Methods for Health Effects Screening of Big Bay Metals Air Monitoring Data

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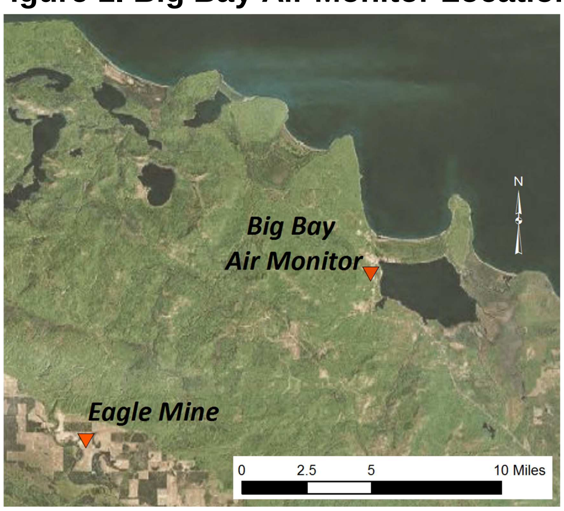
Abstract

The Superior Watershed Partnership and Land Trust (SWP) collected four, 24-hr air samples from May 2013 to May 2014 in Big Bay, Michigan. The Michigan Department of Environmental Quality (MDEQ) was asked by SWP to compare the resulting air metal concentrations to appropriate health protective benchmarks in order to characterize the public health significance of the measured levels. MDEQ Air Quality Division's health-based screening levels (SLs) are intended for use in the permitting process, but they can also be used (with caution) in interpreting the public health significance of ambient air monitoring data. All metal concentrations were below their respective short-term SLs. Although the data thus far are very limited for assessment of long-term public health concerns, the average metal concentrations were compared to long-term health based screening levels. Only arsenic was found to be higher than the long-term SL of a 1-in-100,000 lifetime cancer risk, due to one particularly high sample. Future arsenic air monitoring results would help characterize long-term exposure and potential health impacts.

This report is intended to help interpret the results of recent Superior Watershed Partnership (SWP) monitoring of metals in the ambient air near Big Bay, MI as well as provide a method which with to evaluate future monitoring results. The Big Bay air monitor[1] is located approximately 13 miles northeast of the Eagle Mine (see Figure 1). The potential health risk from exposure is characterized by comparing the measured air concentrations to health-based screening levels (SLs) typically used by Michigan Department of Environmental Quality (MDEQ) Air Quality Division (AQD) to evaluate the acceptability of industrial facility emissions of toxic air contaminants (TACs). During the permitting process, SLs provide a regulatory basis for legally requiring a facility to limit their emissions of pollutants so that public health is protected. It should be noted that no attempt was made by MDEQ to determine the quality of air sampling methods employed by SWP. At MDEQ air monitoring sites, a rigorous quality assurance and quality control (QA/QC) program is used. The MDEQ, as well as the U.S. Environmental Protection Agency (EPA) audit the monitoring network annually using various methods including inspecting the QA/QC records, and site inspections. Field and laboratory sampling QA/QC protocols also include analyzing sampling and field blanks to assess the monitoring equipment and procedure for chemical contamination.

Figure 1. Big Bay Air Monitor Location



[1] Behind Cram's General Store, Box 370 Country Road 550, Big Bay, MI 49855 (46.811802, -87.730272)

The MDEQ-AQD uses a variety of sources for acute and chronic SLs. The National Ambient Air Quality Standards (NAAQS) are the best source for evaluating ambient air concentrations of the six criteria air pollutants. Elemental lead is the only metal among the criteria pollutants, and as such it has a NAAQS. A good source of benchmarks for evaluating ambient air levels of non-criteria pollutants (i.e., the air toxics), is AQD's Initial Threshold Screening Levels (ITSLs) for non-cancer effects, and the Initial Risk Screening Levels (IRSLs) and Secondary Risk Screening Levels (SRSLs) for cancer effects. These SLs take into account that some people are more sensitive to chemical exposures, such as children, the elderly, pregnant women, and people with pre-existing health conditions. Each SL for a particular TAC has an averaging time. The ITSLs represent a continuous air concentration over the averaging time for which adverse health effects are unlikely to occur. The Initial Risk Screening Level (IRSL) is a concentration that represents a probability of cancer risk over a lifetime (at 70 years) of continuous exposure. The IRSL is defined in Michigan's Air Pollution Control Rules as the "upper-bound lifetime cancer risk of 1-in-1,000,000." IRSLs are used to evaluate emissions from a single source at an industrial facility. A Secondary Risk Screening Level (SRSL) is also used in Michigan's air permitting program; however, SRSLs are defined as the "upper-bound lifetime cancer risk of 1-in-100,000." SRSLs are used to evaluate the resulting air impacts from all sources of a TAC from a particular facility. In other words, both IRSLs and SRSLs are considered concentrations that represent acceptable levels of cancer risk, however, IRSLs are applicable to one source at a facility and SRSLs are applicable to all sources of the TAC from a facility. When evaluating ambient air monitoring data, the SRSL better represents an acceptable level of risk because the air sample represents a mixture from all sources emitting that pollutant into the air.

If MDEQ-AQD has not established a SL for a particular substance, SLs from other state and national organizations are used; however, the basis for the SL is evaluated so that these SLs are based on the best available scientific evidence with which to establish an acceptable level of safety. Selection of the acute benchmark was based on a general hierarchy of sources: AQD ITSL with short averaging time > Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Level (MRL) > California Office of Environmental Health Hazard Assessment (Cal OEHHA) Reference Exposure Level (REL) > U.S. Environmental Protection Agency (EPA) Acute Exposure Guidance Level (AEGL) > Texas Commission of Environmental Quality (TCEQ) Air Monitoring Reference Value (AMRV) > 1% of American Conference of Governmental and Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) (See Appendix A for details about acute health benchmarks).

Three laboratory reports from Eastern Research Group were forwarded to MDEQ-AQD. The reports provided the air concentrations from the Big Bay monitor. Various metals concentrations within the PM10 particle size fraction were reported, as well as quality control data. PM10 is the particulate matter that has an aerodynamic diameter of less than or equal to 10 micrometers (µm). Particles of this size are considered respirable, meaning they are small enough to reach the thoracic areas of the respiratory tract. According to the 2014 Work Plan[2], ambient air samples are to be collected at the Big Bay air monitor and analyzed for metals on a quarterly basis (once every 3 months). However, the available sample frequency appears to be once every 4 to 5 months at first, then quarterly thereafter.

[2] 2014 Work Plan for the Community Environmental Monitoring Program of the Eagle Mine. December 31, 2013. http://www.cempmonitoring.com/wp-content/uploads/2012/10/CEMP-2014-Work-Plan-FINAL.pdf

The air was sampled for 24-hr per day ("daily") on the following days: 5/9/2013, 9/1/2013, 2/16/2014 and 5/11/2014. Table 1 below shows the analytical results of the air monitoring for metals and the best available acute and chronic human health-based SLs. Each individual sample result provides a snapshot of ambient air which may serve as a surrogate for potential short-term public exposure levels. These daily levels can be assessed using health-based SLs specifically designed to provide protection from acute health effects (i.e., those health effects that occur over short time periods after relatively short exposures). An annual average air concentration for individual metals can also be calculated from the 4 sample results that exist at this time. However, because of the relatively infrequent sampling, the average concentration of a particular metal should be interpreted with great care, because it may not accurately reflect chronic exposures. The quarterly sampling frequency does not represent a robust exposure assessment and makes it difficult to estimate long-term (i.e., chronic) continuous exposure.

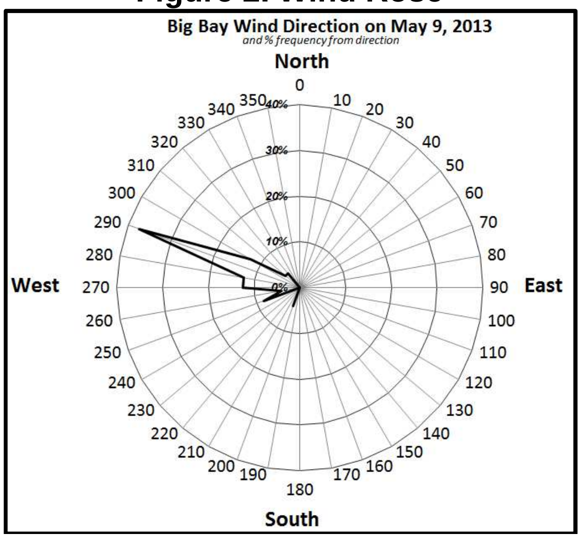
Table 1. Measured Metals Air Concentrations and Health-Based Screening Levels

	Date of Sample Collection				Arithmetic Average ng/m³ *	Acute Screening Level ng/m³	Chronic Screening Level ng/m³
Metal	**5/9/13**	**9/1/13**	**2/16/14**	**5/11/14**			
Aluminum				128		10,000	
Antimony	0.393	0.23	0.138	0.353	0.279	200	
Arsenic	8.53	0.311	0.065	0.381	2.322	15	2 (SRSL)
Barium	49.4	39.5	39.1	46.5	43.63	5,000	
Beryllium	0.039	0.000 9	0.002	0.008	0.013	20	4 (SRSL)
Cadmium	0.164	0.052	0.177	0.083	0.119	41,000	6 (SRSL)
Calcium				474			
Chromium	46.2	38.8	34.7	39	39.7	**	**
Cobalt	0.666	0.065	0.022	0.101	0.214	200	
Copper	173	24.1	192	45.3	108.6	2,000	
Iron				187			
Lead	4.88	0.712	0.619	1.17	1.85	500	150 (NAAQS)
Magnesium	653	58.7	70.5	141	230.8	100,000	
Manganese	52.7	3.38	1.12	8.27	16.4	170	300 (ITSL)
Mercury	0.023	0.008	0.02	0.01	0.016		
Molybdenum				0.237		30,000	
Nickel	2.76	0.72	0.898	1.1	1.37	200	42 (SRSL)
Rubidium				0.033			
Selenium	0.612	0.186	0.045	0.29	0.283	2,000	
Strontium				1.68		2,000,000	
Thallium				0.007		200	
Thorium				0.013			
Uranium				0.015		2,000	
Zinc	65	19.4	19	29.6	33.3	50,000	

* air concentration of ng/m³ or nanograms per cubic meter
** Elemental chromium (Cr^0), trivalent chromium (Cr^{+3}) and hexavalent chromium (Cr^{+6}) have very different toxicity and health effects. In order to evaluate the potential health effects of chromium, each type of chromium would have to be quantitated.

Monitored concentrations above a screening level should not be viewed as an imminent health threat or an unacceptable level of health risk. Rather, if a measured air concentration of a particular substance exceeds its screening level, then the data and health concerns should be further evaluated. All of the individual daily (24-hr) samples taken at the Big Bay monitor were below the acute health screening levels. Short-term health effects from air concentrations of metals are unlikely to occur. All of the average concentrations are below the chronic screening level with the exception of arsenic. It should be noted that the metal concentrations from the sample taken on May 9, 2013 are relatively high compared to the subsequent three samples. Sometimes earth moving activities close to the monitor or high winds can cause a temporary increase in particulate matter resulting in increased metals concentrations that are naturally part of the soil. For example, the arsenic concentration on 5/9/13 was measured as 8.5 ng/m^3, which is roughly 34 times higher than the average of the next three samples [next 3 sample average = 0.25 ng/m^3 = (0.311+0.065+0.381)/3].

Figure 2. Wind Rose



Note that the sample collected on May 9, 2013 had wind direction primarily from the Northwest (see Figure 2). The 8.5 ng/m^3 arsenic level is about 2 to 3 times higher than the maximum observed at a comparable rural site in Merritt, Michigan (Missaukee County) (See Table 2). However, at the AQD's Merritt monitor a different size fraction of particulate matter was used, i.e., Total Suspended Particulates (TSP). TSP includes larger particles than the PM10 size. PM10 is contained within the TSP fraction, so TSP can be used as a rough approximation for this comparison. The value of 8.5 ng/m^3 is similar to the highest values recorded at AQD's Dearborn monitoring site during the early to mid- 2000's. The Dearborn monitor is impacted by many industrial facilities, including a steel mill that is about 1 mile upwind.

Table 2. Air Monitoring Data for Arsenic in 2 Locations in Michigan*

Merritt Arsenic Concentrations (ng/m^3)

Year	Metal (size)	Highest 24 hr.	Annual Average
2002	Arsenic (TSP)	2.27	0.63
2003	Arsenic (TSP)	2.44	0.70
2004	Arsenic (TSP)	1.84	0.55
2005	Arsenic (TSP)	2.23	0.66
2006	Arsenic (TSP)	2.03	0.54
2007	Arsenic (TSP)	1.14	0.35
2010	Arsenic (PM 2.5)	3.50	0.30
2011	Arsenic (PM 2.5)	2.97	0.37
2012	Arsenic (PM 2.5)	2.55	0.44
2013	Arsenic (PM 2.5)	3.03	0.39

Dearborn Arsenic Concentrations (ng/m^3)

Year	Parameter	Highest 24 hr.	Annual Average
2004	Arsenic PM10	45.5	5.53
2005	Arsenic PM10	6.32	1.19
2006	Arsenic PM10	87.4	9.59
2007	Arsenic PM10	7.02	1.09
2008	Arsenic PM10	7.23	1.16
2009	Arsenic PM10	5.09	0.91
2010	Arsenic PM10	6.80	1.36
2011	Arsenic PM10	4.05	0.86
2012	Arsenic PM10	5.34	0.86
2013	Arsenic PM10	3.44	0.79

*Data obtained from MDEQ AQD Monitoring Database

In more recent years, the Dearborn air monitor has been recording lower arsenic values than 8.5 ng/m^3. Extra scrutiny is warranted in the interpretation of the arsenic average concentration of 2.3 ng/m^3 because the one sample taken in May 2013 causes the average to be slightly higher than the chronic screening level of 2 ng/m^3. It would be appropriate to consider if the sampling equipment was operating properly on 5/9/13. Additional sampling results will help to determine if the 5/9/13 sample is representative of ambient air in Big Bay or if the more recent lower air concentrations of arsenic better represent typical arsenic air concentrations.

In conclusion, all the metal concentrations obtained from the 4 samples are below their acute screening levels that are protective for short-term adverse health effects, and are not associated with an increased health risk to the public. The four-sample average arsenic concentration was found to be above the SRSL, yet it is still in range of concentrations that EPA associates with acceptable cancer risk. U.S. EPA has made case-specific determinations such as the 1989 Benzene National Emission Standard for Hazardous Air Pollutants (NESHAP) that set an upper limit of acceptability of 1 in 10,000 lifetime cancer risk for highly exposed individuals. Using this upper limit of acceptability of 1-in-10,000 for lifetime cancer risk for arsenic would result in a screening level of 20 ng/m^3. This screening level for arsenic, however, is not designed to be a definitive tool for determining risk since actual exposure concentrations may not be represented by the ambient air at the Big Bay monitor. The current sampling frequency lacks the level of refinement which would enable a more accurate assessment of the exposures found throughout the year. Consequently, the results should not be used as absolute measures to determine whether risks are acceptable. Rather, they should be used to focus or target further measurement and assessment activities. Finally, given the limited number of samples collected so far, more monitoring is needed to determine if the relatively high arsenic concentration on May 9, 2013 is representative of a normal high value.

Appendix A: Acute Benchmarks

Hierarchy of Acute Benchmarks (highest to lowest): AQD ITSL (short averaging time) > ATSDR acute or intermediate MRL > Cal OEHHA REL > EPA AEGL > TCEQ AMRV > 1% of ACGIH TLV

Table A1. Acute Benchmarks and Their Origin

Metal	Acute Benchmark µg/m^3	Acute Benchmark ng/m^3	Averaging Time	Reference
Aluminum	10	10,000	8-hr	1% of ACGIH TLV*
Antimony	0.2	200	24-hr	AQD ITSL
Arsenic	0.015	15	8-hr	Cal OEHHA
Barium	5	5000	8-hr	ITSL
Beryllium	0.02	20	24-hr	ITSL
Cadmium	41	41000	8-hr	AEGL
Calcium				
Chromium				
Cobalt	0.2	200	8-hr	ITSL
Copper	2	2000	8-hr	AQD ITSL
Iron				
Lead	0.5	500	8-hr	1 % of ACGIH TLV
Magnesium	100	100000	8-hr	AQD ITSL
Manganese	0.17	170	8-hr	Cal OEHHA
Mercury				
Molybdenum	30	30000	8-hr	AQD ITSL
Nickel	0.2	200	2 weeks+	ATSDR MRL
Rubidium				
Selenium	2	2000	8-hr	AQD ITSL
Strontium	2000	2,000,000	24-hr	AQD ITSL
Thallium	0.2	200	24-hr	AQD ITSL
Thorium				
Uranium	2	2000	8-hr	1% of ACGIH TLV
Zinc	50	50,000	8-hr	AQD ITSL

* The TLV can be used to derive a short-term benchmark by dividing by a safety factor of 100. The safety factor is used to protect sensitive individuals.

Abbreviations:

ACGIH: American Conference of Governmental and Industrial Hygienists
AEGL: Acute Exposure Guidance Level (used by EPA)
AMRV: Air Monitoring Reference Value (used by TCEQ)
AQD: Air Quality Division
ATSDR Agency for Toxic Substances and Disease Registry
Cal OEHHA: California Office of Environmental Health Hazard Assessment
EPA: U.S. Environmental Protection Agency
ITSL: Initial Threshold Screening Level (used by AQD)
MRL: Minimal Risk Level (used by ATSDR)
µg/m^3: micrograms per cubic meter
ng/m^3: nanograms per cubic meter
REL: Reference Exposure Level (used by Cal OEHHA)
TCEQ: Texas Commission of Environmental Quality
TLV: Threshold Limit Value (used by ACGIH)