ENVIRONMENTAL MANAGEMENT OF AIRBORNE METAL PARTICULATE EMISSIONS IN THE RECYCLING INDUSTRY

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Introduction

The paper addresses air quality resulting from metal recycling facilities, other human activities, and natural sources. The focus is on environmental management of emissions, especially metal-bearing particulates, during recycling process operations using lessons learned from the coal power industry. The primary metals industry (SIC33XX), which includes 16 industries as well as secondary non-ferrous metal facilities, is the major source of airborne metal emissions in the USA. The 2001 Environmental Outlook Report by the Organization for Economic Co-operation and Development (OECD) representing the thirty most industrialized countries also reported that the non-ferrous metals industry is the most intensive pollution source for airborne bioaccumulative metals. Aluminum, copper, lead and zinc metals comprise 95% of the production in the secondary non-ferrous metal industry. Engineering, administrative, and industrial hygiene recommendations for controlling particulate metal emissions and exposures will be discussed.

Air Quality Indicators

The state of the air has been determined by ambient air quality standards and measurements for six criteria pollutants as promulgated by the U.S. Clean Air Act of 1970. In 2003, the total amount of pollutants emitted into the atmosphere in the U.S. was about 150 million tons (135 million tonnes) of the six criteria air pollutants: carbon monoxide, nitrogen oxides, particulate matter, sulfur dioxide, volatile organic compounds (VOCs), and lead (Table I). Hazardous air pollutants (HAPs) or air toxics are considered to cause serious health effects including cancer, damage to the immune system, as well as neurological, reproductive, developmental, respiratory and other health problems. The ambient air concentrations of hazardous air pollutants (about 4.1 million tons in 2003) have been monitored under the 1990 National Emission Standards for Hazardous Air Pollutants (NESHAP) and other U.S. Environmental Protection Agency (EPA) programs. About half of urban air toxics originate from mobile sources including onroad and nonroad sources (construction, agriculture, recreational). Major stationary industrial sources and area sources such as gas stations, landfills, wildfires, and other natural sources each contribute about a quarter of air toxic emissions. EPA estimates about a third of the atmospheric mercury is from natural sources including volcanic eruptions and evaporation.[1,2] Deposition of air toxics onto soils or surface waters may lead to biomagnification through ingestion exposures.

Despite increases in population and vehicle miles traveled, the concentrations of air toxics are predicted to have decreased about 30% from 1990 to 1999 with further decreases of 75% (four air toxics) by 2020. In 1996, eight-four percent of air toxics were volatile organic compound and particulate matter emissions. The 2003 EPA Urban HAPs monitoring indicated less than 41% of the samples were above the analytical method detection and 95% of the cancer and noncancer risks were attributed to ten hazardous air pollutants. The majority of urban air toxics were not detectable and health risks were dominated by a few measurable compounds.[3,4]

EPA has promulgated 92 national emission standards for hazardous air pollutants for industrial major sources (emit 10 tons/year or more of a listed pollutant or 25 tons/year or more of combination of listed pollutants). EPA relies on state-reported emissions, maximum achievable control technology (MACT) data, the toxics release inventory (TRI) database, and national estimates. For States to provide EPA database information from industrial stack emissions and for EPA to perform QA/QC and compile a complete emission inventory takes three years.[5] The EPA issued a final rule to reduce hazardous air pollutants emitted from the 116 urban area secondary aluminum production plants (40 CFR Part 63, March 2000). The rule is anticipated to reduce air toxics emissions 12,000 tons per year or 70% less than current levels.

"Primary metals products manufacturing" is one of the 50 area source categories which will be subject to HAPs standards in the next three years, per a recent U.S. Court order (http://www.dcd.uscourts.gov/opinions/2006/Friedman/2001-CV-1537~15:11:23~8-2-2006-a.pdf). As mandated by the 1999 Amendments to the Clean Air Act regulation, the air pollutants that are covered under the area source regulation focus on "the 30 hazardous air pollutants that present the greatest threat to public health in the largest number of urban areas" (http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=99-17774-filed.pdf). Those urban air pollutants covered under the area source regulation include arsenic, cadmium, lead, manganese, mercury and nickel compounds. However, once a substantial area source has been identified for one of these urban air pollutants, EPA sets emissions standards for all air toxics emitted from this industry. Consequently, EPA regulations proposed for the primary metals industry will likely cover all air toxics identified for the industry.

The reference source for major source categories is EPA AP-42, Compilation of Air Pollutant Emission Factors, Section 12 Metal Processing. The emission factors are rated according to the quality and quantity of emission data generated by source categories utilizing the maximum achievable control technology (MACT), ratings are from A to E which is the worst-case, most uncertain database information. The majority of the emission factors for primary aluminum production, secondary aluminum production, and gray iron foundries are rated poorly, especially particulate emissions which also represent the metal contaminants. Secondary metal plant emissions have been found to include HAPs such as arsenic, antimony, cadmium, cobalt, and selenium, but specific emission factors for these HAPs have not been recommended due to lack of information.[6,7]

The air emissions from metals industry (SIC 33XX) have been assessed with respect to polycyclic aromatic hydrocarbon and particulate metals emissions, both are reportedly decreasing. EPA TRI releases of total metals decreased from 2001 to 2004 but air emissions have not decreased. The major source of total metal releases shifted from electric utilities to the metal mining industry in 2002, with the metals industry continuing as the leading source in 2003 and 2004. The major source of metal air emissions also shifted from the electric utilities industry to the metals industry, which is now the source of 37% of the total metal air emissions (Figure 1). The metals industry contributed about 6% of the total tons of particulates, 12% of the total tons of 13 metal compounds, and 33% of the 3,000 tons of lead released into ambient air in 2003.[8]

Principles of Controlling Air Emissions

Metal processing involves exposures to dusts, fumes, solvents, noise, heat, acid mists, and other potential hazardous materials and risks. Some process and/or material handling modifications may be feasible to eliminate or reduce the generation of emissions, minimizing handling, lowering pot temperatures, decreasing dross formation and surface generation of dust. Plant layout modifications may reduce material handling or re-entrainment of settled dust. Machines may be selected for performing high exposure tasks, reducing employee exposures and ergonomic hazards due to materials handling.[9]

Processes which generate significant emissions should be isolated to prevent cross contamination of clean areas in the plant. Physical barriers will reduce emissions and exposures. Enclosures with negative draught exhaust ventilation and local exhaust systems at the point of emission generation are recommended. Source capture of emissions also reduces re-entrainment of settled contaminants. Exhaust hood capture velocity must be great enough not to be disrupted by cross drafts or other air movements. All exhaust or dilution ventilation systems require replacement or make-up air systems. Replacement air outlets should be placed so clean air flows across the employees, towards the emission source and to the exhaust. Sufficient space for hoods, ductwork, control rooms, maintenance activities, and equipment storage should be provided. All process equipment, exhaust, dilution and make-up air ventilation systems must be maintained to effectively control hazards, fugitive emissions and material spillage. [9]

Clean areas, such as break rooms, with low ambient air contaminant levels are controlled by fresh filtered air and housekeeping. Employees in contaminated areas can be protected by supplied-air service cabs, islands/workstations, stand-by pulpits, control rooms, and by supplemental personal protective equipment (PPE). Fugitive emissions from vehicles can be reduced by paving surfaces, keeping surfaces free of accumulated dust, reducing vehicle travel distances and speed, and by re-directing vehicle exhaust and cooling fan discharge. Coatings may be applied to some surfaces to facilitate wash down of roadways. [9]

Workplace safety and health programs are not just installed, they require constant maintenance by managers and employees. Low exposure practices require training and commitment. Safety glasses with side shields, coveralls, safety shoes, and work gloves should be routinely worn for all jobs. Aprons and hand protection made of leather or other suitable materials should be worn by casting, melting or other employees exposed to molten metal splatter. Where fume and dust emissions are not controlled by engineering technology, appropriate respiratory protection should be worn. Industrial hygiene standards require a written respiratory protection program, air monitoring, and on-going training if respirators are used. Similarly, workers must be protected from non--isolated noise sources with hearing protection and audiometric testing. [9]

Metal Processing Operations and Air Emissions

The emission of toxic metals from combustion of fossil fuels, municipal and industrial wastes is important globally. Transboundary migration of mercury has been evaluated since China has an estimated 2,000 coal combustion facilities emitting about 600 tons of mercury annually, accounting for nearly a quarter of the world's non-natural mercury emissions.[10] Toxic metals include arsenic, cadmium, chromium, lead, mercury and selenium present in coals and wastes. Toxic metals can be classified as non-volatile (barium, beryllium, chromium, nickel), as semi-volatile (antimony, arsenic, cadmium, lead), or as volatile (mercury, selenium), depending on their volatility at stack temperatures.[11]

The EPA air toxics data quality is reported to have high confidence for analytical measurements of seven compounds including acetaldehyde, benzene, formaldehyde, lead, manganese, methylene chloride and nickel. The median ambient air concentrations of these chemicals were above the method detection limit.[12] Recent technological advances have been reported in real time optical light-scattering particulate concentration monitors and continuous laser-based particle analyses which increase efficiencies in mineral processing and worker exposure assessments.[13]

Air toxic emissions are controlled by environmentally friendly practices such as recycling. According to the Bureau of International Recycling, the energy saved by recycling aluminum, copper, lead, and steel is 95%, 85%, 65%, and 74% respectively, as compared to primary production. Energy saved translates into reduced environmental emissions. The major air contaminants generated in iron and steel operations are presented in Table II.[13] Regarding non-ferrous metals, aluminum, copper, lead and zinc compounds comprise 95% of production in secondary non-ferrous metal industry. Cadmium, cobalt, magnesium, mercury, nickel, precious metals, selenium, tin and titanium are also reclaimed.[9] Engineering and administrative controls for aluminum reclamation operations are described in Table III.[9] Environmental and occupational exposure limits for metal processing air toxics are presented in Table IV. Recycling practices for the non-ferrous metals are described below:

<u>Aluminum Reclamation</u>
The secondary aluminum industry utilizes aluminum bearing scrap to produce metallic aluminum and aluminum alloys. The processes include scrap pre-treatment, remelting, alloying, and casting. The raw material includes new and old scrap, sweated pig, and some primary aluminum. New scrap consists of clippings, forging, and other solids purchased from the aircraft industry, fabricators, automobile, and other manufacturing plants. Borings and turnings are by-product of the machining of castings, rods and forging. Drosses, skimmings, and slags are obtained from primary reduction plants, secondary smelting plants and foundries. Old scrap includes automobile parts, household items, and airplane parts.

Aluminum Recycling Case Study

A case study of environmental management of selenium at three U.S. aluminum facilities indicated uncontrolled reduction furnace particulates emissions had measurable quantities of selenium and arsine gas was detected. Respiratory protection with dust/mist/fume filters are recommended for particulate concentrations up to 1.0 mg/m^3 and powered air-purifying respirators (assigned protection factor of 25) with dust/mist/fume filters. Hazardous waste was generated due to baghouse dust contaminated with selenium from secondary aluminum rotary furnaces.[14]

The metals industry reported total onsite/offsite selenium metal air emissions at about the same levels in 2001 and 2002. In 2003 and 2004, the selenium (total and air) emissions exceeded the mercury emissions (Figure 2). Only six U.S. States with primary metal facilities reported selenium metal releases while seventeen States reportedly released more than 7.8 million pounds of total metals in 2002.[8] The selenium metal releases reported are not representative of the number of operating facilities or of the increased use of selenium-containing manganese (0.15%). It is estimated 75% of the manganese alloy (99.7% electrolytic manganese) used in the world today contains selenium and produces selenium waste products.[14] Managing the environmentally unfriendly content of materials introduced to metal processing operations will reduce hazardous waste management issues.

Copper Reclamation

The secondary copper industry utilizes copper-bearing scrap to produce metallic copper and copper based alloys. The raw materials used can be classified as new scrap produced in the fabrication of finished products or old scrap from automobiles and domestic appliances. Other materials with copper value include slags, drosses, foundry ashes and sweepings from smelters. Copper operations include stripping/sorting, briquetting/crushing, shredding, grinding and gravity separation, drying, insulation burning, sweating, ammonium carbonate leaching, steam distillation, hydrothermal hydrogen reduction, sulphuric acid leaching, converter smelting, electric crucible smelting, fire refining and electrolytic refining. Occupational exposures to metal particulates as well as volatile metals from fluxes, slags, and drosses are likely to occur during most reclamation operations. Other exposures during copper production include aldehydes, ammonia, hydrocarbons and soot, as well as acid mists, gases, vapors, heat and noise.[9]

Lead Reclamation

Secondary lead smelters may have to process raw materials prior to being charged into a smelting furnace. The most common raw material is junk automotive batteries. About half the weight of a battery will be reclaimed as metallic lead in the smelting and refining process. Most automotive batteries use a polypropylene box or case, which are reclaimed by most all secondary lead smelters. Metal fumes include lead and antimony. During battery breaking, there is the potential for forming arsine or stibine due to the presence of arsenic or antimony used as hardening agents in grid metal and presence of nascent hydrogen. Lead dust can generally be found throughout lead reclamation facilities which can be controlled through vehicle operations, engineering, administrative, and worker protection programs. Accumulative metal fume emissions and overexposures may result during furnace, refining, and casting operations.[9]

Zinc Reclamation

The secondary zinc industry utilizes new clippings, skimmings and ashes, die-cast skimmings, galvanizer's dross, flue dust and chemical residue as sources of zinc. Most of the new scrap processed is zinc- and copper-based alloys from galvanizing and die-casting pots. Included in old scrap are zinc engraver's plates, die castings, and rod and die scrap. Particulate metals exposures include aluminum, cadmium, chromium, copper, iron, lead, manganese, and zinc compounds resulting during reverberatory sweating, rotary sweating, muffle and kettle pot sweating, melting, alloying, retort or graphite rod resistor distillation operations.[9]

Mixed Recycling Operations (Hoboken, Belgium Union Miniere)

The 100 year old metallurgical complex smelts and refines lead and copper, as well as precious metals and specialty metals (antimony, arsenic, bismuth, indium, selenium, tellurium, tin). The treatment capacity is 30 tonnes of electronic scrap per day, recovery of 84,000 kWh/day, and the production of granulated slags. Environmentally protective measures introduced included maximizing internal recycling, sulphur dioxide conversion, dust abatement, sulphur and arsenic concentration in intermediate products, baghouse filter addition, heat recovery, and gradual treatment of more secondary materials in lead-blast furnace. Blast furnace exhaust gases (metal particulates) were measured (lead = 0.50 mg/m^3, copper/zinc = 0.10 mg/m^3, and cadmium/arsenic = 0.05 mg/m^3).[15]

Reprocessing Ores

Driven by expanding Asian economies, the demand for metals has grown dramatically. Copper and nickel prices have increased four fold in a decade and other metals have similar trends. The result is that ore cutoff grades are decreasing for mine developments, as illustrated by copper ore cutoff grades decreasing from about 1.0% to 0.2% today. Reprocessing waste rock at abandoned mines is now being economically examined. Since materials have been mined, milled or processed, the costs of reprocessing are reduced since metallurgical facilities can be rehabilitated. Additionally, the existing mining sites are reclaimed and environmental impacts are minimized as opposed to locating viable new ore bodies.

Air Pollution Controls

According to database information, air pollution standards and controls applied to electric utilities have succeeded in reducing coal combustion emissions and further reductions are predicted by 2018.[8] To comply with NESHAP standards, coal fired power plants have applied MACT technologies which include scrubbers, baghouse collectors, and electrostatic precipitators to control total particulates and associated metal emissions. Air toxic field measurements at more than 50 power plants by Electric Power Research Institute (EPRI), found that emissions of particulate trace metals in coal are a function of total particulate emissions as well as initial trace metal concentration. For volatile elements such as chlorine and selenium, average removal efficiencies were based on availability of flue gas desulphurization technologies. Mercury removal estimates were developed for various control technology categories and with coal's chloride content the key dependent variable. Average emission factors for organic compounds proved suitable.[16]

The characteristics of toxic metals from coal and waste combustion were experimentally evaluated with respect to partitioning, flue gas sorbent injections, and emission control effectiveness. Arsenic and selenium from pulverized coal appear to be associated with calcium. Selenium and calcium appear to react rapidly in the combustion zone, while arsenic and calcium react more slowly downstream in the post-flame region. Mercury speciation, oxidized versus elemental, is influenced by chlorine, especially molecular chlorine. The solubility of oxidized forms of mercury promotes their potential removal from stack gases by scrubbing. Results suggest that oxidized mercury can be found only under lean-combustion conditions.

Chromium in the exhaust appears primarily as trivalent chromium in the absence of chlorine, with less than 1% present as the more toxic hexavalent chromium. The addition of sulfur (even in the presence of chlorine) can completely suppress the formation of hexavalent chromium in combustion systems. The outlet chemical valence form appears to be independent of the form that was fed to the furnace. The outlet particle size distribution depended strongly on the initial form fed to the furnace.

Toxic metal emissions can be managed through the injection of commercial sorbents, such as kaolinite, lime and alumina. Kaolinite is very effective at reactively scavenging lead vapor, and moderately effective at capturing cadmium. When both lead and cadmium are present, the kaolinite scavenges lead preferentially to cadmium. With lime, the situation is reversed, lime preferentially scavenges the cadmium. Additional work is needed to evaluate designer sorbents containing calcium, aluminum, and silicon which may be useful for rendering multiple metal mixtures environmentally safe. [11]

Since the metals industry is now the major source of metal air emissions, the air pollution control technology which has been successfully applied in the coal power industry should be evaluated for its applicability in the metals industry.

Air Toxics and Human Health

A number of studies have suggested an association between metal exposures and human health effects. A five-year study of 245 Texas counties revealed a positive relationship between industrial releases of chromium, copper and zinc and lung cancer rates in the Houston and Dallas/Ft. Worth areas. Metals interfere with tumor growth suppression genes (http://www.utsouthwestern.edu/utsw/cda/dept37389/files/318472.html). A study of metal particulates and nine boiler makers showed an association between increased cardiac autonomic dysfunction and lead and vanadium in respirable particulates with a diameter less than 2.5 microns (PM2.5) (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1240986). An analysis of particulate airborne metals in the industrial city of Hettstedt, Germany, found arsenic, cadmium, copper, lead, strontium, and zinc in the PM2.5 component. Based on studies in mice, the metals were suspected of being the primary cause of allergic asthma. (http://pubs.acs.org/subscribe/journals/esthag-w/2003/jun/science/os_asthma.html). The Australian HeALthwise study followed 11,445 workers in aluminum mines, smelters and refineries from January 1983 through December 2002. The study found an increased cancer rate for mesothelioma and melanoma for production and maintenance workers and an increased rate of thyroid, stomach and kidney cancer for office workers. Worker cancer rates for circulatory and respiratory diseases were less than the general population (http://www.alcoa.com).

Based on air toxic inventory reviews, environmental standards are poorly supported by environmental databases and are not generally representative of chronic human exposures. Of the 579 chemicals listed on EPA Toxic Release Inventory, about 9% of the chemicals are measured. Of the 2,800 high-production-volume chemicals (more than 1 million pounds per year imported or produced), complete health effects data exist for about 7% of the chemicals. About thirty of the 189 HAPs have health effects data.[17,18] Worker inhalation health based exposure limits are generally several orders of magnitude greater than ambient air or risk based standards for public health protection. Comparisons of the EPA ambient air quality criteria with the occupational exposures are presented in Table IV.[12,19] The total particulate exposure standards as promulgated by EPA and OSHA (Occupational Health and Safety Administration) are two orders of magnitude different. The application of safety and uncertainty factors to occupational exposure limits result in conservative and non-validated ambient air quality standards.

To link contaminants in the environment with adverse health effects, biological exposure indices or internal exposure levels in human tissues and fluids is considered an accurate measurement. Human blood lead levels monitored since 1976, has been a successful biological monitoring program used to identify at-risk populations, evaluate regulatory actions, improve exposure estimation models, and identify sources of preventable exposures. Removing lead from gasoline has resulted in decreased urban lead concentrations and has been validated by decreasing blood lead levels in children.[1,2] Since no safe blood lead level in children has been identified, the U.S. Centers for Disease Control and Prevention has emphasized that efforts should continue to control or eliminate lead in the environment before children are exposed.[19a] Since the metals industry is a major source of lead emission to air, additional air pollution control technology may be needed in those industries with substantial lead emissions, especially metal industries located in urban areas.

In 1999, blood mercury levels in children were about 25% of levels in women of childbearing age (0.0012 mg/L).[20] Mercury concentration in hair can be used as an indicator of blood mercury concentration, with a ratio of blood to hair of 1:250.[21] Hair and nail concentrations of selenium have been positively correlated with selenium levels in rat livers and muscles. Newborn human hair (0.5 gram) selenium also correlated with umbilical cord blood levels (http://www.atsdr.cdc.gov/HAC/hair_analysis/appendix_c_sharon.html). Biological monitoring of 1-hydroxypyrene, a polyaromatic hydrocarbon metabolite in urine has been a useful indicator of inhalation exposure in coke oven workers.[22] Biological monitoring of Taiwan steel production workers indicated the urinary concentrations of arsenic, beryllium and selenium significantly exceeded the controls.[23] The aluminum case study reviewed above also detected occupational exposure to metal particulates.[14] The largest category of OSHA inspection violations for the metals industry over the past six years is for dust violations (Table V). These reports suggest the need for improvement of workplace conditions with a focus on ventilation and industrial hygiene practices.

The need for improving workplace practices is also reflected by the proportion of metal operator injuries which has increased from about 27% to 38% from 1988 to 1998.[24] The majority of events leading to occupational injuries in mining are contact with equipment or being struck by an object. Overexertion accounts for about 25% of the injuries while overexposures to hazardous substances are less than 5% of the total 1.54 million occupational injuries in 2002.[25] Hazard communication violations are a leading cause of OSHA citations every year, which implies a lack of workplace health and safety training.[12]

The majority of total USA deaths are cased by heart disease and cancer. About 20% of the total deaths and 30% of the cancer deaths are attributed to smoking. Cancer incidence rates from 1992 to 2000 declined with the exception of thyroid cancer, melanoma, kidney, and breast cancer. Respiratory disease accounts for about 5 percent of the total deaths, while about 20% U.S. population has allergies to environmental agents.[25] Death statistics indicate individual lifestyle habits such as smoking, dietary over-consumption, and accidents with objects are the major health risks.[26]

The Organization for Economic Co-operation and Development (OECD) and the World Health Organization (WHO) European Centre for Environment and Health (ECEH) organized a Workshop on Environmental Health Information.[27] When considering data relating to exposure, the hierarchy of value in decreasing relevance is: 1) measurements of internal dose in target organism (especially children), 2) measurement of personal exposures, 3) ambient concentrations in the environmental medium concerned, and 4) emission data.

Summary

Ambient air quality is improving and indicator compounds have been identified which simplify environmental assessments. The major hazardous air pollutants are total particulates, particulate metals and measurable volatile organic compounds reported at low concentrations. The primary metals industry is the major source of total bioaccumulative particulate metals, contributes about one third of the total airborne metal releases, and one third of the urban air lead levels. Air pollution technologies have been successful in reducing mercury emissions from coal combustion sources and selenium metal emissions are now reportedly greater than mercury releases. Metal recycling contributes to reducing air and other emissions by reducing energy consumption 65-95% compared to primary metal production. Since the metals industry is now the major source of metal air emissions, air pollution control technology which has been successfully applied in the coal power industry should be effective in the metals industry. The limited human health and environmental data in the metals industry suggest a need to further reduce airborne particulate metal emissions and to improve workplace ventilation and hazard communication.

Figure 1. Major Industry Airborne Metal Releases

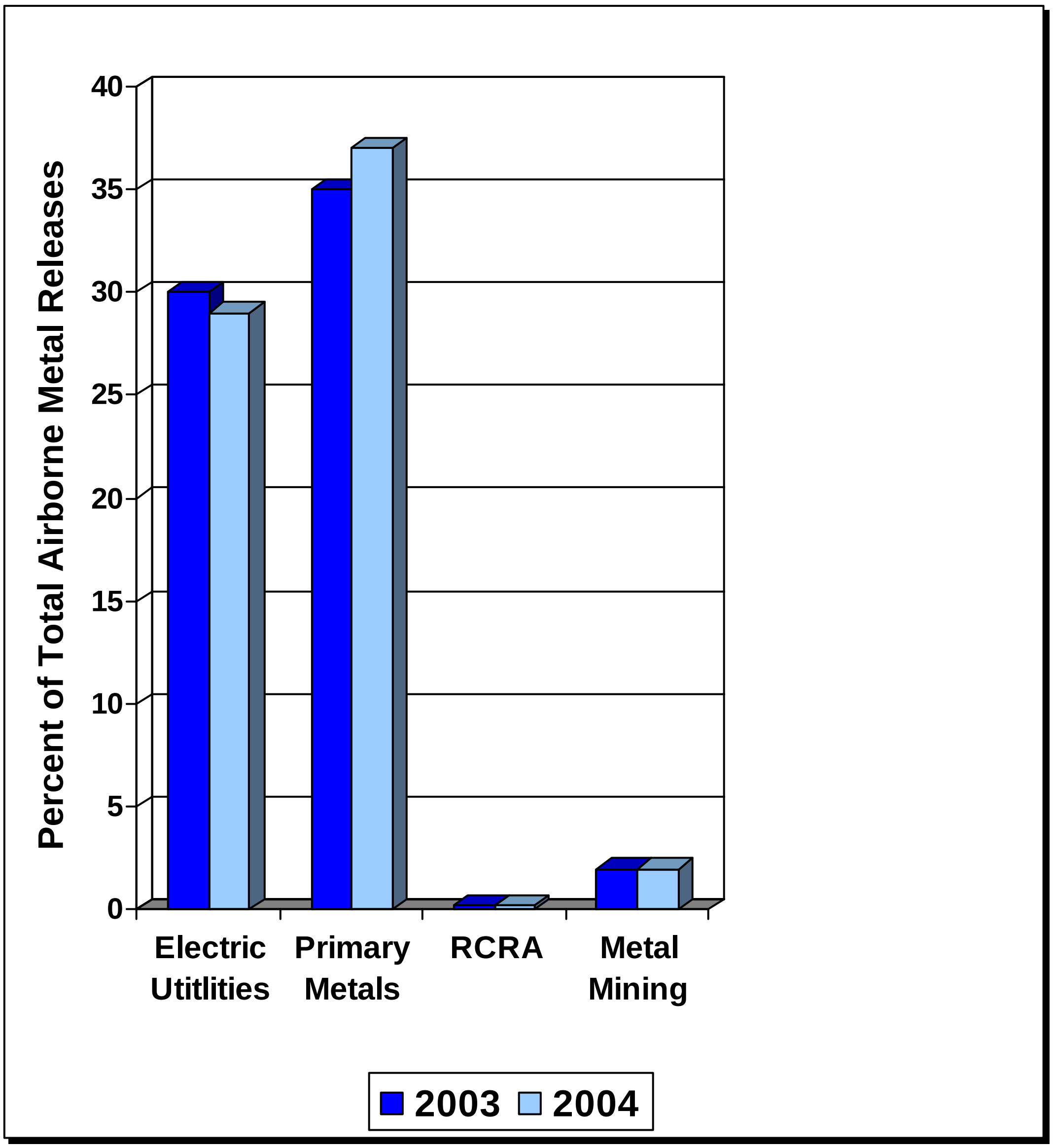

Figure 2. EPA TRI Industry Trends – Mercury and Selenium Releases

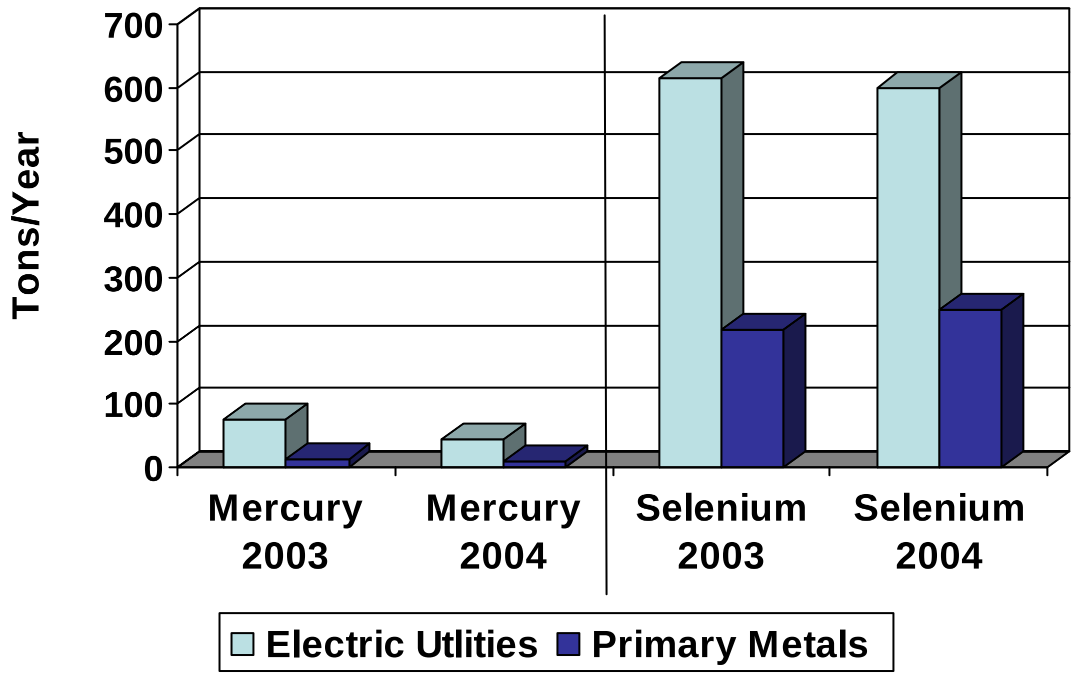

Table I. Air Quality Data & Standards

AIR POLLUTANTS	TOTAL 2003 Million Tons	METAL PROCESSING SIC33XX 2003 Million Tons	EPA AMBIENT Primary Stds. mg/m^3	OSHA OCCUPATIONAL LIMITS 8 HR mg/m^3
CRITERIA POLLUTANTS	147.7 2003			
1. Carbon Monoxide	93.7		10 (8 Hr) 40 (1 Hr)	55
2. Nitrogen Oxides	20.5		0.10 (Annual)	9.0
3. Particulate Matter PM10 PM2.5	4.1	0.24	0.15 (24 Hr) 0.035 (24 Hr)	15 Total 5 Respirable
4. Sulfur Dioxide	15.8		0.08 (Annual) 0.04 (24 Hr) 1.30 (3 Hr)	13
5. Volatile Organic Compounds	15.4	0.072	0.026 Vinyl Chloride	0.2 Coal Tar Pitch Volatiles 50 Naphthalene
6. Lead	0.003	0.001	0.0015 (Quarterly)	0.05
7. Ozone			0.16 (8 Hr) 0.24 (1 Hr)	0.20
AIR TOXICS	4.1			
Particulate Metals 13 Compounds 28 Industries	2.0	0.23 1.5% To Air		

Table II. Major Air Contaminants in Iron and Steel Industries

OPERATION	**EXPOSURES**	**CONTROLS/PPE**
DUST		Respirable Particulates
Mining	Ore and Coal Dust	
Ore Sintering/Pelletizing	Iron Oxide	
Coke Ovens	Coke Oven Emission	Benzo(a)pyrene
Refractory Handling	Silica Dust	Particulates/Silica
Foundries	Silica Sand	
METAL FUMES		
Furnaces	Iron Oxide	Particulates/Metals
Scarfing Operations	Iron Oxide	
Scrap Preparation	Lead Fume	
Galvanizing	Flux Fume, Zinc	
Leaded/Ferromanganese Steels	Lead, Manganese	
GASES/VAPORS		Continuous Gas Monitors
Blast Furnace	Fluorides, CO	Fluorides
Coking Operation	CO, SO_2, H_2S	Benzo(a)pyrene
Welding	Ozone, Oxides of Nitrogen	
Maintenance/Cleaning Motors	Solvent Vapors	VOC
MISTS		Acid Mists Particulate/Metals
Pickling	Sulfuric Acid Mist	
Plating	Various	
Spray Painting	Lead Paints Spray Mist	
EXPOSURE CONTROLS	Local Ventilation Wet Processes Baghouse Filters Dry Scrubbers Electrostatic Precipitators Respirators	Hazard Communication Worker Air Monitoring Biological Monitoring MACT Compliance Noise Controls

Table III. Aluminum Reclamation Operations, Exposures, and Controls

Aluminum Reclamation	Process Operations	Exposures	Controls Ventilation	PPE
Sorting	Manual inspection—free iron, stainless steel, brass, oversized materials removed	Torch desoldering Metal fumes Pb, Cd	Local	Respiratory Hearing
Crushing Screening	Old scrap Vibrating screens	Dust, aerosols Oil mists Particulate metals Noise	Local General	Hearing
Baling	Compacting bulk scrap		No Controls	
Burning Drying		Particulate metals soot, condensed organics, gasses, vapors containing fluorides, sulphur dioxide, chlorides, carbon monoxide, hydrocarbons and aldehydes		Respiratory Hearing Heat stress Fluids
Hot Dross Processing	Batch fluxing Salt-cryolite mixture	Fumes	Local General	
Dry Milling	Cold dross/residues Milling Screening Concentration (60%)	Dust	Local General	
Roasting	Insulation input Carbonaceous Materials separated	Dust	Local General	Hearing Heat stress
Sweating	High iron scrap Reverbatory furnace Slopping hearths Air cooled moulds Collect low melting Aluminum products	Metal fumes Particulate metals Gases Vapors Heat Noise	Local General	Respiratory Hearing Heat stress Fluids
Reverberatory Smelting Refining	Clean Scrap feed Batch or continuous Solvent flux Insolubles float Alloying agents Demagging with Chorine gas or Aluminum fluoride Skimming	Combustion products Chlorine Fluorine Hydrogen chloride Hydrogen fluoride Metal chlorides Metal fluorides Heat Noise	Local General	Respiratory Hearing Heat stress Fluids

Table IV. Metals Processing Industry Air Toxic Limits

AIR TOXICS	EPA & STATE AMBIENT AIR STANDARDS mg/m^3	OSHA OCCUPATIONAL LIMITS 8 HR mg/m^3	BIOLOGICAL MONITORING Blood/Urine
Arsine (AsH_3)	0.000051	0.2 Cancer	
Coke Oven Emissions	0.0000028	0.15 Cancer Benzene Soluble Fraction	Yes
Coal Dust		2.4 Respirable (<5%SiO_2)	
Fluorine		0.2	Yes
Hydrogen Chloride		7.0 Ceiling	
Hydrogen Fluoride		2.5	
Particulate Metals Nuisance Dusts	**0.15 Total 0.05 Respirable**	**15 Total 5 Respirable**	
Aluminum	0.0037 0.003 (ND)	15 Total Particulate 5 Respirable Dust	
Arsenic	0.00000041 C 0.0033 (VA)	0.01 Cancer	Yes
Beryllium	0.00000073 0.0001 (NV)	0.002 Cancer 0.005 Ceiling	
Cadmium	0.00000099	0.005 Fume/Dust Cancer	Yes
Chromium	5.5 Cr III 0.00000015 Cr VI	0.5 to 1.0 Cr Compounds Cr VI Cancer	Yes
Copper	0.15	1.0 Dust	
Iron	1.1	10	
Lead	0.0015	0.05	Yes
Manganese	0.00052	5.0 Ceiling	
Mercury	0.00031 0.0004 (AZ) 0.012 (VT)	0.10 Ceiling	Yes
Nickel	0.073	1.0	
Selenium	0.018	0.2	Hair/Nail
Silver	0.018	0.01	
Zinc	1.1	5.0 Fume/Dust	
Stibine (SbH_3)		0.5	

Table V. OSHA Inspections Results for the Metals Industry, 1/2000 to 8/2005

SIC Code	Industry	Number of Test Substances	Number of Tests	Most Frequent Exceedances
331X (5 Codes)	Steel Works	20-60	130-650	Noise, dust, fumes
332X (4 Codes)	Foundries	20-75	180-1560	Noise, dust, fumes
3334	Primary Aluminum	28	70	Noise
3341	Secondary Non Ferrous	49	710	Noise, dust, fumes
3353	Aluminum Sheet Metal	19	96	Noise
3354	Aluminum Extruded	24	169	(none)
3355	Aluminum Rolling	1	8	(none)
3363	Aluminum Die Casting	42	280	Noise, dust
3365	Aluminum Foundries	58	600	Noise, dust, fumes
5051	Metals Marketing	41	420	Noise, fumes & dust
5093	Scrap/Waste Wholesale	59	970	Noise, dust, fumes

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