Metals Emissions from Taconite Ore Processing Facilities in Minnesota

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ABSTRACT

As a major emission source of particulate matter (PM), Minnesota's seven taconite (low grade iron) ore processing facilities release approximately 20 thousand tons of PM to the atmosphere every year. In 1996, their combined PM emissions made up about one third of PM emissions from all point sources in the state. Emitted with PM from various processing steps are a number of metal and non-metal chemicals (commonly referred to as metals), some of which are among the target chemicals in the air toxics emission inventory. Current emission factors, provided by the U.S. Environmental Protection Agency (EPA), tend to overestimate metals emissions from the taconite ore processing industry.

This paper presents some of the source-specific metals emission data that have become available to the Minnesota Pollution Control Agency (MPCA). These source-specific metals emission data, though generated by the facilities on a voluntary basis to make emission estimates for air quality permitting and other activities, are useful for the air toxics emission inventory.

INTRODUCTION

The Clean Air Act of 1990 includes a list of hazardous air pollutants (HAPs) that are regulated by the Act. A list of source categories that emit certain levels of these HAPs, subsequently published by the EPA, includes taconite ore processing facilities as a major source category, which emits 10 tons/year of any one or 25 tons/year of any combination of HAPs. The EPA also published November 15, 2000 as the scheduled promulgation date for the National Emission Standard for Hazardous Air Pollutants (NESHAP), often called "Maximum Achievable Control Technology" (MACT) standards, for this industry.

The MPCA is preparing, for the EPA, a summary of existing HAPs emission data for the taconite ore processing industry. The MPCA is also committed to develop the Minnesota portion of the Great Lakes Regional Air Toxics Emission Inventory, for which metals are of concern.

The objective of this paper is to present metals emission data from the taconite ore processing facilities, and to compare metal emissions estimated from source-specific information with those estimated from current EPA generic information.

TACONITE MINING AND PROCESSING OPERATIONS

Taconite, a low grade iron ore of approximately 30% iron content or lower, is mined (by open-pit methods) and processed in the Mesabi Range in northern Minnesota and the Marquette Range in the northern part of the Upper Peninsula of Michigan. Pellets of approximately 65% iron content are produced, which are used by blast furnace operators to make iron and steel products. Figure 1 presents general steps of taconite mining and processing operations.

There are seven companies currently operating in Minnesota and two in Michigan. Their ore reserve, production level, and projected mine expectancy are summarized in Table 1. These facilities emit hazardous air pollutants (HAPs) in various steps of mining and processing, most noticeably the pelletizing process.

At pelletizing, a “green” unbaked pellet or ball, of approximately 1 cm in diameter, is formed and then hardened by heating (indurating) in a furnace at a temperature as high as 1315 ºC (2400 ºF). The furnace is called an agglomerator, indurator, or pelletizer. There are three different furnace types: a) grate-kiln, which consists of a traveling grate, a rotary kiln, and an annular cooler; b) straight grate; and c) vertical-shaft, which handles a smaller rate of process throughput.

Two categories of HAPs are generated and emitted from the pelletizing process. The first category includes certain metal and non-metal chemicals naturally associated with taconite ore. These can be in the gas state such as Mercury (Hg), Arsenic (As), Selenium (Se), and Cadmium (Cd), or in the solid state (part of the particulate matter) such as Chromium (Cr), Cobalt (Co), and Nickel (Ni). Some of them may be found in both the gas and solid states. These HAPs are often generically referred to as “metals,” possibly because they are quantified by EPA Reference Method 29 (Determination of metals emissions from stationary sources).[1] Regardless of the title, the reference method can be used for fourteen metals and three non-metals (As, Se, and Phosphorus).

The second category of HAPs associated with the pelletizing process are products of incomplete combustion (PICs), which are compounds in the gas state. Formaldehyde, hydrogen chloride, and hydrogen fluoride have been found through stack testing. Hexane, benzene, and toluene were found to be below respective detection limits, but are suspected to be present. Nonetheless, PICs are beyond the scope of this paper.

METALS EMISSIONS AT PELLETIZING

The flow diagram in Figure 1 can be further simplified as “at pelletizing,” “upstream of pelletizing,”and “downstream of pelletizing” for the purpose of deriving emission factors from metals emission testing results. The blasting operation can be omitted, because, while blasting may be a very significant event on a short-term time scale, it does not cause any significant air quality impact on an hourly basis in the taconite mining area.

Five performance tests have been conducted to quantify pelletizer metals emissions at four of the seven companies in Minnesota.[2] Table 2 summarizes process and production information relevant to metals emission testing. The data show that different pelletizer types and production types lead to different energy demands per unit mass of product (pellets), which are primarily determined by the varied ore chemical composition and individual operational practices. The gas flow, of up to nearly 300,000 dry, standard cubic feet per minute (approximately 140 m^3/s at 20 ºC and 760 mm Hg), makes the pelletizer stack among the largest of all industrial process stacks.

Since the metals are naturally associated with taconite ore, the emission factors derived from stack testing are normalized to process throughput parameters instead of fuel usage. The hourly production rate of pellets is the most used process throughput parameter for deriving emission factors at pelletizing. Emission factors thus derived are presented in Table 3. Notice that detection limits were different from test to test.

Alternatively, one may want to use PM emissions as the normalizing parameter, as shown in Table 4. Once PM emissions data are available, metals emissions can be calculated easily. There are, however, data quality questions for normalizing metals emissions to PM emissions. First, four out of the five stack test reports of metals emissions did not report PM emissions. Even though the two different type of emissions might have been determined for the same test report, they may have different stack-to-stack variation, thus downgrading quality of the resultant emission factors. Of course, improvising with PM emissions from other stack tests can further downgrade quality of the resultant emission factors. Second, unlike hourly rate of pellet production, hour rate of PM emissions is a smaller figure with some variation. This not only makes the figures greater in Table 4 than in Table 3 but also gives the data wide variation. Third, due to low boiling or subliming point temperature, Hg, As, Se,and Sd are volatilized easily at pelletizing, thus suggesting that the corresponding emission rates may be correlated better with the rate of pellet production than with the rate of PM emissions. Finally, PM emissions are variable with collection efficiency of the air pollution control equipment at the time of the test. Metals emissions, especially volatiles, are less influenced by changes in collection efficiency.

Mercury emissions

While they did not conduct multiple metals emission testing, U.S. Steel Minntac and LTV Steel Mining Company did report stack testing results for mercury from the pelletizer waste gas stack. See Table 5 for production and process information not listed in Table 2. Mercury emissions from stacks equipped with a multiclone are considered "uncontrolled" emissions, while those from stacks with a wet scrubber or a wet electrostatic precipitator are "controlled" to a certain extent, depending on operational practices as well as the chemical properties of the mercury species[3] present in the exhaust gas. Recently, one company has attempted to gather speciated mercury emissions data.

There are six taconite mining and processing companies which have source-specific mercury emission data. Their mercury emission data are consistent with mercury balance studies performed by the Coleraine Minerals Research Laboratory (CMRL), of the University of Minnesota Duluth.[4] The mercury emission factor for National Steel Pellet Company, the only company that has not reported any mercury emission data, can be predicted with a regression model from the mercury emission data gathered from the six other companies. See Figure 2.

Table 6 presents mercury emission testing results from U.S. Steel Minntac and LTV Steel Mining Company as well as predicted mercury emissions from National Steel Pellet Company. For a wet scrubber, while mercury in the gas stream may get into the scrubbing water as well as associate with the captured solids, the control effect can only be attributed to the scrubbing water. The reason is that the captured solids and other spilled solid particles, usually of high iron content, are returned to a point upstream of pelletizing for regrind to make green balls. A wet scrubber at one company may remove 11.4% of mercury entering the gas stream inlet with scrubbing water alone. A wet scrubber at another company may remove only 0.64% of the mercury with scrubbing water alone.

Table 7 summarizes total mercury emission estimates for the seven taconite mining and processing companies in Minnesota at the average annual production rates for from 1995 through 1997, with a total mercury emission of 354 kg/year. Given the average Minnesota production of 47.35×10^{9} kg pellets/year (Table 1), the overall emission factor becomes 7.48 ng Hg/g pellets, which is lower than the arithmetic mean of individual emission factors without adjustment for production data of individual companies/lines (8.07 ng Hg/g pellets).

The importance of source-specific metals emission factors is evident. Unlike for mercury, the lack of source-specific metals emission factors from three companies, which produce 57% of taconite pellets in Minnesota, makes estimating total metals emissions for all seven companies difficult.

UPSTREAM AND DOWNSTREAM OF PELLETIZING

Although no stack testing has been conducted for metals emissions upstream or downstream of pelletizing, published bedrock composition data can be used for upstream of pelletizing. Also, metals analysis of materials for the four facilities which have metals emission data at pelletizing can be used for both upstream and downstream of pelletizing. See Table 8.

Fugitive metals emissions from unpaved roads may be omitted, even though fugitive PM_{10} emissions from these roads still are needed for facility (Title V) permitting and other air quality programs. Heavy trucks run on these roads mostly to transport crude ore to the primary crushers or the processing plant. Since metals are not released in significant amounts from crude ore without crushing, the amount of metals emitted with the fugitive PM may be much less than those with PM emissions from point sources upstream of pelletizing. Furthermore, the fugitive PM emissions, attributable in most part to overburden (surface soil layer), are difficult, if not impossible, to estimate.

Metals emissions can be calculated based on PM emissions from all other point and fugitive sources upstream or downstream of pelletizing with a proper set (column) of data provided in Table 8. For the processing steps downstream of crushing but upstream of pelletizing, which are wet operations such as wet magnetic separation, metals emissions do not need to be calculated.

Let us illustrate a simple example of metal emission calculation. A conveyor transfer point, of a process rate of 2410 tons of ore/hour, emits 0.43 lb PM/hr, when the associated wet scrubber is run normally. Assuming PM has the same chemical composition as ore, the emission rate of Manganese (Mn) can be estimated as follows.

$$\text{Mn emissions} = 0.43 \text{ (lb } \textit{ore}\text{/hr)} \times 4700\times10^{-6} \text{ (lb Mn/lb ore)} = 2.02\times10^{-3} \text{ lb Mn/hr,}$$

where 4700×10^{-6} lb Mn/lb ore is taken from the ore composite column from the Inland data in Table 8.

Whether or not heat generated by ore crushing or grinding is sufficient to volatilize Hg, As, Se, or Sd is unknown. As for downstream of pelletizing, pellet temperature is not considered to affect metals emissions from pellet storage and handling.

ESTIMATING FACILITY METALS EMISSIONS: SOURCE-SPECIFIC VS. GENERIC

Although the lack of complete source-specific metals emission factors makes it difficult to estimate metals emissions for all seven companies for this paper, it is useful to make the estimates for some of the companies such as Inland Steel Mining Company, for which source-specific information is available.

To make the metal emission estimates, we started out with pellet production rate and PM emissions from the emission inventory for criteria pollutants. PM emissions were calculated based on AP-42[5]. We also used emission factors at pelletizing in Table 3 and speciation profiles in Table 8 for upstream and downstream of pelletizing. To fill the data gaps associated with copper, we used emission factors and composition information from other facilities.

For comparison, we made the metal emission estimates with generic information available from the EPA and PM emissions from the emission inventory for criteria pollutants. AP-42 provided emission factors for a limited number of metals, with the remaining estimated based on speciation profiles from SPECIATE,[6] version 1.5.

Results using these two approaches for quantifying metal emissions from Inland Steel Mining Company in 1996 are presented in Table 9. The source-specific approach leads to lower emission estimates than does the generic approach, except for Beryllium. Metals emissions at pelletizing accounts for more than 60% of the total metals emissions. Processing steps upstream of pelletizing emit slightly more metals than those downstream of pelletizing, even though PM emissions upstream are far less than PM emissions downstream, which is consistent with the assumption that much of the metal composition is volatilized in the pelletizing process. It should be emphasized that Table 9 is just an example for one company in one particular year, and, in general, emissions vary from facility to facility, from one year to another.

CONCLUSIONS

Existing source-specific emission data, of metal and non-metal chemicals (commonly referred to as metals), have been presented in this paper for the taconite ore processing industry. The information, though limited, can be useful in estimating metals emissions for some, if not all, taconite facilities in Minnesota. The information can be useful for guiding testing efforts at the taconite ore processing facilities for purpose of taconite MACT development, for completing the Great Lakes Regional Air Toxics Emission Inventory, and for addressing concerns of metals emissions from mining activities in a proper manner.

Table 1. Taconite mining and processing in the U.S.

Company or Mine	Ore reserves[a] 10^6 metric ton	Pellets made[b] 10^6 metric ton	Estimated ore demand[d] 10^6 metric ton	Mine expectancy Year
In Minnesota:				
U.S. Steel Minntac	2235	14.11[c]	49.40	45
Hibbing Taconite	890	8.33	29.16	31
LTV Steel Mining	1397	7.76	27.17	51
EVTAC Mining	849	5.16	18.07	47
National Steel	937	5.13	17.96	52
Northshore Mining	1186	4.10	14.37	83
Inland Steel Mining	171	2.74	9.60	18
Butler Mine	1422	inactive		
Sherman Mine	220	inactive		
In Michigan:				
Empire	195	8.26	28.92	7
Tilden	334	6.40	22.40	15
Republic	64	inactive		
Summary:				
U.S. total	9900	62.01	217.0	46
Minnesota in U.S.	94.0%	76.4%		
Michigan in U.S.	6.0%	23.6%		

a. William S. Kirk, Skillings Mining Review, June 6, 1998.[7]
b. Average production data of 1995 through 1997, as reported in Skillings Mining Review.[8]
c. Line-specific production: 1.48×10^6 metric tons of pellets for Line 3, and 12.63×10^6 for Lines 4 - 7 combined.
d. Average ore demand in Minnesota, 3.5 tons of ore for 1 ton of taconite pellets made, is used here.

Table 2. Facility production and process information relevant to metals emission testing

Company	Hibbing Tac.	Northshore		Inland Steel	EVTAC	
Pelletizer type[a]	Straight grate	Straight grate		Straight grate	Grate-kiln	
Number of lines	3	3		1	2	
Test date	June 1994	May 1994	May 1998	June 1994	November 1997	
Stack testing firm	A	B		B	C	
Pelletizer line tested	Line 1	No. 12		Pelletizer	Line 1	Line 2
Stack(s) tested[b]	2 of 4	2 of 5		1 of 4	1 of 1	1 of 2
Control for PM	W. scrubbers	ESP with wet inlet		W. scrubbers	Wet scrubbers	
Production type[c]	Acid pellets	Fluxed pellets		Fluxed pellets	Acid pellets	
Pellets, dry ton/hr	367	224 (estimated)	213	426	236	530
Fuel rate (10^6 Btu/hr) and type	96.2; natural gas	Unknown rate; natural gas	150; nat. gas	167; natural gas	141; nat. gas	235.8; coal, nat. gas, oil[d]
Dry gas flow, ft^3/min @ 20ºC&760 mmHg	164350; 152450	62298; 62132	62909; 65345	150030	282924	286646

a. Straight grate pelletizers have evolved over the years. Pelletizer No. 6 at Northshore may be called the first generation machine; No. 12 the second generation; and those at Hibbing Taconite and Inland the third.
b. Three 1-hour runs per stack, except that at Hibbing Taconite, two 1-hour runs per stack were made.
c. Acid pellets are standard pellets. Fluxstone (lime and/or dolomite) is added to make fluxed pellets; additional burners may be needed as well, depending on the level of fluxstone addition.
d. During the 3-hour testing period, fuel provided a total of 707.4×10^6 Btu/hr, 70% of which came from coal, 20% from natural gas, and 10% from fuel oil.

Table 3. Pelletizer metals emission factors normalized to production rate, ng/g pellets

Element	Hibbing	Northshore 94	Northshore 98	Inland	EVTAC L. 1	EVTAC L. 2
Antimony, Sb	< 0.530	< 59.8	< 4.85	< 13.3	< 1.40	< 1.10
Arsenic, As	< 95.3	53.4	11.1	12.2	53.9	204
Beryllium, Be	N/A	< 1.20	< 0.703	< 0.676	0.163	0.264
Cadmium, Cd	< 1.25	< 1.60	2.32	2.65	1.38	1.27
Chromium, Cr	< 4.07	52.1	65.4	7.84	3.97	18.4
Cobalt, Co	< 5.83	< 1.20	< 1.17	< 0.676	< 1.40	< 0.793
Copper,[a] Cu	< 5.83	N/A	N/A	N/A	4.40	10.1
Lead, Pb	94.0[b]	15.3	46.7	147	12.3	14.2
Manganese, Mn	104	25.2	49.4	108	34.6	37.8
Mercury, Hg	< 11.4	1.73	< 1.29	5.41	12.7	11.2
Nickel, Ni	7.32	244	8.93	20.3	3.28	56.1
Selenium, Se	< 5.35	7.33	13.1	7.84	N/A	N/A

a. Copper is not in the list of hazardous air pollutants (HAPs), but is of concern to the Great Lakes program.
b. Stack testing (not for metals) provided these lead emission data (ng Pb/g pellets): 23.2 for Line 1 (5/94; gas fired & 405 tons pellets/hr), 30.5 for Line 2 (5/94; gas fired & 398 tons pellets/hr), 78.1 for Line 2 again (6/94; oil fired & 332 tons pellets/hr), and 244 for Line 3 (Sept.-Oct. 1994; gas fired & 439 tons pellets/hr).

Table 4. Pelletizer metals emission factors normalized to PM emissions, μg/g PM

Element	Hibbing[a]	Northshore 94[b]	Northshore 98[b]	Inland[c]	EVTAC L.1[d]	EVTAC L.2[d]
Antimony, Sb	< 11.1	< 1020	< 78.8	< 155	< 37.9	< 13.0
Arsenic, As	< 1937	911	180	142	1460	2390
Beryllium, Be	N/A	< 20.4	< 11.4	< 7.91	4.43	< 3.08
Cadmium, Cd	< 26.8	< 27.2	37.7	31.0	36.6	15.0
Chromium, Cr	< 84.6	888	1060	91.7	107	215
Cobalt, Co	< 123	< 20.4	< 19.0	< 7.91	< 37.9	< 9.45
Copper, Cu	< 123	N/A	N/A	N/A	119	120
Lead, Pb	1980	261	759	1710	332	166
Manganese, Mn	2128	430	802	1270	936	444
Mercury, Hg	< 238	29.4	< 20.9	63.2	345	132
Nickel, Ni	155	4170	145	237	89.3	656
Selenium, Se	< 111	125	214	91.7	N/A	N/A

a. Line 1 was tested in May 1994 (PM: 34.82 lb/hr) and in June 1994 (for metals). The PM rate is used here.
b. PM emissions of 6.77 lb/hr total were determined from the two waste gas stacks of pelletizer No. 12 in July 1996; PM emissions of 6.5 lb/hr appeared to be from one of the three hood exhaust stacks of pelletizer No. 12 in April 1996. Thus, PM emissions of 26.3 lb/hr is used to calculate the metals emission factors in this column.
c. PM emissions of 18.2 lb/hr was determined from the same test for metals emissions in June 1994.
d. PM emissions of 17.3 lb/hr for Line 1 and 89.6 lb/hr for Line 2, from stack testing in Nov. 1997, are used here.

Table 5. Production and process information relevant to mercury emissions

Company	U.S. Steel		National Steel	LTV
Pelletizer type	Grate-kiln		Grate-kiln	Vertical-shaft
Number of lines	5 (Lines 3 - 7)		1 (Phase II)	24
Stack (Hg) test date	Not tested[a]	Sept. 1997[a]	Not tested[b]	April 1998
Stack testing firm	N/A	B	N/A	B
Pelletizer line tested	Line 3	Line 7	Phase II	E2 Furnace
Stack(s) tested	1 of 1	1 of 1	2 of 2	1 of 1 (S/V 53)[c]
Control for PM	Multiclone	Wet scrubber	Multiclone	Multiclone
Production type	Fluxed pellets		Acid pellets	Acid pellets
Pellets, dry ton/hr	212	459	697	54.3[d]
Fuel rate (10^6 Btu/hr) and type	153; nat. gas	220.8; nat. gas	233; natural gas	25.2; nat. gas
Gas flow, ft^3/min@20ºC, 760mmHg	241413	339746	238151; 226293	43231

a. Only Line 3 is equipped with a multiclone for PM control. Production and process information of Line 3 is from a stack test in June 1998 (not for mercury emissions; PM: 1568 lb/hr). Line 7 was tested for PM emissions, 51.0 lb/hr, and mercury in the same week.

b. "Semi-fluxed" pellets are made with limestone up to 1.5% at NSPC (c.f. 8% or more at U.S. Steel Minntac). Production and process information is from a compliance test in July 1997 (not for mercury emissions; line PM emissions: 546 lb/hr).

c. Stack 53 is the "top gas" stack; the "bottom gas" stack is assumed to emit a negligible rate of mercury. Emissions of PM, 63.6 lb/hr, and mercury are in the same stack test report.

d. For LTV, this means 54.3 tons of dry products/hr. About 95% of the products are pellets and the rest pellet chips, which are sold as sinter feed. LTV does not regrind pellet chips.

Table 6. Mercury emission factors from the entire pelletizer

Mercury emission factor		U.S. Steel Line 3	U.S. Steel Line 7	National Steel	LTV Furnace E2
Production basis	(ng/g pellets):	7.45	4.99	13.39[a]	4.33
PM basis	(µg/g PM):	2.01	89.9	34.2[b]	7.41

a. The linear regression model is: (ng Hg/g pellets) = 1.679 + 0.2297 × (mile); adjusted R^2: 0.854.

b. This is calculated with 13.39 ng Hg/g pellets and the production and process information given in Table 5.

Table 7. Pelletizer mercury emissions (average annual emissions from 1995 through 1997)[a]

Mercury	U.S. Steel	HibTac	LTV	EVTAC	National	Northshore	Inland	Total
kg/year	74.1	94.3	33.6	61.6	68.7	7.09	14.8	354
lb/year	163	208	74.2	136	151	15.6	32.7	781

a. Production data in Table 1 and emission factors in Tables 3 and 6 are used in the emission calculation.

Table 8. Composition of Biwabik iron-formation and solid samples, μg/g (except that ng/g is used for mercury)

Data Source	MN Geological Survey[a]			Hibbing Taconite[b]		EVTAC[c]		Inland Steel[d]		Northshore Mining Company[e]			
Element	Hole 2	Hole 5	Hole 7	Taconite	Acid pellets	Rod mill feed	Acid pellets	Ore composite	Fluxed pellets	Plant feed	Fluxed pellets	Coal	Acid pellets
Antimony, Sb	10	11	7	0.84	0.42	12	17	< 12	< 12	3.62	0.66	< 0.06	< 0.5
Arsenic, As	13	21	13	13.21	9.26	15	9	< 20.2	< 20.2	7.54	3.69	2.37	1.4
Beryllium, Be	2.9	2.6	3	1.2	1.0	5	6	0.8	1.1	2.2	0.6	0.7	0.41
Cadmium, Cd	< 2	< 2	< 2	0.03	< 0.02	< 0.5	< 0.5	< 0.08	< 0.8	< 0.02	< 0.02	0.11	< 0.05
Chromium, Cr	15	15	13	49.7	4.4	24	124	< 1.0	< 1.0	47.0	42.1	4.5	34.0
Cobalt, Co	15	10	13	6.1	2.5	48	61	6.9	0.8	8.7	9.4	1.9	9.1
Copper, Cu	9.2	7.1	7	21.9	3.0	N/A	N/A	N/A	N/A	6.4	10.7	< 1.5	N/A
Lead, Pb	34	17	91	1.3	1.1	20	27	< 6	< 6	< 0.5	0.6	1.2	0.3
Manganese, Mn	6583	8364	6505	3119	700	3900	940	4700	330	2578	814	61	1347
Mercury, Hg	N/A	N/A	N/A	**14.9**	**0.71**	**< 16**	**0.34**	110 ng/g	80 ng/g	**0.76**	**0.04**	**15.6**	3 **ng/g**
Nickel, Ni	11	9	7	4.3	4.1	13	5	1.5	< 0.4	3.5	8.3	< 2.1	5.5
Selenium, Se	< 20	< 20	< 20	< 0.3	< 0.3	< 5	< 5	< 10	< 10	< 0.3	< 0.3	< 0.3	< 0.3

a. Three holes were drilled in the study reported by G.B. Morey in 1992,[9] Holes 2 (near Biwabik), 5 (near Buhl), and 7 (near Keewatin). Dr. Morey is with Minnesota Geological Survey and the University of Minnesota.

b. This information resulted from analysis done in March 1997 by one of the consulting firms.[10] Mercury data were reported in another study by University of Minnesota Coleraine Minerals Research Laboratory in September 1997.[4] The use of autogenous crushers at Hibbing Taconite Company makes it difficult to sample a representative ore composite. Mercury in the feed to the autogenous crusher is used here to provide an estimate for mercury in "taconite."

c. This information resulted from analysis done in 1993 by one of the consulting firms for EVTAC.[10] Mercury data were reported for another study in November 1997 by University of Minnesota Coleraine Minerals Research Laboratory.[4] Mercury data for green balls in the study is used here to provide an estimate for mercury in rod mill feed.

d. Analysis of samples of ore composite, green ball, and fired fluxed pellets was provided in the 1994 Inland metals testing report.

e. Metals data are taken from a current review process for air toxics associated with a proposed project.[4] Left block is March 1997 analysis results (except for mercury data, which were reported in another study by University of Minnesota Coleraine Minerals Research Laboratory in September 1997,[4] unit used is ng Hg/g solid tested); right block is March 1994 analysis results.

Table 9. Facility metals emission estimates,[a] kg/year

Method	Source-specific (this paper)				Generic[b]	Comparison
Element	Upstream	At pelletizing	Downstream	Facility Total	Facility	(G/S)
Antimony, Sb	< 0.625	< 30.5	< 6.32	< 37.5	7037	188
Arsenic, As	< 1.05	28.0	< 10.6	< 39.7	10099	254
Beryllium, Be	0.0462	< 1.55	0.579	< 2.18	0.252	0.116
Cadmium, Cd	< 0.00464	6.08	< 0.421	< 6.51	2875	442
Chromium, Cr	< 0.0605	18.0	< 0.527	< 18.6	869	46.8
Cobalt, Co	0.362	< 1.55	0.421	< 2.33	269	115
Copper,[c] Cu	0.430	< 13.4	5.63	< 19.4	8259	425
Lead, Pb	< 0.384	337	< 3.16	< 341	18890	55.4
Manganese, Mn	244	248	174	666	2581	3.88
Mercury, Hg	0.0440	12.4	0.0421	12.5	53.5	4.28
Nickel, Ni	0.0914	46.6	< 0.211	46.9	552	11.8
Selenium, Se	< 0.519	18.0	< 5.27	23.8	209	8.78
Total:	< 248	< 761	< 207	< 1216	51694	42.5
Relative level	20.4%	62.6%	17.0%			

a. The 1996 emission inventory report, submitted by Inland Steel Mining Company, lists PM emissions of 54.1 metric ton/year for upstream of pelletizing, 196 metric ton/year at pelletizing, and 527 metric ton/year for downstream of pelletizing. The facility produced 2.30×10^6 metric tons of pellets in 1996.

b. AP-42[5] and SPECIATE,[6] version 1.5, were used to generate the estimates in this column.

c. Copper emission information was taken from other facilites in Tables 3 and 8.

Figure 1. A flow diagram of taconite mining and processing operations

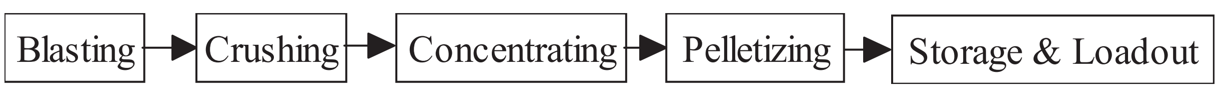
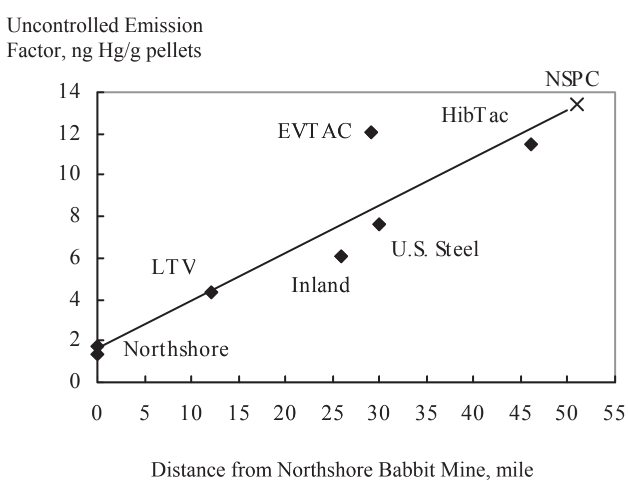


Figure 2. Predicting mercury emissions from the pelletizing process at National Steel Pellet Company (the predicted value, marked with a "×" symbol, is 13.39 ng Hg/g pellets, resulting from UEF = 1.679 + 0.2297 × DFN)



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KEYWORDS
Taconite, metals, pelletizing, emission inventory, HAPs.

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