we did not review non-residential/ occupational exposures and settings, though this is an important exposure pathway, and given the high concentrations of certain constituents, is worthy of review. Lastly, as previously mentioned, surface and groundwater pathways were not evaluated as a part of this review.

Toxicity Overview of Thallium and Manganese

The above exposure scenarios indicate five chemical constituents of Charter Steel slags that may exceed health risk levels: antimony, iron, manganese, thallium, and vanadium. While levels of each of these metals exceed current EPA risk level guidance in several scenarios, and thus increase the risk of health impacts, it is our opinion that thallium and manganese are of the greatest health concern, and as such we highlight the toxicological properties of thallium and manganese below.

Thallium and manganese have both been associated with adverse effects on the central nervous system. Thallium is a highly toxic, naturally occurring element. Thallium was used as a rat poison until 1972 when its use was banned due to its toxicity and the danger it posed to humans. In the environment, it readily forms bonds with other chemicals to form salts. In the body, it is readily absorbed when ingested and is distributed throughout the body.

Thallium may cause death with acute exposure at relatively small amounts (as low as 1 gram). Its non-lethal effects at acute exposure levels include neurological damage, as well as damage to the respiratory and cardiovascular systems, among other organs. Little is known about the health effects to humans from low levels of thallium exposure over long periods of time, though hair loss is commonly the symptom that leads to a diagnosis of thallium exposure. Hair loss, behavior changes, and reproductive effects have been observed in animals due to long-term, low levels of exposure.[12, 13]

Manganese is a naturally occurring element and an essential dietary nutrient, playing a number of roles in the body. Although small amounts are necessary for human health, exposure to high levels of manganese may cause adverse health effects in the body, including neurological effects. Specific neurological effects associated with long-term (chronic) exposures include reduced coordination and dexterity, as well as symptoms of forgetfulness, anxiety, and insomnia.[14]

[12] *Toxicological Profile for Thallium*. Agency for Toxic Substance and Disease Registry. Accessed 3/19/2014 http://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=309&tid=49

[13] *Thallium Salts*. Integrated Risk Information System (IRIS). U.S. Environmental Protection Agency (EPA). Accessed 3/24/14 http://www.epa.gov/iris/subst/1012.htm

[14] *Toxicological Profile for Manganese*. Agency for Toxic Substance and Disease Registry. Accessed 3/19/2014 http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=102&tid=23

In summary, DHS concludes the following:

1) **Incidental Ingestion Exposure Pathway**
Using various exposure scenarios, based on current U.S. EPA health-based exposure guidance, DHS concludes that unhealthy exposures to children may reasonably result from use of slag on residential or daycare properties. **DHS recommends that use of unconfined Charter Steel EAF and mixed slags in residential (i.e., non-commercial and non-industrial) settings be restricted**.

2) **Dust Inhalation Exposure Pathway**
A worst-case exposure analysis of modeled ambient PM10 concentrations produced by traffic on slag-constructed roads, shoulders, and parking lots failed to indicate health hazards from constituents of the slag in the PM10 dust. **DHS recommends no restrictions on the use of unconfined Charter Steel slags in road, shoulder, and parking lot construction, except in settings as noted above.**

3) **Drinking Water Pathway**
Insufficient information is available to determine whether metals or other constituents present in the slag-constructed surfaces are capable of adversely affecting surface or groundwater via runoff or infiltration at levels that may impact human health. **DHS recommends further review of this pathway as environmental data becomes available.**

"This report was supported in part by funds provided through a cooperative agreement with the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. The findings and conclusions in these reports are those of the author(s) and do not necessarily represent the views of the Agency for Toxic Substances and Disease Registry or the U.S. Department of Health and Human Services. This document has not been revised or edited to conform to agency standards."

Tables

Calculations of Exposure of Children to Charter Steel Slags

Table 1. Total Metals Laboratory Analyses

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Sample type [1]	**WDNR NR 538 -Beneficial Reuse - Table 1B Category 1**	**WDNR NR 538 - Beneficial Reuse - Table 2B Category 2**	**Processed EAF Slag Industry Average**[3]	**DNR Data Included: Mixed Slag Max Value**	**DNR Data Included: EAF Slag Max Value**	**DNR Data Included: Ladle Slag Max Value**	**DNR Data Included: Mixed Slag Avg Value**	**DNR Data Included: EAF Slag Avg Value**	**DNR Data Included: Ladle Slag Avg Value**
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Aluminum (Al)			27,561	27,700	18,000	5,900	15,999	15,892	5,352
Antimony (Sb)	6.3		1	**100**	**150**	***22***	12	17	6
Arsenic (As)	0.042	21	***5***	**20**	**20**	**20**	**5**	**5**	**4**
Barium (Ba)	1,100		478	316	335	222	174	225	90
Beryllium (Be)	0.014	7	***1.08***	**5**	**2**	**2**	**1**	**1**	**0.52**
Boron (B)	1,400			660	110	93	114	74	61
Cadmium (Cd	7.8		0.97	***19***	***7.8***	5	3	2	1
Chloride (Cl)				0	0	0	---	---	---
Chromium (Total)			3,136	5,599	8,016	390	3,723	4,895	102
Chromium (VI)	14.5		1.9	2	5	0.45	0	2	0.35
Copper (Cu)			134	241	155	15	99	87	11
Cyanide (total)				1	1	0	<1	<1	---
Fluoride (F)				0	0	0	---	---	---
Iron (Fe)			192,780	258,000	271,000	22,000	204,171	176,867	11,108
Lead (Pb)	50		13	***97***	20	20	13	6	4
Magnesium (Mg)			52,871	80,900	89,400	53,000	61,956	74,396	46,400
Manganese (Mn)			31,182	43,400	48,946	3,765	28,552	30,163	1,979
Mercury (Hg)	4.7		0.01	1.000	1.000	0.050	0.2793	0.1574	0.01539
Molybdenum (Mo)	78		41	***113***	***250***	***160***	44	51	27
Nickel (Ni)	310		49	140	***1,290***	23	40	165	8
Nitrite & Nitrate				0	0	0	---	---	---
Phenol	9,400			0	0	0	0	0	0
Selenium (Se)	78		1	77	***92***	***110***	14	14	18
Silver (Ag)	9,400		1	20	30	10	6	9	4
Strontium (Sr)	9,400			680	7,200	990	229	1,055	363
Sulfate				0	0	0	---	---	---
Thallium (Tl)	1.3		0.21	***23***	***28***	***20***	***4***	***9***	***4***
Titanium				1,942	2,190	1,770	1,279	1,584	1,020
Vanadium (V)	110		***601***	**1,028**	**1,049**	44	**476**	**695**	12
Zinc (Zn)	4,700		209	560	151	10	181	77	6

Sample type [1]	**EPA Child Soil Ingestion Screening Level: Non-cancer**	**EPA Child Soil Ingestion Screening Level: Cancer**	**DNR Data Excluded: Mixed Slag Max Value**	**DNR Data Excluded: EAF Slag Max Value**	**DNR Data Excluded: Ladle Slag Max Value**	**DNR Data Excluded: Mixed Slag Avg Value**	**DNR Data Excluded: EAF Slag Avg Value**	**DNR Data Excluded: Ladle Slag Avg Value**
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Aluminum (Al)	78,000	---	27,700	17,300	5,090	16,256	15,763	4,993
Antimony (Sb)	31	---	**25**	5	*5*	6	2	2
Arsenic (As)	39	0.77	**11**	**10**	**5**	**4**	**3**	**2**
Barium (Ba)	16,000	---	316	305	222	170	215	84
Beryllium (Be)	160	---	**5**	**1**	**1**	**1**	**1**	**0.28**
Boron (B)	16,000	---	660	102	93	118	70	62
Cadmium (Cd	78	---	***19***	***7.8***	5	2	2	1
Chloride (Cl)	7,800	---	0	0	0	---	---	---
Chromium (Total)	120,000	---	5,599	8,016	390	3,499	4,429	116
Chromium (VI)	230	0.31	2	5	0.45	0	2	0.35
Copper (Cu)	3,100	---	241	155	15	101	86	11
Cyanide (total)	47	---	1	1	0	1	0.52	---
Fluoride (F)	3,100	---	0	0	0	---	---	---
Iron (Fe)	55,000	---	258,000	231,400	22,000	204,700	160,050	11,413
Lead (Pb)	---	---	***97***	14	5	13	3	1
Magnesium (Mg)	---	---	80,900	89,400	53,000	61,875	75,944	46,340
Manganese (Mn)	1,900	---	43,400	48,946	3,765	28,603	28,928	1,901
Mercury (Hg)	---	---	1.000	1.000	0.050	0.2793	0.1574	0.01539
Molybdenum (Mo)	390	---	***113***	55	160	44	32	29
Nickel (Ni)	860		140	45	23	41	24	8
Nitrite & Nitrate	---	---	0	0	0	---	---	---
Phenol	23,000	---	0	0	0	0	0	0
Selenium (Se)	390	---	8	4	4	3	1	2
Silver (Ag)	390	---	5	5	0	2	1	0
Strontium (Sr)	47,000	---	680	7,200	990	229	1,179	357
Sulfate	---	---	0	0	0	---	---	---
Thallium (Tl)	0.78	---	***23***	***28***	***4***	***4***	***6***	***1***
Titanium	---	---	1,942	2,190	1,770	1,489	1,561	1,137
Vanadium (V)	390	---	**1,028**	**1,049**	44	**471**	**698**	12
Zinc (Zn)	23,000	---	560	151	9	181	83	6

Table 1. Total Metals Laboratory Analyses
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

			Mixed Slag																			
Sample type [1]	WDNR NR 538 -Beneficial Reuse - Table 1B Category 1	WDNR NR 538 - Beneficial Reuse - Table 2B Category 2	Charter Slag Testing to WDNR for Approval	Charter Slag ENSO Lab Testing to WDNR	Charter Slag Enchem Testing	Charter Slag Cardinal Lab Testing	DNR run, Mixed Slag Belt	DNR run, Mixed Slag Yard	Charter Comngle Slag Pile from Conveyr Cardinal Lab #100778	DNR run, Mixed Slag	Charter Slag Modern Lab #J-07-248	Mixed Slag-Prep#1 assumed 644207	Mixed slag processed through #40 Sieve; SLOH	Comingled Sample C; Brighton	Mixed Slag; EM&T	Co-mingled; IAL, LLC	3/4" x 0" Co-Mingled Slag; Modern Ind., Inc.	3/4" x 0" Co-Mingled Slag; Modern Ind., Inc.	Co-mingled Slag; TestAmerica		Co-mingled Slag; TestAmerica	
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg		mg/kg	
Date	---	---	10/10/1994	12/1/1998	5/26/1999	7/31/2006	11/9/2006	11/9/2006	3/30/2007	3/30/2007	1/17/2008	2/13/2009	2/13/2009	2/13/2009	2/13/2009	3/2/2011[2]	4/21/2011	2/29/2012	12/30/2013		12/9/2014	
Aluminum (Al)										14200	27700	10500	14400	9800			17677	15718	17994			
Antimony (Sb)	6.3		25	25	1.4	1.9			2	100	4	5.8	1	0.4	5.2	0.625	4	5	0.84		5.6	
Arsenic (As)	0.042	21	4.1	5	2.6	3.87			8.01	20	5	1.9	1	2.1	3.1		5	5	3.90		11	
Barium (Ba)	1,100		1	181	61	93.5	205	163	236	206	236	154	178	190	141		272	316	190		130	
Beryllium (Be)	0.014	7	2.2	1	1.3	2.4				2	0.1	0.014	0.75	0.4	5.2		1	1	0.26		0.23	B
Boron (B)	1,400		73	660		89			68	68	70	82.1	100	43	34.2		49	137	72		54	
Cadmium (Cd	7.8		1	19		0.049	8.6	6.4	0.124	2	1	0.034	1.8	0.25	5.2		1	1.6	0.04		0.16	J
Chloride (Cl)																						
Chromium (Total)			1540	2644		4.78	4770	4240	2300	5070	5371	1940	5380	2800	5400	5410	4800	5599			2,300	B
Chromium (VI)	14.5		?	0.1		0.117			1.86		0.04					0.24	0.04	0.04	0.39	H	0.45	
Copper (Cu)			20	99						80	147	42.3	68	38			156	241				
Cyanide (total)													1									
Fluoride (F)																						
Iron (Fe)										201000		195000	196000	120000			224700	234500	258000			
Lead (Pb)	50		7.7	97	3.9	0.642	11		0.498	20	25	17.5	7	8	2		4	4	2.60		0.58	
Magnesium (Mg)										62600		67000	80900	64000	57500		65014	72372	42217		46,000	
Manganese (Mn)									22,888	28000	43,400	17000	29300	19000	21500	31700	38646	43216	30979		17,000	B
Mercury (Hg)	4.7		0.05	0.2		0.007			0.015		1	0.0018	0.015	0.05			1	1	0.0068	H	0.0063	
Molybdenum (Mo)	78		110	113		0.102			49	35.3	40	19.8	31.8	28	25.4		18	44	37		59	
Nickel (Ni)	310		16	10		37.1			40.5	38	3	21.1	27	44	34.4		26	50	79		140	B
Nitrite & Nitrate																						
Phenol	9,400																		0.44	H	0.3	J
Selenium (Se)	78		2.5	5		0.0362	73	77	0.083	40	5	7.5	2	2.1	3.2		4	4	1.60		1.2	
Silver (Ag)	9,400		1	5		0.082	13	14	0.208	20	4						5	5	0.06		0.083	J,B
Strontium (Sr)	9,400		170			84			140			217	171	680	169				190		240	
Sulfate																						
Thallium (Tl)	1.3		0.84	5	1.8	0.5			1.1		4	7.3	23	0.5	5.2	0.313	4	4	0.14		0.016	
Titanium										20		1150	1490	900	1750		1700	1942				
Vanadium (V)	110		140	239		300			290	560	668	275	538	410	238	852	859	1028	380		370	
Zinc (Zn)	4,700		52	362		12.77			194		100	116	92	560	100		72	95	530.00		69	B

Table 1. Total Metals Laboratory Analyses
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

			EAF Slag											
Sample type [1]	**WDNR NR 538 -Beneficial Reuse - Table 1B Category 1**	**WDNR NR 538 - Beneficial Reuse - Table 2B Category 2**	**DNR run, Furnace Slag**	**Charter EAF Slag Cardinal Lab #100780**	**DNR run, Furnace Slag**	**Furnace Slag-Prep#1 644208**	**Furnace Slag Processed through #40 Sieve; SLOH**	**EAF Slag Sample A; Brighton**	**Furnace Slag; EM&T**	**1-1/4" x 0" Pure EAF Slag; Modern Ind., Inc.**	**EAF Slag; TestAmerica**		**Pure EAF Slag; TestAmerica**	
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**		**mg/kg**	
Date	**---**	**---**	**11/9/2006**	**3/30/2007**	**3/30/2007**	**2/13/2009**	**2/13/2009**	**2/13/2009**	**2/13/2009**	**11/30/2011**	**12/30/2013**		**12/9/2014**	
Aluminum (Al)			18000		14300	15500	17300	13000		17253				
Antimony (Sb)	6.3		***7***	0.87	***150***	0.27	1	0.3	4.88	4	0.48		0.46	
Arsenic (As)	0.042	21		***9.56***	***20***	***1.8***	***1***	***1***	**1.52**	**5**	***3.70***		1	
Barium (Ba)	1,100		335	305	194	188	192	220	160	212	270		170	
Beryllium (Be)	0.014	7			***2***	0.013	***0.7***	***0.37***	***0.819***	1	***0.98***		0.25	B
Boron (B)	1,400		110	63	69	93.8	102	56	32.2	35	84		97	
Cadmium (Cd	7.8		1	0.21	2	***7.8***	2.8	0.089	4.88	1	0.36		0.17	J
Chloride (Cl)														
Chromium (Total)			5740	4375	7780	3320	6830	5700	4090	8016	0.39	H	3,100	B
Chromium (VI)	14.5			4.98						0.04			0.44	
Copper (Cu)					90	93	64.9	32		155				
Cyanide (total)							1		0.04					
Fluoride (F)														
Iron (Fe)			150000		271000	27800	221000	160000		231400				
Lead (Pb)	50		12	0.839	20	13.7	4	1	2.6	4	0.78		0.20	
Magnesium (Mg)			62000		77500	72800	89400	89000	57400	79066			68,000	
Manganese (Mn)			34000	26,480	36200	28800	35900	32000	25300	48946	0.0025		34,000	B
Mercury (Hg)	4.7			0.023		0.00075	0.015	0.05		1	0.0068	H	0.0061	
Molybdenum (Mo)	78		9	55	***250***	24	33.5	21	28.3	41	24.00		28	
Nickel (Ni)	310			33.8	***1290***	19.8	24	9.7	22.6	45	27.00		14	B
Nitrite & Nitrate														
Phenol	9,400										0.16	H	0.21	
Selenium (Se)	78		***92***	0.139	40	1.2	2	0.45	2	4	1.30		0.46	J
Silver (Ag)	9,400		19	0.349	29.5					5	0.16		0.056	J,B
Strontium (Sr)	9,400		190	160		180	158	7200	145		180		230	
Sulfate														
Thallium (Tl)	1.3		***20***	0.95	***20***	***14.2***	***28***	0.5	***1.55***	4	1.20		0.017	
Titanium			1700			1530	1640	1100	2190	1344				
Vanadium (V)	110		***670***	***590***		***572***	***780***	***720***	***310***	***1049***	***790***		770	
Zinc (Zn)	4,700		23	127		105	101	23	151	49	60.00		50	B

Table 1. Total Metals Laboratory Analyses

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Sample type [1]	**WDNR NR 538 -Beneficial Reuse - Table 1B Category 1**	**WDNR NR 538 - Beneficial Reuse - Table 2B Category 2**	**Ladle (Falling) Slag**										
			DNR run, Falling (Ladle) Slag	**Charter Falling Slag; Cardinal Lab #100779**	**DNR run, Falling (Ladle) Slag**	**Falling Slag-Prep#1 assumed 644209**	**Falling Slag Processed through #40 Sieve; SLOH**	**Ladle Slag Sample B; Brighton**	**Falling Slag; EM&T**	**Ladle Slag; TestAmerica**		**Pure Ladle Slag; TestAmerica**	
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**		**mg/kg**	
Date	**---**	**---**	**11/9/2006**	**3/30/2007**	**3/30/2007**	**2/13/2009**	**2/13/2009**	**2/13/2009**	**2/13/2009**	**12/30/2013**		**12/9/2014**	
Aluminum (Al)			5900		5880	5090	5090	4800					
Antimony (Sb)	6.3		***22***	2.2	***20***	0.27	3	0.3	4.96	0.22		2.2	
Arsenic (As)	0.042	21		***1.78***	***20***	***1.8***	***1***	***1.3***	***4.96***	***0.86***		3.4	
Barium (Ba)	1,100		101	222	119	42.9	47.2	77	44.7	120		35	
Beryllium (Be)	0.014	7			***2***	0.013	***0.21***	***0.2***	***0.833***	***0.22***		0.18	B
Boron (B)	1,400		83	26	35	78.3	93	68	42.6	51		73	
Cadmium (Cd	7.8			0.202	2	0.027	0.1	0.05	4.96	0.0045		0.091	J
Chloride (Cl)													
Chromium (Total)			27	37.9	78	82.7	106	390	83.1	0.38	H	110	B
Chromium (VI)	14.5			0.25								0.45	
Copper (Cu)					10	12.1	7.3	15					
Cyanide (total)													
Fluoride (F)													
Iron (Fe)			11000		10300	6080	6160	22000					
Lead (Pb)	50			0.806	20	1.9	1	1	4.96	0.22		0.04	
Magnesium (Mg)			43000		50100	49700	51000	53000	43000			35,000	
Manganese (Mn)			2000	3,765	2510	1340	1500	3100	2760	0.0042		840	B
Mercury (Hg)	4.7			0.013		0.00076		0.05		0.007	H	0.006	
Molybdenum (Mo)	78		4	29.4	36.9	1.6	2.1	5	1.5	3.30		160	
Nickel (Ni)	310			9.48	10	1.7	2	6.8	4.2	5.70		23	B
Nitrite & Nitrate													
Phenol	9,400									0.44	H	0.25	J
Selenium (Se)	78		***110***	0.134	40	2.6	4	1.8	2.8	1.30		3.2	
Silver (Ag)	9,400		8	0.336	10					0.02		0.031	J,B
Strontium (Sr)	9,400		410	180		239	219	990	199	430		240	
Sulfate													
Thallium (Tl)	1.3			1.1	***20***	0.89	***4***	0.5	***1.58***	0.02		0.017	
Titanium			550			819	1060	900	1770				
Vanadium (V)	110			3.2	10	2.5	4.4	44	4.96	27		0.72	J
Zinc (Zn)	4,700			8.87	10	5.4	7	6.2	6.8	3.60		2.1	J,B

Notes:

[1] Assumed that sample was mix of EAF and Ladle slag unless otherwise indicated

[2] Plant not run during winter of 2010/2011. Material sampled was material processed in fall of 2010.

[3] From Table 2.2. *Human Health Risk Assessment for Iron and Steel Slag* . December 2011. ToxStrategies.

H - (Red) indicates sample exceeded hold time for laboratory analysis.

J - Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value.

B - Compound was found in the blank and sample.

Bold and italicized data exceeds WI NR 538 Categroy 1 level.

- Denotes exceedance of EPA Soil Screening Level.
- Metals in steel-industry slag occuring at concentrations that are higher than those typically found in U.S. Soils (Protor et all 2000)
- Data provided from Charter steel was presented as a 'less than' value (e.g. <1.0). For purposes of analysis, the 'less than' symbol was dropped, and a worst case value was assumed.
- Oxides converted to elemental mg/kg as follows: Al_2O_3% * ((10,000 mg/kg)/1.889); CaO% * ((10,000 mg/kg)/1.379); Total FE% * ((10,000 mg/kg)/1.000); MgO% * ((10,000 mg/kg)/1.658); MnO% * ((10,000 mg/kg)/1.291);
- Represents DNR run samples

Table 2. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round Scenario (DNR data included)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	200	mg/day
EF =	Exposure Factor[8]	0.5	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (C_{max})	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	Avg Concentration[2] (C_{avg})	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg/day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	100	0.00063	1.56	12	0.00007	0.18
Arsenic (As)	0.0003	20	0.00013	0.42	5	0.00003	0.11
Barium[6]	0.2	316	0.00198	0.010	174	0.00109	0.005
Beryllium[6]	0.002	5	0.00003	0.016	1	0.00001	0.004
Boron[6]	0.2	660	0.00413	0.021	114	0.00071	0.004
Cadmium[6]	0.001	19	0.00012	0.12	3	0.00002	0.02
Chromium Hexavalent (Cr (VI))	0.003	2	0.00001	0.004	0	0.00000	0.001
Iron (Fe)	0.7	258,000	1.61250	2.30	204,171	1.27607	1.8
Lead (Pb)	400 mg/kg soil [7]	97	0.00061	no exceedance	13	0.00008	no exceedance
Magnesium (Mg)	None.	80,900	0.50563	---	61,956	0.38722	---
Manganese (Mn)[4]	0.024	43,400	0.27125	11.30	28,552	0.17845	7.4
Mercury (Hg)	None.	1	0.00001	---	0	0.00000	---
Molybdenum[6]	0.005	113	0.00071	0.14	44	0.00027	0.05
Nickel[6]	0.011	140	0.00088	0.080	40	0.00025	0.02
Thallium (Tl)	0.00001	23	0.00014	14	4	0.00002	2.4
Titanium	None.	1,942	0.01214	---	1,279	0.00799	---
Vanadium (V)	0.005	1,028	0.00643	1.3	476	0.00298	0.6

EAF Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2]	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	Avg Concentration[2]	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	150	0.00094	2.3	17	0.00011	0.26
Arsenic (As)	0.0003	20	0.00013	0.42	5	0.00003	0.103
Barium[6]	0.2	335	0.00209	0.01	225	0.00140	0.007
Beryllium[6]	0.002	2	0.00001	0.01	1	0.00000	0.002
Boron[6]	0.2	110	0.00069	0.003	74	0.00046	0.002
Cadmium[6]	0.001	8	0.00005	0.05	2	0.00001	0.013
Chromium Hexavalent (Cr (VI))	0.003	5	0.00003	0.01	2	0.00001	0.004
Iron (Fe)	0.7	271,000	1.69375	2.4	176,867	1.10542	1.6
Lead (Pb)	400 mg/kg soil [7]	20	0.00013	no exceedance	6	0.00004	no exceedance
Magnesium (Mg)	None.	89,400	0.55875	---	74,396	0.46497	---
Manganese (Mn)[4]	0.024	48,946	0.30591	12.7	30,163	0.18852	7.9
Mercury (Hg)	None.	1.000	0.00001	---	0.157	0.00000	---
Molybdenum[6]	0.005	250	0.00156	0.3	51	0.00032	0.06
Nickel[6]	0.011	1,290	0.00806	0.7	165	0.00103	0.09
Thallium (Tl)	0.00001	28	0.00018	17.5	9	0.00006	5.7
Titanium	None.	2,190	0.01369	---	1,584	0.00990	---
Vanadium (V)	0.005	1,049	0.00656	1.3	695	0.00434	0.87

Table 2. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round Scenario (DNR data included)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Ladle Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2]	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	Avg Concentration[2]	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	22	0.00014	0.34	6	0.00004	0.10
Arsenic (As)	0.0003	20	0.00013	0.42	4	0.00003	0.09
Barium[6]	0.2	222	0.00139	0.007	90	0.00056	0.003
Beryllium[6]	0.002	2	0.00001	0.006	0.52	0.00000	0.002
Boron[6]	0.2	93	0.00058	0.003	61	0.00038	0.002
Cadmium[6]	0.001	5	0.00003	0.031	1	0.00001	0.006
Chromium Hexavalent (Cr (VI))	0.003	0	0.00000	0.001	0.35	0.00000	0.001
Iron (Fe)	0.7	22,000	0.13750	0.196	11,108	0.06943	0.10
Lead (Pb)	400 mg/kg soil [7]	20	0.00013	no exceedance	4	0.00002	no exceedance
Magnesium (Mg)	None.	53,000	0.33125	---	46,400	0.29000	---
Manganese (Mn)[4]	0.024	3,765	0.02353	0.980	1,979	0.01237	0.52
Mercury (Hg)	None.	0	0.00000	---	0.01539	0.00000	---
Molybdenum[6]	0.005	160	0.00100	0.200	27	0.00017	0.034
Nickel[6]	0.011	23	0.00014	0.013	8	0.00005	0.004
Thallium (Tl)	0.00001	20	0.00013	12.5	4	0.00002	2.2
Titanium	None.	1,770	0.01106	---	1,020	0.00637	---
Vanadium (V)	0.005	44	0.00028	0.055	12	0.00008	0.015

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html)

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR)

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child, per ATSDR Guidance Manual, App G; http://www.atsdr.cdc.gov/hac/PHAManual/appg.html
Intake rate assumes 365 days of exposure per year, unless otherwise stated.

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 µg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 - 6 y.o., 50th percentile- ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

Table 3. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter Scenario (DNR data included)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	133	mg/day
EF =	Exposure Factor[8]	0.5	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2] (C_{max})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2] (C_{avg})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg/day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	100	0.00042	1.04	12	0.00005	0.122
Arsenic (As)	0.0003	20	0.00008	0.28	5	0.00002	0.076
Barium[6]	0.2	316	0.00132	0.007	174	0.00072	0.004
Beryllium[6]	0.002	5	0.00002	0.011	1	0.00001	0.003
Boron[6]	0.2	660	0.00275	0.014	114	0.00048	0.002
Cadmium[6]	0.001	19	0.00008	0.079	3	0.00001	0.013
Chromium Hexavalent (Cr (VI))	0.003	2	0.00001	0.003	0	0.00000	0.001
Iron (Fe)	0.7	258,000	1.07500	1.5	204,171	0.85071	1.2
Lead (Pb)	400 mg/kg soil [7]	97	0.00040	no exceedance	13	0.00006	no exceedance
Magnesium (Mg)	None.	80,900	0.33708	---	61,956	0.25815	---
Manganese (Mn)[4]	0.024	43,400	0.18083	7.5	28,552	0.11897	5.0
Mercury (Hg)	None.	1	0.00000	---	0	0.00000	---
Molybdenum[6]	0.005	113	0.00047	0.094	44	0.00018	0.036
Nickel[6]	0.011	140	0.00058	0.053	40	0.00017	0.015
Thallium (Tl)	0.00001	23	0.00010	9.6	4	0.00002	1.6
Titanium	None.	1,942	0.00809	---	1,279	0.00533	---
Vanadium (V)	0.005	1,028	0.00428	0.86	476	0.00199	0.40

EAF Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg-day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	150	0.00063	1.6	17	0.00007	0.18
Arsenic (As)	0.0003	20	0.00008	0.28	5	0.00002	0.069
Barium[6]	0.2	335	0.00140	0.007	225	0.00094	0.005
Beryllium[6]	0.002	2	0.00001	0.004	1	0.00000	0.002
Boron[6]	0.2	110	0.00046	0.002	74	0.00031	0.002
Cadmium[6]	0.001	8	0.00003	0.033	2	0.00001	0.008
Chromium Hexavalent (Cr (VI))	0.003	5	0.00002	0.007	2	0.00001	0.003
Iron (Fe)	0.7	271,000	1.12917	1.6	176,867	0.73694	1.05
Lead (Pb)	400 mg/kg soil [7]	20	0.00008	no exceedance	6	0.00002	no exceedance
Magnesium (Mg)	None.	89,400	0.37250	---	74,396	0.30998	---
Manganese (Mn)[4]	0.024	48,946	0.20394	8.5	30,163	0.12568	5.2
Mercury (Hg)	None.	1.000	0.00000	---	0.157	0.00000	---
Molybdenum[6]	0.005	250	0.00104	0.21	51	0.00021	0.043
Nickel[6]	0.011	1,290	0.00538	0.49	165	0.00069	0.063
Thallium (Tl)	0.00001	28	0.00012	11.7	9	0.00004	3.8
Titanium	None.	2,190	0.00913	---	1,584	0.00660	---
Vanadium (V)	0.005	1,049	0.00437	0.87	695	0.00289	0.58

Table 3. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter Scenario (DNR data included)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Ladle Slag		**200 mg IR**	**Maximum Concentration**		**200 mg IR**	**Average Concentration**	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg-day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	22	0.00009	0.23	6	0.00003	0.064
Arsenic (As)	0.0003	20	0.00008	0.28	4	0.00002	0.061
Barium[6]	0.2	222	0.00093	0.005	90	0.00037	0.002
Beryllium[6]	0.002	2	0.00001	0.004	0.52	0.00000	0.001
Boron[6]	0.2	93	0.00039	0.002	61	0.00025	0.001
Cadmium[6]	0.001	5	0.00002	0.021	1	0.00000	0.004
Chromium Hexavalent (Cr (VI))	0.003	0	0.00000	0.001	0.35	0.00000	0.000
Iron (Fe)	0.7	22,000	0.09167	0.13	11,108	0.04628	0.066
Lead (Pb)	400 mg/kg soil [7]	20	0.00008	no exceedance	4	0.00002	no exceedance
Magnesium (Mg)	None.	53,000	0.22083	---	46,400	0.19333	---
Manganese (Mn)[4]	0.024	3,765	0.01569	0.65	1,979	0.00825	0.34
Mercury (Hg)	None.	0	0.00000	---	0.01539	0.00000	---
Molybdenum[6]	0.005	160	0.00067	0.13	27	0.00011	0.023
Nickel[6]	0.011	23	0.00010	0.009	8	0.00003	0.003
Thallium (Tl)	0.00001	20	0.00008	8.3	4	0.00001	1.5
Titanium	None.	1,770	0.00738	---	1,020	0.00425	---
Vanadium (V)	0.005	44	0.00018	0.037	12	0.00005	0.010

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html)

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR)

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child (Based on ATSDR Guidance Manual, App G) multiplied by 8/12 months, to account for the winter months of snow and ice cover. http://www.atsdr.cdc.gov/hac/PHAManual/appg.html

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 µg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 - 6 y.o., 50th percentile - ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

Table 4. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round Scenario (DNR data excluded)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	200	mg/day
EF =	Exposure Factor[8]	0.5	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2] (C_{max})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2] (C_{avg})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg/day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	25	0.00016	0.39	6	0.00004	0.091
Arsenic (As)	0.0003	11	0.00007	0.23	4	0.00003	0.092
Barium[6]	0.2	316	0.00198	0.010	170	0.00106	0.005
Beryllium[6]	0.002	5	0.00003	0.016	1	0.00001	0.004
Boron[6]	0.2	660	0.00413	0.021	118	0.00074	0.004
Cadmium[6]	0.001	19	0.00012	0.119	2	0.00002	0.015
Chromium Hexavalent (Cr (VI))	0.003	2	0.00001	0.004	0.36	0.00000	0.001
Iron (Fe)	0.7	258,000	1.61250	2.3	204,700	1.27938	1.8
Lead (Pb)	400 mg/kg soil [7]	97	0.00061	no exceedance	13	0.00008	no exceedance
Magnesium (Mg)	None.	80,900	0.50563	---	61,875	0.38672	---
Manganese (Mn)[4]	0.024	43,400	0.27125	11.3	28,603	0.17877	7.4
Mercury (Hg)	None.	1	0.00001	---	0.28	0.00000	---
Molybdenum[6]	0.005	113	0.00071	0.14	44	0.00028	0.055
Nickel[6]	0.011	140	0.00088	0.080	41	0.00025	0.023
Thallium (Tl)	0.00001	23	0.00014	14.4	4	0.00002	2.4
Titanium	None.	1,942	0.01214	---	1,489	0.00930	---
Vanadium (V)	0.005	1,028	0.00643	1.3	471	0.00294	0.59

EAF Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg-day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	5	0.00003	0.076	2	0.00001	0.024
Arsenic (As)	0.0003	10	0.00006	0.20	3	0.00002	0.064
Barium[6]	0.2	305	0.00191	0.010	215	0.00134	0.007
Beryllium[6]	0.002	1	0.00001	0.003	1	0.00000	0.002
Boron[6]	0.2	102	0.00064	0.003	70	0.00044	0.002
Cadmium[6]	0.001	8	0.00005	0.049	2	0.00001	0.014
Chromium Hexavalent (Cr (VI))	0.003	5	0.00003	0.010	2	0.00001	0.004
Iron (Fe)	0.7	231,400	1.44625	2.1	160,050	1.00031	1.4
Lead (Pb)	400 mg/kg soil [7]	14	0.00009	no exceedance	3	0.00002	no exceedance
Magnesium (Mg)	None.	89,400	0.55875	---	75,944	0.47465	---
Manganese (Mn)[4]	0.024	48,946	0.30591	12.7	28,928	0.18080	7.5
Mercury (Hg)	None.	1	0.00001	---	0.16	0.00000	---
Molybdenum[6]	0.005	55	0.00034	0.069	32	0.00020	0.040
Nickel[6]	0.011	45	0.00028	0.026	24	0.00015	0.014
Thallium (Tl)	0.00001	28	0.00018	17.5	6	0.00004	3.9
Titanium	None.	2,190	0.01369	---	1,561	0.00976	---
Vanadium (V)	0.005	1,049	0.00656	1.3	698	0.00436	0.87

Table 4. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round Scenario (DNR data excluded)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Ladle Slag		**200 mg IR**	**Maximum Concentration**		**200 mg IR**	**Average Concentration**	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg-day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	5	0.00003	0.078	2	0.00001	0.029
Arsenic (As)	0.0003	5	0.00003	0.103	2	0.00001	0.045
Barium[6]	0.2	222	0.00139	0.007	84	0.00053	0.003
Beryllium[6]	0.002	1	0.00001	0.003	0.3	0.00000	0.001
Boron[6]	0.2	93	0.00058	0.003	62	0.00039	0.002
Cadmium[6]	0.001	5	0.00003	0.031	1	0.00000	0.005
Chromium Hexavalent (Cr (VI))	0.003	0.5	0.00000	0.001	0.4	0.00000	0.001
Iron (Fe)	0.7	22,000	0.13750	0.20	11,413	0.07133	0.102
Lead (Pb)	400 mg/kg soil [7]	5	0.00003	no exceedance	1	0.00001	no exceedance
Magnesium (Mg)	None.	53,000	0.33125	---	46,340	0.28963	---
Manganese (Mn)[4]	0.024	3,765	0.02353	0.98	1,901	0.01188	0.49
Mercury (Hg)	None.	0.05	0.00000	---	0.02	0.00000	---
Molybdenum[6]	0.005	160	0.00100	0.200	29	0.00018	0.036
Nickel[6]	0.011	23	0.00014	0.013	8	0.00005	0.004
Thallium (Tl)	0.00001	4	0.00003	2.5	1	0.00001	0.72
Titanium	None.	1,770	0.01106	---	1,137	0.00711	---
Vanadium (V)	0.005	44	0.00028	0.055	12	0.00008	0.015

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html)

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR)

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child, per ATSDR Guidance Manual, App G; http://www.atsdr.cdc.gov/hac/PHAManual/appg.html
Intake rate assumes 365 days of exposure per year, unless otherwise stated.

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 μg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 - 6 y.o., 50th percentile - ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

Table 5. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter Scenario (DNR data excluded)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	133	mg/day
EF =	Exposure Factor[8]	0.5	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

Contaminant	Oral Reference Dose (RfD)[3]	200 mg IR: Max Concentration[2] (C_{max})	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	200 mg IR: Avg Concentration[2] (C_{avg})	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg/day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	25	0.00010	0.260	6	0.00002	0.061
Arsenic (As)	0.0003	11	0.00005	0.153	4	0.00002	0.061
Barium[6]	0.2	316	0.00132	0.007	170	0.00071	0.004
Beryllium[6]	0.002	5	0.00002	0.011	1	0.00001	0.003
Boron[6]	0.2	660	0.00275	0.014	118	0.00049	0.002
Cadmium[6]	0.001	19	0.00008	0.079	2	0.00001	0.010
Chromium Hexavalent (Cr (VI))	0.003	2	0.00001	0.003	0.36	0.00000	0.001
Iron (Fe)	0.7	258,000	1.07500	1.536	204,700	0.85292	1.218
Lead (Pb)	400 mg/kg soil [7]	97	0.00040	no exceedance	13	0.00005	no exceedance
Magnesium (Mg)	None.	80,900	0.33708	---	61,875	0.25781	---
Manganese (Mn)[4]	0.024	43,400	0.18083	7.535	28,603	0.11918	4.966
Mercury (Hg)	None.	1	0.00000	---	0.28	0.00000	---
Molybdenum[6]	0.005	113	0.00047	0.094	44	0.00018	0.037
Nickel[6]	0.011	140	0.00058	0.053	41	0.00017	0.015
Thallium (Tl)	0.00001	23	0.00010	9.583	4	0.00002	1.603
Titanium	None.	1,942	0.00809	---	1,489	0.00620	---
Vanadium (V)	0.005	1,028	0.00428	0.857	471	0.00196	0.392

EAF Slag

Contaminant	Oral Reference Dose (RfD)[3]	200 mg IR: Max Concentration[2]	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	200 mg IR: Avg Concentration[2]	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	5	0.00002	0.051	2	0.00001	0.016
Arsenic (As)	0.0003	10	0.00004	0.133	3	0.00001	0.043
Barium[6]	0.2	305	0.00127	0.006	215	0.00089	0.004
Beryllium[6]	0.002	1	0.00000	0.002	1	0.00000	0.001
Boron[6]	0.2	102	0.00043	0.002	70	0.00029	0.001
Cadmium[6]	0.001	8	0.00003	0.033	2	0.00001	0.009
Chromium Hexavalent (Cr (VI))	0.003	5	0.00002	0.007	2	0.00001	0.003
Iron (Fe)	0.7	231,400	0.96417	1.377	160,050	0.66688	0.953
Lead (Pb)	400 mg/kg soil [7]	14	0.00006	no exceedance	3	0.00001	no exceedance
Magnesium (Mg)	None.	89,400	0.37250	---	75,944	0.31643	---
Manganese (Mn)[4]	0.024	48,946	0.20394	8.498	28,928	0.12053	5.022
Mercury (Hg)	None.	1	0.00000	---	0.16	0.00000	---
Molybdenum[6]	0.005	55	0.00023	0.046	32	0.00013	0.027
Nickel[6]	0.011	45	0.00019	0.017	24	0.00010	0.009
Thallium (Tl)	0.00001	28	0.00012	11.667	6	0.00003	2.626
Titanium	None.	2,190	0.00913	---	1,561	0.00650	---
Vanadium (V)	0.005	1,049	0.00437	0.874	698	0.00291	0.581

Table 5. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter Scenario (DNR data excluded)[10]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Ladle Slag

Contaminant	Oral Reference Dose (RfD)[3]	200 mg IR Max Concentration[2]	Maximum Concentration Calculated Dose (D) Child	Maximum Concentration Hazard Quotient (HQ) [D/RfD]	200 mg IR Avg Concentration[2]	Average Concentration Calculated Dose (D) Child	Average Concentration Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	5	0.00002	0.052	2	0.00001	0.020
Arsenic (As)	0.0003	5	0.00002	0.069	2	0.00001	0.030
Barium[6]	0.2	222	0.00093	0.005	84	0.00035	0.002
Beryllium[6]	0.002	1	0.00000	0.002	0.3	0.00000	0.001
Boron[6]	0.2	93	0.00039	0.002	62	0.00026	0.001
Cadmium[6]	0.001	5	0.00002	0.021	1	0.00000	0.003
Chromium Hexavalent (Cr (VI))	0.003	0.5	0.00000	0.001	0.4	0.00000	0.000
Iron (Fe)	0.7	22,000	0.09167	0.131	11,413	0.04756	0.068
Lead (Pb)	400 mg/kg soil [7]	5	0.00002	no exceedance	1	0.00001	no exceedance
Magnesium (Mg)	None.	53,000	0.22083	---	46,340	0.19308	---
Manganese (Mn)[4]	0.024	3,765	0.01569	0.654	1,901	0.00792	0.330
Mercury (Hg)	None.	0.05	0.00000	---	0.02	0.00000	---
Molybdenum[6]	0.005	160	0.00067	0.133	29	0.00012	0.024
Nickel[6]	0.011	23	0.00010	0.009	8	0.00003	0.003
Thallium (Tl)	0.00001	4	0.00002	1.667	1	0.00000	0.483
Titanium	None.	1,770	0.00738	---	1,137	0.00474	---
Vanadium (V)	0.005	44	0.00018	0.037	12	0.00005	0.010

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html).

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR).

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child (Based on ATSDR Guidance Manual, App G) multiplied by 8/12 months, to account for the winter months of snow and ice cover. http://www.atsdr.cdc.gov/hac/PHAManual/appg.html

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 μg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 - 6 y.o., 50^{th} percentile - ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

Table 6. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round, Bioavailability Scenario (DNR data excluded)[10]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	200	mg/day
EF =	Exposure Factor[8]	0.5	unitless
BF =	Bioavailability Factor[11]	0.25	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

Contaminant	Oral Reference Dose (RfD)[3]	200 mg IR Max Concentration[2] (C_{max})	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	200 mg IR Avg Concentration[2] (C_{avg})	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg/day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	25	0.00004	0.10	6	0.00001	0.023
Arsenic (As)	0.0003	11	0.00002	0.06	4	0.00001	0.023
Barium[6]	0.2	316	0.00049	0.002	170	0.00027	0.001
Beryllium[6]	0.002	5	0.00001	0.004	1	0.00000	0.001
Boron[6]	0.2	660	0.00103	0.005	118	0.00018	0.001
Cadmium[6]	0.001	19	0.00003	0.030	2	0.00000	0.004
Chromium Hexavalent (Cr (VI))	0.003	2	0.00000	0.001	0.36	0.00000	0.000
Iron (Fe)	0.7	258,000	0.40313	0.6	204,700	0.31984	0.5
Lead (Pb)	400 mg/kg soil [7]	97	0.00015	no exceedance	13	0.00002	no exceedance
Magnesium (Mg)	None.	80,900	0.12641	---	61,875	0.09668	---
Manganese (Mn)[4]	0.024	43,400	0.06781	2.8	28,603	0.04469	1.9
Mercury (Hg)	None.	1	0.00000	---	0.28	0.00000	---
Molybdenum[6]	0.005	113	0.00018	0.04	44	0.00007	0.014
Nickel[6]	0.011	140	0.00022	0.020	41	0.00006	0.006
Thallium (Tl)	0.00001	23	0.00004	3.6	4	0.00001	0.6
Titanium	None.	1,942	0.00303	---	1,489	0.00233	---
Vanadium (V)	0.005	1,028	0.00161	0.3	471	0.00074	0.15

EAF Slag

Contaminant	Oral Reference Dose (RfD)[3]	200 mg IR Max Concentration[2]	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	200 mg IR Avg Concentration[2]	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	5	0.00001	0.019	2	0.00000	0.006
Arsenic (As)	0.0003	10	0.00001	0.05	3	0.00000	0.016
Barium[6]	0.2	305	0.00048	0.002	215	0.00034	0.002
Beryllium[6]	0.002	1	0.00000	0.001	1	0.00000	0.000
Boron[6]	0.2	102	0.00016	0.001	70	0.00011	0.001
Cadmium[6]	0.001	8	0.00001	0.012	2	0.00000	0.003
Chromium Hexavalent (Cr (VI))	0.003	5	0.00001	0.003	2	0.00000	0.001
Iron (Fe)	0.7	231,400	0.36156	0.5	160,050	0.25008	0.4
Lead (Pb)	400 mg/kg soil [7]	14	0.00002	no exceedance	3	0.00001	no exceedance
Magnesium (Mg)	None.	89,400	0.13969	---	75,944	0.11866	---
Manganese (Mn)[4]	0.024	48,946	0.07648	3.2	28,928	0.04520	1.9
Mercury (Hg)	None.	1	0.00000	---	0.16	0.00000	---
Molybdenum[6]	0.005	55	0.00009	0.017	32	0.00005	0.010
Nickel[6]	0.011	45	0.00007	0.006	24	0.00004	0.003
Thallium (Tl)	0.00001	28	0.00004	4.4	6	0.00001	1.0
Titanium	None.	2,190	0.00342	---	1,561	0.00244	---
Vanadium (V)	0.005	1,049	0.00164	0.3	698	0.00109	0.22

Table 6. Slag Exposure Calculations - Child Incidental Soil Ingestion, Year Round, Bioavailability Scenario (DNR data excluded)[10]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Ladle Slag		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2]	Calculated Dose (D) Child	Hazard Quotient (HQ) [D/RfD]	Avg Concentration[2]	Calculated Dose (D) Child	Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	5	0.00001	0.019	2	0.00000	0.007
Arsenic (As)	0.0003	5	0.00001	0.026	2	0.00000	0.011
Barium[6]	0.2	222	0.00035	0.002	84	0.00013	0.001
Beryllium[6]	0.002	1	0.00000	0.001	0.3	0.00000	0.000
Boron[6]	0.2	93	0.00015	0.001	62	0.00010	0.000
Cadmium[6]	0.001	5	0.00001	0.008	1	0.00000	0.001
Chromium Hexavalent (Cr (VI))	0.003	0.5	0.00000	0.000	0.4	0.00000	0.000
Iron (Fe)	0.7	22,000	0.03438	0.05	11,413	0.01783	0.025
Lead (Pb)	400 mg/kg soil [7]	5	0.00001	no exceedance	1	0.00000	no exceedance
Magnesium (Mg)	None.	53,000	0.08281	---	46,340	0.07241	---
Manganese (Mn)[4]	0.024	3,765	0.00588	0.25	1,901	0.00297	0.12
Mercury (Hg)	None.	0.05	0.00000	---	0.02	0.00000	---
Molybdenum[6]	0.005	160	0.00025	0.050	29	0.00005	0.009
Nickel[6]	0.011	23	0.00004	0.003	8	0.00001	0.001
Thallium (Tl)	0.00001	4	0.00001	0.6	1	0.00000	0.18
Titanium	None.	1,770	0.00277	---	1,137	0.00178	---
Vanadium (V)	0.005	44	0.00007	0.014	12	0.00002	0.004

Notes:
Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html)

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR)

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child, per ATSDR Guidance Manual, App G; http://www.atsdr.cdc.gov/hac/PHAManual/appg.html
Intake rate assumes 365 days of exposure per year, unless otherwise stated.

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 µg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 6 y.o., 50th percentile - ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

[11] Bioavailability is highly variable and dependent on a number of environmental, chemical and physiological factors. A 25% bioavailability factor was chosen to represent a lower bound estimate of bioavailability for the metal constituents in the slags. Due to the complexity of the slag complexes and the multiple factors involve in estimating bioavailability, determining more scenario and metal constituent specific bioavailability estimates are beyond the scope of this document.

Table 7. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter, Bioavailability Scenario (DNR data excluded)[10]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF X CF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/kg = µg Hg/g = ppm
Cavg =	Contaminant Concentration (Average)[2]	varies-see table	mg/kg = µg Hg/g = ppm
IR =	Intake Rate of contaminated soil[5]	133	mg/day
EF =	Exposure Factor[8]	0.5	unitless
BF =	Bioavailability Factor[11]	0.25	unitless
CF =	Conversion Factor (10^{-6} kg/mg)	1.0E-06	kg/mg
BW =	Body Weight[9]	16	kg

Mixed Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2] (C_{max})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2] (C_{avg})**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg/day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	25	0.00003	0.065	6	0.00001	0.015
Arsenic (As)	0.0003	11	0.00001	0.038	4	0.00000	0.015
Barium[6]	0.2	316	0.00033	0.002	170	0.00018	0.001
Beryllium[6]	0.002	5	0.00001	0.003	1	0.00000	0.001
Boron[6]	0.2	660	0.00069	0.003	118	0.00012	0.001
Cadmium[6]	0.001	19	0.00002	0.020	2	0.00000	0.003
Chromium Hexavalent (Cr (VI))	0.003	2	0.00000	0.001	0.36	0.00000	0.000
Iron (Fe)	0.7	258,000	0.26875	0.384	204,700	0.21323	0.305
Lead (Pb)	400 mg/kg soil [7]	97	0.00010	no exceedance	13	0.00001	no exceedance
Magnesium (Mg)	None.	80,900	0.08427	---	61,875	0.06445	---
Manganese (Mn)[4]	0.024	43,400	0.04521	1.88	28,603	0.02979	1.24
Mercury (Hg)	None.	1	0.00000	---	0.28	0.00000	---
Molybdenum[6]	0.005	113	0.00012	0.024	44	0.00005	0.009
Nickel[6]	0.011	140	0.00015	0.013	41	0.00004	0.004
Thallium (Tl)	0.00001	23	0.00002	2.40	4	0.00000	0.401
Titanium	None.	1,942	0.00202	---	1,489	0.00155	---
Vanadium (V)	0.005	1,028	0.00107	0.214	471	0.00049	0.098

EAF Slag

		200 mg IR	Maximum Concentration		200 mg IR	Average Concentration	
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**	**Avg Concentration[2]**	**Calculated Dose (D) Child**	**Hazard Quotient (HQ) [D/RfD]**
	(mg/kg-day)	**(mg/kg)**	**(mg/kg/day)**	---	**(mg/kg)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	5	0.00001	0.013	2	0.00000	0.004
Arsenic (As)	0.0003	10	0.00001	0.033	3	0.00000	0.011
Barium[6]	0.2	305	0.00032	0.002	215	0.00022	0.001
Beryllium[6]	0.002	1	0.00000	0.001	1	0.00000	0.000
Boron[6]	0.2	102	0.00011	0.001	70	0.00007	0.000
Cadmium[6]	0.001	8	0.00001	0.008	2	0.00000	0.002
Chromium Hexavalent (Cr (VI))	0.003	5	0.00001	0.002	2	0.00000	0.001
Iron (Fe)	0.7	231,400	0.24104	0.344	160,050	0.16672	0.24
Lead (Pb)	400 mg/kg soil [7]	14	0.00001	no exceedance	3	0.00000	no exceedance
Magnesium (Mg)	None.	89,400	0.09313	---	75,944	0.07911	---
Manganese (Mn)[4]	0.024	48,946	0.05099	2.12	28,928	0.03013	1.26
Mercury (Hg)	None.	1	0.00000	---	0.16	0.00000	---
Molybdenum[6]	0.005	55	0.00006	0.011	32	0.00003	0.007
Nickel[6]	0.011	45	0.00005	0.004	24	0.00003	0.002
Thallium (Tl)	0.00001	28	0.00003	2.92	6	0.00001	0.66
Titanium	None.	2,190	0.00228	---	1,561	0.00163	---
Vanadium (V)	0.005	1,049	0.00109	0.219	698	0.00073	0.15

Table 7. Slag Exposure Calculations - Child Incidental Soil Ingestion, Winter, Bioavailability Scenario (DNR data excluded)[10]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Ladle Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (200 mg IR)	Maximum Concentration: Calculated Dose (D) Child	Maximum Concentration: Hazard Quotient (HQ) [D/RfD]	Avg Concentration[2] (200 mg IR)	Average Concentration: Calculated Dose (D) Child	Average Concentration: Hazard Quotient (HQ) [D/RfD]
	(mg/kg-day)	(mg/kg)	(mg/kg/day)	---	(mg/kg)	(mg/kg/day)	---
Antimony[6]	0.0004	5	0.00001	0.013	2	0.00000	0.005
Arsenic (As)	0.0003	5	0.00001	0.017	2	0.00000	0.007
Barium[6]	0.2	222	0.00023	0.001	84	0.00009	0.000
Beryllium[6]	0.002	1	0.00000	0.000	0.3	0.00000	0.000
Boron[6]	0.2	93	0.00010	0.000	62	0.00006	0.000
Cadmium[6]	0.001	5	0.00001	0.005	1	0.00000	0.001
Chromium Hexavalent (Cr (VI))	0.003	0.5	0.00000	0.000	0.4	0.00000	0.000
Iron (Fe)	0.7	22,000	0.02292	0.033	11,413	0.01189	0.017
Lead (Pb)	400 mg/kg soil [7]	5	0.00001	no exceedance	1	0.00000	no exceedance
Magnesium (Mg)	None.	53,000	0.05521	---	46,340	0.04827	---
Manganese (Mn)[4]	0.024	3,765	0.00392	0.163	1,901	0.00198	0.082
Mercury (Hg)	None.	0.05	0.00000	---	0.02	0.00000	---
Molybdenum[6]	0.005	160	0.00017	0.033	29	0.00003	0.006
Nickel[6]	0.011	23	0.00002	0.002	8	0.00001	0.001
Thallium (Tl)	0.00001	4	0.00000	0.417	1	0.00000	0.121
Titanium	None.	1,770	0.00184	---	1,137	0.00118	---
Vanadium (V)	0.005	44	0.00005	0.009	12	0.00001	0.003

Notes:
Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html).

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR).

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day.
EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Standard daily incidental ingestion rates of 200 mg soil/kg/d for a child (Based on ATSDR Guidance Manual, App G) multiplied by 8/12 months, to account for the winter months of snow and ice cover. http://www.atsdr.cdc.gov/hac/PHAManual/appg.html

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 µg/dL.

[8] Intake estimates assume 50% of ingested soil is dust from slag. Calculations modified using an Exposure Factor (EF) of 0.5.

[9] Child BW = 16 kg (ATSDR children 1 -6 y.o., 50th percentile- ATSDR PHA Guidance Manual, App G)

[10] This exposure estimate only considered exposure via incidental soil ingestion, and does not take into consideration dietary or other environmental exposures to these contaminants.

[11] Bioavailability is highly variable and dependent on a number of environmental, chemical and physiological factors. A 25% bioavailability factor was chosen to represent a lower bound estimate of bioavailability for the metal constituents in the slags. Due to the complexity of the slag complexes and the multiple factors involve in estimating bioavailability, determining more scenario and metal constituent specific bioavailability estimates are beyond the scope of this document.

Table 8. Slag Exposure Calculations-Child Inhalation - Nasopharyngeal Swallow (DNR values)[13]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= **(C X IR X EF) / BW**

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/m^3
IR[5]=	Air Intake Rate	3.6	m^3/day
EF =	Exposure Factor	1	unitless
BW[5] =	Body Weight	4.8	kg

Intake Rates [5]	Air IR [8] (m^3/day)	Body Weight [9] (kg)
Birth to <1 month	3.6	4.8
1 to <3 months	3.5	5.9
3 to <6 months	4	7.4
6 to <11 months	5	9.2
1 to <2 years	8.0	11.4
2 to <3 years	8.9	13.8
3 to <6 years	10.1	18.6
6 to <11 years	12.0	31.8
11 to <16 years	15.2	56.8
16 to <21 years	16.3	71.6

DNR Modeled Scenarios	Avg annual PM_{10}[10] ($\mu g/m^3$)	(mg/m^3)
Conversion	1	0.001
Farm Lane Scenario 1	0.0281	0.0000281
Farm Lane Scenario 2	0.0913	0.0000913
Road Shoulder Scenario	0.0242	2.421E-05
Parking Lot Scenario 1	0.1109	0.0001109
Parking Lot Scenario 2	0.0833	0.0000833
Maximum (Worst Case)	**0.111**	**0.0001**

Mixed Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (Cmax)	Max Concentration ratio[11] (Cmaxrat)	DNR Worst-case Modeled Scenario: Cmax Converted[12]	Calculated Dose (D) Child, max concentration	Hazard Quotient (HQ) (D/RfD)
	(mg/kg/day)	(mg/kg)	(mg/mg)	(mg/m^3)	(mg/kg/day)	---
Antimony[6]	0.0004	100	0.0001	0.0000000111	0.0000000083	0.00002
Arsenic (As)	0.0003	20	0.00002	0.0000000022	0.0000000017	0.00001
Barium[6]	0.2	316	0.000316	0.0000000350	0.0000000263	0.0000001
Beryllium[6]	0.002	5	0.0000052	0.0000000006	0.0000000004	0.0000002
Boron[6]	0.2	660	0.00066	0.0000000732	0.0000000549	0.0000003
Cadmium[6]	0.001	19	0.000019	0.0000000021	0.0000000016	0.000002
Chromium Hexavalent (Cr (VI))	0.003	2	0.00000186	0.0000000002	0.0000000002	0.00000005
Iron (Fe)	0.7	258,000	0.258	0.0000286013	0.0000214510	0.00003
Lead (Pb)	400 mg/kg soil [7]	97	0.000097	0.0000000108	0.0000000081	no exceedance
Magnesium (Mg)	None.	80,900	0.0809	0.0000089684	0.0000067263	---
Manganese (Mn)[4]	0.024	43,400	0.0434	0.0000048112	0.0000036084	0.00015
Mercury (Hg)	None.	1	0.000001	0.0000000001	0.0000000001	---
Molybdenum[6]	0.005	113	0.000113	0.0000000125	0.0000000094	0.000002
Nickel[6]	0.011	140	0.00014	0.0000000155	0.0000000116	0.000001
Thallium (Tl)	0.00001	23	0.000023	0.0000000025	0.0000000019	0.00019
Titanium	None.	1,942	0.001942	0.0000002153	0.0000001615	---
Vanadium (V)	0.005	1,028	0.001028	0.0000001140	0.0000000855	0.00002

EAF Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (Cmax)	Max Concentration ratio	DNR Worst-case Modeled Scenario: Cmax Converted	Calculated Dose (D) Child, max concentration	Hazard Quotient (HQ) (D/RfD)
	(mg/kg-day)	(mg/kg)	(mg/mg)	(mg/m^3)	(mg/kg/day)	---
Antimony[6]	0.0004	150	0.00015	0.0000000166	0.0000000125	0.00003
Arsenic (As)	0.0003	20	0.00002	0.0000000022	0.0000000017	0.00001
Barium[6]	0.2	335	0.000335	0.0000000371	0.0000000279	0.0000001
Beryllium[6]	0.002	2	0.000002	0.0000000002	0.0000000002	0.0000001
Boron[6]	0.2	110	0.00011	0.0000000122	0.0000000091	0.00000005
Cadmium[6]	0.001	8	0.0000078	0.0000000009	0.0000000006	0.0000006
Chromium Hexavalent (Cr (VI))	0.003	5	0.00000498	0.0000000006	0.0000000004	0.00000014
Iron (Fe)	0.7	271,000	0.271	0.0000300425	0.0000225318	0.00003
Lead (Pb)	400 mg/kg soil [7]	20	0.00002	0.0000000022	0.0000000017	no exceedance
Magnesium (Mg)	None.	89,400	0.0894	0.0000099107	0.0000074330	---
Manganese (Mn)[4]	0.024	48,946	0.048946	0.0000054260	0.0000040695	0.00017
Mercury (Hg)	None.	1.000	0.000001	0.0000000001	0.0000000001	---
Molybdenum[6]	0.005	250	0.00025	0.0000000277	0.0000000208	0.000004
Nickel[6]	0.011	1,290	0.00129	0.0000001430	0.0000001073	0.000010
Thallium (Tl)	0.00001	28	0.000028	0.0000000031	0.0000000023	0.0002
Titanium	None.	2,190	0.00219	0.0000002428	0.0000001821	---
Vanadium (V)	0.005	1,049	0.001049	0.0000001163	0.0000000872	0.00002

Table 8. Slag Exposure Calculations-Child Inhalation - Nasopharyngeal Swallow (DNR values)[13]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Ladle Slag				DNR Worst-case Modeled Scenario		
Contaminant	**Oral Reference Dose (RfD)[3]**	**Max Concentration[2] (Cmax)**	**Max Concentration ratio**	**Cmax Converted**	**Calculated Dose, Child (D)**	**Hazard Quotient (HQ) (D/RfD)**
	(mg/kg-day)	**(mg/kg)**	**(mg/mg)**	**(mg/m^3)**	**(mg/kg/day)**	---
Antimony[6]	0.0004	22	0.000022	0.0000000024	0.0000000018	0.000005
Arsenic (As)	0.0003	20	0.00002	0.0000000022	0.0000000017	0.00001
Barium[6]	0.2	222	0.000222	0.0000000246	0.0000000185	0.0000001
Beryllium[6]	0.002	2	0.000002	0.0000000002	0.0000000002	0.0000001
Boron[6]	0.2	93	0.000093	0.0000000103	0.0000000077	0.0000000
Cadmium[6]	0.001	5	0.00000496	0.0000000005	0.0000000004	0.000000
Chromium Hexavalent (Cr (VI))	0.003	0	0.00000045	0.0000000000	0.0000000000	0.00000001
Iron (Fe)	0.7	22,000	0.022	0.0000024389	0.0000018292	0.00000
Lead (Pb)	400 mg/kg soil [7]	20	0.00002	0.0000000022	0.0000000017	no exceedance
Magnesium (Mg)	None.	53,000	0.053	0.0000058755	0.0000044	---
Manganese (Mn)[4]	0.024	3,765	0.003765	0.0000004174	0.0000003130	0.00001
Mercury (Hg)	None.	0	0.00000005	0.0000000000	0.0000000000	---
Molybdenum[6]	0.005	160	0.00016	0.0000000177	0.0000000133	0.00000
Nickel[6]	0.011	23	0.000023	0.0000000025	0.0000000019	0.0000002
Thallium (Tl)	0.00001	20	0.00002	0.0000000022	0.0000000017	0.00017
Titanium	None.	1,770	0.00177	0.0000001962	0.0000001472	---
Vanadium (V)	0.005	44	0.000044	0.0000000049	0.0000000037	0.000001

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html). Intake estimates assume that 100% of PM_{10} in the exposure scenario is composed of slag.

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR)

[3] Reference Dose (RfD) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. EPA recommends that the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. EPA further recommends using a modifying factor of 3 when calculating risks associated with non-food sources due to a number of uncertainties, leading to a RfD of 0.024 mg/kg-day. Source: EPA Region 3 Screening Table, User Guide. May 2014. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

[5] Air intake rates and body weight used in calculations was chosen based on max ratio of IR/BW, to represent the worst case exposure. Intake rate assumes 365 days of exposure per year, unless otherwise stated.

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfD for Lead. Evaluation is based on the EPA soil screening value of 400 mg/kg, and then divided by two to accommodate the new CDC target blood lead level reduction from 10 to 5 µg/dL.

[8] Air Intake Rates per EPA Exposure Factors Handbook, September 2011, chapter 6. http://www.epa.gov/ncea/efh

[9] Body weights per EPA Exposure Factors Handbook, September 2011, chapter 8. http://www.epa.gov/ncea/efh

[10] PM_{10} estimates for the five scenarios are based on air dispersion models produced by Wisconsin Department of Natural Resources (DNR).

[11] Maximum Concentration Ratio (C_{maxrat}) = C_{max} / (1 x 10^6) ---> [mg/mg = (mg/kg) x (1kg / 1,000,000mg)]

[12] C_{max} converted = C_{maxrat} x avg. annual PM_{10} concentration ---> [mg/m^3 = (mg/mg) x (mg/m^3)]

[13] This exposure estimate only considered exposure via soil that is captured in the upper respiratory tract and swallowed. The estimate does not take into consideration dietary or other environmental exposures to these contaminants. It is also assumed for in these calculations that 100% of exposure of PM10 dust particles are in the upper respiratory tract and swallowed, and does not subtract out a percentage of smaller respirable (PM2.5) particles that are inhaled, resulting in a different route of exposure. This represents as a worst case exposure via the nasopharyngeal route.

Table 9. Slag Exposure Calculations-Child Inhalation - Respirable Fraction (PM2.5) (DNR values)[12]
Charter Steel Slag Health Assessment
Wisconsin Division of Public Health

Exposure Dose calculations[1]

D= (C X IR X EF) / BW

		Value	Units
D =	Exposure Dose	See Results	mg/kg/day
Cmax =	Contaminant Concentration (Maximum)[2]	varies-see table	mg/m^3
IR[5] =	Air Intake Rate	3.6	m^3/day
EF =	Exposure Factor	1	unitless
BW[5] =	Body Weight	4.8	kg

Intake Rates [5]	Air IR [8] (m^3/day)	Body Weight [9] (kg)
Birth to <1 month	3.6	4.8
1 to <3 months	3.5	5.9
3 to <6 months	4	7.4
6 to <11 months	5	9.2
1 to <2 years	8.0	11.4
2 to <3 years	8.9	13.8
3 to <6 years	10.1	18.6
6 to <11 years	12.0	31.8
11 to <16 years	15.2	56.8
16 to <21 years	16.3	71.6

DNR Modeled Scenarios	Avg annual PM_{10} [4]	
	($\mu g/m^3$)	(mg/m^3)
Conversion	1	0.001
Farm Lane Scenario 1	0.0281	0.0000281
Farm Lane Scenario 2	0.0913	0.0000913
Road Shoulder Scenario	0.0242	2.421E-05
Parking Lot Scenario 1	0.1109	0.0001109
Parking Lot Scenario 2	0.0833	0.0000833
Maximum (Worst Case)	**0.1109**	**0.0001109**

Mixed Slag

Contaminant	Reference Concentration (RfC)[3]	Max Concentration[2] (Cmax)	Max Concentration ratio[10] (Cmaxrat)	DNR Worst-case Modeled Scenario: Cmax Converted[11]	DNR Worst-case Modeled Scenario: Calculated Dose (D) Child, max concentration	DNR Worst-case Modeled Scenario: Hazard Quotient (HQ) (D/RfC)	Cancer Screening Value Concentration (at $1/1x10^6$ risk)
	(mg/m^3)	(mg/kg)	(mg/mg)	(mg/m^3)	(mg/kg/day)	---	Calculated risk value of
Antimony[6]	None.	100	0.0001	0.0000000111	0.0000000083	---	1.11E-05 $\mu g/m^3$ for antimony
Arsenic (As)	1.5E-05	20	0.00002	0.0000000022	0.0000000017	0.0001	is less than screening value of:
Barium[6]	5.0E-04	316	0.000316	0.0000000350	0.0000000263	0.0001	4.30E-03 ug/m3
Beryllium[6]	2.0E-05	5	0.0000052	0.0000000006	0.0000000004	0.00002	
Boron[6]	2.0E-02	660	0.00066	0.0000000732	0.0000000549	0.000003	Calculated risk value of
Cadmium[6]	1.0E-05	19	0.000019	0.0000000021	0.0000000016	0.0002	2.06E-07 $\mu g/m^3$ for chromium VI
Chromium Hexavalent (Cr (VI))	1.0E-04	2	0.00000186	0.0000000002	0.0000000002	0.000002	is less than screening value of:
Iron (Fe)	None.	258,000	0.258	0.0000286013	0.0000214510	---	8.00E-05 $\mu g/m^3$
Lead (Pb)	400 mg/kg soil [7]	97	0.000097	0.0000000108	0.0000000081	no exceedance	
Magnesium (Mg)	None.	80,900	0.0809	0.0000089684	0.0000067263	---	
Manganese (Mn)	5.0E-05	43,400	0.0434	0.0000048112	0.0000036084	0.1	
Mercury (Hg)	3.0E-04	1	0.000001	0.0000000001	0.0000000001	---	
Molybdenum[6]	None.	113	0.000113	0.0000000125	0.0000000094	---	
Nickel[6]	1.4E-05	140	0.00014	0.0000000155	0.0000000116	0.001	
Thallium (Tl)	None.	23	0.000023	0.0000000025	0.0000000019	---	
Titanium	None.	1,942	0.001942	0.0000002153	0.0000001615	---	
Vanadium (V)	1.0E-04	1,028	0.001028	0.0000001140	0.0000000855	0.001	

EAF Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (Cmax)	Max Concentration ratio	DNR Worst-case Modeled Scenario: Cmax Converted	DNR Worst-case Modeled Scenario: Calculated Dose (D) Child, max concentration	DNR Worst-case Modeled Scenario: Hazard Index (HI) (D/RfD)
	(mg/m^3)	(mg/kg)	(mg/mg)	(mg/m^3)	(mg/kg/day)	---
Antimony[6]	None.	150	0.00015	0.0000000166	0.0000000125	---
Arsenic (As)	1.5E-05	20	0.00002	0.0000000022	0.0000000017	0.0001
Barium[6]	5.0E-04	335	0.000335	0.0000000371	0.0000000279	0.0001
Beryllium[6]	2.0E-05	2	0.000002	0.0000000002	0.0000000002	0.00001
Boron[6]	2.0E-02	110	0.00011	0.0000000122	0.0000000091	0.000000
Cadmium[6]	1.0E-05	8	0.0000078	0.0000000009	0.0000000006	0.0001
Chromium Hexavalent (Cr (VI))	1.0E-04	5	0.00000498	0.0000000006	0.0000000004	0.00000
Iron (Fe)	None.	271,000	0.271	0.0000300425	0.0000225318	---
Lead (Pb)	400 mg/kg soil [7]	20	0.00002	0.0000000022	0.0000000017	no exceedance
Magnesium (Mg)	None.	89,400	0.0894	0.0000099107	0.0000074330	---
Manganese (Mn)	5.0E-05	48,946	0.048946	0.0000054260	0.0000040695	0.1
Mercury (Hg)	3.0E-04	1.000	0.000001	0.0000000001	0.0000000001	---
Molybdenum[6]	None.	250	0.00025	0.0000000277	0.0000000208	---
Nickel[6]	1.4E-05	1,290	0.00129	0.0000001430	0.0000001073	0.01
Thallium (Tl)	None.	28	0.000028	0.0000000031	0.0000000023	---
Titanium	None.	2,190	0.00219	0.0000002428	0.0000001821	---
Vanadium (V)	1.0E-04	1,049	0.001049	0.0000001163	0.0000000872	0.001

Table 9. Slag Exposure Calculations-Child Inhalation - Respirable Fraction (PM2.5) (DNR values)[12]

Charter Steel Slag Health Assessment

Wisconsin Division of Public Health

Ladle Slag

Contaminant	Oral Reference Dose (RfD)[3]	Max Concentration[2] (Cmax)	Max Concentration ratio	DNR Worst-case Modeled Scenario: Cmax Converted	DNR Worst-case Modeled Scenario: Calculated Dose, Child (D)	DNR Worst-case Modeled Scenario: Hazard Index (HI) (D/RfD)
	(mg/m^3)	(mg/kg)	(mg/mg)	(mg/m^3)	(mg/kg/day)	---
Antimony[6]	None.	22	0.000022	0.0000000024	0.0000000018	---
Arsenic (As)	1.5E-05	20	0.00002	0.0000000022	0.0000000017	0.0001
Barium[6]	5.0E-04	222	0.000222	0.0000000246	0.0000000185	0.0000
Beryllium[6]	2.0E-05	2	0.000002	0.0000000002	0.0000000002	0.00001
Boron[6]	2.0E-02	93	0.000093	0.0000000103	0.0000000077	0.000000
Cadmium[6]	1.0E-05	5	0.00000496	0.0000000005	0.0000000004	0.0000
Chromium Hexavalent (Cr (VI))	1.0E-04	0	0.00000045	0.0000000000	0.0000000000	0.000000
Iron (Fe)	None.	22,000	0.022	0.0000024389	0.0000018292	---
Lead (Pb)	400 mg/kg soil [7]	20	0.00002	0.0000000022	0.0000000017	no exceedance
Magnesium (Mg)	None.	53,000	0.053	0.0000058755	0.0000044066	---
Manganese (Mn)	5.0E-05	3,765	0.003765	0.0000004174	0.0000003130	0.01
Mercury (Hg)	3.0E-04	0	0.00000005	0.0000000000	0.0000000000	---
Molybdenum[6]	None.	160	0.00016	0.0000000177	0.0000000133	---
Nickel[6]	1.4E-05	23	0.000023	0.0000000025	0.0000000019	0.0001
Thallium (Tl)	None.	20	0.00002	0.0000000022	0.0000000017	---
Titanium	None.	1,770	0.00177	0.0000001962	0.0000001472	---
Vanadium (V)	1.0E-04	44	0.000044	0.0000000049	0.0000000037	0.0000

Notes:

Exceed Hazard Index (HQ) of 1; HQ = D/RfD

[1] Equation based on guidance from ATSDR Public Health Assessment Guidance Manual, Appendix G (http://www.atsdr.cdc.gov/hac/phamanual/appg.html). Intake estimates assume that 100% of PM_{10} in the exposure scenario is composed of slag.

[2] Concentration values from laboratory data of Charter Steel site-specific samples, as provided by Wisconsin Department of Natural Resources (DNR).

[3] Reference Concentration (RfC) from EPA Region 3 risk-based screening tables. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm

[4] PM10 estimates for the five scenarios are based on air dispersion models produced by Wisconsin Department of Natural Resources (DNR).

[5] Air intake rates and body weight used in calculations was chosen based on max ratio of IR/BW, to represent the worst case exposure. Intake rate assumes 365 days of exposure per year, unless otherwise stated.

[6] These constituents were reviewed in the 2008 DHS Slag reuse evaluation authored by Lynda Knobeloch, which included all toxic metal constituents as reported by Charter Steel. Based on Charter Steel and Industry laboratory analysis, these constituents do not exceed EPA screening level, but are included in this report for completeness.

[7] There is no RfC for Lead. Evaluation is based on EPA soil screening value and professional judgement

[8] Air Intake Rates per EPA Exposure Factors Handbook, September 2011, chapter 6. http://www.epa.gov/ncea/efh

[9] Body weights per EPA Exposure Factors Handbook, September 2011, chapter 8. http://www.epa.gov/ncea/efh

[10] Maximum Concentration Ratio (C_{maxrat}) = C_{max} / (1 x 10^6) ---> [mg/mg = (mg/kg) x (1kg / 1,000,000mg)]

[11] C_{max} converted = C_{maxrat} x avg. annual PM_{10} concentration ---> [mg/m^3 = (mg/mg) x (mg/m^3)]

[12] This exposure estimate only considers exposure via soil that is respired into the lungs, corresponding to particles at or below the PM2.5 size. The estimate does not take into consideration dietary or other environmental exposures to these contaminants. It is also assumed for in these calculations that 100% of PM10 dust particles, as estimated by Wisconsin DNR are composed of PM2.5 size particles, and thus 100% of PM10 particles are inhaled and involved in the exposure (as a worst case exposure). No subtraction is made for a non-respirable fraction, or other exposure reductions.

Appendix 1

PM10 Air Exposure Assessment from Road-Applied Slag

PM10 Air Exposure Assessment from Road-Applied Slag

Charter Steel's electric arc furnace (EAF) and ladle slag are proposed to be used as roadway and parking lot construction material. Due to the nature of the material, an assessment was performed to determine potential breathing zone concentrations of particulate matter. There are two components of the assessment: (1) estimating fugitive particulate matter emissions, and (2) conducting air dispersion modeling to derive estimated concentrations resulting from the estimated emissions. The modeled estimate of annual particulate matter exposures can then be used to assess exposures to the slag components of interest (e.g., metals). PM10 (particles size 10 microns and smaller) is the main focus of the analysis, which only estimates emissions from vehicles and does not consider background PM10 concentrations or the impacts from any other source.

Where applicable, the assessment used local data and methods from the National Slag Association's document titled "Human Health Risk Assessment for Iron and Steel Slag"(December 2011). Source: http://www.acobrasil.org.br/siderurgiaemfoco/CCABrasil/Human_Health_Risk_Assessment_for_Steel_Slag_1211.pdf . In addition, emission methods in EPA AP-42 for unpaved roads were used when applicable (Source: http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s0202.pdf)

After discussions with DHS and other DNR staff, it was decided to assess three inhalation exposure scenarios (discussed below), each using the U.S. EPA regulatory air dispersion model (AERMOD) and following U.S. EPA guidance on estimating annual average PM10 emissions and modeling roadway impacts (e.g., modeled as area sources and using the plume depletion algorithm to account for particulate matter settling out of the air). For both roadway related scenarios, a range of particulate concentrations was calculated along a cross section (i.e., perpendicular to the roadway at varying distances from the center of the roadway-related activity being assessed). The industrial parking lot scenario also included particulate matter concentrations as a function of distance from the parking lot. The range of concentrations from all three scenarios takes into account both varying orientations of the roads or parking lots relative to the wind (e.g., north-south or east-west) and varying degrees of conservatism in the emission calculation (e.g., the silt content of slag, range of 3.9% - 12%, and the percent moisture, range of 4.3% - 6.5%).

The three scenarios, with sub-scenarios in the case of the farm road and the parking lot scenarios, were developed to aid in sensitivity analysis. Basic assumptions used are in given in each section as well as in Appendix A at the end of the document.

Farm Road with Residential Driveway Scenario
e.g., a driveway leading to a farmstead or other farm-related property that is used for family trips but is also used for farm-related activities, including trips generated by farm employees.

Two basic sub-scenarios:

- ***Lane1= 26 trips/day:*** *Family vehicles (16 trips/day) and farm equipment (10 trips/day). Avg. vehicle weight = 7.54 tons. Height of middle of plume = 7.4 feet.*
- ***Lane2 = 88 trips/day****: Family vehicles (16 trips/day), 12x Worker's vehicles @ 4 trips/day (48 trips/day) and farm equipment (24 trips/day). Avg. vehicle weight = 5.64 tons. Height of middle of plume = 6.7 feet.*

Basic Physical Description

12' wide, unpaved roadway, 300 meters length (0.56 miles; 984 feet)

- **Basis of assumption for width** - 12 ft. width was based on 12/5/14 email from Chery Skjolaas, Interim Director and Agricultural Safety Specialist, UW Center for Agricultural Safety and Health. Quote from the email: "Your farm lane is basically a driveway? Depending on the size of farm you're considering, a 10 ft. wide drive may be narrow. "
- **Basis of assumption for length chosen** - Best professional judgment was used to conduct dispersion modeling for roads, as well as aerial photographs for various farmsteads in the area. The cross section concentration is what will be used for the results of concentration estimates as a function of distance. Those will change slightly with increased length of driveway, but a longer road reduces the variance of concentration estimates as a function of variations in wind directions.

March to November emissions (this assumes that snow/ice cover/moisture in winter months prevents emissions of particulate matter from occurring)

- **Basis of assumption for not modeling the months of December, January and February** - Professional judgment regarding moisture content, snow/ice cover and frozen conditions.

Every day emissions (5a-8p) (assumes travel only during daylight hours)

- **Basis of assumption for timeframe chosen** - Model unit of analysis is hourly and in order to make the analysis straightforward, we need to round to closest hour for the entire modeling period (a year). The longest day of the year is June 20 (15:23 minutes) in Milwaukee (closest large city to Saukville, Wisconsin). In addition, the earliest sunrise for Milwaukee is at 5:12 am on June 12; latest sunset is at 8:35 pm on June 29. Thus, 5 am - 8 pm (15 hours) is a reasonable maximum estimate (but an overestimate on average) of the length of day for the entire modeling period. It would be too difficult to set up and run a model with varying length of day for each day or period of interest (e.g., daily, monthly, from March to November, etc.), thus this is a simplifying, but conservative, assumption.

Unpaved Road Shoulder

e.g., farm machinery traveling alongside a paved public road.

Basic Assumptions: Unpaved roadway

- ***20 trips[1] on shoulder/day by heavy farm equipment.*** *Avg. vehicle weight is 18 tons. Height of middle of plume = 11.1 ft. Length of roadway = 1,600 meters (~1 mile)*

Basic Physical Description

10' wide, unpaved shoulder, 1.6 kilometers (1 mile) length of travel to get to the field(s).

- **Basis of assumption of 10' width** - Based on personal knowledge and experience with certain Wisconsin highways where farm vehicles travel on shoulder. Also of note: see email dated December 5, 2014 from Cheryl Skjolaas, Interim Director and Agricultural Safety Specialist, UW Center for Agricultural Safety and Health. Quote from the email: "Most town roads have no shoulder or a few inches. County road shoulders are about 2 ft. 10 feet is almost the whole lane of traffic wide. We do not recommend driving on the shoulder but staying in the traffic lane. Know that in areas where there are wide shoulders, smaller equipment will operate on the shoulder. For example, Highway 33 in Dodge County there's a stretch between Beaver Dam and Horicon that it is common for a couple of farms to operate on the shoulder."
- Taking into account Cheryl Skjolaas' comments, WDNR Air Program staff recommend that we model the full weight of farm equipment on a shoulder that is wide enough that both wheels are on the unpaved shoulder (10 ft). If we wish to consider a vehicle traveling on a 2 ft wide shoulder (only tires on one side of the vehicle are on the unpaved shoulder), we will propose (for sensitivity analysis purposes and using best professional judgment) that half of the weight of the vehicle is on this smaller shoulder (e.g., a 2 ft shoulder that Cheryl Skjolass suggests). Since only half of the wheels are on the unpaved shoulder, this results in only a fraction (assumption would be half) of the emissions as from travel on the 10 ft wide shoulder. There is really no ability in the emissions equations and dispersion modeling, that we can think of, to account fully for a scenario where less than the full weight of the vehicle is traveling on the unpaved shoulder.

March to November emissions

Every day emissions (5 am - 8 pm) (assumes travel only during daylight hours)

[1] Two farms using the same unpaved roadway shoulder, each with 10 trips/day per farm.

- **Basis of Assumption for hours of the day** - See discussion above for the farm road with residential driveway scenario.

Industrial Parking Lot

Two basic sub-scenarios for a 100m X 100m parking lot - 10,000 m2 parking lot (~2.47 acres):

- ***Lot # 1= 700 trips/day (350 employees x 2 trips/day****). Avg. vehicle weight = 1 ton. This would represent a factory or other business without a lot of heavy vehicles. Height of middle of plume = 5.1 ft.*
- ***Lot #2= 400 trips/day (200 employees x 2 trips/day).*** *Avg. vehicle weight = 2 tons. This would represent a large industry, grain cooperative, or large construction company where larger vehicles would increase the average weight of vehicle trips. Height of middle of plume = 5.1 feet.*
- *Trip length for both sub-scenarios = 50 meter, to center of lot, on average.*

Basic Physical Description

100 meters square (equal to 10,000 m^2; 107, 639 ft2; 2.47 acres)

- **Basis of Assumption** - Estimate is based on both experience/professional judgment as well as observation. In viewing aerial photographs of unpaved parking lots in the area surrounding charter steel in Saukville, Wisconsin, there were some properties of this size with large unpaved parking lots in this range of size. In addition, larger commercial and retail establishments that have a lot of customer visits or a large number of employees will typically have paved parking lots (due to maintenance and liability issues with damage to vehicles). Our assumption is that such a parking lot will have about 350 parking stalls, and the travel onto the property will be approximately half way into the center of the 100 meter square area; a distance of 50 meters (150 feet).

Emissions occur during all months of the year

- **Basis of Assumption** - A commercial business is assumed to operate year round.

Every day emissions (5 am – 8 pm) (assumes travel only during daylight hours)

- **Basis of Assumption** - The commercial business will operate during daylight hours (a total of 15 hours per day).

Results

The results are presented in summary format here. The AERMOD dispersion analysis files contain the output of the analysis and those results were used to create an Excel spreadsheet for each scenario modeled. The minimum and maximum annual concentrations of PM10 were graphed as a function of distance from the center line of the traffic lane on a roadway or the center of the parking lot modeled. Due to wind speed and direction profiles, the concentrations are nearly, but not totally symmetric around the center line of the road or parking lot. It is recommended that the highest of the values at a given distance from a roadway or parking lot be used for assessment of exposure to PM10. See the Excel spreadsheet for specific details.

Farm Road with Residential Driveway Scenario
e.g., a driveway leading to a farmstead or other farm-related property that is used for family trips but is also used for farm-related activities, including trips generated by farm employees.

Lane1= 26 trips/day*: Family vehicles (16 trips/day) and farm equipment (10 trips/day). Avg. vehicle weight = 7.54 tons*

PM10 modeled emission rate = 4.77E-8 g/s-m2 (low) or 1.33E-7 g/s-m2 (high).

The results from the center line of the traffic lane on a roadway (the highest concentrations from half of the graph of monitoring results. Those from 5 meters to 400 meters out) are given in the table below. Also attached is a graph of the results. The range of estimated annual average PM10 concentrations at 5 meters from the center line of the traffic lane on a roadway, was 0.008826 to 0.028055 micrograms per cubic meter (ug/m3). Other concentrations can be extrapolated from the table below, or from the Excel spreadsheet.

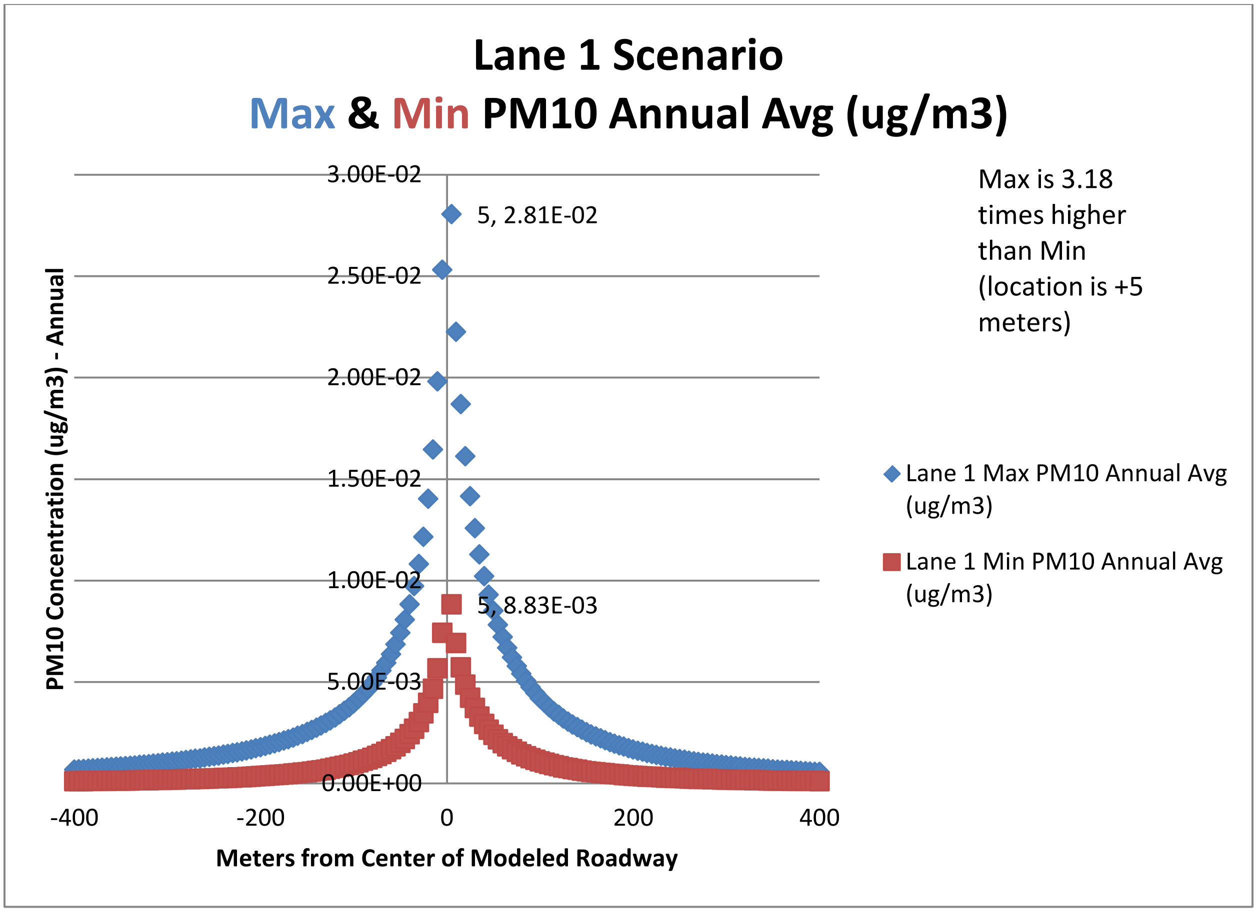
Lane 1: Annual PM10 Concentrations in micrograms per cubic meter as a function of distance (meters)

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
5	0.008826	0.028055
10	0.006919	0.022249
15	0.005717	0.01869
20	0.004865	0.016123
25	0.004221	0.014148
30	0.003715	0.012573
35	0.00329	0.011283
40	0.002938	0.010206
45	0.002643	0.009291
50	0.002391	0.008503
55	0.002176	0.007818
60	0.001989	0.007215
65	0.001825	0.006682
70	0.001681	0.006206
75	0.001553	0.005781
80	0.001439	0.005398
85	0.001337	0.005052
90	0.001245	0.00474
95	0.001161	0.004457
100	0.001086	0.004199
105	0.001017	0.003964
110	0.000954	0.003749
115	0.000896	0.003552
120	0.000843	0.003371
125	0.000794	0.003203
130	0.00075	0.003048
135	0.000709	0.002904

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
140	0.000671	0.00277
145	0.000636	0.002645
150	0.000604	0.002527
155	0.000574	0.002417
160	0.000546	0.002314
165	0.00052	0.002217
170	0.000496	0.002126
175	0.000474	0.002039
180	0.000453	0.001958
185	0.000433	0.001881
190	0.000414	0.001808
195	0.000397	0.00174
200	0.00038	0.001675
205	0.000365	0.001613
210	0.00035	0.001555
215	0.000336	0.0015
220	0.000323	0.001449
225	0.000311	0.001402
230	0.000299	0.001357
235	0.000288	0.001313
240	0.000278	0.001272
245	0.000268	0.001233
250	0.000259	0.001195
255	0.00025	0.001159
260	0.000242	0.001125
265	0.000234	0.001092
270	0.000227	0.001061

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
275	0.00022	0.001031
280	0.000213	0.001002
285	0.000207	0.000974
290	0.000201	0.000948
295	0.000195	0.000922
300	0.000189	0.000898
305	0.000184	0.000875
310	0.000179	0.000852
315	0.000174	0.000831
320	0.000169	0.00081
325	0.000165	0.00079
330	0.000161	0.000771
335	0.000156	0.000752
340	0.000153	0.000734
345	0.000149	0.000717
350	0.000145	0.0007
355	0.000142	0.000684
360	0.000138	0.000669
365	0.000135	0.000654
370	0.000132	0.000639
375	0.000129	0.000625
380	0.000126	0.000612
385	0.000123	0.000599
390	0.00012	0.000586
395	0.000117	0.000574
400	0.000115	0.000562

Source: Wisconsin Department of Natural Resources



Lane2 = 88 trips/day: *Family vehicles (16 trips/day), 12x Worker's vehicles @ 4 trips/day (48 trips/day), and farm equipment (24 trips/day). Avg. vehicle weight = 5.64 tons.*

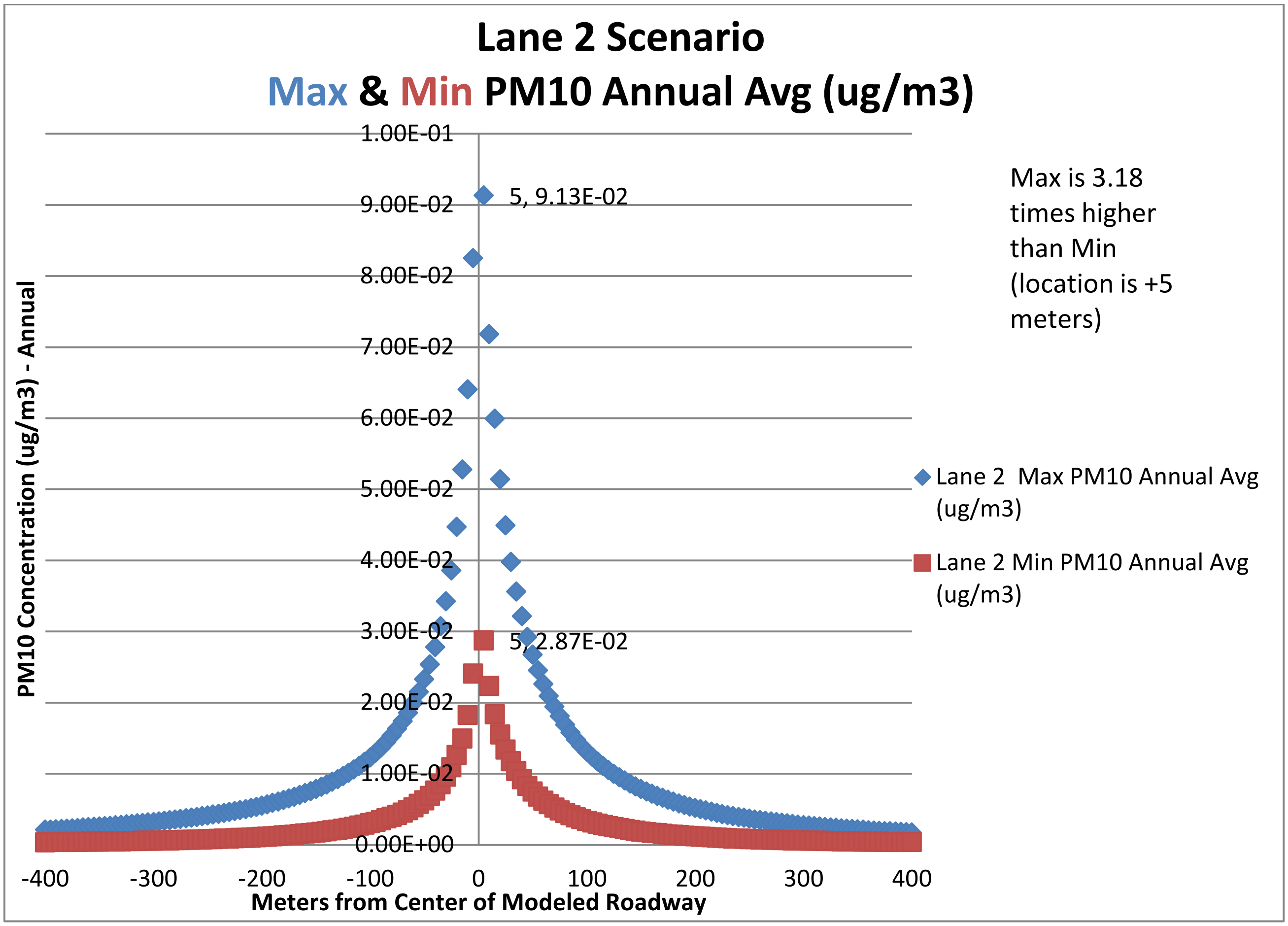
PM10 modeled emission rate = 1.44E-7 g/s-m2 (low) or 4.00E-7 g/s-m2 (high).

The results from the center line of the traffic lane on a roadway (on the highest half of the graph of monitoring results) are given in the table below. Also attached is a graph of the results.

Lane 2: Annual PM10 Concentrations in micrograms per cubic meter as a function of distance (meters)

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
5	0.028731	0.091288
10	0.022331	0.071787
15	0.018316	0.059875
20	0.015494	0.051363
25	0.013379	0.044881
30	0.011701	0.039757
35	0.01033	0.035592
40	0.009203	0.032132
45	0.00826	0.029206
50	0.007461	0.026695
55	0.006777	0.024513
60	0.006185	0.022601
65	0.00567	0.02091
70	0.005216	0.019406
75	0.004815	0.01806
80	0.004457	0.01685
85	0.004137	0.01576
90	0.003848	0.014775
95	0.003587	0.013882
100	0.003351	0.013071
105	0.003135	0.012332
110	0.002938	0.011657
115	0.002759	0.011037
120	0.002594	0.010468
125	0.002443	0.009942
130	0.002304	0.009456
135	0.002177	0.009004
140	0.00206	0.008583
145	0.001952	0.00819
150	0.001852	0.007822
155	0.001759	0.007478
160	0.001674	0.007154
165	0.001594	0.00685
170	0.001519	0.006563
175	0.001449	0.006293
180	0.001384	0.006039
185	0.001323	0.005798
190	0.001265	0.005571
195	0.001211	0.005357
200	0.00116	0.005154
205	0.001113	0.004963
210	0.001067	0.004781
215	0.001025	0.004609
220	0.000985	0.004446
225	0.000947	0.004291
230	0.000911	0.004148
235	0.000878	0.004014
240	0.000846	0.003887
245	0.000816	0.003765
250	0.000788	0.003649
255	0.000761	0.003538
260	0.000736	0.003432
265	0.000712	0.003331
270	0.000689	0.003234
275	0.000667	0.003141
280	0.000647	0.003052
285	0.000627	0.002968
290	0.000608	0.002886
295	0.000591	0.002808
300	0.000574	0.002733
305	0.000558	0.002661
310	0.000542	0.002592
315	0.000527	0.002526
320	0.000513	0.002462
325	0.0005	0.002401
330	0.000487	0.002342
335	0.000474	0.002285
340	0.000462	0.00223
345	0.00045	0.002177
350	0.000439	0.002126
355	0.000428	0.002077
360	0.000418	0.00203
365	0.000408	0.001984
370	0.000398	0.00194
375	0.000389	0.001897
380	0.00038	0.001855
385	0.000371	0.001815
390	0.000363	0.001776
395	0.000355	0.001739
400	0.000347	0.001702

Source: Wisconsin Department of Natural Resources



Source: Wisconsin Department of Natural Resources

Unpaved Road Shoulder
e.g., farm machinery traveling alongside a paved public road

Basic Assumptions: Unpaved roadway

- ***20 trips on shoulder/day by heavy farm equipment.*** *Avg. vehicle weight is 18 tons. Length of roadway = 1,600 meters (~1 mile)*

PM10 modeled emission rate = 6.22E-8 g/s-m2 (low) or 1.73E-7 g/s-m2 (high).

The results from the center line of the traffic on the unpaved shoulder (on the highest half of the graph of monitoring results) are given in the table below. Also attached is a graph of the results.

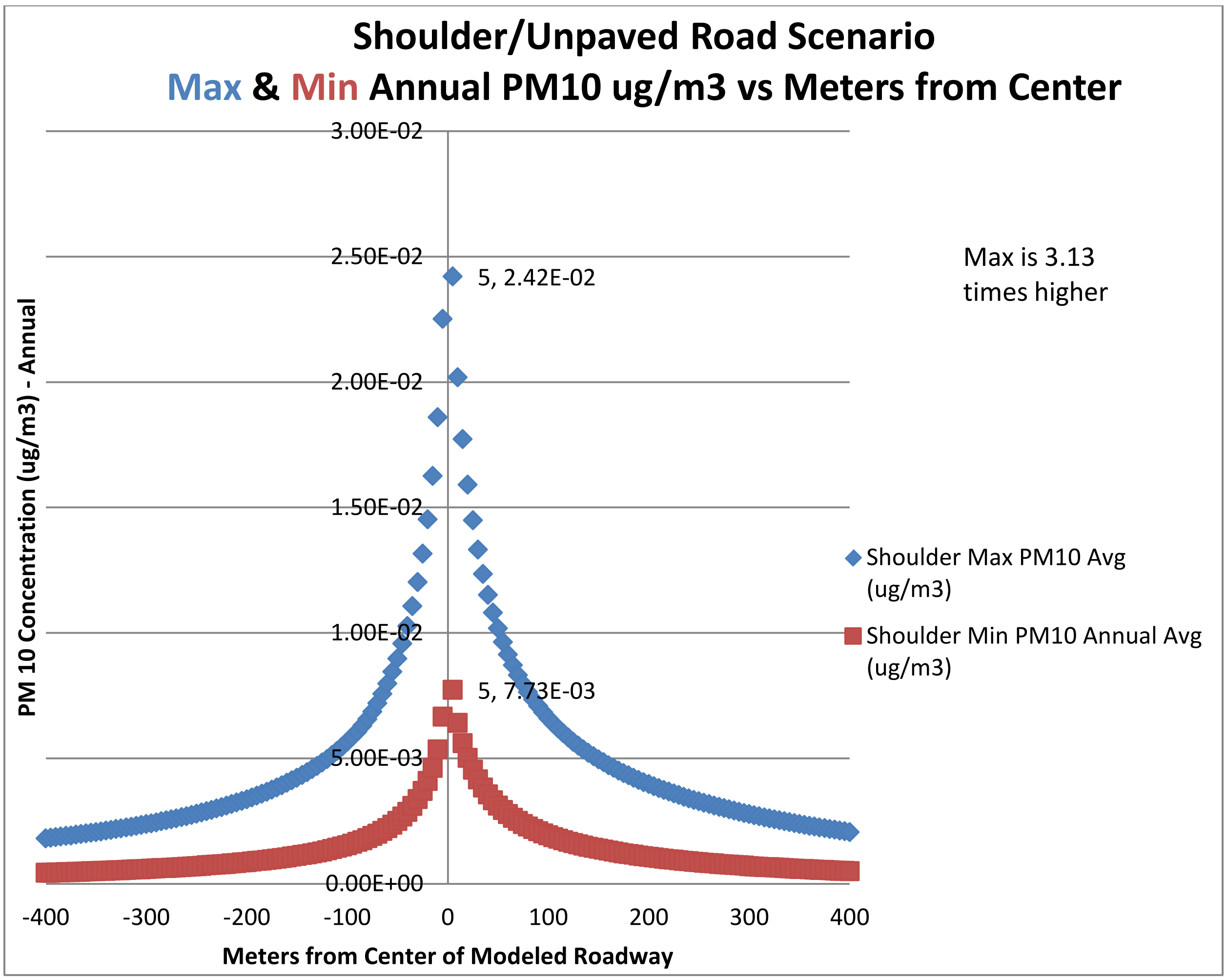
Unpaved Shoulder: Annual PM10 Concentrations in micrograms per cubic meter as a function of distance (meters)

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 -MAX
5	0.007728	0.024209
10	0.006411	0.020185
15	0.005608	0.017722
20	0.005015	0.015914
25	0.004544	0.014488
30	0.004158	0.013321
35	0.003834	0.012345
40	0.003559	0.011515
45	0.003321	0.0108
50	0.003115	0.010177
55	0.002933	0.009629
60	0.002772	0.009143
65	0.002629	0.00871
70	0.002499	0.008319
75	0.002382	0.007966
80	0.002276	0.007645
85	0.002179	0.007351
90	0.002089	0.007081
95	0.002007	0.006831
100	0.001931	0.0066
105	0.00186	0.006386
110	0.001794	0.006185
115	0.001732	0.005998
120	0.001675	0.005822
125	0.00162	0.005657
130	0.001569	0.005501
135	0.001521	0.005354
140	0.001475	0.005215
145	0.001432	0.005083
150	0.001391	0.004957
155	0.001352	0.004838
160	0.001315	0.004723
165	0.00128	0.004615
170	0.001246	0.00451
175	0.001214	0.004411
180	0.001183	0.004315
185	0.001154	0.004223
190	0.001125	0.004135
195	0.001098	0.00405
200	0.001072	0.003968
205	0.001047	0.003889
210	0.001023	0.003812
215	0.000999	0.003739
220	0.000977	0.003667
225	0.000955	0.003598
230	0.000934	0.003531
235	0.000914	0.003467
240	0.000894	0.003404
245	0.000876	0.003343
250	0.000857	0.003284
255	0.00084	0.003226
260	0.000823	0.00317
265	0.000806	0.003116
270	0.00079	0.003063
275	0.000775	0.003012
280	0.00076	0.002961
285	0.000745	0.002913
290	0.000731	0.002865
295	0.000717	0.002819
300	0.000704	0.002774
305	0.000691	0.00273
310	0.000679	0.002687
315	0.000666	0.002645
320	0.000655	0.002604
325	0.000643	0.002564
330	0.000632	0.002525

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
335	0.000621	0.002487
340	0.00061	0.00245
345	0.0006	0.002414
350	0.00059	0.002378
355	0.00058	0.002343
360	0.00057	0.002309

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
365	0.000561	0.002276
370	0.000552	0.002243
375	0.000543	0.002211
380	0.000534	0.00218
385	0.000526	0.002149
390	0.000518	0.002119

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
395	0.00051	0.00209
400	0.000502	0.002061



Source: Wisconsin Department of Natural Resources

Industrial Parking Lot

Two basic sub-scenarios for a 100m X 100m parking lot - 10,000 m2 parking lot (~2.47 acres)

Lot # 1= 700 trips/day (350 employees 2 trips/day). *Avg. vehicle weight = 1 ton. This would represent a factory or other business without a lot of heavy vehicles.*

PM10 modeled emission rate = 1.04E-8 g/s-m2 (low) or 2.91E-8 g/s-m2 (high).

The results from the center of the parking lot (on the highest half of the graph of monitoring results) are given in the table below. Also attached is a graph of the results.

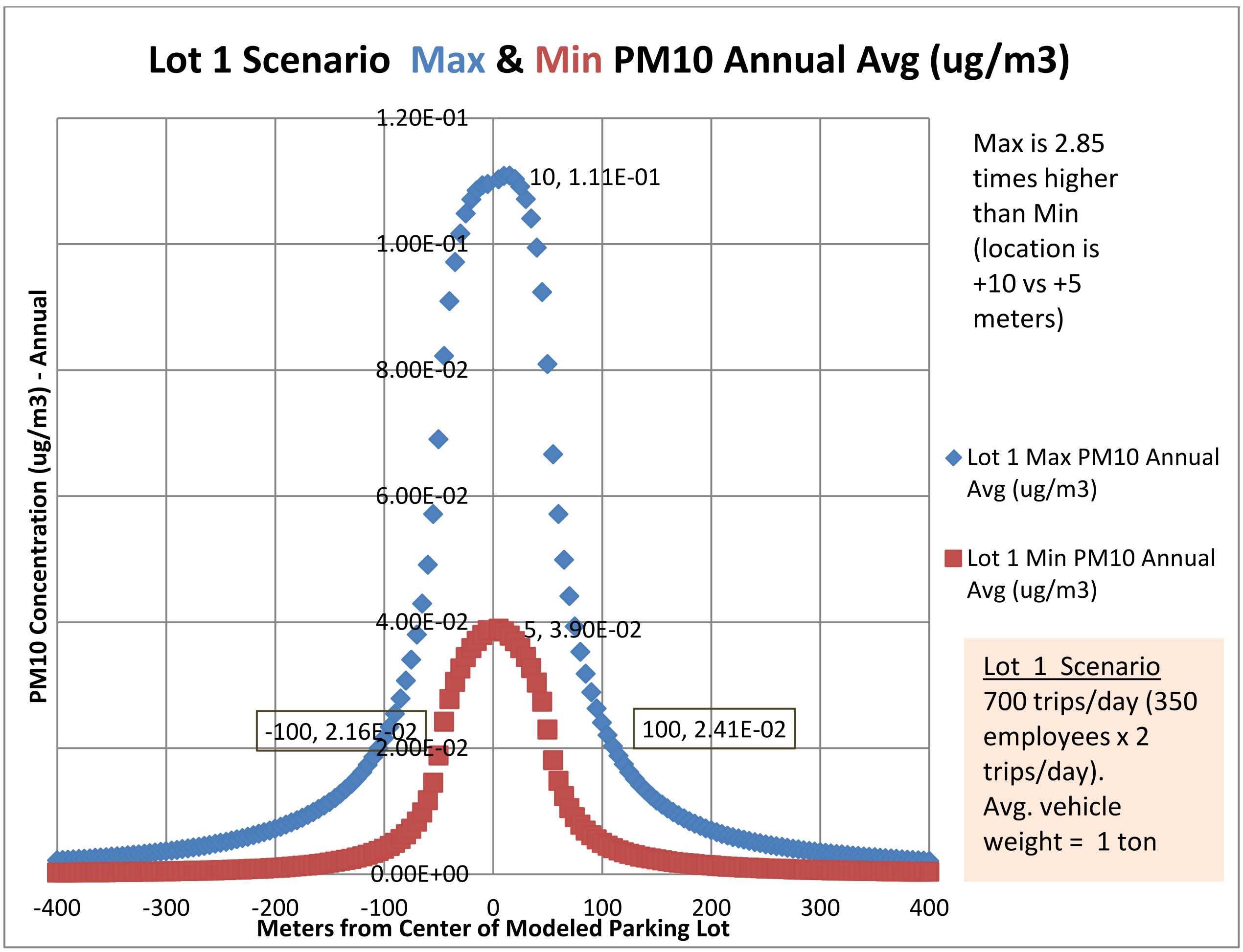
Parking Lot 1: Annual PM10 Concentrations in micrograms per cubic meter as a function of distance (meters)

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 -MAX	Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 -MAX	Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 -MAX
5	0.038995	0.110261	110	0.004147	0.020361	215	0.00123	0.006126
10	0.038526	0.110816	115	0.00381	0.018826	220	0.00118	0.005899
15	0.037867	0.110858	120	0.003517	0.01746	225	0.001134	0.005684
20	0.036998	0.110333	125	0.00326	0.016239	230	0.00109	0.005481
25	0.035888	0.109148	130	0.003033	0.015144	235	0.001049	0.005289
30	0.034485	0.107144	135	0.002831	0.014158	240	0.00101	0.005107
35	0.032712	0.104055	140	0.002651	0.013267	245	0.000973	0.004934
40	0.030441	0.099433	145	0.002488	0.012458	250	0.000938	0.00477
45	0.027426	0.092416	150	0.002341	0.011722	255	0.000906	0.004615
50	0.022994	0.080956	155	0.002208	0.011051	260	0.000875	0.004466
55	0.018135	0.066638	160	0.002086	0.010437	265	0.000845	0.004326
60	0.014839	0.057153	165	0.001974	0.009874	270	0.000818	0.004191
65	0.012397	0.049924	170	0.001872	0.009356	275	0.000791	0.004063
70	0.010524	0.044124	175	0.001777	0.008879	280	0.000766	0.003941
75	0.009057	0.039326	180	0.00169	0.008439	285	0.000742	0.003825
80	0.007889	0.035283	185	0.00161	0.008031	290	0.00072	0.003713
85	0.006945	0.031836	190	0.001535	0.007654	295	0.000698	0.003607
90	0.006171	0.02887	195	0.001465	0.007303	300	0.000677	0.003505
95	0.00553	0.0263	200	0.0014	0.006977	305	0.000658	0.003407
100	0.004993	0.024059	205	0.001339	0.006673	310	0.000639	0.003314
105	0.004537	0.022094	210	0.001283	0.006389	315	0.000621	0.003224

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
320	0.000604	0.003138
325	0.000588	0.003055
330	0.000572	0.002976
335	0.000557	0.0029
340	0.000543	0.002827
345	0.000529	0.002756

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
350	0.000515	0.002689
355	0.000503	0.002623
360	0.00049	0.002561
365	0.000479	0.0025
370	0.000467	0.002442
375	0.000456	0.002385

Distance from Center (Meters)	PM10 Ann Con ug/m3 -MIN	PM10 Ann Con ug/m3 - MAX
380	0.000446	0.002331
385	0.000436	0.002278
390	0.000426	0.002228
395	0.000416	0.002179
400	0.000407	0.002132



Source: Wisconsin Department of Natural Resources

Lot #2= 400 trips/day (200 employees 2 trips/day). *Avg. vehicle weight = 2 tons. This would represent a large industry, grain cooperative or large construction company where larger vehicles would increase the average weight of vehicle trips.*

PM10 modeled emission rate = 7.87E-9 g/s-m2 (low) or 2.19E-8 g/s-m2 (high).

The results from the center of the parking lot (on the highest half of the graph of monitoring results) are given in the table below. Also attached is a graph of the results.

Parking Lot 2: Annual PM10 Concentrations in micrograms per cubic meter as a function of distance (meters)

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX	Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX	Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
5	0.029402	0.082894	125	0.002458	0.012209	245	0.000734	0.003709
10	0.029048	0.083311	130	0.002287	0.011385	250	0.000708	0.003586
15	0.028551	0.083343	135	0.002135	0.010644	255	0.000683	0.003469
20	0.027897	0.082948	140	0.001999	0.009974	260	0.00066	0.003358
25	0.027059	0.082058	145	0.001876	0.009366	265	0.000637	0.003252
30	0.026002	0.080551	150	0.001765	0.008813	270	0.000616	0.003151
35	0.024665	0.078228	155	0.001665	0.008308	275	0.000597	0.003055
40	0.022952	0.074754	160	0.001573	0.007847	280	0.000578	0.002963
45	0.020679	0.069478	165	0.001489	0.007423	285	0.00056	0.002875
50	0.017338	0.060863	170	0.001411	0.007034	290	0.000543	0.002792
55	0.013673	0.050098	175	0.00134	0.006675	295	0.000526	0.002711
60	0.011188	0.042968	180	0.001274	0.006344	300	0.000511	0.002635
65	0.009347	0.037533	185	0.001214	0.006038	305	0.000496	0.002561
70	0.007935	0.033172	190	0.001157	0.005754	310	0.000482	0.002491
75	0.006829	0.029565	195	0.001105	0.00549	315	0.000468	0.002424
80	0.005949	0.026526	200	0.001056	0.005245	320	0.000455	0.002359
85	0.005236	0.023934	205	0.00101	0.005017	325	0.000443	0.002297
90	0.004653	0.021704	210	0.000967	0.004803	330	0.000431	0.002237
95	0.00417	0.019772	215	0.000927	0.004606	335	0.00042	0.00218
100	0.003764	0.018088	220	0.00089	0.004435	340	0.000409	0.002125
105	0.003421	0.01661	225	0.000855	0.004273	345	0.000399	0.002072
110	0.003127	0.015307	230	0.000822	0.00412	350	0.000389	0.002021
115	0.002873	0.014153	235	0.000791	0.003976	355	0.000379	0.001972
120	0.002652	0.013126	240	0.000761	0.003839	360	0.00037	0.001925

Source: Wisconsin Department of Natural Resources

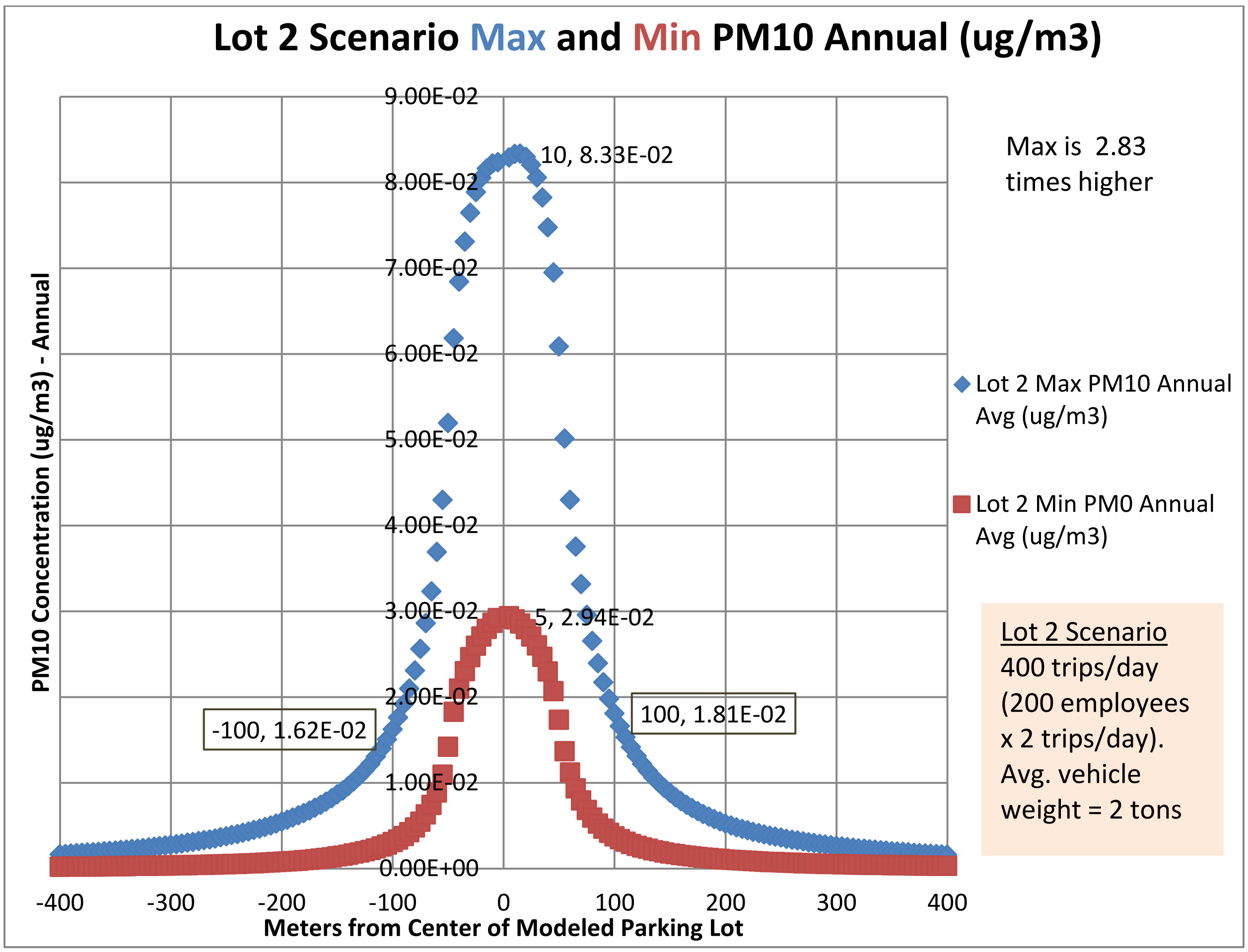
Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
365	0.000361	0.00188
370	0.000352	0.001836
375	0.000344	0.001793
380	0.000336	0.001752

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
385	0.000329	0.001713
390	0.000321	0.001675
395	0.000314	0.001638
400	0.000307	0.001602

Distance from Center (Meters)	PM10 Ann Con ug/m3 - MIN	PM10 Ann Con ug/m3 - MAX
5	0.008826	0.028055
10	0.006919	0.022249
15	0.005717	0.01869
20	0.004865	0.016123
25	0.004221	0.014148
30	0.003715	0.012573
35	0.00329	0.011283
40	0.002938	0.010206
45	0.002643	0.009291
50	0.002391	0.008503
55	0.002176	0.007818
60	0.001989	0.007215
65	0.001825	0.006682
70	0.001681	0.006206
75	0.001553	0.005781
80	0.001439	0.005398
85	0.001337	0.005052
90	0.001245	0.00474
95	0.001161	0.004457
100	0.001086	0.004199
105	0.001017	0.003964
110	0.000954	0.003749
115	0.000896	0.003552
120	0.000843	0.003371
125	0.000794	0.003203
130	0.00075	0.003048

135	0.000709	0.002904
140	0.000671	0.00277
145	0.000636	0.002645
150	0.000604	0.002527
155	0.000574	0.002417
160	0.000546	0.002314
165	0.00052	0.002217
170	0.000496	0.002126
175	0.000474	0.002039
180	0.000453	0.001958
185	0.000433	0.001881
190	0.000414	0.001808
195	0.000397	0.00174
200	0.00038	0.001675
205	0.000365	0.001613
210	0.00035	0.001555
215	0.000336	0.0015
220	0.000323	0.001449
225	0.000311	0.001402
230	0.000299	0.001357
235	0.000288	0.001313
240	0.000278	0.001272
245	0.000268	0.001233
250	0.000259	0.001195
255	0.00025	0.001159
260	0.000242	0.001125
265	0.000234	0.001092
270	0.000227	0.001061
275	0.00022	0.001031
280	0.000213	0.001002
285	0.000207	0.000974
290	0.000201	0.000948
295	0.000195	0.000922
300	0.000189	0.000898
305	0.000184	0.000875
310	0.000179	0.000852
315	0.000174	0.000831
320	0.000169	0.00081
325	0.000165	0.00079
330	0.000161	0.000771
335	0.000156	0.000752
340	0.000153	0.000734

345	0.000149	0.000717
350	0.000145	0.0007
355	0.000142	0.000684
360	0.000138	0.000669
365	0.000135	0.000654
370	0.000132	0.000639
375	0.000129	0.000625
380	0.000126	0.000612
385	0.000123	0.000599
390	0.00012	0.000586
395	0.000117	0.000574
400	0.000115	0.000562



Source: Wisconsin Department of Natural Resources

Appendix A: Additional Modeling Information, Emissions Equation and Assumptions

Silt Content: We will use two assumptions for percent of silt as a range of possible values for analysis (12% and 3.9%):

a) The charter steel slag particle size determination = 12.0% on average[1]

b) The National Slag Assumption of silt = 3.9% for Electric Arc Furnace Slag[2]

Basis of Assumption: [1]The 12% value is from an August 15, 2005 letter from Charter Steel to Frank Schultz (WDNR) and also from the definition of silt from the American Association of State Highway and Transportation Officials. Silt is all material passing through a #200 sieve (particles <75 micrometers (microns), or 0.075 millimeters.

[2]For the 3.9% silt content estimate, see HHRA Steel-Making Slag Document from the American Slag Association (December 2011), p. 40. However, note that on page 41 the Tube City IMS Ellwood steel slag processing site 's slag from EAF was estimated to be 8.03%. This shows that the data can vary from site to site, and 3.9% silt is toward the low end of the potential range of silt percentages in steel-making slag.

Percent Moisture in Foundry Slag: We will use two assumptions for percent of moisture as a range of possible values for analysis (4.3% and 6.5%):

Basis of Assumption: The HHRA Steel-Making Slag (December 2011) assumed a value of 6.5% moisture, which is approximately half of the range of moisture found in EPA AP-42, section 13.2.2 Unpaved Roads: Range of moistures 0.3 – 13.0% (Table 13.2.2-3). However, since by design, roads (including unpaved roads) are designed to minimize standing water using proper material selection and design, it is more likely that the roadway surfaces that will contact vehicle will dry out quickly, a value of 4.3% moisture is also considered as part of the range of likely moistures for this analysis (based on professional judgment). Per AP-42 section 13.2.2, 120 days per year (~33%) are assumed to have precipitation; 4.3% is 33% of the maximum value of 13% moisture.

Vehicle Weights, Trips, and Speeds

Each scenario uses a different assumption for vehicle weights and trips. In the latest versions of the equations from EPA in AP-42 and the 2011 Slag study (from the 2002 USEPA Soil Study), speeds were not used in emissions calculations as they had been previously.

Weights

Basis of Assumption: Professional judgment and consideration of National Slag Association Human Health Risk Assessment.

- Farm road with residential driveway: weights are a weighted mix of cars, trucks, and highway equipment (family and employee vehicles – 1 ton; farm equipment – 18 tons)
- Unpaved road shoulder (farm tractors, trailers, wagons, and other farm equipment, up to and including heavy farm vehicles such as combines [farm equipment – 18 tons])
    - Unpaved parking lot (employee vehicles – 1 ton or 2 tons)

Vehicle trips

Basis of Assumption: Professional judgment and consideration of National Slag Association Human Health Risk Assessment.

- Farm road with residential driveway:
  Scenario 1: 26 total trips per day = 16 family (2 veh x 8 trips) and 10 farm (5 veh x 2 trips)
  Scenario 2: 88 total trips per day = 16 family (2 veh x 8 trips) and 24 farm (6 veh x 4 trips) and 48 employee (12 veh x 4 trips)
- Unpaved road shoulder: 20 trips per day (5 veh x 2 trips x 2 farms)
- Unpaved parking lot day:
  Scenario 1: 700 trips @ 1 ton (350 veh * 2 trips)
  Scenario 2: 400 trips @ 2 ton (200 veh * 2 trips)

Technical Air Modeling Details:

- Road segments and parking lots were modeled as area sources with plume depletion flag used, but without the FASTAREA option in AERMOD.
- EPA's Regulatory Air Dispersion Model - AERMOD version 14134 .
- Meteorological Data: 5 consecutive years of hourly meteorological data (43824 hourly values) from Sheboygan (SBM), using Green Bay upper air. Minute reported wind information used to generate the average hour wind speed and direction.
- Rainfall days was estimated from the map in AP-42 section 13.2.2 Unpaved Roads, titled: "Figure 13.2.2-1. Mean number of days with 0.01 inch or more of precipitation in United States" that showed 120 days per year, on average, with precipitation.
- Modeling results are summarized in a spreadsheet - see file named: Charter Steel Slag PM10 Air Modeling_1-28-15.xlsx.