Public Health Assessment

Final Release

Evaluation of inhalation of airborne stampsands in the Torch Lake Superfund site and surrounding area Houghton and Keweenaw Counties, Michigan

EPA FACILITY ID: MID980901946

Prepared by
Michigan Department of Community Health

SEPTEMBER 30, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 60-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Foreword

The Michigan Department of Community Health (MDCH) conducted this evaluation for the federal Agency for Toxic Substances and Disease Registry (ATSDR) under a cooperative agreement. ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination. The purpose of this document is to identify potentially harmful exposures and recommend actions that would minimize those exposures. This is not a regulatory document and does not evaluate or confirm compliance with laws. This is a publicly available document and is provided to the appropriate regulatory agencies for their consideration.

The following steps are necessary to conduct public health assessments/consultations:

- Evaluating exposure: MDCH toxicologists begin by reviewing available information about environmental conditions at the site: how much contamination is present, where it is found on the site, and how people might be exposed to it. This process requires the measurement of chemicals in air, water, soil, or animals. Usually, MDCH does not collect its own environmental sampling data. We rely on information provided by the Michigan Department of Environmental Quality (MDEQ), U.S. Environmental Protection Agency (EPA), and other government agencies, businesses, and the general public.

- Evaluating health effects: If there is evidence that people are being exposed – or could be exposed – to hazardous substances, MDCH toxicologists then determine whether that exposure could be harmful to human health, using existing scientific information. The report focuses on public health – the health impact on the community as a whole.

- Developing recommendations: In its report, MDCH outlines conclusions regarding any potential health threat posed by a site, and offers recommendations for reducing or eliminating human exposure to chemicals. If there is an immediate health threat, MDCH will issue a public health advisory warning people of the danger, and will work with the appropriate agencies to resolve the problem.

- Soliciting community input: The evaluation process is interactive. MDCH solicits and considers information from various government agencies, parties responsible for the site, and the community. If you have any questions or comments about this report, we encourage you to contact us.

Please write to: Toxicology and Response Section
Division of Environmental Health
Michigan Department of Community Health
PO Box 30195
Lansing, MI 48909
Or call us at: 1-800-648-6942 (toll free)
For more information, please visit:
www.michigan.gov/mdch-toxics

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Acronyms and Abbreviations

µg	microgram
a	numerical constant
A	area size
AEGL	Acute Exposure Guideline Level
AIR	adjusted inhalation rate
AP-42	Compilation of Air Pollutant Emission Factors
AQD	Air Quality Division
As	aggregate size *or* arsenic
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
b	numerical constant
c	numerical constant
C	emission factor for 1980's vehicle fleet exhaust, brake wear, and tire wear
ca	carcinogenic chemical
CF	conversion factor *or* correction factor
cm	centimeter
COPD	chronic obstructive pulmonary disease
CREG	Cancer Risk Evaluation Guide
CV	Comparison Value
d	numerical constant
E	annual emissions
E_{10}	emission factor for vehicles traveling on paved or unpaved roads, for PM10
ED	exposure duration
EF	exposure frequency
EMEG	Environmental Media Evaluation Guide
EPA	U.S. Environmental Protection Agency
Ev	emission due to vehicle traffic
Ew	emission due to wind
ft	foot
F(x)	mathematical function of variable derived from Cowherd et al. (1985)
g	gram
HQ	Hazard Quotient
ITSL	Initial Threshold Screening Level
IURF	Inhalation Unit Risk Factor
k	particle size multiplier
kg	kilogram
L	length of driveway or route, *or* liter
lb	pound
m	meter
M	surface material moisture content
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNRE	Michigan Department of Natural Resources and Environment
MDOT	Michigan Department of Transportation

mg	milligram
mm	millimeter
Mn	manganese
mph	miles per hour
MRI	magnetic resonance imaging
MRL	Minimal Risk Level
MSUE	Michigan State University Extension
N	number of days in averaging period
NA	not available
NAAQS	National Ambient Air Quality Standard
nc	non-carcinogenic chemical
NC	not calculated
ND	not detected
ng	nanogram
NIOSH	National Institute for Occupational Safety and Health
OU	Operable Unit
P	number of days with at least 0.01 inch precipitation during a specified averaging period
PEF	Particulate Emission Factor
PHA	Public Health Assessment
PM2.5	particulate matter less than 2.5 microns in aerodynamic diameter
PM10	particulate matter less than 10 microns in aerodynamic diameter
ppb	parts per billion
PSIC	Particulate Soil Inhalation Criteria
Q/C	air dispersion factor
REL	Recommended Exposure Limit
RfC	Reference Concentration
RRD	Remediation and Redevelopment Division
s	surface material silt content
S	mean vehicle speed
sec	second
sL	road surface silt loading
sqm	square meters
Sr	strontium
T	time duration
THQ	target hazard quotient
TR	target cancer risk
TSG	Toxics Steering Group
TSP	Total Suspended Particulates
TWA	time-weighted average
UCL	Upper Confidence Limit of the mean
UF	uncertainty factor
Um	mean annual wind speed, adjusted to a height of 7 meters
$Um_{(z)}$	mean annual wind speed at height z
U*t	equivalent threshold friction velocity for a specified surface soil mode aggregate size

Ut_{adj}	threshold friction velocity
V	vegetative cover *or* number of trips or vehicles per day
Vkm	vehicle-kilometer travel
VM	vehicle-mile travel
W	mean vehicle weight
WUPHD	Western Upper Peninsula Health Department
x	variable derived from Cowherd et al. (1985)
yr	year
z	wind speed measurement height
z_0	roughness height

Torch Lake Superfund Site Public Health Assessment Documents: An Introduction

The federal Agency for Toxic Substances and Disease Registry (ATSDR) is mandated to provide public health activities (assessments, advisories, education) at National Priorities List (NPL, or "Superfund") sites. The Michigan Department of Community Health (MDCH) conducts these activities for ATSDR in Michigan, under a cooperative agreement.

Due to its size and complexity, the Torch Lake Superfund site in Michigan's Upper Peninsula was divided into three Operable Units (OUs), as stated in the United States Environmental Protection Agency (EPA)'s 1992 Record of Decision[1]:

OU1 includes surface tailings, drums, and slag pile/beach on the western shore of Torch Lake. These tailing piles include stampsands in Lake Linden, Hubbell/Tamarack City, and Mason, while a slag pile/beach is located in Hubbell.

OU2 includes groundwater, surface water, submerged tailings and sediments in Torch Lake, Portage Lake, the Portage Channel, and other water bodies at the site.

OU3 includes tailings and slag deposits located in the north entry of Lake Superior, Michigan Smelter, Quincy Smelter, Calumet Lake, Isle-Royale, Boston Pond, and Grosse-Point.

MDCH previously produced several documents for the Torch Lake Superfund site: a Preliminary Health Assessment in 1989; a Site Review and Update in 1995; and a Health Consultation in 1998, per a request by the Michigan Department of Environmental Quality (MDEQ), which was conducting a Brownfields assessment at various locations within the site.

In 2007, MDEQ requested that MDCH provide further public health input on exposure issues for which there was new environmental and toxicological information. MDCH visited the site in June 2008 to gain a better understanding of MDEQ's concerns. The Western Upper Peninsula Health Department (WUPHD) accompanied MDCH, MDEQ, and EPA on this site visit. Issues discussed included:

- ►physical hazards
- ►inhalation of resuspended stampsands
- ►the potential for drinking water to be contaminated
- ►recreational exposure at beaches
- ►exposure via local sport-caught fish consumption.

Following the site visit, WUPHD requested that MDCH determine the public health implications of these various exposure pathways.

MDCH will address the issues listed above in separate Public Health Assessment (PHA) documents. Each document will be released for public review and comment, following which MDCH will respond in a final document. Comments should be addressed to the first MDCH author of the report (see "Preparers of Report" page) and sent to the address in the Foreword section.

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[1] United States Environmental Protection Agency (EPA). Superfund Record of Decision: Torch Lake, MI. Washington, D.C.: Office of Emergency and Remedial Response, United States Environmental Protection Agency; 1992 Sept. Report No.: EPA/ROD/R05-92/215.

Summary

The Michigan Department of Environmental Quality (MDEQ) and the Western Upper Peninsula Health Department (WUPHD) requested an updated public health assessment of the Torch Lake Superfund site and vicinity in Houghton and Keweenaw Counties in Michigan. The Torch Lake Superfund site is complex, with three Operable Units (OUs) covering hundreds of acres within Houghton County in the Keweenaw Peninsula of Michigan's Upper Peninsula, dealing primarily with contamination left behind by copper mining, processing, and reclamation activities. This document addresses inhalation exposure to stampsands from excavation work, recreation, or when road-applied stampsands are resuspended in air.

The evaluation of inhalation exposure to stampsands involved many factors: MDCH estimated concentrations of airborne metals in stampsands at Gay and Calumet, Michigan using default values from various guidance documents, site-specific data, and assumptions made for this evaluation. The confidence in the values used for these calculations varies and is discussed in further detail in this document. Conclusions regarding stampsand inhalation at specific locations are below.

1. *MDCH has determined that the estimated concentrations of metals in airborne stampsands at the Gay tailings pile along Lake Superior are not expected to cause harm to heavy equipment operators or recreational vehicle users at the site.* MDCH has medium to high confidence in the values used for the Gay evaluation. Most of the estimated concentrations are orders of magnitude less than health-based screening levels.

   Next Steps:
   - No additional steps are needed by MDCH to address this conclusion.

2. *MDCH cannot determine whether airborne Point Mills stampsands used for road traction in the Calumet area would cause harm to persons living, working, or visiting in Calumet.* (Note that there are other areas, not just Calumet, that receive stampsands for road traction. Also, stampsands are often used for gravel road construction and maintenance. The evaluation for Calumet does not stand as a surrogate for the other areas or for other uses of stampsands.) MDCH has low to medium confidence in the values used for the Calumet evaluation. Additional site-specific data are needed to better characterize potential exposures.

   Next Steps:
   - MDCH has provided its recommendations to MDEQ and the U.S. Environmental Protection Agency (EPA).
   - If and when additional site-specific data for Calumet are collected, MDCH will recalculate and re-evaluate expected exposures or will provide public health input if the regulatory agencies conduct a risk assessment on inhalation of the stampsands.

MDCH does not have the resources to evaluate each stampsand pile individually. We understand that there are many stampsand piles in the Torch Lake area, within and outside of the Superfund

site's Operable Units (OUs). Each stampsand pile is unique in chemical and physical attributes. We suggest that the exercises and evaluations discussed in this document inform and guide any future stampsand-inhalation risk assessments for the Torch Lake Superfund site and surrounding area.

Purpose and Health Issues

Previously, the Michigan Department of Community Health (MDCH) produced several documents discussing public health issues at the Torch Lake Superfund site (ATSDR 1989, 1995, 1998b). In 2007, the Michigan Department of Environmental Quality (MDEQ)[2] requested that MDCH provide public health input regarding potential exposures at the Torch Lake Superfund site and surrounding area based on new or updated information. This document addresses inhalation exposures to airborne stampsands during excavation work, recreation, or when road-applied stampsands are resuspended in air. This document does not include an ecological assessment, such as discussion of impacts to wildlife or benthic communities.

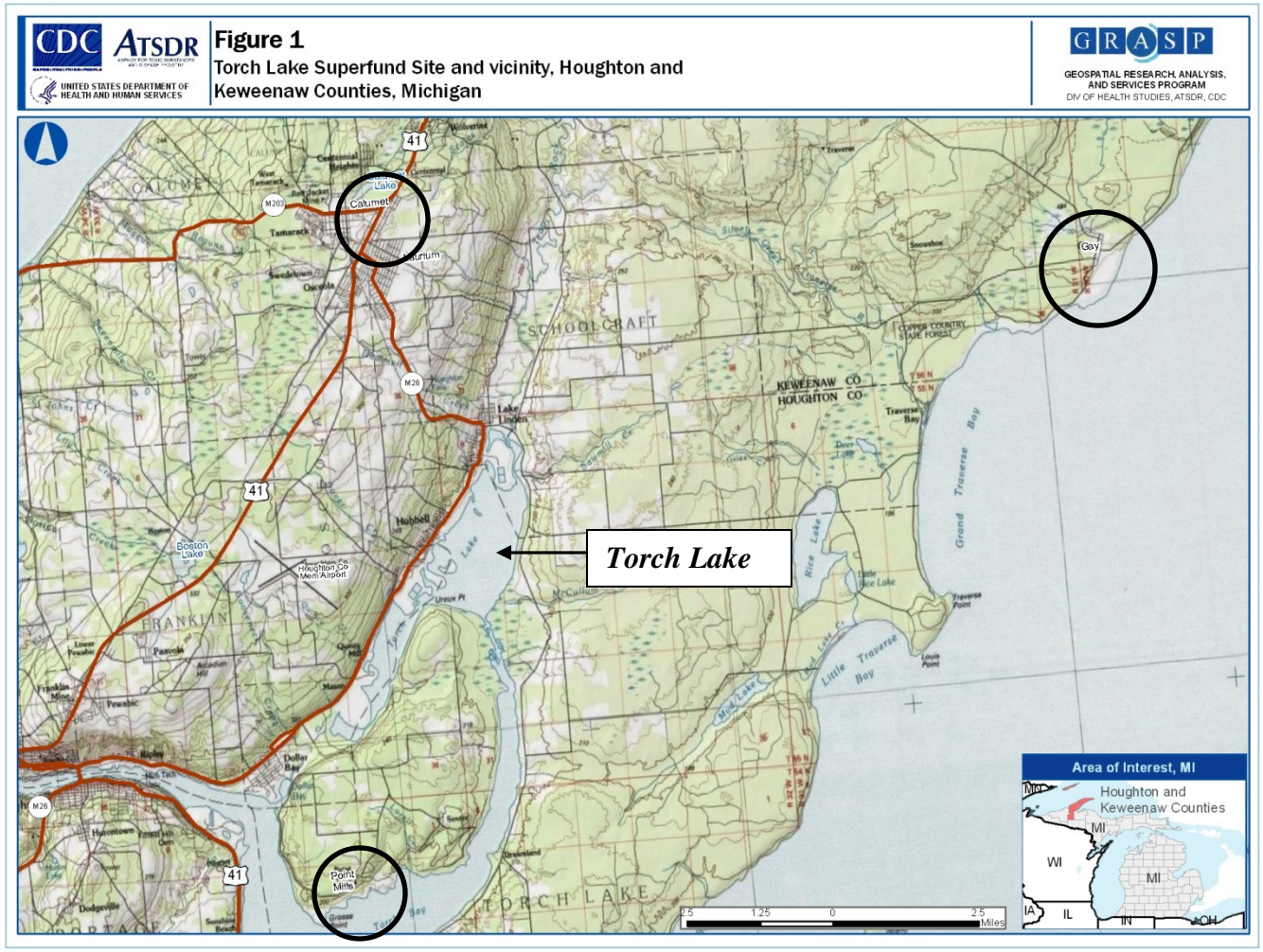
MDCH conducted this public health assessment under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination and concern. ATSDR is primarily an advisory agency. Therefore, its reports usually identify what actions are appropriate to be undertaken by the regulatory agency overseeing the site, responsible parties, other health agencies, and communities to reduce exposures and the possibility of adverse health effects. As such, ATSDR recommendations may not encompass all types of federal and state requirements from a regulatory perspective. The purpose of a public health assessment is not to evaluate or confirm regulatory compliance but to determine if any potentially harmful exposures have occurred, are occurring, or may occur in the future and to identify actions needed to mitigate these exposures.

Background

The Torch Lake Superfund site is located in Houghton County in the Keweenaw Peninsula of Michigan's Upper Peninsula (Figure 1). It was added to the National Priorities List (NPL), also known as Superfund, in 1984 due to the presence of copper mining, processing, and reclamation waste and tumors of unknown origin in fish from Torch Lake. Copper mining occurred in this area from the 1860s until the late 1960s. Waste from the copper mining includes stampsands (a type of mine tailing), slag piles, and remains of industrial facilities. Stampsands are the crushed rock or ore left over after removal of the copper. Initially, stampsands were disposed of in Torch Lake and on land. Chemical processes allowed mining companies to extract additional copper

[2] In 2010, the Michigan Department of Environmental Quality (MDEQ) merged with the Michigan Department of Natural Resources (MDNR) and became the Michigan Department of Natural Resources and Environment (MDNRE). In 2011, the MDNRE was separated back into the MDEQ and MDNR. In this document, "MDEQ" is used within the text, regardless of timeline. However, citations refer to the agency name at the time the reference was created.

Figure 1. Torch Lake Superfund site and vicinity, including Gay, Point Mills, and Calumet (Houghton and Keweenaw Counties), Michigan.



from the tailings, which were dredged from the lake and selected stampsand piles, and reprocessed. Waste was again dumped into Torch Lake or on land (Weston 2007).

In June 2008, MDCH toxicologists conducted a site visit of the Torch Lake Superfund site and surrounding area with staff from MDEQ, the U.S. Environmental Protection Agency (EPA), and the Western Upper Peninsula District Health Department (WUPHD). The visit included stops at the vast stampsand pile along Lake Superior at Gay in Keweenaw County (Figure 2), which is not part of the Superfund site; the Point Mills stampsand pile at the Houghton County Road Commission property (Figure 3); and the town of Calumet in Houghton County (Figure 1). MDEQ reported that county road commissions have used the stampsands as road-traction material in winter for some years (A. Keranen, MDEQ Remediation and Redevelopment Division [RRD], personal communication, 2008). MDOT has reported that they have not and do not use the stampsands for this purpose (A. Sikkema, MDOT, personal communication, 2009). The county road commissions use the stampsands with other material to construct and improve gravel roads (K. Harju, Houghton County Road Commission, personal communication, 2011; G. Patrick, Keweenaw County Road Commission, personal communication, 2011). MDEQ expressed concern that stampsands resuspended in the air might pose an inhalation hazard and asked MDCH to evaluate this exposure pathway. The MDEQ RRD district office had previously contracted with Weston Solutions of Michigan, Inc. to conduct toxicological evaluations of the Gay and Point Mills stampsands (Weston 2006a, b) but improvements in the understanding of this pathway warranted further study of the sites.

Based on discussions with MDEQ and WUPHD, MDCH decided that the following exposure scenarios should be evaluated:

- inhalation of resuspended stampsands at Gay when excavation is taking place (when stampsands are removed for road commission, construction, or other purposes);
- inhalation of resuspended stampsands at Gay when people are using the area recreationally (riding motorcycles, off-road vehicles, or four-wheel-drive trucks); and
- inhalation of resuspended Point Mills stampsands at Calumet, which is an area where the county road commission applies stampsands for road-traction purposes in the winter. (The evaluation for Calumet does not stand as a surrogate for other areas and other uses of stampsands.)

MDCH understands that there are many stampsand piles in the Torch Lake area, within and outside of the Superfund site's Operable Units (OUs). Each stampsand pile is unique in chemical and physical attributes. Metal concentrations differ between and within stampsand areas. MDCH does not have the resources to evaluate each pile individually. MDCH suggests to MDEQ and EPA that the exercises and evaluations discussed in this document inform and guide future stampsand-inhalation risk assessments for the Torch Lake Superfund site and surrounding area.

Discussion

Ideally, to evaluate the health risk of inhaling chemicals, air monitoring or air sampling data would be used to determine the level of exposure. Because extensive air sampling data are not available for many sites, dispersion models are often used to estimate exposures to airborne

Figure 2. Aerial view of stampsands in Gay (Keweenaw County), Michigan, with northern and southern sampling areas identified.

Figure 3. Aerial view of Point Mills stampsands at the Houghton County Road Commission pile, Point Mills (Houghton County), Michigan.

chemicals (ATSDR 2010). The MDEQ Part 201 Particulate Soil Inhalation Criteria (PSIC) are concentrations of hazardous substances in soil that are not expected to create ambient air concentrations of contaminated particulates that would, in turn, cause adverse human health effects via inhalation. PSIC are intended for assessment of soils, although the algorithms for the criteria may be used to derive a screening level for non-soils, such as stampsands. Rather than derive a screening level for the stampsands, however, MDCH used the PSIC algorithms to estimate an air concentration based on stampsand concentration data.

The stampsands in this evaluation are at Gay, with the assumption of on-site exposure, and Point Mills, assuming exposure at Calumet where the Point Mills stampsands are used as road traction material. The values used for calculating expected concentrations of airborne metals in the stampsands were either default values from various guidance documents, derived from site-specific data, or estimated based on assumptions made for the evaluation. The calculations should *not* be considered definitive. Some of the estimated values, particularly those for Point Mills/Calumet, should be refined (e.g., the collection of additional site-specific data) to more accurately predict the expected air concentrations.

Detailed discussions of the air-concentration calculations are in Appendices A, B, and C. The contaminant concentration estimates for the Gay and Point Mills/Calumet sites, and their public health implications, are discussed briefly below.

Environmental Contamination and Estimated Air Concentrations

In 2003, the MDEQ RRD Geological Services Unit conducted sampling activities at the Gay and Point Mills stampsand piles. MDCH used the analytical results to estimate air concentrations based on assumed exposure scenarios (discussed further in the *Exposure Pathways Analysis* section). MDCH then compared the estimated air concentrations to health-based screening values: the EPA Reference Concentration (RfC), the National Ambient Air Quality Standard (NAAQS; only for lead in this document), the ATSDR chronic Environmental Media Evaluation Guide (EMEG) or Cancer Risk Evaluation Guide (CREG), or the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL).

- An RfC is an estimate (with uncertainty spanning perhaps an order of magnitude [a factor of 10]) of a continuous inhalation exposure that is not likely to cause harm in a person's lifetime (EPA 2010b).
- The Clean Air Act required EPA to set NAAQS for wide-spread pollutants considered harmful to public health and the environment. NAAQS have been established for six principal pollutants, known as "criteria" pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. Primary standards set limits to protect public health, including sensitive populations (asthmatics, children, elderly; EPA 2011b).
- A chronic EMEG (based on a Minimal Risk Value [MRL]) for air is similar in derivation to an RfC but, due to differing interpretations and risk assessment practices between EPA and ATSDR, may result in a different value. EMEGs are for non-cancer-causing chemicals. For carcinogenic chemicals in soil, water or air, ATSDR derives CREGs, which are concentrations of a chemical that result in a one-in-one-million cancer risk (ATSDR 2005).

▪An REL is a health-based, non-regulatory time-weighted average that an employee can be exposed to for up to a 10-hour workday during a 40-hour workweek (NIOSH 2006).

Tables 1 and 2 show the results of the calculations and the comparisons for the stampsands at Gay and from Point Mills, respectively.

Table 1. 95% Upper Confidence Limits of the mean concentrations (95UCLs) detected in stampsands, maximum[A] estimated air concentrations (as an exposure-specific time-weighted average), and screening values for selected metals in stampsand samples taken September 2003 from the northern end of the stampsand pile in Gay (Keweenaw County), Michigan. (Bolded metal exceeds its screening value.)

Metal	**95UCL (µg/kg)**	**Estimated Air Concentration (µg/m^3)**	**Screening Value (µg/m^3)**
Aluminum	15,872,000	0.3	10,000 [B]
Arsenic	2,700	0.00006	0.0002 [C]
Beryllium	480	0.00001	0.0004 [C]
Chromium	**29,000**	**0.0006**	**0.00008 [C,D]**
Cobalt	23,000	0.0005	0.1 [E]
Copper	2,972,000	0.06	1,000 [B]
Lead	2,600	0.00005	0.15[F]
Lithium	6,200	0.0001	NA
Manganese	549,000	0.01	0.05 [G]
Mercury	28	0.0000006	0.3 [G]
Nickel	31,000	0.0006	0.09 [E]
Silver	1,800	0.00004	10 [B]
Strontium	17,000	0.0003	NA
Zinc	75,000	0.002	5,000 [B]

Reference: Weston 2006a

Acronyms:

µg/kg	micrograms per kilogram	µg/m^3	micrograms per cubic meter
CREG	Cancer Risk Evaluation Guide	EMEG	Environmental Media Evaluation Guide
NA	not available	NAAQS	National Ambient Air Quality Standard
REL	Recommended Exposure Limit	RfC	Reference Concentration

Notes:

A. Air concentrations were estimated for occupational and recreational exposures (Appendices A and B). The higher estimate is presented in the table.
B. REL
C. CREG
D. Value is for hexavalent chromium.
E. Chronic air EMEG
F. NAAQS
G. RfC

Table 2. 95% Upper Confidence Limits of the mean concentrations (95UCLs) detected in stampsands, estimated air concentrations in Calumet, and screening values for selected metals in stampsand samples taken August and September 2003 from the Point Mills stampsand pile (Houghton County), Michigan. (Bolded metals exceed their screening value.)

Metal	**95UCL (µg/kg)**	**Estimated Air Concentration (µg/m^3)**	**Screening Value (µg/m^3)**
Aluminum	2,077,000	0.06	10,000 [A]
Arsenic	4,200	0.0001	0.0002 [B]
Beryllium	440	0.00001	0.0004 [B]
Chromium	**40,000**	**0.001**	**0.00008** [B,C]
Cobalt	23,000	0.0006	0.1 [D]
Copper	2,209,000	0.06	1,000 [A]
Lead	2,800	0.00008	0.15 [E]
Lithium	8,200	0.0002	NA
Manganese	503,000	0.01	0.05 [F]
Mercury	3.1	0.00000008	0.3 [F]
Nickel	42,000	0.001	0.09 [D]
Silver	1,300	0.00004	10 [A]
Strontium	24,000	0.0007	NA
Zinc	70,000	0.002	5,000 [A]

Reference: Weston 2006b

Acronyms:

µg/kg	micrograms per kilogram	µg/m^3	micrograms per cubic meter
CREG	Cancer Risk Evaluation Guide	EMEG	Environmental Media Evaluation Guide
NA	not available	NAAQS	National Ambient Air Quality Standard
REL	Recommended Exposure Limit	RfC	Reference Concentration

Notes:

A. REL
B. CREG
C. Value is for hexavalent chromium.
D. Chronic air EMEG
E. NAAQS
F. RfC

The RfC, chronic EMEG, and CREG address long-term daily exposures, whereas the lead NAAQS uses a rolling three-month average. The REL addresses a workplace exposure (up to a 10-hour workday in a 40-hour workweek).

The RELs in Tables 1 and 2 may not be adequately protective for non-occupational populations. The ratio between the estimated air concentration of a metal (specifically aluminum, copper, silver, and zinc), in this evaluation, and its REL ranges from four to seven orders of magnitude (a factor of 10,000 to 10,000,000). EPA and ATSDR apply uncertainty factors (UFs) to experimental data when deriving RfCs and MRLs (EPA 2002, ATSDR 2005). If UFs were applied to an REL in a similar manner, the total UF would be 10,000, which is the smallest magnitude of difference between the estimated air concentration and its REL. This suggests that an adequate margin of safety exists between the estimated and acceptable (specifically, the REL

screening value) exposures at Gay and Calumet. More detail on this argument is presented in Appendices A, B, and C.

In both tables, the estimated air concentrations of chromium exceed the CREG for the hexavalent (VI) form of the metal. In most environmental situations, however, the less toxic, trivalent form (chromium III) predominates (Kimbrough et al. 1999, ATSDR 2000a). Therefore, one would not expect the hexavalent form to occur in the stampsands. There is no RfC, EMEG, or CREG for chromium III. The REL for chromium metal and chromium III compounds is 500 $\mu g/m^3$ (NIOSH 2006), which is five to six orders of magnitude greater than the estimated air concentrations in the tables. Chromium in airborne stampsands is not expected to cause harm.

The estimated air concentrations of arsenic and manganese at Gay (Table 1) are within about an order of magnitude of their respective screening levels. The estimated air concentration of arsenic at Calumet, from the Point Mills stampsands (Table 2), is one-half its screening value. Arsenic and manganese are retained for further analysis in this document. Also, neither lithium nor strontium has an RfC, chronic EMEG, CREG or REL. They are retained for further analysis.

Aluminum, beryllium, chromium, cobalt, copper, lead, mercury, nickel, silver, and zinc are not evaluated further, because their respective estimated air concentrations are not a public health concern (i.e., they were well below their respective screening levels).

MDCH is aware of concerns about short-term (acute) exposure to higher-than-normal concentrations of airborne stampsands, such as when street-sweeping activities occur. Empirical evidence from air monitors throughout the state indicates that peak PM10 (particulate matter less than 10 microns in aerodynamic diameter) levels measured over 24-hour periods were roughly twice the annual average concentration (MDEQ 2009). (The MDEQ database did not indicate what attributed to the peak air concentrations.) Thus, doubling the estimated air concentrations in Tables 1 and 2 would result in expected peak, or acute, exposure levels of PM10 metals in the air at Gay and Calumet. Acute exposure situations (discussed further in the *Exposure Pathways Analysis* section) would be expected to be brief and intermittent, not the norm.

Exposure Pathways Analysis

To determine whether persons are, have been, or may likely be exposed to contaminants, MDCH evaluates the environmental and human components that could lead to human exposure. An exposure pathway contains five elements:

- a source of contamination
- contaminant transport through an environmental medium
- a point of exposure
- a route of human exposure
- a receptor population

An exposure pathway is considered complete if there is evidence, or a high probability, that all five of these elements are, have been, or will be present at a site. It is considered either a potential or an incomplete pathway if there is a lower probability of exposure or there is no evidence that at least one of the elements above are, have been, or will be present. Table 3 details the stampsand inhalation exposure pathways at Gay and Calumet.

Table 3. Exposure pathways analysis for airborne stampsands at Gay and Calumet, Michigan.

Source	Environmental Medium	Chemicals of Interest	Exposure Point	Exposure Route	Exposed Population	Time Frame	Exposure
Gay stampsands	Airborne stampsands	Arsenic, lithium, manganese, strontium	Ambient air (at Gay)	Inhalation, dermal contact, incidental ingestion[3]	Workers and recreational users of the site	Past	Complete
						Present	Complete
						Future	Complete
Point Mills stampsands (at Calumet)	Airborne stampsands	Arsenic, lithium, manganese, strontium	Ambient air (at Calumet)	Inhalation, dermal contact, incidental ingestion	People living, working, or visiting in Calumet	Past	Complete
						Present	Complete
						Future	Complete
NOTE: The presence of a complete exposure pathway in this table does *not* imply that an exposure would be substantial or that harm would occur.							

Exposure at Gay

In the past, the Keweenaw County Road Commission has excavated and used the Gay stampsands for traction material on winter roads. Although this practice had stopped for several years, stampsands were used on roads during the 2010-2011 winter (G. Patrick, Keweenaw County Road Commission, personal communication, 2011). Heavy trucks traversing the site are expected to generate dust at times. The vast amount of stampsands still at Gay suggests they may be excavated for various uses well into the future.

Although the main road entrance to the Gay stampsands is gated and locked, recreational vehicle users reportedly can gain access and drive their motorcycles, off-road vehicles ("quads"), or trucks over the stampsand "dunes" (A. Keranen, MDEQ RRD, personal communication, 2008). Light-vehicle traffic likely generates dust at times, although heavier traffic (excavation equipment) may generate more dust, depending on conditions. The stampsands extend for about five miles along the Lake Superior shoreline, starting at Gay and extending south and west (Figure 2). Therefore, it may be difficult to prevent people from accessing the site.

Exposure at Calumet

The Houghton County Road Commission has used stampsands in the past on area roads to improve traction in the winter, and intends to deplete the pile at Point Mills eventually. Some dust may be generated when stampsands are applied to roads, if no precipitation is occurring at the time. The bigger dust issue occurs in the warmer months, when the roads are dry and stampsand residue remains on the pavement and shoulder. Traffic on these roads, both light-duty and heavy vehicles, can grind the stampsands into smaller particles making it even easier for them to become airborne.

[3] Although the exposure route of concern at this site is inhalation, ingestion of airborne particulates often occurs following inhalation. Smaller particulates will usually deposit in the lungs and alveoli whereas larger particles may adhere to the trachea and throat lining. The mucosa moves the deposited material upward toward the mouth. When a person coughs, the particles are expelled from the upper respiratory tract and may be spit out or swallowed. A person may also experience oral exposure via incidental ingestion of contaminated soil. However, ingestion of metals in stampsands, for the scenario described here, is of less public health concern than inhalation of the metal. Similarly, skin contact is not a primary exposure concern.

Additionally, county road commissions, municipalities, MDOT, and local businesses conduct street-sweeping, or brooming, activities to reduce the amount of loose material on the road surface. According to local officials, brooming by public agencies occurs once per year, usually after a rain event or with a water truck wetting down the material first (T. Bausano, City of Calumet, personal communication, 2009; K. Harju, Houghton County Road Commission, personal communication, 2009). However, businesses may rent street-sweeping equipment at any time, to clean their individual properties (A. Keranen, MDEQ RRD, personal communication, 2009). MDCH does not know if there are local or county ordinances that govern when or how street-sweeping activities by private parties can occur. Figures 4 and 5 provide examples of the dust generated when street-sweeping occurs.

Figure 4. Representative picture of street sweeping in residential neighborhood in Michigan's Upper Peninsula. (Location and date taken unknown. Source: www.pasty.com)

Figure 5. Picture of dust generated by a street sweeper along Oneco Road, east of US41, in Houghton County, Michigan. (Photograph taken May 6, 2010. Source: MDEQ.)

A private citizen in Calumet sent a letter to EPA expressing his concerns regarding the dust generated by street-sweeping activities. He was worried that the dust was affecting his lawn and garden and might also affect his health. This acute exposure is discussed further in the *Toxicological Evaluation* and *Community Health Concerns* sections, and in Appendix C, of this document.

Toxicological Evaluation

Arsenic

Arsenic occurs naturally in the environment. Foods that contain arsenic, mainly in the form of organic arsenic, are dairy products, meat, poultry, fish, grains, and cereal (IOM 2001). Typical levels of arsenic in food are 20-140 micrograms per kilogram (µg/kg). The form of arsenic that naturally occurs in water is the inorganic form. Levels of inorganic arsenic in surface and groundwater are usually 1.0 microgram per liter (µg/L). A majority (80%) of U.S. drinking water has less than 2.0 µg/L inorganic arsenic (ATSDR 2007). Although there currently is no known function for arsenic in humans, animal studies have shown that arsenic is necessary in the diet (IOM 2001).

The single-most characteristic effect of long-term exposure to inorganic arsenic (the form most likely to be present in the stampsands) is a pattern of skin changes: patches of darkened skin interspersed with whitened areas, and small "corns" or "warts" on the palms, soles of the feet, and the torso. While these effects are typical of chronic oral exposure, they have also been seen, though rarely, in workers exposed via inhalation. The exposure level that would produce these

effects is uncertain but probably above 100 µg/m^3 for a brief exposure and less than that value for longer exposure periods (ATSDR 2007). The highest estimated concentration of arsenic in airborne stampsands was calculated to be 0.0001 µg/m^3 (in Calumet, as shown in Table 2 and estimated in Appendix C). The expected peak, short-term exposure concentration (MDEQ 2009) would be twice that, or 0.0002 µg/m^3, almost six orders of magnitude (1,000,000 times) less than 100 µg/m^3. Therefore, based on the values used, it is *not* expected that the estimated exposure at Gay or Calumet would produce skin effects.

A person breathing airborne stampsands as dust may experience throat irritation and cough or clear their throat. The person would then either spit out or swallow that which was coughed up, which may contain a small amount of arsenic. Low levels of ingestion (300 to 30,000 µg/L in water) can result in gastrointestinal upset (nausea, stomachache, vomiting). Other effects may include decreased production of red and white blood cells, abnormal heart rhythm, damage to the blood vessels and sensation of pins and needles in hands and feet. Chronic oral exposures of 50-100 µg/kg/day are associated with neurological (nervous system) or hematological (blood) signs of arsenic toxicity (ATSDR 2007). If an 80-kg adult breathes 20 m^3 of air per day (default risk-assessment assumptions [EPA 2011]) containing the highest estimated concentration of arsenic (0.0001 µg/m^3) and actually swallows the total amount of arsenic inhaled, the daily dose received would be 0.000025 µg/kg/day ([20 X 0.0001]/80). This is more than six orders of magnitude less than 50 µg/kg/day. Therefore, based on the values used, it is *not* expected that the estimated exposure of arsenic would cause health effects as described above.

Inorganic arsenic is a known carcinogen to humans. The ATSDR Cancer Risk Evaluation Guide (CREG) for arsenic is 0.0002 µg/m^3 for a one-in-one-million cancer risk (i.e., one extra person in one million people exposed to that concentration of airborne arsenic would be expected to develop cancer). At an air concentration of 0.0001 µg/m^3, the number of extra cancers expected to occur is less than one in one million. Therefore, based on the values used, it is *not* expected that the estimated exposure of arsenic in airborne stampsands would cause an increase in cancer risk.

Lithium

Lithium is widely distributed in nature. Lithium compounds are used in ceramics and glass, primary aluminum production, the manufacture of lubricants and greases, primary and secondary (rechargeable) batteries, the production of synthetic rubber, the manufacture of polyester fiber, the production of antioxidants and antihistamines, as catalysts, and in the treatment of mood disorders (HSDB 2010).

Lithium is present in human plasma and serum. The human body contains about 2.2 milligrams (mg) of lithium. Intake from food was reported to be 2 mg/day, whereas intake from drinking water was reported to be 34 µg/day (which is equal to 0.034 mg/day) (HSDB 2010). If an adult breathes 20 m^3 of air per day (default risk-assessment assumption [EPA 2011]) containing the highest estimated concentration of lithium (0.0002 µg/m^3) and actually swallows the total amount of lithium inhaled, the daily intake would be 0.004 µg/day (20 X 0.0002) or 0.000004 mg/day, which contributes hardly any additional lithium when considering dietary and water intake. Therefore, it is *not* expected that the estimated exposure to lithium in airborne stampsands will cause harm.

Manganese

Manganese is a naturally occurring metal as well as an essential trace element. It is used in the manufacture of various types of steel, in the production of batteries, dietary supplements, and some pesticides and fertilizers. Many foods contain manganese, especially nuts, legumes, grains, and tea. Insufficient dietary manganese can lead to slowed blood clotting, skin problems, changes in hair color, and alterations in metabolism (ATSDR 2000b). Healthy humans maintain efficient control over ingested manganese in the body. The body absorbs and uses what is nutritionally necessary and excretes the remainder. Thus, ingested manganese has rarely been associated with toxicity (EPA 1996). Individuals who cannot efficiently excrete excess metals from their bodies, such as persons with liver disorders, may be more at risk to potential toxicity (ATSDR 2000b).

Manganese miners or steel workers exposed to high levels of manganese dust in air may develop mental and emotional disturbances. Their body movements may become slow and clumsy. These symptoms, when associated with manganese exposure, describe a disease called "manganism." Less severe symptoms of excessive manganese exposure include difficulty in: holding one's hand steady, performing fast hand movements, and maintaining balance when tested (Roels et al. 1992, 1999; Mergler et al. 1994, 1999; Crump and Rousseau 1999; Lucchini et al. 1999; Beuter et al. 1999; ATSDR 2000b; Bast-Pettersen et al. 2004). Exposed males may experience sexual dysfunction. Inhalation of manganese-containing dust may cause respiratory problems (ATSDR 2000b). Existing studies are inadequate to assess the carcinogenicity of manganese (EPA 1993, 1996).

A recent health study conducted in Ohio demonstrated that people who lived in an area with elevated airborne manganese (about three times the RfC) did *not* suffer adverse health effects (Bowler 2010). The highest estimated air concentration of manganese in the stampsands was one-fifth the RfC. Therefore, based on the values used, it is *not* expected that the estimated exposure to manganese in the stampsands in the Gay or Calumet area will cause harm.

Strontium

Strontium occurs naturally, usually in the form of minerals, and exists to some extent in all environmental media. Leafy vegetables, along with grain and dairy products, contribute the greatest percentage of dietary strontium to humans, with concentrations up to 64 mg/kg recorded for cabbage. After strontium ore is extracted from the ground, it is chemically processed and concentrated into carbonate and other forms. Strontium compounds are used in making ceramics and glass products, pyrotechnics, paint pigments, fluorescent lights, and medicines (ATSDR 2004).

In the body, strontium acts like calcium and accumulates in the bone. Problems with bone growth may occur in children eating or drinking unusually high levels of strontium, especially if the diet is low in calcium and protein (ATSDR 2004).

Although some radioactive forms of strontium exist, most airborne strontium is not radioactive (i.e., it is stable). The only chemical form of stable strontium that is very harmful by inhalation is strontium chromate, but this is because of toxic chromium and not strontium itself. The

average concentration of strontium that has been measured in air in the U.S. is 20 nanograms per cubic meter (ng/m^3, equal to 0.02 µg/m^3; ATSDR 2004), which is higher than the highest estimated air concentration of strontium in stampsands (0.0007 µg/m^3, see Table 2). Therefore, it is *not* expected that the estimated exposure to strontium in airborne stampsands will cause harm.

Particulate Matter and "Nuisance" Dust

"Particulate matter" refers to solid particles and liquid droplets (or aerosols) in the air. Many health studies have shown that the size of airborne particles is closely related to potential health effects among exposed populations. As a result, regulatory and public health agencies focus on the size of particulate matter when evaluating levels of air pollution. Particulate matter is generally classified into three categories (ATSDR 2003):

1. **Total suspended particulates (TSP)** refer to a wide range of solid particles and liquid droplets found in air. TSP typically contains particles with aerodynamic diameters of 25 to 40 microns or less. Many different industrial, mobile, and natural sources release TSP to the air. Until 1987, EPA's health-based National Ambient Air Quality Standards (NAAQS) regulated air concentrations of TSP.
2. **Particulate matter smaller than 10 microns (PM10)** refers to the subset of TSP comprised of particles smaller than 10 microns in diameter. In 1987, as research started to show that PM10 can penetrate into sensitive regions of the respiratory tract, EPA stopped regulating airborne levels of TSP and began regulating airborne levels of PM10. In studies where coarse fraction particles were the dominant fraction of PM10, major short-term effects observed included aggravation of asthma and increased upper respiratory illness (Bascom et al. 1996). Typical sources of PM10 include wind-blown dust and dusts from paved and unpaved roads (EPA 2008). This suggests that the most likely size of particulate occurring in airborne stampsands would be PM10.
3. **Particulate matter smaller than 2.5 microns (PM2.5)**, or "fine particulates," refers to the subset of TSP and PM10 comprised of particles with aerodynamic diameters of 2.5 microns or less. EPA proposed regulating ambient air concentrations of PM2.5 in 1997, based on evidence linking inhalation of fine particles to adverse health effects in children and other sensitive populations such as persons with cardiovascular disease. Sources of PM2.5 include wood smoke, motor vehicle exhaust, power plant emissions, and certain industrial processes (EPA 2008).

The visible dust emissions from the street-sweeping shown in Figures 4 and 5 may contain small particles; however, there are no air data to indicate levels of TSP, PM10, or PM2.5, nor chemical content, of the dust. It is possible that the dust is more "nuisance" (an aesthetic issue or temporary respiratory irritation) than a threat to public health. However, people with respiratory complications, such as asthma or chronic obstructive pulmonary disease (COPD), may be at risk of negative health effects if they inhale the airborne dust.

Children's Health Considerations

In general, children may be at greater risk than adults from exposure to hazardous substances at sites of environmental contamination. Children engage in activities such as playing outdoors and hand-to-mouth behaviors that could increase their intake of hazardous substances. They are

shorter than most adults, and therefore breathe dust, soil, and vapors found closer to the ground. Their lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. The developing body systems of children can sustain permanent damage if toxic exposures are high enough during critical growth stages. Fetal development involves the formation of the body's organs. Injury during key periods of prenatal growth and development could lead to malformation of organs (teratogenesis), disruption of function, and premature death. Exposure of the mother could lead to exposure of the fetus, via the placenta, or affect the fetus because of injury or illness sustained by the mother (ATSDR 1998a). The implication for environmental health is that children can experience substantially greater exposures to toxicants in soil, water, or air than adults can.

Children with respiratory conditions such as asthma may have adverse reactions if they inhale airborne stampsands, due to the physical nature of the particulate matter. Regarding the chemicals that may be present, children do not appear to be any more susceptible than adults to any toxic effects that could occur as a result of inhaling the dust.

Community Health Concerns

A Calumet citizen sent a letter to EPA with concerns about the dust generated by street-sweeping activities (Figures 4 and 5; Appendix C). He was worried about the effect of the dust on his lawn and garden and the potential for effects on his health. MDCH contacted the local Michigan State University Extension (MSUE) office for guidance on the plants. They provided the following information (M. Schira, MSUE, personal communication, 2009):

- Dust should not affect a plant's ability to "breathe" because the stomata (plant pores) are on the underside of the leaf and not likely to get clogged with settled dust. Nor should the dust reduce the plant's ability to photosynthesize, as evidenced by plants along dusty gravel roads withstanding coatings of dust.
- Most metals are micronutrients and beneficial or vital to plant growth, but can be phytotoxic at high concentrations. Soil pH (acidity) can affect how easily a plant takes up metals. Concerned gardeners may want to have their soil tested through their Extension office.
- If roadside plants are dying, it might be a salt issue instead, either mixed with the stampsand or used separately. Amending the soil with gypsum (calcium sulfate) can help neutralize the impact of salt.
- The Michigan Technological University School of Forest Resources and Environmental Science has conducted research on growing plants in stampsands. Interested parties should contact the university (www.mtu.edu/forest/) or MSUE (www.msue.msu.edu) to find out more.

Regarding the citizen's concern about potential human health effects, MDCH considered short-term acute exposures in the evaluation of airborne stampsands at both Gay and Calumet. While exposures at Gay do not appear to be of concern (Appendices A and B), more site-specific data are needed to better characterize expected exposures in Calumet (Appendix C).

While MDCH was conducting its evaluation of the stampsands, the agency contacted local officials to inform them of the work being done. The president of the city of Calumet expressed

concern regarding exposures to the persons operating the street sweepers (T. Bausano, City of Calumet, personal communication, 2009). The operators would probably be exposed to higher concentrations of the dust than would residents, since they would be located right next to the emission source. Due to the dusty nature of the job, it is possible that the operators would be wearing masks that would reduce their exposure. Also, surface material is usually wetted down before the sweeping. Nonetheless, because dust can be generated (Figures 4 and 5), characterization of expected exposures would help address this concern.

MDEQ has heard from the owner of a cottage in the Point Mills area who did not understand why there was a cover put on portions on the Superfund site (to prevent wind-generated dust) yet the Houghton County Road Commission uses stampsands on the roads (A. Keranen, MDEQ RRD, personal communication, 2010). MDCH cannot speak to why some stampsands were covered while others are being used and potentially becoming airborne. Rather, in this document, MDCH is evaluating exposure to airborne stampsands and determining whether those exposures are potentially harmful.

The road commissions use stampsands in the construction and improvement of unpaved roads. Road workers, as well as people traveling on or living near these roads, may be exposed to large amounts of airborne stampsands. Dust control measures are applied only to about 1% of Houghton County's gravel and dirt roads and about 10% of Keweenaw County's unpaved roads (K. Harju, Houghton County Road Commission, personal communication, 2011; G. Patrick, Keweenaw County Road Commission, personal communication, 2011.) The evaluation of emissions from unpaved roads constructed or improved with stampsands is beyond the scope of this evaluation. It may be necessary to characterize exposure to the dust emissions from these roads, such as through activity-based sampling. EPA conducted this type of sampling for asbestos and metals at and near the Quincy Smelter site, which is part of the Torch Lake Superfund site (ATSDR 2006).

Conclusions

MDCH has determined that the estimated concentrations of metals in airborne stampsands at the Gay tailings pile along Lake Superior are not expected to cause harm to heavy equipment operators or recreational vehicle users at the site. MDCH has medium to high confidence in the values used for the Gay evaluation. Most of the estimated concentrations are orders of magnitude less than health-based screening levels.

MDCH cannot determine whether airborne Point Mills stampsands used for road traction in the Calumet area would cause harm to persons living, working, or visiting in Calumet. (Note that, as stated earlier in this document, there are other areas, not just Calumet, that receive stampsands for road traction. Also, stampsands are often used for gravel road construction and maintenance. The evaluation for Calumet does not stand as a surrogate for the other areas or for other uses of stampsands.) MDCH has low to medium confidence in the values used for the Calumet evaluation. Additional site-specific data are needed to better characterize potential exposures.

MDCH does not have the resources to evaluate each stampsand pile individually. MDCH understands that there are many stampsand piles in the Torch Lake area, within and outside of

the Superfund site's Operable Units (OUs). Each stampsand pile is unique in chemical and physical attributes.

Recommendations

1. Obtain site-specific data to recalculate estimated air concentrations at Calumet.

2. Use the exercises and evaluations discussed in this document to inform and guide future stampsand inhalation risk assessments.

3. Notify communities when street sweeping takes place so that sensitive individuals, such as asthmatics, can protect themselves.

Public Health Action Plan

MDCH has provided this public health assessment document to regulatory agencies and local officials.

MDCH will remain available as needed for future consultation at this site.

If any citizen has additional information or health concerns regarding this public health assessment, please contact MDCH's Division of Environmental Health at 1-800-648-6942.

Report Preparation

This Public Health Assessment was prepared by the Michigan Department of Community Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented.

Author

Michigan Department of Community Health
Division of Environmental Health

Christina Bush
Toxicologist

Reviewers

Michigan Department of Community Health
Division of Environmental Health

Jennifer Gray, PhD
Toxicologist

ATSDR Division of Community Health Investigations

Mark Johnson, PhD
Region V Director

Trent LeCoultre, Technical Project Officer
Central Branch

References

Agency for Toxic Substances and Disease Registry (ATSDR). Preliminary health assessment for Torch Lake. Atlanta: U.S. Department of Health and Human Services; 1989 Apr 24.

Agency for Toxics Substances and Disease Registry (ATSDR). Site review and update – Torch Lake, Hubbell, Houghton County, Michigan. Atlanta: U.S. Department of Health and Human Services; 1995 May 25.

Agency for Toxic Substances and Disease Registry (ATSDR). Guidance on including child health issues in Division of Health Assessment and Consultation documents. July 2, 1998 (1998a).

Agency for Toxic Substances and Disease Registry (ATSDR). Health consultation concerning Torch Lake, Hubbell, Houghton County, Michigan. Atlanta: U.S. Department of Health and Human Services; 1998 Mar 23 (1998b).

Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological profile for chromium. Atlanta: U.S. Department of Health and Human Services; 2000 Sept. (2000a) Draft update available at http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=62&tid=17

Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological profile for manganese. Atlanta: U.S. Department of Health and Human Services; 2000 Sept. (2000b) Draft update available at http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=102&tid=23

Agency for Toxic Substances and Disease Registry (ATSDR). Public Health Assessment - Air Pathway Evaluation for Isla de Vieques Bombing Range, Vieques, Puerto Rico. Atlanta: U.S. Department of Health and Human Services; 2003. Available at http://www.atsdr.cdc.gov/HAC/PHA/reports/isladevieques_08262003pr/index.html

Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological profile for strontium. Atlanta: U.S. Department of Health and Human Services: 2004 April. Available at http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=656&tid=120

Agency for Toxic Substances and Disease Registry (ATSDR). Public health assessment guidance manual – Appendix F: Derivation of Comparison Values. Atlanta (GA): U.S. Department of Health and Human Services; 2005. Available at http://www.atsdr.cdc.gov/HAC/PHAmanual/appf.html

Agency for Toxic Substances and Disease Registry (ATSDR). Health consultation concerning review of activity-based sampling on the Hancock/Ripley Trail, former Quincy Smelter site, Town of Ripley, Houghton County, Michigan. Atlanta: U.S. Department of Health and Human Services; 2006 Nov 27. http://www.michigan.gov/documents/mdch/QuincySmelterHC112706_230587_7.pdf

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for arsenic. Atlanta: U.S. Department of Health and Human Services; 2007 Aug. Available at http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=22&tid=3

Agency for Toxic Substances and Disease Registry (ATSDR). "Air Sampling and Modeling – Measuring and Estimating Levels of Air Pollution" (factsheet). Accessed July 16, 2010 at http://www.michigan.gov/documents/mdch/ATSDR_Air_SamplingModeling_Booklet_3226967.pdf

Bascom R, PA Bromberg, DA Costa, R Devlin, DW Dockery, MW Framptom, W Lambert, JM Samet, FE Speizer, M Utell. 1996. Health effects of outdoor air pollution. Am. J. Respir. Crit. Care Med. 153:3-50.

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

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

Bowler RM. "Health study of manganese exposure of adults in Marietta and Mt. Vernon, Ohio: preliminary results." June 24, 2010 Power Point presentation, available at http://online.sfsu.edu/~mnstudy/study.html

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

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

Cowherd Jr. C, Muleski GE, Englehart PJ, Gillette DA. Rapid assessment of exposure to particulate emissions from surface contamination sites. Kansas City (MO): Midwest Research Institute, for U.S. Environmental Protection Agency Office of Health and Environmental Assessment; 1985 Feb. Contract Report No. EPA/600/8-85/002.

Cowherd Jr. C, Muleski GE, Kinsey JS. 1988. Control of open fugitive dust sources. Research Triangle Park (NC): U. S. Environmental Protection Agency Office of Air Quality Planning and Standards; 1988 Sept. Report No. EPA 450/3-88-008.

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

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

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

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

Hazardous Substances Data Bank. Accessed July 17, 2010 at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

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

Institute of Medicine (IOM). 2001. Dietary Reference Intakes: Elements. Washington, DC: The National Academies Press. Accessed July 17, 2010 at http://www.iom.edu/Global/News%20Announcements/~/media/48FAAA2FD9E74D95BBDA2236E7387B49.ashx

Kerfoot WC, G Lauster, JA Robbins. 1994. Paleolimnological study of copper mining around Lake Superior: artificial varves from Portage Lake provide a high resolution record. Limnol. Oceanogr. 39(3):649-669.

Kimbrough DE, Y Cohen, AM Winer, L Creelman, C Mabinu. 1999. A critical assessment of chromium in the environment. Critical Reviews in Environmental Science and Technology 29(1):1-46.

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

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

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

Michigan Department of Natural Resources and Environment (MDEQ). Final report of the Toxics Steering Group Subcommittee for the application of the Manganese Particulate Soil Inhalation Criteria in the Detroit Area. Lansing (MI): MDEQ Toxics Steering Group; 2009 May.

Available at http://www.michigan.gov/documents/deq/DEQ-AQD-toxics-Manganese_PSIC_279828_7.pdf

Michigan Department of Environmental Quality (MDEQ). Interoffice communication to Amy Keranen, Remediation and Redevelopment Division (RRD) Baraga Field Office Project Manager, from Jeff Pincumbe, RRD Geological Services Unit Geologist, concerning Gay Stamp Sands Geoprobe Investigation. June 29, 2004 (2004a).

Michigan Department of Environmental Quality (MDEQ). Remediation and Redevelopment Division (RRD) Operational Memorandum No. 1, Technical Support Document – Attachment 3: Part 201 Drinking Water Criteria, Part 213 Tier I Drinking Water Risk-Based Screening Levels. Lansing (MI): MDEQ RRD; 2004 December (2004b). http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_1-Attachment3DrinkingWaterCriteriaTechnicalSupportDocument_284872_7.pdf

Michigan Department of Environmental Quality (MDEQ). Remediation and Redevelopment Division (RRD) Operational Memorandum No. 1, Technical Support Document - Attachment 6: Part 201 Soil Direct Contact Criteria, Part 213 Tier I Soil Direct Contact Risk-Based Screening Levels. Lansing (MI): MDEQ RRD; 2005 April. http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_1-Attachment6_285488_7.pdf

Michigan Department of Environmental Quality (MDEQ). Remediation and Redevelopment Division (RRD) Operational Memorandum No. 1, Technical Support Document – Attachment 7: Part 201 Generic Soil Inhalation Criteria for Ambient Air, Part 213 Tier I Soil Inhalation Risk-Based Screening Levels for Ambient Air. Lansing (MI): MDEQ RRD; 2007 July. Available at http://www.michigan.gov/documents/deq/deq-rrd-Op_Memo1_Attach7-SoilInhalationCleanupCriteria-TSD_285498_7.pdf

Michigan Department of Environmental Quality (MDEQ). Attachment 1: Table 2. Soil: Residential Part 201 Generic Cleanup Criteria and Screening Levels; Part 213 Tier 1 Risk-based Screening Levels (RBSLs). Lansing (MI): MDEQ Remediation Division; 2011 March (2011a). Available at http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_1-Attachment1Table2SoilResidential_283553_7.pdf

Michigan Department of Environmental Quality (MDEQ). Attachment 1: Table 3. Soil: Non-residential Part 201 Generic Cleanup Criteria and Screening Levels; Part 213 Tier 1 Risk-based Screening Levels (RBSLs). Lansing (MI): MDEQ Remediation Division; 2011 March (2011b). Available at http://www.michigan.gov/documents/deq/deq-rrd-OpMemo_1-Attachment1Table3SoilCommercial_233124_7.pdf

Michigan Department of Transportation (MDOT). Michigan 2011 Annual Average 24-Hour Traffic Volumes. Accessed December 10, 2012 at http://mdotwas1.mdot.state.mi.us/public/maps_adtmaparchive/pdf/2011adt/AADT_STATE_FrontPg-2011_29x30_NO_INSETS.pdf

National Institute for Occupational Safety and Health (NIOSH). Pocket guide to chemical hazards. Cincinnati (OH): U.S. Department of Health and Human Services; 2006 Aug. Publication No. 2005-149. Available at http://www.cdc.gov/niosh/npg/

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

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

U.S. Army Corps of Engineers (USACE). Quantification and fate of Keweenaw stamp sand. Detroit (MI): USACE Detroit District; 2001 Dec.

U.S. Environmental Protection Agency (EPA). 1989. Risk assessment guidance for Superfund, Volume I, Human Health Evaluation Manual. Washington DC: EPA Office of Emergency and Remedial Response; 1989 Dec. Report No. EPA/540/1-89/002.

U.S. Environmental Protection Agency (EPA). 1993a. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Appendix C.1 – Procedure for sampling surface/bulk dust loading. Research Triangle Park (NC): U.S. EPA Office of Air Quality Planning and Standards. Available at http://www.epa.gov/ttn/chief/ap42/appendix/app-c1.pdf

U.S. Environmental Protection Agency (EPA). 1993b. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Appendix C.2 – Procedure for laboratory analysis of surface/bulk dust loading samples. Research Triangle Park (NC): U.S. EPA Office of Air Quality Planning and Standards. Available at http://www.epa.gov/ttn/chief/ap42/appendix/app-c2.pdf

U.S. Environmental Protection Agency (EPA). Integrated Risk Information System – Manganese (CASRN 7439-96-5): Reference Concentration for Chronic Inhalation Exposure (RfC). Last revised 12/1/1993. Accessed July 17, 2010 at http://www.epa.gov/iris/subst/0373.htm#refinhal

U.S. Environmental Protection Agency (EPA). Integrated Risk Information System – Manganese (CASRN 7439-96-5): Reference Dose for Chronic Oral Exposure (RfD). Last revised 5/1/1996. Accessed July 17, 2010 at http://www.epa.gov/iris/subst/0373.htm#reforal

U.S. Environmental Protection Agency (EPA). Exposure Factors Handbook: 2011 Edition. Washington, DC: EPA Office of Research and Development; 2011 September. Report No.: EPA/600/R090/052F. http://www.epa.gov/ncea/efh/pdfs/efh-complete.pdf

U.S. Environmental Protection Agency (EPA). A Review of the Reference Dose and Reference Concentration Processes. Washington, DC: EPA Risk Assessment Forum; 2002 December. Report No.: EPA/630/P-02/002F. http://www.epa.gov/raf/publications/pdfs/rfdrfcextrevdrft.pdf

U.S. Environmental Protection Agency (EPA). 2006. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 13.2.2 – Unpaved Roads. Research Triangle Park (NC): U.S. EPA Office of Air Quality Planning and Standards. Available at http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf

U.S. Environmental Protection Agency (EPA). Fine Particle (PM2.5) Designations: Frequent Questions. Last updated 12/22/2008. Accessed July 20, 2010 at http://www.epa.gov/pmdesignations/faq.htm

U.S. Environmental Protection Agency (EPA). Acute Exposure Guideline Levels (AEGLs). Accessed July 6, 2010 (2010a) at http://www.epa.gov/oppt/aegl/index.htm

U.S. Environmental Protection Agency (EPA). Integrated Risk Information System (IRIS) glossary. Accessed July 6, 2010 (2010b), at http://www.epa.gov/NCEA/iris/help_gloss.htm

U.S. Environmental Protection Agency (EPA). 2011a. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, Chapter 13.2.1 – Paved Roads. Research Triangle Park (NC): U.S. EPA Office of Air Quality Planning and Standards. Available at http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0201.pdf

U.S. Environmental Protection Agency (EPA). 2011b. Technology Transfer Network: National Ambient Air Quality Standards (NAAQS). Accessed May 26, 2011 at http://www.epa.gov/ttn/naaqs/

Weston Solutions of Michigan Inc. (Weston). Toxicological evaluation for the Gay, Michigan stamp sand. Houghton (MI): State of Michigan Department of Environmental Quality Remediation and Redevelopment Division Calumet Field Office, Calumet, Michigan; 2006 Sept. (2006a) Work Order No. 20083.032.002.

Weston Solutions of Michigan Inc. (Weston). Toxicological evaluation for the Point Mills, Michigan stamp sand. Houghton (MI): State of Michigan Department of Environmental Quality Remediation and Redevelopment Division Calumet Field Office, Calumet, Michigan; 2006 Sept. (2006b) Work Order No. 20083.032.002.

Weston Solutions, Inc. (Weston). Summary report for the Torch Lake Area Assessment, Torch Lake NPL site and surrounding areas, Keweenaw Peninsula, Michigan. Okemos (MI): U.S. Environmental Protection Agency, Region V Emergency Response Branch, Grosse Ile, Michigan; 2007 Dec. Contract No. EP-S5-06-04. Available at http://www.epaosc.org/sites/3450/files/torch%20lake%20area%20assessment%20report.pdf

Appendix A. Estimating Air Concentrations of Metals as Particulate Matter at the Gay Stampsands Site in Michigan – On-site Heavy Truck Use

Assumed Exposure Scenario at Gay

The following exercise estimates air concentrations of stampsand-related chemicals expected at the large tailing pile at Gay, Michigan when heavy trucks are on the site. The exercise applies assumptions of 20 vehicle-trips per day on the stampsands for 20 days per month, five months out of the year. The exercise also assumes that the same person is exposed to those conditions for 20 years. (Although there may be different drivers at different times, this assumption allows a protective estimate.)

Basic PSIC Equations

The Michigan Department of Environmental Quality (MDEQ) Particulate Soil Inhalation Criteria (PSIC) identify concentrations of hazardous substances in soil that are not expected to create ambient air concentrations of contaminated particulates that would, in turn, cause adverse human health effects via inhalation. Soils can become resuspended by wind or vehicular erosion. One must consider, among other parameters, source size, vegetative cover, wind speed, and vehicle use of the area (MDEQ 2007).

The algorithm used to calculate an acceptable soil concentration of a non-carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{nc} = \frac{THQ \times AT_{nc}}{EF \times ED \times (1/ITSL \times 1/(PEF/2))}$$

The algorithm used to calculate an acceptable soil concentration of a carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{ca} = \frac{TR \times AT_{ca} \times AIR}{IURF \times EF \times ED \times (1/PEF)}$$

where PSIC = the soil criterion, given in micrograms of chemical per kilogram soil (µg/kg) or parts per billion (ppb);

nc = non-carcinogenic chemical

ca = carcinogenic chemical

THQ = target hazard quotient, the ratio of the expected dose to the acceptable dose, and is unitless;

TR = target cancer risk (the number of excess cancers expected due to exposure to the chemical), which is 1 in 100,000 and is unitless;

AT_{nc} the averaging time for non-carcinogens, which is the years of exposure duration times the number of days of exposure per year, in days;

AT_{ca} the averaging time for carcinogens, which is considered to be a lifetime (70 years), in days (25,550 days);

AIR	=	adjusted inhalation rate; assumes a worker breathes twice as much air during a 24-hour day versus a non-worker; value is 2 (20 cubic meters per day [m^3/day] / 10 m^3/day); used only for carcinogens when considering industrial or commercial exposure scenarios;
EF	=	the exposure frequency, given in days/year;
ED	=	the exposure duration, given in years;
ITSL	=	the MDEQ Initial Threshold Screening Level, the acceptable air concentration of the chemical, in micrograms of chemical per cubic meter air ($\mu g/m^3$);
IURF	=	the MDEQ Inhalation Unit Risk Factor, the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at 1 $\mu g/m^3$ concentration in air; units are $(\mu g/m^3)^{-1}$;
PEF	=	the Particulate Emission Factor, specific for source size, in m^3/kg. The divisor of 2 for non-carcinogenic chemicals is used when the averaging time for the ITSL is less than annual, in order to achieve an appropriately protective PSIC.

Note that values given for the parameters described above are default values. Values specific for this exercise are discussed in later sections of this appendix (see Tables A-1, A-2, and A-3).

Solving for Expected Air Concentrations

For this exercise, the algorithms above will be rearranged and the risk-assessment parameters (EF, ED, THQ, TR, AT, and AIR) removed to estimate an expected air concentration based on soil concentration data. Risk-assessment parameters will be considered at a later point in this appendix. For the purposes of this exercise (estimating expected air concentrations), the divisor of 2 for the PEF for non-carcinogenic chemicals is removed.

To start, note that the PSIC criteria are specific for soils and cannot be used when discussing stampsands, which are not soil but a mining by-product. Therefore, rather than use acronyms with specific regulatory meanings ("ITSL," "PSIC," and "IURF"), the Michigan Department of Community Health (MDCH) is using the following substitutions:

For "ITSL," substitute "$[\textit{non-carcinogen}]_{air}$", meaning "concentration of 'non-carcinogenic chemical X' in air"

For "PSIC," substitute "$[\textit{chemical name}]_{stampsand}$", meaning "concentration of 'chemical X' in stampsand"

For "IURF," substitute "Potency$[\textit{carcinogen}]_{air}$", meaning the "estimated upper-bound excess lifetime cancer risk resulting from continuous exposure to an airborne carcinogen at a concentration of 1 $\mu g/m^3$"

Solving for $[\textit{non-carcinogen}]_{stampsand}$, the resulting equation, without risk-assessment parameters, is:

$$[non-carcinogen]_{stampsand} = \frac{1}{1/[non-carcinogen]_{air} \times 1/PEF} = [non-carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[non-carcinogen]_{air} = [non-carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for manganese (Mn): } [Mn]_{air} = \frac{[Mn]_{stampsand}}{PEF}$$

Solving for $[carcinogen]_{\text{stampsand}}$, the resulting equation, without risk-assessment parameters, is:

$$[carcinogen]_{stampsand} = \frac{1}{Potency[carcinogen]_{air} \times 1/PEF} = \frac{1}{Potency[carcinogen]_{air}} \times PEF$$

The carcinogen equation needs further adjusting to reach an air concentration, versus an excess cancer risk (potency). In cancer risk assessment, the risk of a chemical exposure is the potency of the chemical multiplied by the concentration (risk = potency X concentration; EPA 1989). Solving for the concentration, the risk is divided by the potency (concentration = risk/potency). For this exercise, recall that the units for "Potency$[carcinogen]_{\text{air}}$" (formerly "IURF") are $(\mu g/m^3)^{-1}$. Inverting "Potency$[carcinogen]_{\text{air}}$" yields "$[carcinogen]_{\text{air}}$" and the appropriate units for an air concentration ($\mu g/m^3$):

$$[carcinogen]_{stampsand} = [carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[carcinogen]_{air} = [carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for arsenic (As): } [As]_{air} = \frac{[As]_{stampsand}}{PEF}$$

Thus, regardless of whether a chemical is a carcinogen or not, the air concentration of that chemical, as airborne stampsands, is calculated as the stampsand concentration divided by the PEF. Then, for this exercise, exposure assumptions and acceptable hazard or risk values are considered in determining whether the air concentration may be hazardous.

<u>Recommended Updates to PSIC Variables and Their Use in this Exercise</u>

The Michigan interagency Toxics Steering Group (TSG) is composed of toxicologists from MDEQ, MDCH, and the Michigan Department of Agriculture and Resource Development. The TSG provides a forum for discussion of human health risk assessment issues related to exposure to chemical contaminants in environmental media. In 2006, a TSG subcommittee was formed in response to identification of challenges associated with the application of the manganese PSIC at several facilities in Detroit, Michigan. The subcommittee evaluated the derivation of the manganese PSIC, which involved review of the variables used to derive the criteria. The results of this evaluation, along with recommendations for updating development of the criteria, were reported in 2009 (MDEQ 2009). Although not all recommendations have been adopted into MDEQ's regulatory process, as of this writing, MDCH chose to use the updated state of the

science in this exercise. The updated values mainly affect the parameter for emission due to vehicle traffic, Ev.

Particulate Emission Factor (PEF) Equation and Air Dispersion (Q/C) Factor
Several parameters affect the value of PEF (MDEQ 2007):

$$PEF = (Q/C) \times \frac{1}{[(Ew \times (1 - V)) + Ev]}$$

where PEF = the Particulate Emission Factor, which relates the concentration of a particulate contaminant in ambient air to the corresponding concentration of contaminant in soil (or, in this case, stampsands), in m^3/kg;
Q/C = an air dispersion factor, based on a site-specific source size, in grams per square meter-second per kilogram per cubic meter (g/m^2-sec per kg/m^3);
Ew = emission due to wind, in g/m^2-sec;
V = the source's vegetative cover, in percent; and
Ev = emission due to vehicle traffic, in g/m^2-sec.

The Q/C factor represents the dispersion of airborne contaminants. Air-dispersion modeling is used to estimate air concentrations of particulates released from soil (or a matrix other than soil). The model can use either default regional or local meteorological data to predict an air concentration (C) for various source sizes. Using a constant emission rate from the soil (Q), a table of Q/C values can be generated. (The generic PSIC value shown in the MDEQ Part 201 criteria tables [MDEQ 2011a, b] is for one-half acre. A modifier is applied to adjust this Q/C value for larger or smaller source sizes when a site-specific Q/C is not available [MDEQ 2007]).

The default value for V is 50% (MDEQ 2007).

The Ew and Ev factors are broken down further, as discussed in the following sections.

Emission Due To Wind (Ew) Assumptions and Calculation
Ew considers a mean annual wind speed, adjusted to a height of 7 meters (Um, in meters per second [m/sec]); a threshold friction velocity (the minimum wind velocity needed for soil [or other matrix] erosion [by wind] to occur), adjusted to a height of 7 meters (Ut_{adj}, in m/sec); and the mathematical function of a unitless variable (F[x]) derived from Cowherd et al. (1985) (MDEQ 2007).

The equation for Um is (MDEQ 2007):

$$Um = Um_{(z)} \times (7 / z)^{(0.15)}$$

where $Um_{(z)}$ = the mean annual wind speed at height z, in m/sec,
7 = the adjustment height, in m, and
z = wind speed measurement height, in m.

The equation for Ut_{adj} is (MDEQ 2007):

$$Ut_{adj} = ((U*t \times CF)/0.4) \times (\ln(7.0/z_0))$$

where U*t = the equivalent threshold friction velocity for a specified surface soil mode aggregate size (As, which can be the default value of 0.35 mm or derived from site-specific data), in m/sec;

CF = a unitless correction factor, with a default value of 1.25, for non-erodible elements (e.g. stones larger than 1 centimeter [cm] diameter, clumps of vegetation);

7 = the adjustment height, in m, and

z_0 = the roughness height, in m.

The variable derived from Cowherd et al. (1985) is designated "x," which is an adjusted ratio of the threshold friction velocity to the mean annual wind speed (MDEQ 2007):

$$x = 0.886 \frac{Ut_{adj}}{Um}$$

The function dependent on "x" is designated "F(x)." "F(x)" tends to 1.91 as "x" tends to zero, as seen in Figure 4-3 of Cowherd et al. (1985). The figure should be used to determine "F(x)" when "x" is less than 2. However, when "x" is greater than 2, "F(x)" is derived from the following equation (Cowherd et al. 1985):

$$F(x) = 0.18(8x^3 + 12x)\exp(-x^2)$$

The equation for Ew is (MDEQ 2007):

$$Ew = 0.036(U_m / Ut_{adj})^3 \times F(x)/3{,}600$$

where 0.036 = the default respirable fraction emission rate, in grams per square meter-hour (g/m^2-hr), and

3,600 = a conversion factor to convert hours to seconds (sec/hr).

The resulting units for Ew are g/m^2-sec.

<u>Emission Due To Vehicle Traffic (Ev) Assumptions and Calculation</u>

Ev considers vehicle factors, such as mean weight and speed of the vehicles using the area, and soil (or other matrix) factors, such as moisture and silt content. The first step in deriving Ev is calculating E_{10}, the emission factor for vehicles traveling on paved or unpaved roads, in kilogram of particulate matter less than 10 microns in aerodynamic diameter (PM10) per vehicle-kilometer travel (kg/Vkm). The equation for E_{10} of *unpaved* roads used for *industrial* purposes (versus residential or commercial) is (EPA 2006, MDEQ 2009):

$$E_{10} = k \times (s/12)^a \times (W/3)^b$$

where k = an industrial-road particle size multiplier for PM10, in pounds per vehicle mile;

s = the surface material silt content, in percent;

W = mean vehicle weight, in tons (note that the units for W are not inserted into the equation above: according to EPA [2006], s and W "are referred to as correction parameters for adjusting the emission estimate to local conditions"; as such, it is not necessary to include the units for W in the calculation exercise); and

a and b are constants used when considering PM10 generated from industrial roads.

Initially, the units for the above equation result in pound per vehicle-mile travel (lb/VM). Multiplying the product above by 0.454 kg/lb and 0.621 mile/km results in the kilograms per vehicle-kilometer travel (kg/Vkm) equivalent. E_{10} is then used to calculate the annual emissions, E, in kg/year. The equation for E is (MDEQ 2007):

$$E = E_{10} \times V \times L \times T \times 1/CF$$

where V = the number of trips or vehicles per day (note that this variable is different than the vegetative cover "V" in the PEF equation, described earlier), in vehicles/day;

L = the length of the driveway or road used, in m;

T = the time duration, in days per year (days/yr); and

CF = a conversion factor, converting km to m (1,000; note that this "CF" variable is different than the "CF" in the Ut_{adj} equation, described earlier).

E is used to derive Ev. The equation for Ev is (MDEQ 2007):

$$Ev = E \times 1/A \times (CF_1/CF_2)$$

where A = the size of the area from which emissions are expected to occur (this would usually be the roads on the site and not include buildings and other areas where vehicles would not go), in square meters (m^2);

CF_1 = a conversion factor, converting kg to grams (g) (1,000); and

CF_2 = a conversion factor, to convert years to seconds (sec) (31,500,000).

The resulting units for Ev are g/m^2-sec.

Site-Specific Particulate Emission Factor (PEF) Calculations

Site-specific values for the PEF calculation are shown in the following tables.

Table A- 1. Air dispersion factor (**Q/C**) value for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
Q/C	43.26 (g/m^2-sec per kg/m^3)	The MDEQ Air Quality Division's (AQD's) Modeling and Meteorology Unit conducted modeling for the Gay stampsands evaluation. The modeling covered the northern end of the site (see Figure 2), a total of about 84 acres (D. Mason, MDEQ AQD, personal communication, 2009). Because this value is site-specific, not a one-half acre source size, a modifier is not necessary.

Table A- 2. Exposure due to wind (**Ew**) variables and calculation for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
$Um_{(z)}$	4.34 (m/sec)	2004-2008 mean annual wind speed data from Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
z	7.92 (m)	Anemometer height at Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
Um	4.26 (m/sec)	Calculated from above values
U*t	0.50 (m/sec)	Approximated, for As of 0.521 mm (below), from Figure 3-4 in Cowherd et al. (1985)
CF	1.25 (unitless)	Default correction factor
As	0.521 (mm)	Average of the modes of 10 stampsand sieve analysis samples from Gay, Michigan (M. Petrie, MDEQ RRD, personal communication, 2003); the mode for eight of the 10 samples was 0.595 mm, the remaining two being 0.297 and 0.149 mm (data not shown)
z_0	0.005 (m)	Default value (MDEQ 2007); represents a surface between "natural snow" and "plowed field" (Cowherd et al. 1985)
Ut_{adj}	11.32 (m/sec)	Calculated from above values
x	2.354 (unitless)	Calculated from above values
F(x)	0.094 (unitless)	Calculated from above value
Ew	0.00000005 (g/m^2-sec)	Calculated from above values

Table A- 3. Vehicular erosion (**Ev**) variables and calculation for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
k	1.5 (lb/VM)	PM10 constant for unpaved industrial roads (EPA 2006)
s	1.2 (%)	Average silt content of 10 stampsand sieve analysis samples from Gay, Michigan (M. Petrie, MDEQ RRD, personal communication, 2003)
W	19 (tons)	Average between empty tandem-axle dump truck (13 tons) and loaded truck (25 tons) (G. Patrick, Keweenaw County Road Commission, personal communication, 2010)
a	0.9 (unitless)	PM10 constant for unpaved industrial roads (EPA 2006)
b	0.45 (unitless)	PM10 constant for unpaved industrial roads (EPA 2006)
E10	0.433 (lb/VM)	Calculated from above values
E10	0.122 (kg/VKm)	Converted from above
V (vehicles per day)	20 (V/day)	Assumes 20 total vehicle-trips per day
L	675 (m)	Approximation of total length of route shown in pink in Figure A-1, depicting a route walked by MDEQ staff along the lower edge of the pile (extent of excavation by the road commission and others; N. Ekel, MDEQ RRD, personal communication, 2011), about 0.4 mile (675 m)
T	100 (days/yr)	Assumes 20 days/month for 5 months/year
CF	1,000 (m/km)	Conversion factor
E	165 (kg/yr)	Calculated from above values
A	1,620 (sqm)	Length of route (L, above) times width of truck (8 feet or 2.4 m)
CF_1	1,000 (g/kg)	Conversion factor
CF_2	31,500,000 (sec/yr)	Conversion factor
Ev	0.00000323 (g/m^2-sec)	Calculated from above values

For this exercise, vegetative cover (V) is assumed to be 0%. Nothing appears to be growing on the Gay stampsands in the area south of the concrete sluiceway (green line in Figure A-1). Trucks would not be expected to use the area north of the sluiceway.

Thus, the PEF calculation for the Gay stampsands, when the vehicle traffic is heavy trucks, is:

$$PEF_{Gay(trucks)} = 43.26 \times \frac{1}{0.00000005 \times (1-0) + 0.00000323} = 13{,}200{,}000 m^3 / kg$$

Figure A- 1. Map of "northern study area" at Gay stampsands area, Gay (Keweenaw County), Michigan. (1997; source: MDEQ)

Uncertainty Discussion, Sensitivity Analysis for, and Confidence in Selected PEF Variables

This section discusses the uncertainty of selected PEF variables and shows how the use of default or other values for certain parameters would change the results for the estimated air concentrations. This section does *not* discuss uncertainty within default values that were used.

Air Dispersion Factor (Q/C)

The Q/C value used in this exercise (43.26 g/m^2-sec per kg/m^3) was derived from modeling that relied on data from the meteorological station at the Houghton County Memorial Airport in Hancock, Michigan (Figure 1). If the generic Q/C value had been used (82.33 g/m^2-sec per kg/m^3 for a ½-acre source size [MDEQ 2007], derived from an older modeling program and using meteorological data from three Michigan cities [MDEQ 2009]) and a modifier applied (that for a 100-acre source being 0.43 [MDEQ 2007]), the resulting applicable Q/C would have been about 35.4 g/m^2-sec per kg/m^3. That is less than the site-specific value used and would have resulted in a lower PEF, which would result in higher estimated air concentrations.

Mean Annual Wind Speed [$Um_{(z)}$] and Measurement Height (z)

Data from the airport in Hancock also supplied the $Um_{(z)}$ and z values used in this exercise (4.34 m/sec and 7.92 m, respectively). If the default $Um_{(z)}$ and default height (z) had been used (4.56 m/sec and 6.4 m, respectively), the resulting PEF would have been lower, which would result in higher estimated air concentrations.

Surface Soil Mode Aggregate Size (As)

The As value of 0.521 mm may have been biased low. The protocol for conducting sieve analyses to determine As indicates that the sieves should be shaken by hand, not mechanically, when determining aggregate size (Cowherd et al. 1988). Mechanical sifting is used for determining silt content (EPA 1993b). Since the Gay samples were shaken only by machine (M. Petrie, MDEQ RRD, personal communication, 2010), agglomerates that normally would not have been subject to wind erosion likely broke apart in the sieves. Therefore, the true As value may actually be higher, between a #30 and #8 sieve (the largest sizes reported for the analyses, which are between 0.595 and 2.36 mm, respectively [J. Pincombe, MDEQ RRD, personal communication, 2009]). If the As value had actually been within the higher range (midpoint equals 1.48 mm), then the resulting U*t and PEF would have been higher and the estimated air concentrations lower. If the As value had been the MDEQ (2007) default value of 0.35 mm, then the resulting U*t and PEF would have been lower, which would result in higher estimated air concentrations. Future sieving to determine As should be done by hand.

*Equivalent Threshold Friction Velocity (U*t)*

The U*t value was based on the As value, discussed above. Therefore, the uncertainty for As would also affect U*t, as was discussed in the previous section. In addition, U*t was approximated visually from a graph in Cowherd et al. (1985) rather than calculated from a regression equation that would fit the curve of the graph. (Such an equation was not available.) This imprecise measurement introduces further uncertainty.

Silt Content (s)

The samples that were subjected to sieve analysis may not be representative of the majority of the stampsands at Gay. The s value of 1.2% reflects an average of 10 samples collected about 50

feet south of and parallel to the concrete sluiceway at the north end of the stampsands (green line in Figure A-1). The sample locations were not geocoded and, therefore, not mapped (A. Keranen, MDEQ RRD, personal communication, 2011). The entire stretch of the Gay stampsands, from the town of Gay to the Traverse River outlet, covers up to 411 acres, as determined in 2001 (USACE 2001). The sampling area was less than one quarter acre. The sands have eroded over time (see 1938 versus 1998 shoreline comparison in Figure A-2). It is likely that wind and wave action have caused a greater degree of dispersion to finer stampsands as compared to the coarser grains, at least for surficial tailings. However, deeper deposits may have a greater silt content since they were exposed to the elements only for a limited time before being covered by more stampsands. More discussion on the fate and transport of stampsands at Gay is in USACE (2001) and Kerfoot et al. (1994).

If the s value had been the MDEQ (2007) default value of 15% (i.e., containing more silt), then the resulting PEF would have been lower, which would result in higher estimated air concentrations. (Stampsands applied off-site for road traction material would likely have a higher silt content if sampled from roadways, due to the traffic grinding the stampsands into finer particles. This is discussed in Appendix C.) It may be necessary to use a higher s value as a protective measure when evaluating health impacts of inhalation stampsands at Gay, especially those that currently are at depth.

Combined Sensitivity Analysis

If all of the default values discussed in this section, including the adjusted generic Q/C, were used in place of the site-specific values, the resulting PEF would have been lower by about one order of magnitude (a factor of 10), which would result in higher estimated air concentrations.

Confidence

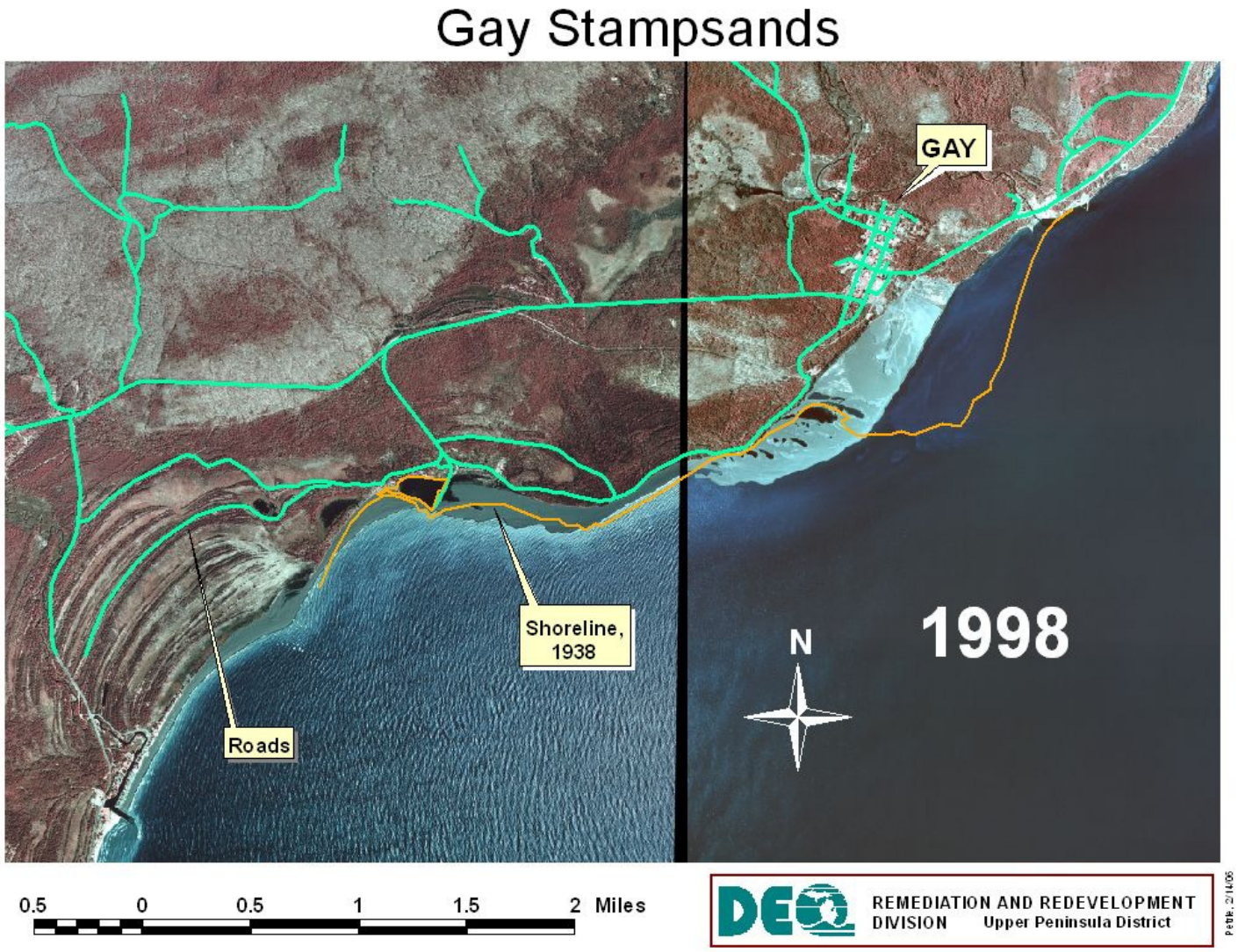
The confidence in the appropriateness of the values discussed here is medium to high. Most of the values are based on extensive site-specific data; however, the mode aggregate size (As) and silt content (s) are based on limited data.

Stampsand Concentration Data

Staff from the MDEQ Remediation and Redevelopment Division (RRD) collected stampsands at the Gay site in September 2003. They took a total of 274 samples at various depths in 63 locations in the northern deposit area (Figures 2 and A-1). The northern deposit area is closest to the former conveyor that was used to transport sands into Lake Superior during the stamp mill's operation. Thus it is believed to be the oldest, least disturbed location at Gay, with the highest likelihood of being accessible for excavation. During this field work, RRD staff also collected 24 surficial stampsand samples from the southern deposit area, near the Traverse River outlet (Figure 2). This area represents the stampsand that has accumulated after being eroded from the main deposit (MDEQ 2004a, Weston 2006a).

The stampsands were analyzed for the following metals: aluminum, arsenic, beryllium, chromium, cobalt, copper, lead, lithium, manganese, mercury, nickel, silver, strontium, and zinc.

Figure A- 2. Map of Gay (Keweenaw County), Michigan, stampsands and vicinity in 1998 with 1938 shoreline (orange line) superimposed. (1988; source: MDEQ)



The 95% Upper Confidence Limits of the mean concentrations (95 UCLs; a statistical value that represents an upper estimate of the true mean) are shown in Table A-4. The results for all depths at the northern area, not just surficial, are considered in this exercise because, as shallower depths are removed during excavation or erosion, the deeper depths are exposed and become available for inhalation. (The southern area will be considered only if the results for the northern area raise a concern. This is because, since the stampsand concentrations are lower in the southern area and less finer-grained material would be present [USACE 2001, Kerfoot et al. 1994], estimated air concentrations would also be lower than in the northern area.)

Table A- 4. 95% Upper Confidence Limits of the mean concentrations (95UCLs) of selected metals in stampsand samples taken September 2003 in Gay (Keweenaw County), Michigan. (Results are in micrograms per kilogram [µg/kg].)

Metal	**Northern 95UCL**	**Southern 95UCL**
Aluminum	15,872,000	11,791,000
Arsenic	2,700	1,600
Beryllium	480	460
Chromium	29,000	29,000
Cobalt	23,000	19,000
Copper	2,972,000	1,713,000
Lead	2,600	not detected (ND)
Lithium	6,200	5,800
Manganese	549,000	407,000
Mercury	28	ND
Nickel	31,000	27,000
Silver	1,800	1,300
Strontium	17,000	13,000
Zinc	75,000	66,000

Reference: Weston 2006a

Air Concentration Calculations

The estimated air concentrations for the metals in the Gay stampsands are the respective concentrations within the stampsands divided by the PEF. Table A-5 shows the expected air concentrations for the metals in the northern area.

The air concentrations in Table A-5 assume that exposure is occurring 24 hours/day, 365 days/year. As stated at the beginning of this exercise, it is assumed that a worker would only be exposed 20 days/month, five months/year, which is 100 days/year. (Although wind erosion would still occur, the exercise assumes that exposure is occurring to an on-site truck driver. If the truck driver is not present, this specific exposure scenario is not occurring and wind erosion is a moot point.) Therefore, each air concentration shown in Table A-5 is adjusted by 100/365, or 0.27, to account for the less frequent exposure. The estimated exposure-specific time-weighted average air concentrations are shown in Table A-6.

Table A- 5. Estimated air concentrations of selected metals in stampsands in the northern area at Gay (Keweenaw County), Michigan.

Metal	Stampsand Concentration (µg/kg)	PEF (m^3/kg)	Air Concentration[A] (µg/m^3)
Aluminum	15,872,000	13,200,000	1.2
Arsenic	2,700	13,200,000	0.0002
Beryllium	480	13,200,000	0.00004
Chromium	29,000	13,200,000	0.002
Cobalt	23,000	13,200,000	0.002
Copper	2,972,000	13,200,000	0.2
Lead	2,600	13,200,000	0.0002
Lithium	6,200	13,200,000	0.0005
Manganese	549,000	13,200,000	0.04
Mercury	28	13,200,000	0.000002
Nickel	31,000	13,200,000	0.002
Silver	1,800	13,200,000	0.0001
Strontium	17,000	13,200,000	0.001
Zinc	75,000	13,200,000	0.006

Acronyms:

µg/kg micrograms per kilogram
m^3/kg cubic meters per kilogram
µg/m^3 micrograms per cubic meter
PEF Particulate Emission Factor

Note:

A. Calculation assumes exposure is occurring 24 hours/day, 365 days/year.

Table A- 6. Estimated exposure-specific time-weighted average (based on on-site exposure assumptions) air concentrations of selected metals in stampsands in the northern area at Gay (Keweenaw County), Michigan.

Metal	Estimated Air Concentration (µg/m^3)[A]
Aluminum	0.3
Arsenic	0.00006
Beryllium	0.00001
Chromium	0.0006
Cobalt	0.0005
Copper	0.06
Lead	0.00005
Lithium	0.0001
Manganese	0.01
Mercury	0.0000006
Nickel	0.0006
Silver	0.00004
Strontium	0.0003
Zinc	0.002

Acronym:

µg/kg micrograms per kilogram

Note:

A. Time-weighted calculation assumes exposure is occurring 20 days/month, five months/year.

Comparison of Estimated Air Concentrations to Health-Based Screening Values

To determine whether the exposure-specific time-weighted average air concentration might be harmful, MDCH compared the concentration to a health-based number, prioritizing the screening values as follows:

1. The first choice of a comparison value to use was the EPA Reference Concentration (RfC). This is a regulatory number that is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is not likely to cause harm in a person's lifetime (EPA 2010b). Lead does not have an RfC but, as a "criteria" pollutant (per the Clean Air Act), has a National Ambient Air Quality Standard (NAAQS), which is a regulatory number and was used as a comparison value here. Primary standards set limits to protect public health, including sensitive populations (asthmatics, children, elderly; EPA 2011b).
2. If an RfC or NAAQS was not available for a chemical, then MDCH used a Comparison Value (CV) derived by the federal Agency for Toxic Substances and Disease Registry (ATSDR), if available. CVs are not regulatory numbers but advisory levels. For non-carcinogenic chemicals in soil, water or air, ATSDR derives Environmental Media Evaluation Guides (EMEGs). Chronic air EMEGs (based on Minimal Risk Levels [MRLs]) are similar in derivation to the RfCs but, due to differing interpretations and risk assessment practices between the agencies, may result in a different value. For carcinogenic chemicals in soil, water or air, ATSDR derives Cancer Risk Evaluation Guides (CREGs). These are different from the Inhalation Unit Risk Factors (IURFs) discussed earlier in this appendix, wherein the CREGs are not potencies but, rather, are concentrations of a chemical that result in a one-in-one-million increased cancer risk (ATSDR 2005).
3. If neither an RfC nor a CV were available, then MDCH used the occupational Recommended Exposure Limit (REL), as established by the National Institute for Occupational Safety and Health (NIOSH). These health-based, non-regulatory values are Time-Weighted Averages (TWAs) for up to a 10-hour workday during a 40-hour workweek (NIOSH 2006). Because RELs are not 24-hour exposure numbers, they can be much higher than RfCs and CVs. In the past, MDCH has used Acute Exposure Guideline Levels (AEGLs) to consider risks of short-term exposures. AEGLs address emergency exposures to the public for 10 minutes to eight hours and are usually more protective (lower) than occupational limits (EPA 2010a). However, no AEGLs were available for the metals that did not have RfCs or CVs.
4. Lithium and strontium did not have RfCs, CVs, or RELs available. They are discussed later in this section.

The REL screening values may not be adequately protective for non-occupational populations. The ratio between the estimated air concentration of a metal, in this exercise, and its REL ranges from five to six orders of magnitude (100,000 to 1,000,000 times; see Table A-7). When deriving an RfC or MRL, agencies apply uncertainty factors (UFs) to experimental data to estimate a protective value for public exposure. The value of a UF is typically 1, 3 or 10, and is applied to account for animal data to human extrapolation, inter-individual differences in humans, extrapolating less-than-lifetime exposure to lifetime exposure, extrapolating from a study without a no-effect level, and an inadequate database (EPA 2002). If the maximum UF for each consideration except animal-data-to-human were applied to an REL, the total UF would be

Table A- 7. Comparison between calculated and acceptable margins of safety for airborne stampsands at Gay (Keweenaw County), Michigan.

Metal	Estimated Air Concentration (µg/m^3)	Screening Value (µg/m^3)	"Calculated Margin" (unitless)	"Acceptable Margin" (unitless)
Aluminum	0.3	10,000 [A]	0.00003	0.5
Arsenic	0.00006	0.0002 [B]	0.3	0.5
Beryllium	0.00001	0.0004 [B]	0.02	0.5
Chromium	0.0006	0.00008 [B,C]	7.5	0.5
Cobalt	0.0005	0.1 [D]	0.005	0.5
Copper	0.06	1,000 [A]	0.00006	0.5
Lead	0.00005	0.15[E]	0.000001	0.5
Lithium	0.0001	NA	NC	0.5
Manganese	0.01	0.05 [F]	0.2	0.5
Mercury	0.0000006	0.3 [F]	0.000002	0.5
Nickel	0.0006	0.09 [D]	0.007	0.5
Silver	0.00004	10 [A]	0.000004	0.5
Strontium	0.0003	NA	NC	0.5
Zinc	0.002	5,000 [A]	0.0000003	0.5

Acronyms:

µg/m^3	micrograms per cubic meter	CREG	Cancer Risk Evaluation Guide
EMEG	Environmental Media Evaluation Guide	NA	not available
NAAQS	National Ambient Air Quality Standard	NC	not calculated
REL	Recommended Exposure Limit	RfC	Reference Concentration

Notes:

A. REL
B. CREG
C. Value is for hexavalent chromium.
D. Chronic air EMEG
E. NAAQS
F. RfC

10,000, which is smaller than the minimum ratio between the estimated air concentration and its REL in this exercise. This suggests that an adequate margin of safety exists between estimated and acceptable (REL screening values) exposures in this exercise.

If the exposure-specific time-weighted average air concentration, which is the expected exposure, is divided by the screening value, the resulting ratio indicates the extent of exposure. The smaller the quotient is, compared to 1 (meaning expected exposure is less than the screening value), the larger the margin of safety. This "Calculated Margin" assumes that people are exposed to the chemical only at the site and nowhere else. This assumption may not be appropriate for the Gay stampsands because they have been used for many years as road-traction material on winter roads. Stampsands can remain for some time on the roadways, though they will, for the most part, settle eventually onto the shoulders of the roads. However, they still can become resuspended in air and people can be exposed to them. To compensate for this possibility, MDCH chose an "Acceptable Margin" of 0.5 instead of 1. (This rationale is similar to that used for Relative Source Contribution factors used for drinking water and soil evaluations

[MDEQ 2004b, 2005].) The comparison between "Calculated Margins" and "Acceptable Margins" is shown in Table A-7.

Although the "Calculated Margin" for chromium is 7.5, well above the "Acceptable Margin," the screening value used is for the hexavalent (VI) form of the metal. In most environmental situations, however, the less toxic, trivalent form (chromium III) predominates (Kimbrough et al. 1999, ATSDR 2000a). Therefore, one would not expect the hexavalent form to occur in the stampsands. There is no RfC, EMEG, or CREG for chromium III. The REL for chromium metal and chromium III compounds is 500 $\mu g/m^3$ (NIOSH 2006), which is six orders of magnitude greater than the estimated air concentration. Chromium in airborne stampsands in this occupational scenario is not expected to cause harm.

Only the ratios for arsenic and manganese are within an order of magnitude of the "Acceptable Margin," about one-half the value. Arsenic and manganese are discussed further in the *Toxicological Evaluation* section in this document.

Lithium and strontium do not have RfCs, NAAQS, CVs, or RELs. They are discussed further in the *Toxicological Evaluation* section in this document.

Considering Acute Exposures

Empirical evidence from state-wide air monitors indicate that ambient peak PM10 levels measured over 24-hour periods were roughly twice the annual average concentration (MDEQ 2009). (The MDEQ database did not indicate what attributed to the peak air concentrations.) Thus, multiplying the estimated air concentration by 2 would result in expected peak, or acute, exposure levels of PM10 metals in the air at Gay. Most of these concentrations would still be well below the health-based screening values used in Table A-7. Although the Calculated Margins for arsenic and manganese would increase to 0.6 and 0.4, respectively, the estimated acute air concentration is being compared to a chronic screening value. (Chronic screening levels, such as the RfC and EMEG or CREG, are more protective [lower] than acute screening levels.) Therefore, short-term acute exposure situations are not expected to cause harm.

Conclusions

Based on the values used in this exercise, some of which are site-specific data-based values whereas others are default assumptions, the estimated exposure-specific time-weighted average concentrations of selected metals at the Gay stampsands would not be expected to cause harm in the short or long term to a worker during on-site heavy truck use. If new information becomes available that would change the values, re-evaluation may be necessary. This exercise can inform and guide future risk assessments that evaluate contaminated airborne soil or stampsands.

Appendix B. Estimating Air Concentrations of Metals as Particulate Matter at the Gay Stampsands Site in Michigan – Recreational Vehicle Use

Assumed Exposure Scenario at Gay

The following exercise estimates air concentrations of stampsand-related chemicals expected at the large tailing pile at Gay, Michigan when recreational vehicles (trucks, motorcycles, off-road vehicles) are on the site. The exercise applies exposure assumptions of 10 vehicle-trips three times per day on the stampsands for 15 days per month, five months out of the year. The exercise also assumes that the same persons are exposed to those conditions for 10 years. (Although there may be different persons using the area at different times, this assumption allows a protective estimate.)

Basic PSIC Equations

The Michigan Department of Environmental Quality (MDEQ) Particulate Soil Inhalation Criteria (PSIC) identify concentrations of hazardous substances in soil that are not expected to create ambient air concentrations of contaminated particulates that would, in turn, cause adverse human health effects via inhalation. Soils can become resuspended by wind or vehicular erosion. One must consider, among other parameters, source size, vegetative cover, wind speed, and vehicle use of the area (MDEQ 2007).

The algorithm used to calculate an acceptable soil concentration of a non-carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{nc} = \frac{THQ \times AT_{nc}}{EF \times ED \times (1/ITSL \times 1/(PEF/2))}$$

The algorithm used to calculate an acceptable soil concentration of a carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{ca} = \frac{TR \times AT_{ca} \times AIR}{IURF \times EF \times ED \times (1/PEF)}$$

where PSIC = the soil criterion, given in micrograms of chemical per kilogram soil (µg/kg) or parts per billion (ppb);

nc = non-carcinogenic chemical

ca = carcinogenic chemical

THQ = target hazard quotient, the ratio of the expected dose to the acceptable dose, and is unitless;

TR = target cancer risk (the number of excess cancers expected due to exposure to the chemical), which is 1 in 100,000 (1E-05) and is unitless;

AT_{nc} the averaging time for non-carcinogens, which is the years of exposure duration times the number of days of exposure per year, in days;

AT_{ca} the averaging time for carcinogens, which is considered to be a lifetime

(70 years), in days (25,550 days);

AIR = adjusted inhalation rate; assumes a worker breathes twice as much air during a 24-hour day versus a non-worker; value is 2 (20 cubic meters per day [m^3/day] / 10 m^3/day); used only for carcinogens when considering industrial or commercial exposure scenarios;

EF = the exposure frequency, given in days/year;

ED = the exposure duration, given in years;

ITSL = the MDEQ Initial Threshold Screening Level, the acceptable air concentration of the chemical, in micrograms of chemical per cubic meter air ($\mu g/m^3$);

IURF = the MDEQ Inhalation Unit Risk Factor, the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at 1 $\mu g/m^3$ concentration in air; units are $(\mu g/m^3)^{-1}$;

PEF = the Particulate Emission Factor, specific for source size, in m^3/kg. The divisor of 2 for non-carcinogenic chemicals is used when the averaging time for the ITSL is less than annual, in order to achieve an appropriately protective PSIC.

Note that values given for the parameters described above are default values. Values specific for this exercise are discussed in later sections of this appendix (see Tables B-1, B-2, and B-3).

Solving for Expected Air Concentrations

For this exercise, the algorithms above will be rearranged and the risk-assessment parameters (EF, ED, THQ, TR, AT, and AIR) removed to estimate an expected air concentration based on soil concentration data. Risk-assessment parameters will be considered at a later point in this appendix. For the purposes of this exercise (estimating expected air concentrations), the divisor of 2 for the PEF for non-carcinogenic chemicals is removed.

To start, note that the PSIC criteria are specific for soils and cannot be used when discussing stampsands, which are not soil but a mining by-product. Therefore, rather than use acronyms with specific regulatory meanings ("ITSL," "PSIC," and "IURF"), the Michigan Department of Community Health (MDCH) is using the following substitutions:

For "ITSL," substitute "[*non-carcinogen*]$_{air}$", meaning "concentration of 'non-carcinogenic chemical X' in air"

For "PSIC," substitute "[*chemical name*]$_{stampsand}$", meaning "concentration of 'chemical X' in stampsand"

For "IURF," substitute "Potency[*carcinogen*]$_{air}$", meaning the "estimated upper-bound excess lifetime cancer risk resulting from continuous exposure to an airborne carcinogen at a concentration of 1 $\mu g/m^3$"

Solving for [*non-carcinogen*]$_{stampsand}$, the resulting equation, without risk-assessment parameters, is:

$$[non-carcinogen]_{stampsand} = \frac{1}{1/[non-carcinogen]_{air} \times 1/PEF} = [non-carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[non-carcinogen]_{air} = [non-carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for manganese (Mn):} \quad [Mn]_{air} = \frac{[Mn]_{stampsand}}{PEF}$$

Solving for $[carcinogen]_{\text{stampsand}}$, the resulting equation, without risk-assessment parameters, is:

$$[carcinogen]_{stampsand} = \frac{1}{Potency[carcinogen]_{air} \times 1/PEF} = \frac{1}{Potency[carcinogen]_{air}} \times PEF$$

The carcinogen equation needs further adjusting to reach an air concentration, versus an excess cancer risk (potency). In cancer risk assessment, the risk of a chemical exposure is the potency of the chemical multiplied by the concentration (risk = potency X concentration; EPA 1989). Solving for the concentration, the risk is divided by the potency (concentration = risk/potency). For this exercise, recall that the units for "Potency$[carcinogen]_{\text{air}}$" (formerly "IURF") are $(\mu g/m^3)^{-1}$. Inverting "Potency$[carcinogen]_{\text{air}}$" yields "$[carcinogen]_{\text{air}}$" and the appropriate units for an air concentration ($\mu g/m^3$):

$$[carcinogen]_{stampsand} = [carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[carcinogen]_{air} = [carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for arsenic (As):} \quad [As]_{air} = \frac{[As]_{stampsand}}{PEF}$$

Thus, regardless of whether a chemical is a carcinogen or not, the air concentration of that chemical, as airborne stampsands, is calculated as the stampsand concentration divided by the PEF. Then, for this exercise, exposure assumptions and acceptable hazard or risk values are considered in determining whether the air concentration may be hazardous.

<u>Recommended Updates to PSIC Variables and Their Use in this Exercise</u>

The Michigan interagency Toxics Steering Group (TSG) is composed of toxicologists from MDEQ, MDCH, and the Michigan Department of Agriculture and Resource Development. The TSG provides a forum for discussion of human health risk assessment issues related to exposure to chemical contaminants in environmental media. In 2006, a TSG subcommittee was formed in response to identification of challenges associated with the application of the manganese PSIC at several facilities in Detroit, Michigan. The subcommittee evaluated the derivation of the manganese PSIC, which involved review of the variables used to derive the criteria. The results of this evaluation, along with recommendations for updating development of the criteria, were reported in 2009 (MDEQ 2009). Although not all recommendations have been adopted into MDEQ's regulatory process, as of this writing, MDCH chose to use the updated state of the

science in this exercise. The updated variables mainly affect the parameter for emission due to vehicle traffic, Ev.

Particulate Emission Factor (PEF) Equation and Air Dispersion (Q/C) Factor
Several parameters affect the value of PEF (MDEQ 2007):

$$PEF = (Q/C) \times \frac{1}{[(Ew \times (1 - V)) + Ev]}$$

where PEF = the Particulate Emission Factor, which relates the concentration of a particulate contaminant in ambient air to the corresponding concentration of contaminant in soil (or, in this case, stampsands), in m^3/kg;
Q/C = an air dispersion factor, based on a site-specific source size, in grams per square meter-second per kilogram per cubic meter (g/m^2-sec per kg/m^3);
Ew = emission due to wind, in g/m^2-sec;
V = the source's vegetative cover, in percent; and
Ev = emission due to vehicle traffic, in g/m^2-sec.

The Q/C factor represents the dispersion of airborne contaminants. Air-dispersion modeling is used to estimate air concentrations of particulates released from soil (or a matrix other than soil). The model can use either default regional or local meteorological data to predict an air concentration (C) for various source sizes. Using a constant emission rate from the soil (Q), a table of Q/C values can be generated. (The generic PSIC value shown in the MDEQ Part 201 criteria tables [MDEQ 2011a, b] is for one-half acre. A modifier is applied to adjust this Q/C value for larger or smaller source sizes when a site-specific Q/C is not available [MDEQ 2007]).

The default value for V is 50% (MDEQ 2007).

The Ew and Ev factors are broken down further, as discussed in the following sections.

Emission Due To Wind (Ew) Assumptions and Calculation
Ew considers a mean annual wind speed, adjusted to a height of 7 meters (Um, in meters per second [m/sec]); a threshold friction velocity (the minimum wind velocity needed for soil [or other matrix] erosion [by wind] to occur), adjusted to a height of 7 meters (Ut_{adj}, in m/sec); and the mathematical function of a unitless variable (F[x]) derived from Cowherd et al. (1985) (MDEQ 2007).

The equation for Um is (MDEQ 2007):

$$Um = Um_{(z)} \times (7 / z)^{(0.15)}$$

where $Um_{(z)}$ = the mean annual wind speed at height z, in m/sec,
7 = the adjustment height, in m, and
z = wind speed measurement height, in m.

The equation for Ut_{adj} is (MDEQ 2007):

$$Ut_{adj} = ((U*t \times CF)/0.4) \times (\ln(7.0/z_0))$$

where U*t = the equivalent threshold friction velocity for a specified surface soil mode aggregate size (As, which can be the default value of 0.35 mm or derived from site-specific data), in m/sec;

CF = a unitless correction factor, with a default value of 1.25, for non-erodible elements (e.g. stones larger than 1 centimeter [cm] diameter, clumps of vegetation);

7 = the adjustment height, in m, and

z_0 = the roughness height, in m.

The variable derived from Cowherd et al. (1985) is designated "x," which is an adjusted ratio of the threshold friction velocity to the mean annual wind speed (MDEQ 2007):

$$x = 0.886 \frac{Ut_{adj}}{Um}$$

The function dependent on "x" is designated "F(x)." "F(x)" tends to 1.91 as "x" tends to zero, as seen in Figure 4-3 of Cowherd et al. (1985). The figure should be used to determine "F(x)" when "x" is less than 2. However, when "x" is greater than 2, "F(x)" is derived from the following equation (Cowherd et al. 1985):

$$F(x) = 0.18(8x^3 + 12x)\exp(-x^2)$$

The equation for Ew is (MDEQ 2007):

$$Ew = 0.036(U_m / Ut_{adj})^3 \times F(x)/3{,}600$$

where 0.036 = the default respirable fraction emission rate, in grams per square meter-hour (g/m^2-hr), and

3,600 = a conversion factor to convert hours to seconds (sec/hr).

The resulting units for Ew are g/m^2-sec.

<u>Emission Due To Vehicle Traffic (Ev) Assumptions and Calculation</u>

Ev considers vehicle factors, such as speed of the vehicles using the area, and soil factors, such as moisture and silt content. The first step in deriving Ev is calculating E_{10}, the emission factor for vehicles traveling on paved or unpaved roads, in kilogram of particulate matter less than 10 microns in aerodynamic diameter (PM10) per vehicle-kilometer travel (kg/Vkm). The equation for E_{10} of *publicly accessible unpaved* roads used primarily by *light-duty vehicles* (such as recreational vehicles) is (EPA 2006, MDNRE 2009):

$$E_{10} = \frac{k \times (s/12)^a \times (S/30)^d}{(M/0.5)^c} - C$$

where k = a public-road particle size multiplier for PM10, in pounds per vehicle mile;
s = the surface material silt content, in percent;
S = mean vehicle speed, in miles per hour (mph; note that the units for S are not inserted into the equation above, since S serves to adjust the emission estimate to site-specific conditions; as such, it is not necessary to include the units in the calculation exercise);
M = surface material moisture content, in percent;
C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear, in pound per vehicle-miles travel (lb/VM); and
a,c and d are constants used when considering PM10 generated from public roads.

Initially, the units for the above equation result in pound per vehicle-mile travel (lb/VM). Multiplying the product above by 0.454 kg/lb and 0.621 mile/km results in the kilograms per vehicle-kilometer travel (kg/Vkm) equivalent. E_{10} is then used to calculate the annual emissions, E, in kg/year. The equation for E is (MDEQ 2007):

$$E = E_{10} \times V \times L \times T \times 1/CF$$

where V = the number of trips or vehicles per day (note that this variable is different than the vegetative cover "V" in the PEF equation, described earlier), in vehicles/day;
L = the length of the driveway or road used, in m;
T = the time duration, in days per year (days/yr); and
CF = a conversion factor, converting km to m (1,000; note that this "CF" variable is different than the "CF" in the Ut_{adj} equation, described earlier).

E is used to derive Ev. The equation for Ev is (MDEQ 2007):

$$Ev = E \times 1/A \times (CF_1/CF_2)$$

where A = the size of the area from which emissions are expected to occur (this would usually be the roads on the site and not include buildings and other areas where vehicles would not go), in square meters (m^2);
CF_1 = a conversion factor, converting kg to grams (g) (1,000); and
CF_2 = a conversion factor, to convert years to seconds (sec) (31,500,000).

The resulting units for Ev are g/m^2-sec.

Site-Specific Particulate Emission Factor (PEF) Calculations

Site-specific values for the PEF calculation are shown in the following tables.

Table B- 1. Air dispersion factor (**Q/C**) value for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
Q/C	43.26 (g/m^2-sec per kg/m^3)	The MDEQ Air Quality Division's (AQD's) Modeling and Meteorology Unit conducted modeling for the Gay stampsands evaluation. The modeling covered the northern end of the site (see Figure 2), a total of about 84 acres (D. Mason, MDEQ AQD, personal communication, 2009). Because this value is site-specific, not a one-half acre source size, a modifier is not necessary.

Table B- 2. Exposure due to wind (**Ew**) variables and calculation for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
$Um_{(z)}$	4.34 (m/sec)	2004-2008 mean annual wind speed data from Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
z	7.92 (m)	Anemometer height at Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
Um	4.26 (m/sec)	Calculated from above values
U*t	0.50 (m/sec)	Approximated, for As of 0.521 mm (below), from Figure 3-4 in Cowherd et al. (1985)
CF	1.25 (unitless)	Default correction factor
As	0.521 (mm)	Average of the modes of 10 stampsand sieve analysis samples from Gay, Michigan (M. Petrie, MDEQ RRD, personal communication, 2003); the mode for eight of the 10 samples was 0.595 mm, the remaining two being 0.297 and 0.149 mm (data not shown)
z_0	0.005 (m)	Default value (MDEQ 2007); represents a surface between "natural snow" and "plowed field" (Cowherd et al. 1985)
Ut_{adj}	11.32 (m/sec)	Calculated from above values
x	2.354 (unitless)	Calculated from above values
F(x)	0.094 (unitless)	Calculated from above value
Ew	0.00000005 (g/m^2-sec)	Calculated from above values

Table B- 3. Vehicular erosion (**Ev**) variables and calculation for evaluation of stampsands in Gay (Keweenaw County), Michigan.

Variable	Value (Units)	Discussion
k	1.8 (lb/VM)	PM10 constant for unpaved, publicly accessible roads used by light-duty vehicles (EPA 2006)
s	1.2 (%)	Average silt content of 10 stampsand sieve analysis samples from Gay, Michigan (M. Petrie, MDEQ RRD, personal communication, 2003)
S	33.3 (mph)	Assumes traffic evenly divided between light four-wheel-drive trucks at a mean (average) speed of 35 mph, off-road vehicles ("quads") at 25 mph, and motorcycles at 40 mph
M	5 (%)	Worst-case scenario, derived from stampsand analyses for Gay, Michigan (J. Pincombe, MDEQ RRD, personal communication, 2009)
C	0.00047 (lb/VM)	PM10 default value for unpaved, publicly accessible roads used by light-duty vehicles (EPA 2006)
a	1 (unitless)	PM10 constant for unpaved, publicly accessible roads used by light-duty vehicles (EPA 2006)
c	0.2 (unitless)	PM10 constant for unpaved, publicly accessible roads used by light-duty vehicles (EPA 2006)
d	0.5 (unitless)	PM10 constant for unpaved, publicly accessible roads used by light-duty vehicles (EPA 2006)
E10	0.119 (lb/VM)	Calculated from above values
E10	0.034 (kg/VKm)	Converted from above
V (vehicles per day)	30 (V/day)	Assumes 10 vehicles conducting 3 trips per day
L	1,828 (m)	Assumes each vehicle is driven the entire length of the northern area (see Figure 2), about 3,000 feet, and returns (914 m X 2 = 1,828 m)
T	75 (days/yr)	Assumes 15 days/month for 5 months/year
CF	1,000 (m/km)	Conversion factor
E	138 (kg/yr)	Calculated from above values
A	2,315 (sqm)	Length of route (L, above) times average of width of light four-wheel-drive truck (about 6 feet or 1.8 m), quad (about 4 feet or 1.2 m), and motorcycle (about 2.5 feet or 0.8 m); average is about 1.3 m
CF_1	1,000 (g/kg)	Conversion factor
CF_2	31,500,000 (sec/yr)	Conversion factor
Ev	0.00000189 (g/m^2-sec)	Calculated from above values

For this exercise, vegetative cover (V) is assumed to be 0%. Nothing appears to be growing on the Gay stampsands in the area south of the concrete sluiceway (green line in Figure B-1). Recreational vehicles would not be expected to use the area north of the sluiceway.

Thus, the PEF calculation for the Gay stampsands, when the vehicle traffic is dominated by light-duty (recreational) vehicles, is:

$$PEF_{Gay(recreational)} = 43.26 \times \frac{1}{0.00000005 \times (1-0) + 0.00000189} = 22{,}200{,}000 m^3 / kg$$

<u>Uncertainty Discussion, Sensitivity Analysis for, and Confidence in Selected PEF Variables</u>
This section discusses the uncertainty of selected PEF variables and shows how the use of default or other values for certain parameters would change the results for the estimated air concentrations. This section does *not* discuss uncertainty within default values that were used.

Air Dispersion Factor (Q/C)

The Q/C value used in this exercise (43.26 g/m^2-sec per kg/m^3) was derived from modeling that relied on data from the meteorological station at the Houghton County Memorial Airport in Hancock, Michigan (Figure 1). If the generic Q/C value had been used (82.33 g/m^2-sec per kg/m^3 for a ½-acre source size [MDEQ 2007], derived from an older modeling program and using meteorological data from three Michigan cities [MDEQ 2009]) and a modifier applied (that for a 100-acre source being 0.43 [MDEQ 2007]), the resulting applicable Q/C would have been about 35.4 g/m^2-sec per kg/m^3. That is less than the site-specific value used and would have resulted in a lower PEF, which would result in higher estimated air concentrations.

Mean Annual Wind Speed [$Um_{(z)}$] and Measurement Height (z)

Data from the airport in Hancock also supplied the $Um_{(z)}$ and z values used in this exercise (4.34 m/sec and 7.92 m, respectively). If the default $Um_{(z)}$ and default height (z) had been used (4.56 m/sec and 6.4 m, respectively), the resulting PEF would have been lower, which would result in higher estimated air concentrations.

Surface Soil Mode Aggregate Size (As)

The As value of 0.521 mm may have been biased low. The protocol for conducting sieve analyses to determine As indicates that the sieves should be shaken by hand, not mechanically, when determining aggregate size (Cowherd et al. 1988). Mechanical sifting is used for determining silt content (EPA 1993b). Since the Gay samples were shaken only by machine (M. Petrie, MDEQ RRD, personal communication, 2010), agglomerates that normally would not have been subject to wind erosion likely broke apart in the sieves. Therefore, the true As value may actually be higher, between a #30 and #8 sieve (the largest sizes reported for the analyses, which are between 0.595 and 2.36 mm, respectively [J. Pincombe, MDEQ RRD, personal communication, 2009]). If the As value had actually been within the higher range (midpoint equals 1.48 mm), then the resulting U*t and PEF would have been higher and the estimated air concentrations lower. If the As value had been the MDEQ (2007) default value of 0.35 mm, then the resulting U*t and PEF would have been lower, which would result in higher estimated air concentrations. Future sieving to determine As should be done by hand.

Figure B- 1. Map of "northern study area" at Gay stampsands area, Gay (Keweenaw County), Michigan. (1997; source: MDEQ)

*Equivalent Threshold Friction Velocity (U*t)*

The U*t value was based on the As value, discussed above. Therefore, the uncertainty for As would also affect U*t, as was discussed in the previous section. In addition, U*t was approximated visually from a graph in Cowherd et al. (1985) rather than calculated from a regression equation that would fit the curve of the graph. (Such an equation was not available.) This imprecise measurement introduces further uncertainty.

Silt Content (s)

The samples that were subjected to sieve analysis may not be representative of the majority of the stampsands at Gay. The s value of 1.2% reflects an average of 10 samples collected about 50 feet south of and parallel to the concrete sluiceway at the north end of the stampsands (green line in Figure B-1). The sample locations were not been geocoded and therefore not mapped (A. Keranen, MDEQ RRD, personal communication, 2011). The entire stretch of the Gay stampsands, from the town of Gay to the Traverse River outlet, covers up to 411 acres, as determined in 2001 (USACE 2001). The sampling area was less than one quarter acre. The sands have eroded over time (see 1938 versus 1998 shoreline comparison in Figure B-2). It is likely that wind and wave action have caused a greater degree of dispersion to finer stampsands as compared to the coarser grains, at least for surficial tailings. However, deeper deposits may have a greater silt content since they were exposed to the elements only for a limited time before being covered by more stampsands. More discussion on the fate and transport of stampsands at Gay is in USACE (2001) and Kerfoot et al. (1994).

If the s value had been the MDEQ (2007) default value of 15% (i.e., containing more silt), then the resulting PEF would have been lower, which would result in higher estimated air concentrations. (Stampsands applied off-site for road traction material would likely have a higher silt content if sampled from roadways, due to the traffic grinding the stampsands into finer particles. This is discussed in Appendix C.) It may be necessary to use a higher s value as a protective measure when evaluating health impacts of inhalation stampsands at Gay, especially those that currently are at depth.

Combined Sensitivity Analysis

If all of the default values discussed in this section, including the adjusted generic Q/C, were used in place of the site-specific values, the resulting PEF would have been lower by about one order of magnitude (a factor of 10), which would result in higher estimated air concentrations.

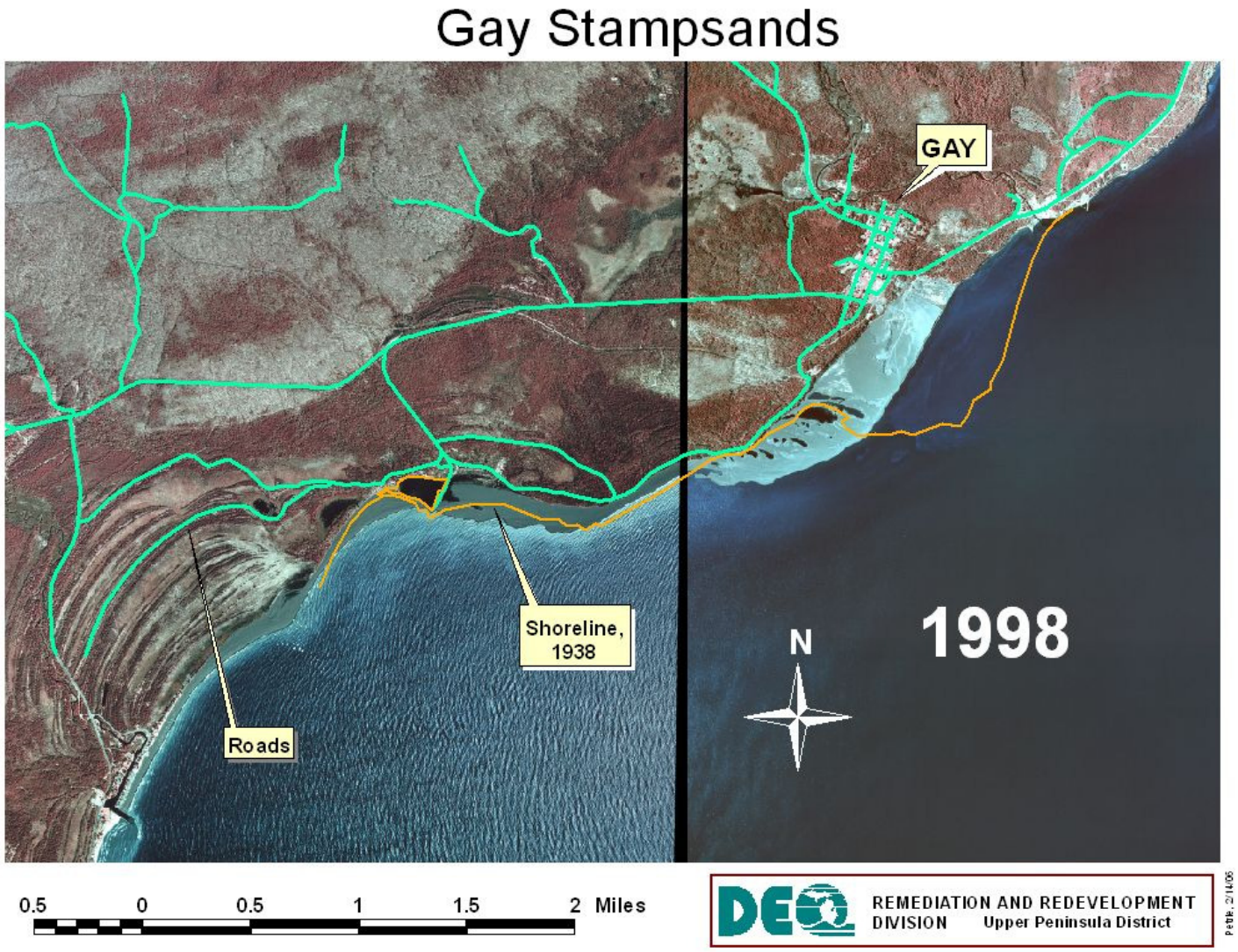
Confidence

The confidence in the appropriateness of the values discussed here is medium to high. Most of the values are based on extensive site-specific data, however the mode aggregate size (As) and silt content (s) are based on limited data.

<u>Stampsand Concentration Data</u>

Staff from the MDEQ Remediation and Redevelopment Division (RRD) collected stampsands at the Gay site in September 2003. They took a total of 274 samples at various depths in 63 locations in the northern deposit area (Figures 2 and B-1). The northern deposit area is closest to the former conveyor that was used to transport sands into Lake Superior during the stamp mill's

Figure B- 2. Map of Gay (Keweenaw County), Michigan, stampsands and vicinity in 1998 with 1938 shoreline (orange line) superimposed. (1998; source: MDEQ)



operation. Thus it is believed to be the oldest, least disturbed location at Gay, with the highest likelihood of being accessible for excavation. During this field work, RRD staff also collected 24 surficial stampsand samples from the southern deposit area, near the Traverse River outlet (Figure 2). This area represents the stampsand that has accumulated after being eroded from the main deposit (MDEQ 2004a, Weston 2006a).

The stampsands were analyzed for the following metals: aluminum, arsenic, beryllium, chromium, cobalt, copper, lead, lithium, manganese, mercury, nickel, silver, strontium, and zinc. The 95% Upper Confidence Limits of the mean concentrations (95 UCLs; a statistical value that represents an upper estimate of the true mean) are shown in Table B-4. The results for all depths at the northern area, not just surficial, are considered in this exercise because, as shallower depths are removed by excavation or erosion, the deeper depths are exposed and become available for inhalation. (The southern area will be considered only if the results for the northern area raise a concern. This is because, since the stampsand concentrations are lower in the southern area and less finer-grained material would be present [USACE 2001, Kerfoot et al. 1994], estimated air concentrations would also be lower than in the northern area.)

Table B- 4. 95% Upper Confidence Limits of the mean concentrations (95UCLs) of selected metals in stampsand samples taken September 2003 in Gay (Keweenaw County), Michigan. (Results are in micrograms per kilogram [µg/kg].)

Metal	**Northern 95UCL**	**Southern 95UCL**
Aluminum	15,872,000	11,791,000
Arsenic	2,700	1,600
Beryllium	480	460
Chromium	29,000	29,000
Cobalt	23,000	19,000
Copper	2,972,000	1,713,000
Lead	2,600	not detected (ND)
Lithium	6,200	5,800
Manganese	549,000	407,000
Mercury	28	ND
Nickel	31,000	27,000
Silver	1,800	1,300
Strontium	17,000	13,000
Zinc	75,000	66,000

Reference: Weston 2006a

Air Concentration Calculations

The estimated air concentrations for the metals in the Gay stampsands are the concentrations within the stampsands divided by the PEF. Table B-5 shows the expected air concentrations for the metals in the northern area.

The air concentrations in Table B-5 assume that exposure is occurring 24 hours/day, 365 days/year. As stated at the beginning of this exercise, it is assumed that a person using the site

for recreational purposes would only be exposed 15 days/month, five months/year, which is 75 days/year. (Although wind erosion would still occur, the exercise assumes that the person in/on

Table B- 5. Estimated air concentrations of selected metals in stampsands in the northern area at Gay (Keweenaw County), Michigan.

Metal	**Stampsand Concentration (µg/kg)**	**PEF (m^3/kg)**	**Air Concentration[A] (µg/m^3)**
Aluminum	15,872,000	22,200,000	0.7
Arsenic	2,700	22,200,000	0.0001
Beryllium	480	22,200,000	0.00002
Chromium	29,000	22,200,000	0.001
Cobalt	23,000	22,200,000	0.001
Copper	2,972,000	22,200,000	0.1
Lead	2,600	22,200,000	0.0001
Lithium	6,200	22,200,000	0.0003
Manganese	549,000	22,200,000	0.02
Mercury	28	22,200,000	0.000001
Nickel	31,000	22,200,000	0.001
Silver	1,800	22,200,000	0.00008
Strontium	17,000	22,200,000	0.0008
Zinc	75,000	22,200,000	0.003

Acronyms:

µg/kg micrograms per kilogram
m^3/kg cubic meters per kilogram
µg/m^3 micrograms per cubic meter
PEF Particulate Emission Factor

Note:

A. Calculation assumes exposure is occurring 24 hours/day, 365 days/year.

the vehicle is the exposed person at the site. If the person is not present, this specific exposure scenario is not occurring and wind erosion is a moot point.) Therefore, each air concentration shown in Table B-5 is adjusted by 75/365, or 0.21, to account for the less frequent exposure. The estimated exposure-specific time-weighted average daily air concentrations are shown in Table B-6.

Comparison of Estimated Air Concentrations to Health-Based Screening Values

To determine whether the exposure-specific time-weighted average air concentration might be harmful, MDCH compared the concentration to a health-based number, prioritizing the screening values as follows:

1. The first choice of a comparison value to use was the EPA Reference Concentration (RfC). This is a regulatory number that is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is not likely to cause harm in a person's lifetime (EPA 2010b). Lead does not have an RfC but, as a "criteria" pollutant (per the Clean Air Act), has a National Ambient Air Quality Standard (NAAQS), which is a regulatory number and was used as a comparison value here. Primary standards set limits to protect public health, including sensitive populations (asthmatics, children, elderly; EPA 2011b).
2. If an RfC or NAAQS was not available for a chemical, then MDCH used a Comparison Value (CV) derived by the federal Agency for Toxic Substances and Disease Registry

Table B- 6. Estimated exposure-specific time-weighted average (based on on-site exposure assumptions) air concentrations of selected metals in stampsands in the northern area at Gay (Keweenaw County), Michigan.

Metal	Estimated Air Concentration (µg/m^3)[A]
Aluminum	0.1
Arsenic	0.00003
Beryllium	0.000005
Chromium	0.0003
Cobalt	0.0002
Copper	0.03
Lead	0.00002
Lithium	0.00006
Manganese	0.005
Mercury	0.0000003
Nickel	0.0003
Silver	0.00002
Strontium	0.0003
Zinc	0.0007

Acronym:
µg/kg micrograms per kilogram
Note:
A. Time-weighted calculation assumes exposure is occurring 15 days/month, five months/year.

(ATSDR), if available. CVs are not regulatory numbers but advisory levels. For non-carcinogenic chemicals in soil, water or air, ATSDR derives Environmental Media Evaluation Guides (EMEGs). Chronic air EMEGs (based on Minimal Risk Levels [MRLs]) are similar in derivation to the RfCs but, due to differing interpretations and risk assessment practices between the agencies, may result in a different value. For carcinogenic chemicals in soil, water or air, ATSDR derives Cancer Risk Evaluation Guides (CREGs). These are different from the Inhalation Unit Risk Factors (IURFs) discussed earlier in this appendix, wherein the CREGs are not potencies but, rather, are concentrations of a chemical that result in a one-in-one-million increased cancer risk (ATSDR 2005).

3. If neither an RfC nor a CV were available, then MDCH used the occupational Recommended Exposure Limit (REL), as established by the National Institute for Occupational Safety and Health (NIOSH). These health-based, non-regulatory values are Time-Weighted Averages (TWAs) for up to a 10-hour workday during a 40-hour workweek (NIOSH 2006). Because RELs are not 24-hour exposure numbers, they can be much higher than RfCs and CVs. In the past, MDCH has used Acute Exposure Guideline Levels (AEGLs) to consider risks of short-term exposures. AEGLs address emergency exposures to the public for 10 minutes to eight hours and are usually more protective (lower) than occupational limits (EPA 2010a). However, no AEGLs were available for the metals that did not have RfCs or CVs.
4. Lithium and strontium did not have RfCs, CVs, or RELs available. They are discussed later in this section.

The REL screening values may not be adequately protective for non-occupational populations. The ratio between the estimated air concentration of a metal, in this exercise, and its REL ranges from five to seven orders of magnitude (100,000 to 10,000,000 times; see Table B-7). When deriving an RfC or MRL, agencies apply uncertainty factors (UFs) to experimental data to estimate a protective value for public exposure. The value of a UF is typically 1, 3 or 10, and is applied to account for animal data to human extrapolation, inter-individual differences in humans, extrapolating less-than-lifetime exposure to lifetime exposure, extrapolating from a study without a no-effect level, and an inadequate database (EPA 2002). If the maximum UF for each consideration except animal-data-to-human were applied to an REL, the total UF would be 10,000, which is smaller than the minimum ratio between the estimated air concentration and its REL in this exercise. This suggests that an adequate margin of safety exists between estimated and acceptable (REL screening values) exposures in this exercise.

Table B- 7. Comparison between calculated and acceptable margins of safety for airborne stampsands at Gay (Keweenaw County), Michigan.

Metal	**Estimated Air Concentration (µg/m^3)**	**Screening Value (µg/m^3)**	**"Calculated Margin" (unitless)**	**"Acceptable Margin" (unitless)**
Aluminum	0.1	10,000 [A]	0.00001	0.5
Arsenic	0.00003	0.0002 [B]	0.1	0.5
Beryllium	0.000005	0.0004 [B]	0.01	0.5
Chromium	0.0003	0.00008 [B,C]	3.7	0.5
Cobalt	0.0002	0.1 [D]	0.02	0.5
Copper	0.03	1,000 [A]	0.00003	0.5
Lead	0.00002	0.15[E]	0.00000004	0.5
Lithium	0.00006	NA	NC	0.5
Manganese	0.005	0.05 [F]	0.1	0.5
Mercury	0.0000003	0.3 [F]	0.000001	0.5
Nickel	0.0003	0.09 [D]	0.003	0.5
Silver	0.00002	10 [A]	0.000002	0.5
Strontium	0.0003	NA	NC	0.5
Zinc	0.0007	5,000 [A]	0.0000001	0.5

Acronyms:

µg/m^3	micrograms per cubic meter	CREG	Cancer Risk Evaluation Guide
EMEG	Environmental Media Evaluation Guide	NA	not available
NAAQS	National Ambient Air Quality Standard	NC	not calculated
REL	Recommended Exposure Limit	RfC	Reference Concentration

Notes:

A. REL
B. CREG
C. Value is for hexavalent chromium.
D. Chronic air EMEG
E. NAAQS
F. RfC

If the exposure-specific time-weighted average air concentration, which is the expected exposure, is divided by the screening value, the resulting ratio indicates the extent of exposure.

The smaller the quotient is, compared to 1 (meaning expected exposure is less than the screening value), the larger the margin of safety. This "Calculated Margin" assumes that people are exposed to the chemical only at the site and nowhere else. This assumption may not be appropriate for the Gay stampsands because they have been used for many years as road-traction material on winter roads. Stampsands can remain for some time on the roadways, though they will, for the most part, settle eventually onto the shoulders of the roads. However, they still can become resuspended in air and people can be exposed to them. To compensate for this possibility, MDCH chose an "Acceptable Margin" of 0.5 instead of 1. (This rationale is similar to that used for Relative Source Contribution factors used for drinking water and soil evaluations [MDEQ 2004b, 2005].) The comparison between "Calculated Margins" and "Acceptable Margins" is shown in Table B-7.

Although the "Calculated Margin" for chromium is 3.7, well above the "Acceptable Margin," the screening value used is for the hexavalent (VI) form of the metal. In most environmental situations, however, the less toxic, trivalent form (chromium III) predominates (Kimbrough et al. 1999, ATSDR 2000a). Therefore, one would not expect the hexavalent form to occur in the stampsands. There is no RfC, EMEG, or CREG for chromium III. The REL for chromium metal and chromium III compounds is 500 $\mu g/m^3$ (NIOSH 2006), which is six orders of magnitude greater than the estimated air concentration. Chromium in airborne stampsands in this recreational scenario is not expected to cause harm.

Only the ratios for arsenic and manganese are within an order of magnitude of the "Acceptable Margin," about one-fifth the value. Arsenic and manganese are discussed further in the *Toxicological Evaluation* section in this document.

Lithium and strontium do not have RfCs, NAAQS, CVs, or RELs. They are discussed further in the *Toxicological Evaluation* section in this document.

Considering Acute Exposures

Empirical evidence from state-wide air monitors indicate that ambient peak PM10 levels measured over 24-hour periods were roughly twice the annual average concentration (MDNRE 2009). (The MDEQ database did not indicate what attributed to the peak air concentrations.) Thus, multiplying the estimated air concentration (in this case, the Time-Weighted Average Air Concentration) by 2 would result in expected peak, or acute, exposure levels of PM10 metals in the air at Gay. These concentrations are still well below the health-based screening values used in Table B-7. (Chronic screening levels, such as the RfC and EMEG or CREG, are more protective [lower] than acute screening levels.) Therefore, short-term acute exposure situations are not expected to cause harm.

Conclusions

Based on the values used in this exercise, some of which are site-specific data-based values whereas others are default assumptions, the estimated exposure-specific time-weighted average concentrations of selected metals at the Gay stampsands would not be expected to cause harm in the short or long term to someone using the site with a recreational vehicle. If new information becomes available that would change the values, re-evaluation may be necessary. This exercise

can inform and guide future risk assessments that evaluate contaminated airborne soil or stampsands.

Appendix C. Estimating Air Concentrations of Metals as Particulate Matter at Calumet, Michigan – Use of Point Mills Stampsands for Road Traction Material

Assumed Exposure Scenario at Calumet

The following exercise estimates air concentrations of stampsand-related chemicals expected at Calumet, Michigan, where stampsands from Point Mills, Michigan are used by the county road commission for road-traction material. (The Michigan Department of Transportation [MDOT], which is responsible for US41, M-26, and M-203 in Calumet, does not use stampsands for traction material [A. Sikkema, MDOT, personal communications, 2009, 2012].) The exercise assumes that exposure occurs year-round, although greater amounts of airborne particulates would occur during dry weather.

Note that there are other areas, not just Calumet, that receive stampsands for road traction. Also, stampsands are often used for gravel road construction and maintenance. This evaluation for Calumet does not stand as a surrogate for the other areas or for other uses of stampsands.

Basic PSIC Equations

The Michigan Department of Environmental Quality (MDEQ) Particulate Soil Inhalation Criteria (PSIC) identify concentrations of hazardous substances in soil that are not expected to create ambient air concentrations of contaminated particulates that would, in turn, cause adverse human health effects via inhalation. Soils can become resuspended by wind or vehicular erosion. One must consider, among other parameters, source size, vegetative cover, wind speed, and vehicle use of the area (MDEQ 2007).

The algorithm used to calculate an acceptable soil concentration of a non-carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{nc} = \frac{THQ \times AT_{nc}}{EF \times ED \times (1/ITSL \times 1/(PEF/2))}$$

The algorithm used to calculate an acceptable soil concentration of a carcinogen for the inhalation scenario is (MDEQ 2007):

$$PSIC_{ca} = \frac{TR \times AT_{ca} \times AIR}{IURF \times EF \times ED \times (1/PEF)}$$

where PSIC = the soil criterion, given in micrograms of chemical per kilogram soil (µg/kg) or parts per billion (ppb);

nc = non-carcinogenic chemical

ca = carcinogenic chemical

THQ = target hazard quotient, the ratio of the expected dose to the acceptable dose, and is unitless;

TR = target cancer risk (the number of excess cancers expected due to exposure to the chemical), which is 1 in 100,000 (1E-05) and is unitless;

AT_{nc} the averaging time for non-carcinogens, which is the years of exposure

duration times the number of days of exposure per year, in days;

AT_{ca} the averaging time for carcinogens, which is considered to be a lifetime (70 years), in days (25,550 days);

AIR = adjusted inhalation rate; assumes a worker breathes twice as much air during a 24-hour day versus a non-worker; value is 2 (20 cubic meters per day [m^3/day] / 10 m^3/day); used only for carcinogens when considering industrial or commercial exposure scenarios;

EF = the exposure frequency, given in days/year;

ED = the exposure duration, given in years;

ITSL = the MDEQ Initial Threshold Screening Level, the acceptable air concentration of the chemical, in micrograms of chemical per cubic meter air ($\mu g/m^3$);

IURF = the MDEQ Inhalation Unit Risk Factor, the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to a chemical at 1 $\mu g/m^3$ concentration in air; units are $(\mu g/m^3)^{-1}$;

PEF = the Particulate Emission Factor, specific for source size, in m^3/kg. The divisor of 2 for non-carcinogenic chemicals is used when the averaging time for the ITSL is less than annual, in order to achieve an appropriately protective PSIC.

Note that values given for the parameters described above are default values. Values specific for this exercise are discussed in later sections of this appendix (see Tables C-1, C-2, and C-3).

Solving for Expected Air Concentrations

For this exercise, the algorithms above will be rearranged and the risk-assessment parameters (EF, ED, THQ, TR, AT, and AIR) removed to estimate an expected air concentration based on soil concentration data. Risk-assessment parameters will be considered at a later point in this appendix. For the purposes of this exercise (estimating expected air concentrations), the divisor of 2 for the PEF for non-carcinogenic chemicals is removed.

To start, note that the PSIC criteria are specific for soils and cannot be used when discussing stampsands, which are not soil but a mining by-product. Therefore, rather than use acronyms with specific regulatory meanings ("ITSL," "PSIC," and "IURF"), the Michigan Department of Community Health (MDCH) is using the following substitutions:

For "ITSL," substitute "$[\textit{non-carcinogen}]_{air}$", meaning "concentration of 'non-carcinogenic chemical X' in air"

For "PSIC," substitute "$[\textit{chemical name}]_{stampsand}$", meaning "concentration of 'chemical X' in stampsand"

For "IURF," substitute "Potency$[\textit{carcinogen}]_{air}$", meaning the "estimated upper-bound excess lifetime cancer risk resulting from continuous exposure to an airborne carcinogen at a concentration of 1 $\mu g/m^3$"

Solving for $[\textit{non-carcinogen}]_{stampsand}$, the resulting equation, without risk-assessment parameters, is:

$$[non-carcinogen]_{stampsand} = \frac{1}{1/[non-carcinogen]_{air} \times 1/PEF} = [non-carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[non-carcinogen]_{air} = [non-carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for manganese (Mn):} \quad [Mn]_{air} = \frac{[Mn]_{stampsand}}{PEF}$$

Solving for $[carcinogen]_{\text{stampsand}}$, the resulting equation, without risk-assessment parameters, is:

$$[carcinogen]_{stampsand} = \frac{1}{Potency[carcinogen]_{air} \times 1/PEF} = \frac{1}{Potency[carcinogen]_{air}} \times PEF$$

The carcinogen equation needs further adjusting to reach an air concentration, versus an excess cancer risk (potency). In cancer risk assessment, the risk of a chemical exposure is the potency of the chemical multiplied by the concentration (risk = potency X concentration; EPA 1989). Solving for the concentration, the risk is divided by the potency (concentration = risk/potency). For this exercise, recall that the units for "Potency$[carcinogen]_{\text{air}}$" (formerly "IURF") are $(\mu g/m^3)^{-1}$. Inverting "Potency$[carcinogen]_{\text{air}}$" yields "$[carcinogen]_{\text{air}}$" and the appropriate units for an air concentration ($\mu g/m^3$):

$$[carcinogen]_{stampsand} = [carcinogen]_{air} \times PEF$$

Solving for the expected air concentration, the equation becomes:

$$[carcinogen]_{air} = [carcinogen]_{stampsand} / PEF$$

$$\text{e.g., for arsenic (As):} \quad [As]_{air} = \frac{[As]_{stampsand}}{PEF}$$

Thus, regardless of whether a chemical is a carcinogen or not, the air concentration of that chemical, as airborne stampsands, is calculated as the stampsand concentration divided by the PEF. Then, for this exercise, exposure assumptions and acceptable hazard or risk values are considered in determining whether the air concentration may be hazardous.

<u>Recommended Updates to PSIC Variables and Their Use in this Exercise</u>

The Michigan interagency Toxics Steering Group (TSG) is composed of toxicologists from MDEQ, MDCH, and the Michigan Department of Agriculture and Resource Development. The TSG provides a forum for discussion of human health risk assessment issues related to exposure to chemical contaminants in environmental media. In 2006, a TSG subcommittee was formed in response to identification of challenges associated with the application of the manganese PSIC at several facilities in Detroit, Michigan. The subcommittee evaluated the derivation of the manganese PSIC, which involved review of the variables used to derive the criteria. The results

of this evaluation, along with recommendations for updating development of the criteria, were reported in 2009 (MDEQ 2009). Although not all recommendations have been adopted into MDEQ's regulatory process, as of this writing, MDCH chose to use the updated state of the science in this exercise. The updated values mainly affect the parameter for emission due to vehicle traffic, Ev.

Since the finalization of the MDEQ 2009 report, EPA has updated Chapter 13.2.1, "Paved Roads," in its *AP 42, Fifth Edition, Compilation of Air Pollutant Emissions Factors, Volume 1: Stationary Point and Area Sources* (2011). These updates affect the variables to the parameter for emissions due to vehicle traffic (Ev), discussed below. For this exercise, MDCH used the EPA updates for Ev rather than the recommendations in the MDEQ report.

<u>Particulate Emission Factor (PEF) Equation and Air Dispersion (Q/C) Factor</u>
Several parameters affect the value of PEF (MDEQ 2007):

$$PEF = (Q/C) \times \frac{1}{[(Ew \times (1-V)) + Ev]}$$

where PEF = the Particulate Emission Factor, which relates the concentration of a particulate contaminant in ambient air to the corresponding concentration of contaminant in soil (or, in this case, stampsands), in m^3/kg;
Q/C = an air dispersion factor, based on a site-specific source size, in grams per square meter-second per kilogram per cubic meter (g/m^2-sec per kg/m^3);
Ew = emission due to wind, in g/m^2-sec;
V = the source's vegetative cover, in percent; and
Ev = emission due to vehicle traffic, in g/m^2-sec.

The Q/C factor represents the dispersion of airborne contaminants. Air-dispersion modeling is used to estimate air concentrations of particulates released from soil (or a matrix other than soil). The model can use either default regional or local meteorological data to predict an air concentration (C) for various source sizes. Using a constant emission rate from the soil (Q), a table of Q/C values can be generated. (The generic PSIC value shown in the MDEQ Part 201 criteria tables [MDEQ 2011a, b] is for one-half acre. A modifier is applied to adjust this Q/C value for larger or smaller source sizes when a site-specific Q/C is not available [MDEQ 2007]).

The default value for V is 50% (MDEQ 2007).

The Ew and Ev factors are broken down further, as discussed in the following sections.

<u>Emission Due To Wind (Ew) Assumptions and Calculation</u>
Ew considers a mean annual wind speed, adjusted to a height of 7 meters (Um, in meters per second [m/sec]); a threshold friction velocity (the minimum wind velocity needed for soil [or other matrix] erosion [by wind] to occur), adjusted to a height of 7 meters (Ut_{adj}, in m/sec); and the mathematical function of a unitless variable (F[x]) derived from Cowherd et al. (1985) (MDEQ 2007).

The equation for Um is (MDEQ 2007):

$$Um = Um_{(z)} \times (7/z)^{(0.15)}$$

where $Um_{(z)}$ = the mean annual wind speed at height z, in m/sec,
7 = the adjustment height, in m, and
z = wind speed measurement height, in m.

The equation for Ut_{adj} is (MDEQ 2007):

$$Ut_{adj} = ((U*t \times CF)/0.4) \times (\ln(7.0/z_0))$$

where U*t = the equivalent threshold friction velocity for a specified surface soil mode aggregate size (As, which can be the default value of 0.35 mm or derived from site-specific data), in m/sec;
CF = a unitless correction factor, with a default value of 1.25, for non-erodible elements (e.g. stones larger than 1 centimeter [cm] diameter, clumps of vegetation);
7 = the adjustment height, in m, and
z_0 = the roughness height, in m.

The variable derived from Cowherd et al. (1985) is designated "x," which is an adjusted ratio of the threshold friction velocity to the mean annual wind speed (MDEQ 2007):

$$x = 0.886 \frac{Ut_{adj}}{Um}$$

The function dependent on "x" is designated "F(x)." "F(x)" tends to 1.91 as "x" tends to zero, as seen in Figure 4-3 of Cowherd et al. (1985). The figure should be used to determine "F(x)" when "x" is less than 2. However, when "x" is greater than 2, "F(x)" is derived from the following equation (Cowherd et al. 1985):

$$F(x) = 0.18(8x^3 + 12x)\exp(-x^2)$$

The equation for Ew is (MDEQ 2007):

$$Ew = 0.036(U_m / Ut_{adj})^3 \times F(x)/3{,}600$$

where 0.036 = the default respirable fraction emission rate, in grams per square meter-hour (g/m^2-hr), and
3,600 = a conversion factor to convert hours to seconds (sec/hr).

The resulting units for Ew are g/m^2-sec.

Emission Due To Vehicle Traffic (Ev) Assumptions and Calculation

Ev considers vehicle factors, such as mean weight and number of vehicles using the area, and other factors, such as precipitation and silt loading to the road. The first step in deriving Ev is calculating E_{10}, the emission factor for vehicles traveling on paved or unpaved roads, in kilogram of particulate matter less than 10 microns in aerodynamic diameter (PM10) per vehicle-kilometer travel (kg/Vkm). The equation for E_{10} of *paved* roads is (EPA 2011a):

$$E_{10} = [k \times (sL)^{0.91} \times (W)^{1.02}] \times [1 - (P/4N)]$$

where k = a paved-road particle size multiplier for PM10, in pounds per vehicle mile;
sL = the road surface silt loading, in g/m^2 (note that the units for sL are not inserted into the equation above, since sL serves to adjust the emission estimate to site-specific conditions; as such, it is not necessary to include the units in the calculation exercise)
W = mean vehicle weight, in tons (note that the units for W are not inserted into the equation above, since W serves to adjust the emission estimate to site-specific conditions; as such, it is not necessary to include the units in the calculation exercise);
P = number of "wet" days with at least 0.01 inch of precipitation during the averaging period; and
N = number of days in the averaging period.

Initially, the units for the above equation result in pound per vehicle-mile travel (lb/VM). Multiplying the product above by 0.454 kg/lb and 0.621 mile/km results in the kilograms per vehicle-kilometer travel (kg/Vkm) equivalent. E_{10} is then used to calculate the annual emissions, E, in kg/year. The equation for E is (MDEQ 2007):

$$E = E_{10} \times V \times L \times T \times 1/CF$$

where V = the number of trips or vehicles per day (note that this variable is different than the vegetative cover "V" in the PEF equation, described earlier), in vehicles/day;
L = the length of the driveway or road used, in m;
T = the time duration, in days/yr; and
CF = a conversion factor, converting km to m (1,000; note that this "CF" variable is different than the "CF" in the Ut_{adj} equation, described earlier).

E is used to derive Ev. The equation for Ev is (MDEQ 2007):

$$Ev = E \times 1/A \times (CF_1/CF_2)$$

where A = the size of the area from which emissions are expected to occur (this would usually be the roads on the site and not include buildings and other areas where vehicles would not go), in square meters (m^2);
CF_1 = a conversion factor, converting kg to grams (g) (1,000); and
CF_2 = a conversion factor, to convert years to seconds (sec) (31,500,000).

The resulting units for Ev are g/m^2-sec.

Site-Specific Particulate Emission Factor (PEF) Calculations
Site-specific values to the PEF calculation are shown in the following tables.

Table C- 1. Air dispersion factor (**Q/C**) value for evaluation of stampsands on roads in Calumet (Houghton County), Michigan.

Variable	Value (Units)	Discussion
Q/C	156.03 (g/m^2-sec per kg/m^3)	The MDEQ Air Quality Division's (AQD's) Modeling and Meteorology Unit conducted modeling for the Calumet (using Point Mills stampsands) evaluation. Emissions were modeled as only coming from the roads and in the more "densely roaded" area around Calumet, including Laurium, Osceola, and Tamarack, covering about 232 acres of pavement (D. Mason, MDEQ AQD, personal communication, 2012; see Figure C-1). While the modeling included US41, M-26, and M-203, these roadways are maintained by MDOT and do not receive stampsands for road traction material (A. Sikkema, MDOT, personal communication, 2009, 2012). According to MDEQ AQD, removing state-maintained roads from the model would not significantly alter the Q/C value, since all roads were treated the same, regardless of size. Receptors were placed on a 100-m square grid within the city, which means that a receptor may be located on the road, next to a road, or within a yard. [D. Mason, MDEQ AQD, personal communications, 2009, 2010, 2012]). Because this value is site-specific, not a one-half acre source size, a modifier is not necessary.

Figure C- 1. Road map of Calumet and area (Houghton County), Michigan.

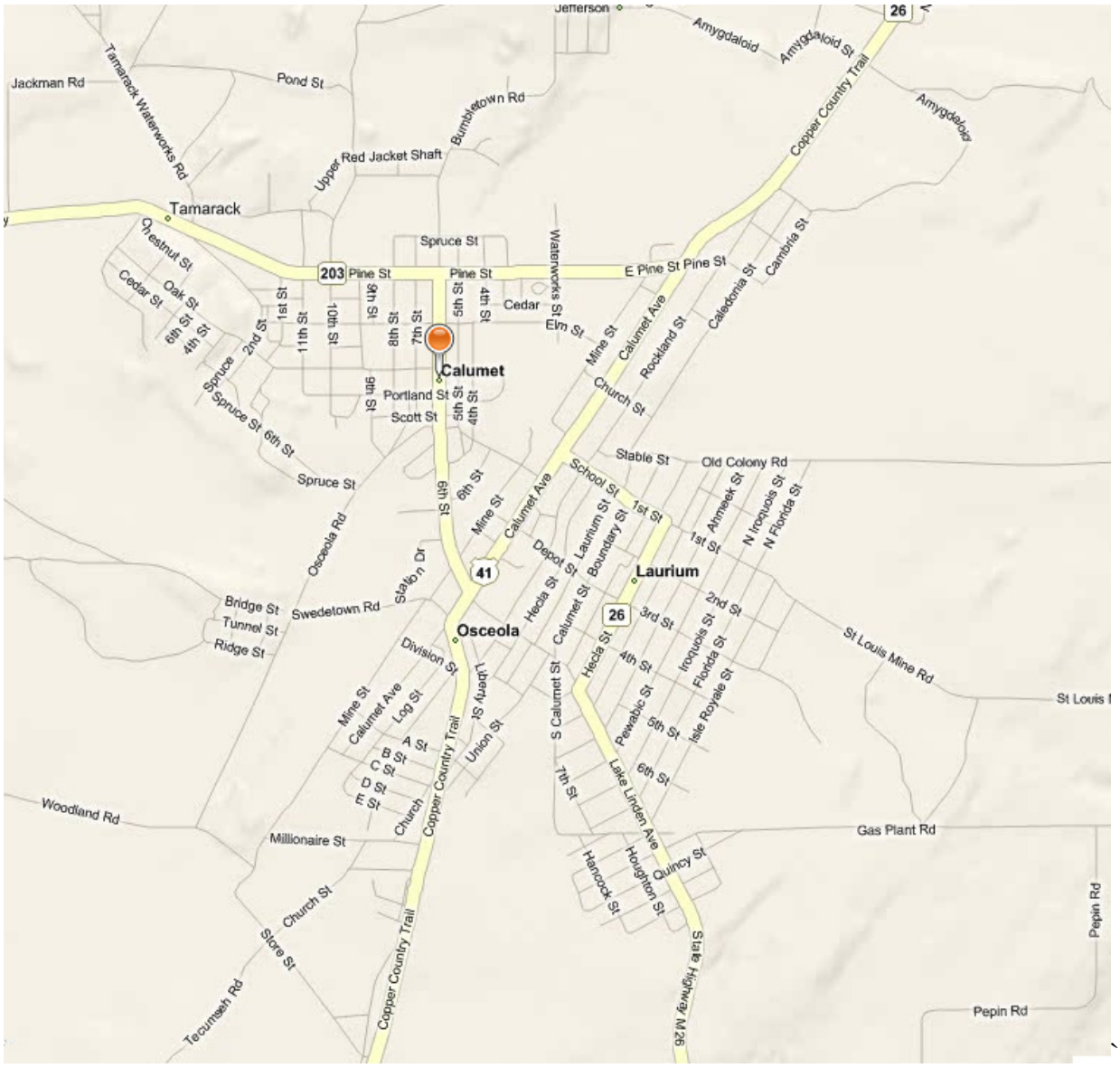


Table C- 2. Exposure due to wind (**Ew**) variables and calculation for evaluation of stampsands on roads in Calumet (Houghton County), Michigan.

Variable	Value (Units)	Discussion
$Um_{(z)}$	4.34 (m/sec)	2004-2008 mean annual wind speed data from Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
z	7.92 (m)	Anemometer height at Hancock, Michigan meteorological station (D. Mason, MDEQ AQD, personal communication, 2009)
Um	4.26 (m/sec)	Calculated from above values
U*t	0.29 (m/sec)	Approximated, for As of 0.149 mm (below), from Figure 3-4 in Cowherd et al. (1985)
CF	1.25 (unitless)	Default correction factor
As	0.149 (mm)	No sieve-analysis data are available for Point Mills stampsands. Value shown is the mode for Gay, Michigan stampsand Sample #10 sieve analysis data (M. Petrie, MDEQ RRD, personal communication, 2009). This sample was described as being the most fine-grained of the ten samples taken (data not shown). Over time, stampsands on roadways are likely smaller in aggregate size than stampsands first taken from tailing piles, due to grinding by traffic.
z_0	0.005 (m)	Default value (MDEQ 2007); represents a surface between "natural snow" and "plowed field" (Cowherd et al. 1985)
Ut_{adj}	6.57 (m/sec)	Calculated from above values
x	1.365 (unitless)	Calculated from above values
F(x)	1.025 (unitless)	Calculated from above value
Ew	0.0000028 (g/m^2-sec)	Calculated from above values

Table C- 3. Vehicular erosion (**Ev**) variables and calculation for evaluation of stampsands on roads in Calumet (Houghton County), Michigan.

Variable	Value (Units)	Discussion
k	0.0022 (lb/VM)	PM10 constant for paved roads (EPA 2011a)
sL	0.23 (g/m^2)	"Ubiquitous Silt Loading Default Values with Hot Spot Contributions from Anti-Skid Abrasives" calculation in AP-42, Table 13.2.1-3 (EPA 2011a)
W	3.3 (tons)	Calculated from the Michigan Department of Transportation (MDOT) Vehicle Classification Report for US41 in Houghton County, four miles southwest of M26, August 23-26, 2010 (K. Krzeminski, MDOT, personal communication, 2012). Although US41 is a state-maintained road and does not receive stampsands, there are no data for county-maintained paved roads in Calumet. MDCH assumed that double-trailer trucks would rarely, if at all, drive on the sidestreets in the area and removed data on those vehicles when calculating mean vehicle weight.
P	150 (days)	Average of 1980-2008 data from Houghton County Memorial Airport (J. Haywood, MDEQ AQD, personal communication, 2009)
N	365 (days/yr)	Annual averaging time
E10	0.002 (lb/VM)	Calculated from above values
E10	0.0006 (kg/VKm)	Converted from above
V (vehicles per day)	4,700 (V/day)	2011 Average Daily Traffic count for Calumet, Michigan (MDOT 2012). This is the count for a state-maintained road in Calumet, which would not receive stampsands. There are no data for county-maintained paved roads in Calument.
L	3,048 (m)	Approximate scale-length of a diagonal line drawn northwest to southeast on the map in Figure C-1 (about 10,000 feet [ft])
T	365 (days/yr)	Assumes year-round emissions
CF	1,000 (m/km)	Conversion factor
E	2,580 (kg/yr)	Calculated from above values
A	55, 742 (sqm)	Length of route (L, above) times width of road (60 ft [18.3 m]). Sidestreets may be narrower.
CF_1	1,000 (g/kg)	Conversion factor
CF_2	31,500,000 (sec/yr)	Conversion factor
Ev	0.00000147 (g/m^2-sec)	Calculated from above values

For this exercise, vegetative cover (V) is assumed to be 0%. This exercise is evaluating the expected airborne concentrations of stampsands coming off the roads in Calumet, which would not have vegetative cover.

Thus, the PEF calculation for the Point Mills stampsands, used as road-traction material in Calumet, is:

$$PEF_{Calumet} = 156.03 \times \frac{1}{0.0000028 \times (1-0) + 0.00000147} = 37{,}500{,}000 m^3 / kg$$

<u>Uncertainty Discussion, Sensitivity Analysis for, and Confidence in Selected PEF Variables</u>
This section discusses the uncertainty of selected PEF variables and shows how the use of default or other values for certain parameters would change the results for the estimated air concentrations. This section does *not* discuss uncertainty within default values that were used.

Air Dispersion Factor (Q/C)

The air dispersion factor (**Q/C**) value used in this exercise (156.03 g/m^2-sec per kg/m^3) was derived from modeling that relied on data from the meteorological station at the Houghton County Memorial Airport in Hancock, Michigan (Figure 1). If the generic Q/C value had been used (82.33 g/m^2-sec per kg/m^3 [MDEQ 2007], derived from an older modeling program and using meteorological data from three Michigan cities [MDEQ 2009]) and a modifier applied (that for a 200-acre source being 0.42 [MDEQ 2007]), the resulting applicable Q/C would have been about 34.98 m^2-sec per kg/m^3. That is less than the site-specific value used and would have resulted in a lower PEF, which would result in higher estimated air concentrations.

Mean Annual Wind Speed [$Um_{(z)}$] and Measurement Height (z)

Data from the airport in Hancock also supplied the $Um_{(z)}$ and z values used in this exercise (4.34 m/sec and 7.92 m, respectively). If the default $Um_{(z)}$ and default height (z) had been used (4.56 m/sec and 6.4 m, respectively), the resulting PEF would have been lower, which would result in higher estimated air concentrations.

Surface Soil Mode Aggregate Size (As)

The surface soil mode aggregate size (**As**) value of 0.149 mm is an assumed value and not specific to Calumet. If the As value had been the MDEQ (2007) default value of 0.35 mm, then the resulting U*t and PEF would have been higher, which would result in lower estimated air concentrations. Stampsands differ between piles (Point Mills, Gay, elsewhere), in both chemical and physical attributes. *Site-specific As data are necessary to accurately estimate expected air concentrations.* The AP-42 provides guidance on acquiring such data (EPA 1993a, b).

*Equivalent Threshold Friction Velocity (U*t)*

The equivalent threshold friction velocity (**U*t**) value was based on the As value, discussed above. Therefore, the uncertainty for As would also affect U*t, as was discussed in the previous paragraph. In addition, U*t was approximated visually from a graph in Cowherd et al. (1985) rather than calculated from a regression equation that would fit the curve of the graph. (Such an equation was not available.) This imprecise measurement introduces further uncertainty.

Correction Factor for Non-erodibles (CF)

The value MDCH used for the correction factor (**CF**, in the derivation for Ew) for non-erodibles (for stones and other materials on the road surface that are at least 1 cm in size) was the default value of 1.25. It may be more appropriate to use a factor of 1 or some value in between. The default value considers that there might be gravel and/or rocks as well as stampsands on the roads, which may or may not be the case for paved roads. However, if one is including the road shoulder in the assessment, the default CF value of 1.25 is appropriate. If the CF value had been 1, then the resulting Ew would have been higher and the PEF lower, which would result in higher estimated air concentrations. *Site-specific data may provide information on the degree of non-erodibles on the paved roads in Calumet.*

Silt Loading (sL)

Currently, MDEQ does not use the Ev equation that includes the road surface silt loading (**sL**) variable (MDEQ 2009). Therefore, a sensitivity analysis for that parameter is not shown here.

The sL value shown in Table C-3 was calculated using AP-42 guidance (EPA 2011a). The ubiquitous baseline for paved roads with average daily traffic of 5,000 to 10,000 vehicles is 0.06 g/m^2. Then there is a multiplier of 2 for months with frozen precipitation, for which MDCH assumed six months. This resulted in 183 days with an sL value of 0.06 and 182 days with a value of 0.12. There is a factor of 2 as an "initial peak additive contribution from application of the antiskid abrasive," taking one day to return to baseline. MDCH assumed that stampsands were applied as road-traction material one day per week during the six months of frozen precipitation (26 days total). Therefore, the overall sL was [(183 days * 0.06 g/m^2) + (156 days * 0.12 g/m^2) + (26 days * 2.12 g/m^2)]/365 days, or 0.23 g/m^2.

Percent silt content in the stampsand piles may differ from that on the roads, which may affect the sL value. Silt loading to the roads may actually be higher than estimated in this exercise, due to the stampsands being ground into smaller particle sizes by traffic.

Similar to As, above, the sL value was not specific to Calumet. While MDCH assumed a stampsand application frequency of one day per week, true application rates can range from every day to only several times per month (K. Harju, Houghton County Road Commission, personal communication, 2011). *Site-specific sL data are necessary to accurately estimate expected air concentrations.* The AP-42 provides guidance on acquiring such data (EPA 1993a, b).

Combined Sensitivity Analysis

If all of the default values discussed in this section, and the adjusted generic Q/C, were used in place of the site-specific values, the resulting PEF would have been lower (about one quarter the value calculated originally), which would result in higher estimated air concentrations.

Confidence

The confidence in the appropriateness of the values discussed here is low to medium. More site-specific data, regarding As, CF, and sL, are needed to accurately estimate expected air concentrations. For purposes of completeness, the data are used here to estimate air concentrations.

Stampsand Concentration Data

Staff from the MDEQ Remediation and Redevelopment Division (RRD) collected stampsands at the Point Mills site (see Figure 3) in August and September 2003. They took a total of 217 samples at various depths in 59 locations in the 15-acre deposit area (Weston 2006b; J. Walczak, MDEQ RRD, personal communication, 2010).

The stampsands were analyzed for the following metals: aluminum, arsenic, beryllium, chromium, cobalt, copper, lead, lithium, manganese, mercury, nickel, silver, strontium, and zinc. The 95% Upper Confidence Limits of the mean concentrations (95 UCLs; a statistical value that represents an upper estimate of the true mean) are shown in Table C-4. The results for all depths, not just surficial, are considered in this exercise because, as shallower depths are removed during excavation or erosion, the deeper depths are exposed and become available for inhalation.

Table C- 4. 95% Upper Confidence Limits of the mean concentrations (95UCLs) of selected metals in stampsand samples taken August and September 2003 at Point Mills (Houghton County), Michigan. (Results are in micrograms per kilogram [µg/kg].)

Metal	**95UCL**
Aluminum	2,077,000
Arsenic	4,200
Beryllium	440
Chromium	40,000
Cobalt	23,000
Copper	2,209,000
Lead	2,800
Lithium	8,200
Manganese	503,000
Mercury	3.1
Nickel	42,000
Silver	1,300
Strontium	24,000
Zinc	70,000

Reference: Weston 2006b

Air Concentration Calculations

The estimated air concentrations for the metals in the Point Mills stampsands are the concentration within the stampsands divided by the PEF. Table C-5 shows the expected air concentrations for the metals in Calumet.

Table C- 5. Estimated air concentrations of selected metals in Point Mills stampsands used on Calumet roads (Houghton County), Michigan.

Metal	**Stampsand Concentration (µg/kg)**	**PEF (m^3/kg)**	**Estimated Air Concentration (µg/m^3)**
Aluminum	2,077,000	36,500,000	0.06
Arsenic	4,200	36,500,000	0.0001
Beryllium	440	36,500,000	0.00001
Chromium	40,000	36,500,000	0.001
Cobalt	23,000	36,500,000	0.0006
Copper	2,209,000	36,500,000	0.06
Lead	2,800	36,500,000	0.00008
Lithium	8,200	36,500,000	0.0002
Manganese	503,000	36,500,000	0.01
Mercury	3.1	36,500,000	0.00000008
Nickel	42,000	36,500,000	0.001
Silver	1,300	36,500,000	0.00004
Strontium	24,000	36,500,000	0.0007
Zinc	70,000	36,500,000	0.002

Acronyms:

µg/kg micrograms per kilogram
m^3/kg cubic meters per kilogram
µg/m^3 micrograms per cubic meter

Comparison of Estimated Air Concentrations to Health-Based Screening Values

To determine whether the estimated air concentration might be harmful, MDCH compared the concentration to a health-based number, prioritizing the screening values as follows:

1. The first choice of a comparison value to use was the EPA Reference Concentration (RfC). This is a regulatory number that is an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure that is not likely to cause harm in a person's lifetime (EPA 2010b). Lead does not have an RfC but, as a "criteria" pollutant (per the Clean Air Act), has a National Ambient Air Quality Standard (NAAQS), which is a regulatory number and was used as a comparison value here. Primary standards set limits to protect public health, including sensitive populations (asthmatics, children, elderly; EPA 2011b).
2. If an RfC or NAAQS was not available for a chemical, then MDCH used a Comparison Value (CV) derived by the federal Agency for Toxic Substances and Disease Registry (ATSDR), if available. CVs are not regulatory numbers but advisory levels. For non-carcinogenic chemicals in soil, water or air, ATSDR derives Environmental Media Evaluation Guides (EMEGs). Chronic air EMEGs (based on Minimal Risk Levels [MRLs]) are similar in derivation to the RfCs but, due to differing interpretations and risk assessment practices between the agencies, may result in a different value. For carcinogenic chemicals in soil, water or air, ATSDR derives Cancer Risk Evaluation Guides (CREGs). These are different from the Inhalation Unit Risk Factors (IURFs) discussed earlier in this appendix, wherein the CREGs are not potencies but, rather, are

concentrations of a chemical that result in a one-in-one-million increased cancer risk (ATSDR 2005).

3. If neither an RfC nor a CV were available, then MDCH used the occupational Recommended Exposure Limit (REL), as established by the National Institute for Occupational Safety and Health (NIOSH). These health-based, non-regulatory values are Time-Weighted Averages (TWAs) for up to a 10-hour workday during a 40-hour workweek (NIOSH 2006). Because RELs are not 24-hour exposure numbers, they can be much higher than RfCs and CVs. In the past, MDCH has used Acute Exposure Guideline Levels (AEGLs) to consider risks of short-term exposures. AEGLs address emergency exposures to the public for 10 minutes to eight hours and are usually more protective (lower) than occupational limits (EPA 2010a). However, no AEGLs were available for the metals that did not have RfCs or CVs.
4. Lithium and strontium did not have RfCs, CVs, or RELs available. They are discussed later in this section.

The REL screening values may not be adequately protective for non-occupational populations. The ratio between the estimated air concentration of a metal, in this exercise, and its REL ranges from four to seven orders of magnitude (10,000 to 10,000,000 times; see Table C-6). When deriving an RfC or MRL, agencies apply uncertainty factors (UFs) to experimental data to estimate a protective value for public exposure. The value of a UF is typically 1, 3 or 10, and is applied to account for animal data to human extrapolation, inter-individual differences in humans, extrapolating less-than-lifetime exposure to lifetime exposure, extrapolating from a study without a no-effect level, and an inadequate database (EPA 2002). If the maximum UF for each consideration except animal-data-to-human were applied to an REL, the total UF would be 10,000, which is the minimum ratio between the estimated air concentration and its REL in this exercise. This suggests that an adequate margin of safety exists between estimated and acceptable (specifically, the REL screening values) exposures in this exercise.

If the exposure-specific time-weighted average air concentration, which is the expected exposure, is divided by the screening value, the resulting ratio indicates the extent of exposure. The smaller the quotient is, compared to 1 (meaning expected exposure is less than the screening value), the larger the margin of safety. This "Calculated Margin" assumes that people are exposed to the chemical only at the site and nowhere else. This assumption may not be appropriate for the Point Mills stampsands because they have been used for many years as road-traction material on winter roads. Stampsands can remain for some time on the roadways, though they will, for the most part, settle eventually onto the shoulders of the roads. However, they still can become resuspended in air and people can be exposed to them. To compensate for this possibility, MDCH chose an "Acceptable Margin" of 0.5 instead of 1. (This rationale is similar to that used for Relative Source Contribution factors used for drinking water and soil evaluations [MDEQ 2004b, 2005].) The comparison between "Calculated Margins" and "Acceptable Margins" is shown in Table C-6.

Table C- 6. Comparison between calculated and acceptable margins of safety for airborne Point Mills stampsands used on Calumet roads (Houghton County), Michigan.

Metal	**Estimated Air Concentration ($\mu g/m^3$)**	**Screening Value ($\mu g/m^3$)**	**"Calculated Margin" (unitless)**	**"Acceptable Margin" (unitless)**
Aluminum	0.06	10,000 [A]	0.000006	0.5
Arsenic	0.0001	0.0002 [B]	0.5	0.5
Beryllium	0.00001	0.0004 [B]	0.025	0.5
Chromium	0.001	0.00008 [B,C]	12.5	0.5
Cobalt	0.0006	0.1 [D]	0.006	0.5
Copper	0.06	1,000 [A]	0.00006	0.5
Lead	0.00008	0.15[E]	0.0005	0.5
Lithium	0.0002	NA	NC	0.5
Manganese	0.01	0.05 [F]	0.2	0.5
Mercury	0.00000008	0.3 [F]	0.0000002	0.5
Nickel	0.001	0.09 [D]	0.01	0.5
Silver	0.00004	10 [A]	0.000004	0.5
Strontium	0.0007	NA	NC	0.5
Zinc	0.002	5,000 [A]	0.0000004	0.5

Acronyms:

$\mu g/m^3$	micrograms per cubic meter	CREG	Cancer Risk Evaluation Guide
EMEG	Environmental Media Evaluation Guide	NA	not available
NAAQS	National Ambient Air Quality Standard	NC	not calculated
REL	Recommended Exposure Limit	RfC	Reference Concentration

Notes:

A. REL
B. CREG
C. Value is for hexavalent chromium.
D. Chronic air EMEG
E. NAAQS
F. RfC

Although the "Calculated Margin" for chromium is 12.5, seemingly well above the "Acceptable Margin," the screening value used is for the hexavalent (VI) form of the metal. In most environmental situations, however, the less toxic, trivalent form (chromium III) predominates (Kimbrough et al. 1999, ATSDR 2000a). Therefore, one would not expect the hexavalent form to occur in the stampsands. There is no RfC, EMEG, or CREG for chromium III. The REL for chromium metal and chromium III compounds is 500 $\mu g/m^3$ (NIOSH 2006), which is more than five orders of magnitude greater than the estimated air concentration. Chromium in airborne stampsands in this scenario is not expected to cause harm.

The "Calculated Margin" for arsenic equals the "Acceptable Margin" for that metal. This does not automatically imply that the air is unsafe. Rather, further evaluation is necessary, including refining calculations with site-specific data, as discussed in the *Uncertainty Discussion, Sensitivity Analysis for, and Confidence in Selected PEF Variables* section earlier.

As stated earlier in this section, lithium and strontium do not have RfCs, CVs, or RELs. These metals are discussed further in the main body of this document.

Considering Acute Exposures

The U.S. Environmental Protection Agency (EPA) forwarded to MDCH a complaint from a Calumet resident regarding street-sweeping activities causing large dust clouds. The following text, edited for readability, is from the citizen's letter (dated April 22, 2008):

> "I have a question about the stamp sand that Houghton County uses on our roads in the winter to prevent slippery conditions. Where I live in Calumet on a 4-way intersection it is dumped out in huge quantities. When spring approaches it is ground to a fine dust and blown all over in huge dust storms. It covers my lawn, garden, and cedar shrubs. If left on the grass, the grass does not grow. Garden plants later become covered with it. I hose it off the tomatoes etc. My question is, has this ever been tested to see if it is harmful for inhaling the dust? It must contain copper particles and arsenic. Could the EPA conduct a test on this to see the harmful effects on humans?"

Although the complainant did not include photographs of the dust, MDCH found a representative picture on a website about Michigan's Upper Peninsula (see Figure 4), and MDEQ provided photographs taken of street sweepers operating in Houghton County (see Figures 5 and C-2).

Figure C- 2. Picture of dust generated by street sweeper in Houghton County, Michigan. (Photograph taken May 6, 2010. Source: MDEQ.)

Empirical evidence from state-wide air monitors indicate that ambient peak PM10 levels measured over 24-hour periods were roughly twice the annual average concentration (MDEQ 2009). (The MDEQ database did not indicate what attributed to the peak air concentrations.) Thus, multiplying the estimated air concentration by 2 would result in expected peak, or acute, exposure levels of PM10 metals in the air. Except for arsenic, doubling the expected air concentrations for metals in Point Mills stampsands used on Calumet roads does not result in exceedances of the health-based screening values used in Table C-6, which suggests no risk from short-term, higher-than-normal exposures to those metals. Doubling the expected air concentration of arsenic results in the value being equal to the CREG. This does not raise public health concern, however, since peak concentrations would be short-term (acute) exposures. (Chronic screening levels, such as the RfC and EMEG or CREG shown in Table C-6, are more protective [lower] than acute screening levels.) Further discussion of arsenic is in the main body of this document.

Dust generated by street-sweeping may be more of a nuisance issue or may be hazardous due to the amount of particulate matter in the air in general. Further discussion is in the main body of this document.

Conclusions

Based on the values used in this exercise, some of which are site-specific data-based values whereas others are default assumptions, the estimated air concentrations of selected metals from Point Mills stampsands in Calumet might cause harm in the short or long term. More discussion regarding exposure and public health implications is in the main text of this document. If new information becomes available that would change the values, re-evaluation may be necessary. This exercise can inform and guide future risk assessments.

Appendix D. MDCH Response to Public Comments and Questions Received on the "Evaluation of Inhalation of Airborne Stampsands in the Torch Lake Superfund Site and Surrounding Area" Public Health Assessment

MDCH compiled the comments and questions received at the May 15, 2013 community meeting in Lake Linden, Michigan. Questions and comments pertaining to the stampsands-inhalation document are addressed here.

Questions and comments pertaining to the exposure-during-outdoor-activities public health assessment, "Evaluation of recreational uses at beach areas at Lake Linden and along Torch Lake, Houghton County, Michigan," are addressed in an appendix of that document. That document is available on-line and in print at the locations mentioned in the next paragraph.

Other questions and comments received that did not apply to either document specifically are listed in a separate responsiveness summary. The responsiveness summary is available at www.michigan.gov/mdch-toxics, under "Health Assessments and Related Documents," then "Torch Lake Superfund Area." It also is available at the public repositories for the Torch Lake Superfund Site: the Lake Linden-Hubbell Public School Library in Lake Linden, Michigan, and the Portage Lake District Library in Houghton, Michigan.

EPA said the stampsands are supposed to be covered but the pile at the road commission isn't. Why? How come covering stampsands isn't applied to everyone equally?

According to the MDEQ, the capping done by the U.S. EPA was to prevent large dust events at several sites. The chemical composition of the materials below the caps was not determined and the caps were not intended to prevent contact with contaminated materials. Landowners can choose to cap small areas of tailings even if they are not required to do so by the U.S. EPA or DEQ.

According to the U.S. EPA, the Houghton County Road Commission was temporarily exempted from covering the stampsands so they could use the material for the road construction and maintenance. The Road Commission was required to cover the pile when done using it. According to the U.S. EPA, the pile is no longer in use.

Do local dirt roads have stampsands on them? It gets very dusty in the summer.

According to the Houghton County Road Commission, the majority of gravel roads in Houghton County are constructed of crushed mine rock, which is coarser than stampsands. About one half of the roads in Houghton County are gravel or dirt, with dust control applied to about 10 percent of unpaved roads. The road commission uses about 10,000 cubic yards of stampsands per year for winter ice control.

According to the Keweenaw County Road Commission, stampsands are used to improve unpaved roads (fill soft spots, level out "washboard" roads, fill in mud holes, etc.) and for winter ice control. The road commission also uses Gay stampsands, along with "poor rock" (waste rock), to construct gravel roads.

As discussed in the stampsands inhalation document, dust from street-sweeping, or from unpaved roads, may be more of a nuisance issue or may be hazardous due to the amount of

particulate matter in the air in general. MDCH was unable to determine if airborne stampsands, coming off of roadways, presents a chemical hazard.

How were mercury levels that went into the airborne stampsand risk calculations set? How variable is the mercury content in the stampsand samples that have been collected? Is the variability at the two sites representative of the variability in mercury content in windblown stampsands in this area? Does the mercury content of the stampsand vary with depth, i.e., does the mercury leach deeper in the sands over time so that freshly exposed stampsand has higher mercury content?

MDCH used the 95% Upper Confidence Limit (UCL) of the mean concentration of mercury in the northern sampling area of the Gay stampsands and in the Point Mills stampsands to estimate air concentrations at Gay and Calumet, respectively. The UCL is a statistical value that represents an upper estimate of the true mean of mercury concentration in the stampsands. As such, MDCH is being health protective when using the UCL to represent mercury concentrations.

MDCH used sampling results from all depths, not just surficial, in its calculations. MDEQ sampled at the northern deposit area at Gay at depth increments of four feet, up to 26 feet below surrounding grade. MDCH sorted the data by sample depth, resulting in the following concentrations per four-foot increment (concentrations are in mg/kg):

	0 feet	1-4 feet	5-8 feet	9-12 feet	13-16 feet	17-20 feet	21-24 feet	25-28 feet
Aluminum	15,000	15,762	15,458	16,130	16,419	14,571	14,800	14,000
Arsenic	2.2	2.3	2.7	2.7	2.8	3.4	3.1	3.9
Beryllium	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5
Chromium	25.2	27.9	28.7	31.1	33.1	32.4	32.6	33.0
Cobalt	21.3	22.7	22.9	24.0	25.0	24.1	23.2	24.0
Copper	2,444	2,590	3,153	3,130	2,965	3,700	3,500	3,200
Lead	5.3	5.5	Not detected	5.1	6.1	Not detected	Not detected	Not detected
Lithium	5.1	5.9	6.2	6.6	7.2	7.0	6.2	7.4
Manganese	441.4	509.5	541.0	602.6	630.0	528.6	452.0	600.0
Mercury	0.1	0.1	0.1	Not detected	Not detected	Not detected	Not detected	Not detected
Nickel	27.3	30.6	31.4	33.2	34.5	33.0	31.0	33.0
Silver	1.3	1.5	1.9	2.1	2.1	2.7	2.0	2.7
Strontium	13.7	16.7	17.5	18.2	18.9	17.0	14.4	21.0
Zinc	69.9	74.2	74.7	76.2	79.6	82.0	84.6	75.0
Number of samples	59	63	59	46	31	7	5	1

Lead and mercury were rarely detected in the samples. All of the other metals were detected in all samples. For the northern deposit area at Gay, mercury was detected only in the top eight feet of the stampsands, suggesting that the metal is not leaching deeper. But it is not known why the first eight feet of stampsands occasionally contained mercury (four detections at 0 feet, eight detections at 1 to 4 feet, and one detection at 5 to 8 feet) whereas deeper samples contained no mercury (detection limit of 50 µg/kg).

According to MDEQ, the samples taken at the southern deposit area at Gay were all surficial (A. Keranen, MDEQ Remediation and Redevelopment Division, 2013, personal communication), so a concentration-by-depth comparison cannot be made for that area.

As with the Gay stampsands, MDCH used samples from all depths to calculate the UCL for the Point Mills area. MDEQ sampled in depth increments of four feet, up to 20 feet below the surrounding grade. Mercury does not seem to be in the deeper stampsands; it was only detected in the first 12 feet (four detections at 0 feet, five detections at 1 to 4 feet, four detections at 5 to 8 feet, and three detections at 9 to 12 feet). MDCH sorted the data by sample depth, resulting in the following concentrations per four-foot increment (concentrations are mg/kg):

	0 feet	1-4 feet	5-8 feet	9-12 feet	13-16 feet	17-20 feet
Aluminum	2,658	2,007	1,631	1,519	1,783	1,300
Arsenic	4.6	4.1	3.8	3.4	3.8	2.9
Beryllium	Not detected	0.4	0.4	0.4	0.4	0.3
Chromium	50.6	38.0	31.7	30.1	35.7	29.8
Cobalt	25.2	22.4	20.5	20.9	22.3	21.3
Copper	2,153	2,144	2,155	2,078	1,900	2,850
Lead	8.0	5.3	7.7	Not detected	Not detected	Not detected
Lithium	10.2	8.0	6.8	6.1	7.1	5.0
Manganese	Not detected	489.5	411.0	396.4	438.3	360.0
Mercury	0.1	0.1	0.1	0.1	Not detected	Not detected
Nickel	51.9	40.6	34.3	31.9	36.7	30.0
Silver	1.2	1.3	1.3	1.3	1.2	2.0
Strontium	20.0	21.8	22.0	22.6	20.5	20.8
Zinc	Not detected	69.5	65.8	67.1	68.2	63.5
Number of samples	59	59	51	36	6	4

There are no air data regarding resuspended stampsands. Therefore, MDCH cannot compare the variability between ground and air concentrations.

Did MDCH consider, during the public health assessment process, the August 10, 1992 letter from Life Systems Inc. (the consultant who conducted the Remedial Investigation of the site) to the EPA Remedial Project Manager, regarding mine tailings used on roads?

The letter mentioned refers to the Baseline Risk Assessment conducted for Operable Unit III, in which the consultant concluded that predicted airborne stampsand concentrations at the Isle-Royale area were within acceptable limits. (MDCH has the risk assessment document in its files.) While the conclusions reached in 1992 may have been valid at the time, the understanding of resuspension of stampsands, their toxicity, and exposure assessment has increased over the intervening decades. When changes in risk assessment practice occur, it is prudent to review past conclusions, using the best available science, to ensure they are still valid.

The PAC (Public Action Council) stated that water has been used for brooming in recent years.

MDCH is aware that water has been used in some brooming activities, to keep down dust, but the use does not appear to happen consistently.

When the PHA reports say, "More information needed," who will do that – EPA and MDEQ? When? Where will the sampling take place? What will you test for? If EPA/MDEQ won't sample, why not? The health reports say it's needed. It sounds like MDCH doesn't do the sampling. Will MDCH conduct follow-up assessment after any additional data is collected?

The MDEQ Remediation and Redevelopment Division chief, present at the May 15, 2013 meeting, indicated that MDEQ would collect environmental samples where a risk is suspected (e.g., areas where PCBs were used or released, odd-colored media). The agency would be interested in results of the "Integrated Assessment of the Torch Lake Area of Concern" being conducted by Noel Urban and colleagues at Michigan Technological University, to help guide investigative efforts. Also, MDEQ would work with the WUPHD regarding sampling local drinking water wells. Other divisions at MDEQ, such as the Water Resource Division, may obtain data as well. In some instances, MDEQ may request assistance from EPA's Emergency Removal program.

MDCH will evaluate any future data as needed.

Do we also have to worry about the iron tailings in the rest of the Upper Peninsula?

Iron tailings could have elevated chemical levels. Samples would have to be collected and analyzed to know for sure.

MDCH has evaluated fish contamination associated with iron mines located near certain waterbodies: selenium contamination in Goose Lake in Marquette County (http://www.michigan.gov/documents/mdch/Goose_Lake_Selenium_LHC-_FINAL-3-10-2011_369145_7.pdf) and mercury contamination in Deer Lake in Marquette County (http://www.michigan.gov/mdch/0,4612,7-132-54783_54784_54785_58671-266093--,00.html). MDCH did not evaluate other exposure pathways at these sites.