A COMPREHENSIVE APPROACH TO POWER PLANT TOXIC RELEASE INVENTORIES

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ABSTRACT

Beginning in 1998, coal-fired and oil-fired power plants will be required to estimate and report their annual mass emissions to the national Toxic Release Inventory (TRI). The TRI is a publicly reported inventory of emissions to air, water and land of approximately 600 chemicals designated as "toxic" by the U.S. Environmental Protection Agency (EPA). This paper reviews the current status of TRI reporting requirements for electric utilities. The recently enhanced version of the EPRI PISCES Model is used to estimate the magnitude of reportable TRI emissions, and their uncertainties, for a variety of typical power plant designs, operating conditions, and fuel choices. The ability of environmental control technologies and plant operating practices to reduce emissions of TRI chemicals also is explored using the PISCES Model.

INTRODUCTION

In May 1997, the U.S. Environmental Protection Agency (EPA) promulgated its final rulemaking requiring oil- and coal-burning electric power plants to report chemical releases under the national Toxics Release Inventory (TRI) [1]. Affected facilities must report TRI emissions on an annual basis, beginning with 1998 emissions. EPA expects nearly 1,000 facilities, representing a third of the U.S. electric power sector to be affected.

This paper briefly reviews the TRI requirements for electric power plants. Then, several case studies are presented to illustrate the types and magnitudes of chemical releases subject to TRI reporting. These case studies employ the TRI-enhanced PISCES Model developed for the Electric Power Research Institute (EPRI).

TRI REQUIREMENTS

The Toxics Release Inventory was established by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. This requires facilities in designated industry sectors to report annually the amounts of toxic chemicals released to the environment. TRI is a publicly available database established to provide U.S. communities with information on the presence and releases of toxic chemicals. Approximately 300 chemicals were included on the original TRI list.

The reporting requirements of TRI were expanded by the Pollution Prevention Act of 1990, which created additional reporting elements including waste management and pollution prevention activities. Expansion of the original TRI data and reporting requirements is taking place in three phases, two of which now have been completed. Phase I called for the addition of toxic chemicals and chemical categories to the original EPCRA Section 313 list. This was accomplished in 1994, when 286 chemicals were added to the list, bringing the current total to 584 chemicals and 28 chemical categories. Phase II of the expansion occurred in May 1997, when seven industry groups were added to the twenty industrial sectors initially covered. The newly added industries include coal mining, commercial waste treatment, and electric utilities. Phase III, which may be enacted within the next few years, would require the addition of chemical use data to the TRI reporting requirements, as well as material accounting and worker exposure data.

Affected industries are identified by Standard Industrial Classification (SIC) categories. Electric utility plants covered by TRI are in SIC codes 4911, 4931 and 4939. Any facility within a covered industry sector is required to report to TRI if it has the equivalent of ten or more full-time employees, and "manufactures" or "processes" more than 25,000 pounds of any listed toxic chemical during the reporting year, or "otherwise uses" more than 10,000 pounds of any listed chemical. A toxic chemical is considered to be manufactured if it is "produced, prepared, compounded, or imported," including coincidental manufacture as a byproduct or impurity. A chemical is considered to be processed if it is "prepared after manufacture for distribution in commerce." Finally, a chemical is considered to be otherwise used if its use does not fall under the categories of manufactured or processed.

The TRI deals only with the quantities (mass) of listed chemicals, and not with the effects or impacts of those chemicals on people or the environment. The question of whether TRI releases actually pose any risk is outside the scope of EPCRA Section 313. Similarly, the fact that power plant releases such as flyash have been found by EPA to be non-hazardous under the Resource Conservation and Recovery Act (RCRA) does not preclude them from reporting under TRI.

Implications for Power Plants

For oil- and coal-burning power plants, the most relevant set of TRI chemicals are typically those designated as manufactured or otherwise used. Any substance in the fuel which is chemically converted to a listed TRI substance as a result of the combustion process is considered by EPA to be coincidentally manufactured. As elaborated below, such substances include most metals commonly found in coal and oil. Chemicals that are "otherwise used" include a variety of cleaning fluids, water treatment additives, and other substances commonly employed at power stations. Table 1 lists some of the TRI chemicals potentially relevant to the electric utility industry. Trace chemicals found in air and water intake streams are excluded from TRI reporting.

The TRI exempts toxic chemicals that appear in low concentrations in some types of products. This exemption states that, "a listed toxic chemical does not have to be considered if it is present in a mixture at a concentration below a specified *de minimus* level," which is 0.1% for carcinogens and 1.0% for all other toxic chemicals. However, the *de minimus* exemption applies only to "a listed toxic chemical in a mixture or trade name product received by the facility," and "a listed toxic chemical manufactured during a process where the toxic chemical remains in a mixture or trade name product distributed by the facility." It does not apply to "a toxic chemical manufactured at the facility that does not remain in a product distributed by the facility." Thus, a plant which sells a byproduct (such as flyash or gypsum) containing TRI chemicals may be able to apply the *de minimus* exemption to that byproduct stream. If the concentration limit is not exceeded — as is typically the case — the quantity of chemical in the byproduct is exempt from TRI reporting.

All TRI data are reported on EPA Form R [4]. One copy of Form R must be filled out and submitted for every chemical subject to reporting. Form R requires information about each chemical's uses, releases, transfers, and on-site treatment methods, as well as facility source reduction and recycling activities. Table 2 outlines the information requested on Form R. The sections below highlight some of the principal TRI constituents found in the power industry.

Chemicals Manufactured in Combustion

Although electric utilities don't commonly think of themselves as a chemical manufacturing industry, the TRI ground rules indeed consider the combustion process to "manufacture" new chemicals from the trace constituents in coal or oil used to generate power. Such manufactured chemicals include not only the trace organics that may be found in some combustion flue gas streams, but also the metal oxides and other constituents present in flyash, bottom ash and particulate stack emissions. Coincidental manufacturing is considered by EPA to have occurred any time a chemical substance in fuel is transformed into a different chemical compound in the combustion gas or residual solids [1]. For example, if any zinc in coal is converted to zinc oxide (ZnO), then ZnO is considered to have been coincidentally manufactured.

Any compounds of 16 listed metals that are manufactured in amounts totaling more than 25,000 lb/yr are reportable. In addition, specific toxic forms of aluminum, molybdenum and vanadium also are listed. These are the fibrous (man-made) form of aluminum oxide, aluminum dust or fume, vanadium dust or fume, and molybdenum trioxide. Since aluminum and vanadium are converted to natural oxides, rather than elemental metal, only the last of these four substances is likely to be formed in a power plant. Though chemical forms of molybdenum in flyash are not routinely measured, experience in other industries indicates that MoO_3 is the principal compound formed at combustion temperatures above 1000°C (1832°F) [5], which is typical of power plant conditions.

EPCRA Section 313 does not require affected sources to conduct any new measurement programs for purposes of TRI reporting. Rather, a facility can estimate its reportable emissions using currently available information. Since data are generally lacking on the specific chemical forms of metals in fuel and ash, EPA has stated that in the absence of better site-specific information, metals that take part in the combustion process may be assumed to convert completely into the lowest weight metal oxide per unit of the metal possible for each metal [1]. Table 3 lists our evaluation of the lowest weight oxides per unit of metal for common metals potentially reportable to TRI. The last column gives the threshold release in terms of equivalent elemental emissions, which is the quantity reportable on Form R. If the total quantity oxidized (or otherwise converted) at a given facility exceeds this amount, then *all* releases of that substance at the facility must be reported.

Other inorganic TRI chemicals that may be manufactured during combustion include hydrochloric acid (HCl), hydrogen fluoride (HF), and sulfuric acid (H_2SO_4). HCl and HF are formed from chlorides and fluorides in coal. Sulfuric acid is formed in the flue gas stream from the reaction of sulfur trioxide and water vapor. Sulfuric acid mist or condensation can be expected whenever the flue gas temperature falls below the acid dewpoint, which is a function of the SO_3 and H_2O content of the flue gas. Dewpoint temperatures for coal plants typically are in the range of 260-300°F [7]. For stack gas exit temperatures above the acid dewpoint, H_2SO_4 exists in gaseous form [8,9]. However, since EPA defines an aerosol to include gases and vapors as well as mixtures of gases and particles, H_2SO_4 emissions are likely to be a reportable TRI release for most coal-fired plants.

Chemicals Otherwise Used

This category of TRI chemicals includes a variety of substances commonly used at power plants for water treatment, boiler cleaning, and other miscellaneous purposes. Chemical additives are used to control alkalinity, biofouling, deposition and corrosion in plant cooling and makeup water streams. Chemicals also are used to regenerate ion exchangers, treat and clean boiler tubes, remove suspended solids in clarifiers, and prevent freezing of coal piles in cold weather. Table 1 indicates the EPCRA Section 313 toxic chemicals identified by EPA in its discussion of otherwise used chemicals at coal and oil-fired power plants [3]. The EPA list is by no means exhaustive; additional TRI chemicals may be employed at U.S. power plants for maintenance, cleaning or purifying operations. It remains to be determined on a facility-by-facility basis whether the use of such chemicals exceeds 10,000 lbs/yr, making it reportable to TRI.

ESTIMATING TRI EMISSIONS

As noted earlier, a facility may use whatever method it deems reasonable to quantify annual usage and releases of reportable TRI chemicals. EPA has developed a series of industry-specific guideline documents to assist affected facilities in complying with TRI requirements. The electric utility guideline [10] deals primarily with definitions and procedures related to TRI reporting requirements; relatively little is provided in the way of tools or methods for quantifying major TRI releases from power plants.

The electric power industry also is developing materials and tools to assist in TRI reporting. One such effort, underway at EPRI, involves two products of EPRI's PISCES (Power Plant Integrated System: Chemical Emissions Studies) program — the PISCES Database and the PISCES Model. The PISCES Database, developed by Radian International, contains empirical information on the concentration of trace chemicals found in fuels and in various power plant streams [11]. The data come from a variety of sources including EPRI's Field Chemical Emission Studies (FCEM) program [12] and the open technical literature.

The PISCES Model is a mass and energy balance model that computes all chemical flows into and out of a single user-specified power plant. Coal-fired, oil-fired and gas-fired units are included. The model originally was developed to account for emissions of hazardous air pollutants (HAPs) as well as trace chemicals in liquid and solid waste streams. A unique model feature is a probabilistic capability that allows uncertainties in plant parameters and mass flows to be quantified and modeled explicitly if the user desires. To calculate emissions of trace substances, the model employs information from the PISCES Database to quantify the trace substance removal efficiency of all plant components and emission control systems. Version 2.0 of the PISCES Model [13] includes 35 trace chemicals selected on the basis of their potential relevance to the utility sector in the context of HAPs and TRI. The PISCES Model also contains extensive default information on the trace species concentration of fuels and reagents used by U.S. power plants. Additional details on the model and its validation are available elsewhere [14, 15].

TRI CASE STUDY

Here we present an illustrative case study to identify and quantify the EPCRA Section 313 chemicals reportable for TRI. The case study plant is a 650 MW (net) facility burning an average 1995 bituminous coal (12,205 Btu/lb, 1.5% S) in compliance with the Phase I acid rain emission cap of 2.5 lbs SO_2/MBtu. This plant was selected to approximate the average size of U.S. coal-fired facilities, whose size range spans nearly two orders of magnitude (see Figure 1) [16]. The model plant is equipped with an electrostatic precipitator (ESP) and a zero discharge wastewater treatment system. Its heat rate is 9400 Btu/kWh. All collected ash is landfilled (flyash) or ponded (bottom ash) on-site. Figure 2 shows a diagram of the plant.

The PISCES Model was used to calculate all annual mass and energy flows into this plant, assuming a 65 percent capacity factor. For this example, the model was run deterministically (no uncertainty in input parameters) using the median values of trace species concentrations for all bituminous coals (Table 4). Model default values and median values from the PISCES database were used for all site-specific plant parameters used to determine the partitioning of each substance to air, water and land streams. The partition factors used for this case study reflected a composite of all boiler types (tangential, wall and cyclone), and all ESPs with total particulate emissions less than 0.1 lbs/MBtu. All trace species concentrations in plant inlet water were set to zero since these quantities are exempt from TRI reporting. In this way, the PISCES Model reports only the incremental contribution of “manufactured” substances rather than the total chemical mass in liquid streams.

Reportable species are those which exceed the adjusted threshold amounts in Table 3. These include 7 of the 17 elements in Table 3, plus HCl, HF and H_2SO_4. Emissions of stack gas organic compounds formed during combustion also were estimated based on data collected by EPRI and DOE [12, 19]. Emissions of all organic species were well below TRI threshold limits, ranging from zero to 300 lbs/yr for different compounds.

Table 5 summarizes the magnitude of reportable combustion-related releases for the 650 MW case study facility. The dominant emissions are HCl, H_2SO_4 and HF released at the power plant stack. To obtain the latter values, the PISCES Database was used to estimate the percentages of total chlorides and fluorides released as gaseous HCl and HF, respectively. For H_2SO_4, sulfur trioxide in the flue gas was assumed to react completely with water vapor to form sulfuric acid gas [17]. The magnitude of SO_3 concentration was estimated from the PISCES Database and EPA emission factors [18], which indicate that approximately 0.7% of the flue gas sulfur is SO_3. The underlying data exhibit substantial variability, however, indicating large uncertainty in this point value estimate. Since EPA has defined an aerosol to include vapors and gases as well as suspensions of particles in a gas, it appears that any H_2SO_4 in flue gas is reportable for purposes of TRI, whether or not it has condensed into a “true” aerosol. Similarly, all gaseous HCl is reportable as an acid aerosol.

Table 5 shows that HCl accounts for more than half the total mass emissions, while land releases amount to only 15 percent of the plant total. Trace metal air emissions account for less than 0.1 percent of the total plant inventory.

Chemicals that are “otherwise used” at the facility typically are associated with cooling water and wastewater treatment processes. For the case study plant, if chlorine is used as a biofouling control agent, the annual (reportable) use would be approximately 19,000 lbs/yr. The TRI estimates of hydrazine (for boiler corrosion control) and ammonia (for pH control and ion bed regeneration) are 2200 lbs/yr and 2800 lbs/yr, respectively [20]. These quantities would not be reportable since they do not exceed 10,000 lbs/yr. The PISCES Model is currently being expanded to provide annual usage estimates for a variety of TRI chemicals commonly employed for water treatment and periodic maintenance tasks.

Factors Affecting TRI Releases

The example above illustrated the magnitude of TRI based on an average plant size and median trace element coal composition. Several key factors will affect the nature and quantity of TRI releases. Some of these factors are discussed briefly below.

Plant Size and Operation

The size of a given facility is a key determinant of annual chemical discharges. For affected utilities, the combined release from all generating units at a given site must be used to determine threshold quantities and reportable emissions. Thus, a generating station with two 400 MW coal-fired units must quantify TRI releases for the entire 800 MW facility. Quantitatively, TRI releases would scale in direct proportion to plant size for a fixed plant design and fuel composition. Similarly, the annual plant capacity factor has a proportional effect on combustion-generated emissions. Thus, increasing the station capacity factor to 80 percent from the base value of 65 percent would increase annual emissions by 23 percent. Larger plant sizes or higher capacity factors also could cause additional chemical species to exceed the TRI threshold and become reportable.

Fuel Properties

For any given plant, the concentration of trace elements in coal or oil is the most critical factor affecting the quantity of manufactured compounds as defined under TRI. Across the U.S., there is a high degree of variability in the concentration of TRI chemicals in coal. Data in the PISCES Model reflect this variability. For example, Figure 3 shows the cumulative distribution of chromium concentration in bituminous coals, which spans two orders of magnitude.

To gauge the impact of such variability on annual TRI releases, Table 6 shows a range of annual release values estimated with the PISCES Model for a 650 MW facility. Here, the probabilistic capabilities of the model were employed to calculate a 90 percent probability interval corresponding to the 5th and 95th percentile values for coal concentration (see Figure 3). One sees that variations in coal composition across the United States can have a marked impact on the number of reportable TRI chemicals and the magnitude of TRI releases.

Figure 4 illustrates this point by showing the number of reportable combustion-generated chemicals as a function of plant size and coal composition. Large facilities could be required to report as many as 18 manufactured species, while small plants may have to report as few as three. HCl, H_2SO_4 and barium are likely to always exceed TRI thresholds, while mercury and silver are well below current reportable levels for all U.S. plants. Of course, for any particular coal seam or coal supply, a much smaller variation can be expected than the ranges shown in Table 6, which includes all utility coals in the PISCES database. Similarly, the heating value of coal directly affects TRI emissions. As the heating values decreases, more coal is needed to provide a given power output. The trace element composition then determines the mass of TRI emissions.

Plant Configuration

For a given fuel composition and plant size, the specific configuration of a power plant also can have a marked effect on the quantities of TRI chemicals released to different environmental media. For example, if the case study power plant described earlier were retrofitted with a wet limestone flue gas desulfurization (FGD) system downstream of the ESP, atmospheric emissions of metallic compounds would be reduced by an average of 76 percent of the values shown in Table 5, according to data in the PISCES Model. Stack gas emissions of HF and HCl would be reduced by approximately 85 to 95 percent, while stack gas H_2SO_4 would fall by roughly an order of magnitude. Overall air releases and total TRI emissions are thus substantially reduced. However, chemical releases to land will increase slightly as a result of solid wastes generated by the FGD system. To estimate these quantities, the PISCES Model tracks all trace elements in the lime and limestone reagents commonly employed for sulfur dioxide removal. For the case study plant, an additional total of about 26,000 lb/yr of reportable trace metal chemicals, primarily barium and manganese in limestone reagent, would be released in the FGD waste (based on 90 percent SO_2 removal). Overall, the total reportable releases for the case study plant with FGD would be 76 percent lower than before, with solid wastes now accounting for the preponderance (67 percent) of emissions.

Configuration of the plant water systems, including the choice of cooling water system (e.g., once-through cooling versus a recirculating system) and wastewater treatment technologies, also can alter the magnitude of TRI releases and the inventory of chemicals that are “otherwise used.” The case study plant modeled earlier assumed zero wastewater discharge. Most U.S. power plants have a non-zero discharge with allowable effluent limits specified under the National Pollutant Discharge Elimination System (NPDES). The PISCES Model currently simulates approximately 50 different water system configurations prevalent in the United States. At the present time, however, there is relatively little data to characterize the partitioning of most TRI chemicals in wastewater treatment systems, or their releases in effluent streams. EPRI currently is conducting a field sampling program which will help provide more reliable estimates for TRI reporting. Such data will be incorporated into a new water systems model being constructed for the next release of the PISCES Model in late 1998.

Plant Operating Practices

The specific operating practices at a particular facility can influence the types and quantities of reportable TRI chemicals, especially those that are “otherwise used.” For example, utilities may have a choice of chemicals or methods for waste treatment processes and periodic plant maintenance activities that contribute to TRI releases. The site-specific use of chemicals for auxiliary activities not directly related to power generation is not reflected in the PISCES Model or Database, and must be evaluated on a case-by-case basis for each affected facility. Table 1, shown earlier, provides a guideline to some of the TRI chemicals whose use may depend strongly on site-specific operating practices.

Pollution prevention programs undertaken as part of power plant operations also can yield benefits for TRI reporting. For example, reduced use or elimination of listed chemicals such as hydrazine or solvents may be possible at some facilities. Comprehensive pollution prevention programs are an important element of on-going activities to reduce environmental releases from electric power plants. As noted earlier, the distribution in commerce of plant byproducts such as flyash, bottom ash, and FGD-generated gypsum also can reduce the quantities of reportable TRI chemicals where markets for such byproducts exist.

CONCLUSION

Beginning in 1998, the Emergency Planning and Community Right-to-Know Act (EPCRA) will place new reporting requirements on electric power plants burning coal or oil. Affected plants must estimate their annual releases to air, water and land of all chemicals listed in the Toxic Release Inventory (TRI), and report all releases that exceed the threshold limits.

The PISCES Model developed for EPRI was used to estimate multi-media TRI emissions from fossil-fueled power plants. Case studies showed that power plant size, fuel properties, plant configuration, and site-specific operating practices will strongly affect the number of reportable TRI chemicals, and the magnitude of annual releases. Additional enhancements of the PISCES Model and database, tailored to TRI reporting, are planned for 1998 to assist utilities in complying with TRI requirements.

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Table 1. Toxic Release Inventory Chemicals Potentially Relevant to the Electric Utility Industry[a]

Metals and Compounds[b]	Organics	Other
Antimony	Benzene	Ammonia*
Arsenic*	Dichloromethane	Asbestos (friable)
Barium	Ethylbenze	Bromine*
Beryllium*	Ethylene Glycol*	Chlorine*
Cadmium*	Formaldehyde*	Chlorine Dioxide
Chromium*	Formic Acid*	Hydrazine*
Cobalt	Methanol	Hydrogen fluoride*
Copper*	Naphthalene	Hydrochloric Acid[d]
Lead*	PCBs	Nitric Acid
Manganese*	Polycylic aromatics	Ozone
Mercury*	Propylene	Sulfuric Acid*[d]
Molybdenum[c]	Toluene	Thiourea*
Nickel*	Xylene	
Selenium		
Silver		
Thallium		
Zinc		

[a]Based on the final EPA survey of SIC Code 49 [2] and the PISCES Database. An asterisk denotes chemicals mentioned in EPA's proposed rulemaking [3].
[b]Except for molybdenum, any compound of these metals is considered by EPA to be toxic.
[c]Only molybdenum trioxide is listed as toxic.
[d]Limited to acid aerosols including mists, vapors, gas, fog, and other airborne forms of any particle size.

Table 2. Annual Releases (lbs/yr) Reportable on TRI Form R [4]

- Fugitive Air Emissions
- Stack Air Emissions
- Water Discharges
  - -By water body name
  - -% from stormwater
- Underground Injections
- Land Releases to:
  - -Landfill
  - -Land treatment/application farming
  - -Surface impoundment
  - -Other disposal
- Transfers Off-Site to:
  - -Publicly Owned Treatment Works
  - -Other Sites (divided by site)
  - -For treatment
  - -For disposal
  - -For recycling
  - -For energy recovery
- On-Site Waste Treatment Methods and Efficiency
  - -List of methods, concentration and efficiency
  - -Divided by waste stream
- Source Reduction and Recycling Activities
  (a through g are reported for the previous year and current year and projected for the following two years)
  - a. Quantity released
  - b. Quantity used for on-site energy recovery
  - c. Quantity used for off-site energy recovery
  - d. Quantity recycled on-site
  - e. Quantity recycled off-site
  - f. Quantity treated on-site
  - g. Quantity treated off-site
  - h. Quantity released to environment not associated with production process
  - i. Production ratio or activity index

Table 3. Elemental Threshold Release Values for Combustion-Generated Manufactured Compounds

Metal	Lowest Weight Oxide[a]	Molecular Weight	Ratio[b]	Adjusted Threshold[c] (lbs/yr)
Antimony	Sb_2O_3	291.50	.833	20,833
Arsenic	As_2O_3	197.84	.758	18,939
Barium	BaO	153.33	.895	22,391
Beryllium	BeO	25.01	.360	9,009
Cadmium	CdO	128.41	.876	21,891
Chromium	CrO	68.00	.765	19,113
Cobalt	CoO	74.93	.787	19,670
Copper	Cu_2O	143.09	.888	22,202
Lead	PbO	223.20	.929	23,213
Manganese	MnO	70.94	.775	19,365
Mercury	Hg_2O	417.18	.962	25,000[d]
Molybdenum	MoO_3[e]	143.94	.667	16,663[e]
Nickel	NiO	74.70	.786	19,645
Selenium	SeO_2	110.96	.712	17,790
Silver	Ag_2O	231.74	.931	23,273
Thallium	Tl_2O	424.74	.962	24,058
Zinc	ZnO	81.38	.803	20,080

[a]Per unit of metal, based on Ref [6].
[b]Ratio of molecular weight of metal to total weight of the compound.
[c]Equal to 25,000 lbs/yr times the ratio in the previous column. This is the threshold quantity of the metals. Only the amount of elemental metal is reported on Form R, except for Mo where the amount of MoO_3 is reported.
[d]The EPA rule states that the threshold in this case can be increased to 25,000 lbs/yr since mercury is believed to be manufactured primarily in elemental form.
[e]Only molybdenum trioxide is a listed TRI chemical.

Table 4. PISCES Model Summary of Trace Element Concentration in U.S. Bituminous Coals Used for Power Generation (ppmw, dry basis)

Trace Element	Median Value	No. of Data Points
Antimony	1.0	95
Arsenic	10.0	208
Barium	94.5	163
Beryllium	1.3	155
Cadmium	0.52	180
Chlorine	750.	108
Chromium	18.6	200
Cobalt	6.4	147
Copper	20.8	154
Fluorine	65.0	92
Lead	8.1	194
Manganese	22.4	165
Mercury	0.12	209
Molybdenum	2.1	107
Nickel	16.1	169
Selenium	3.2	198
Silver	0.2	88
Thallium	1.6	26
Zinc	22.0	144

Table 5. Summary of Reportable TRI Releases (lbs/yr) for Case Study Power Plant (650 MW, 65% CF, Zero Wastewater Discharge)[a]

Chemical	Air Releases	Land Releases	Total Releases
Arsenic	1,100	25,000	27,000
Barium	910	250,000	250,000
Chromium	250	49,000	49,000
Copper	220	55,000	55,000
Hydrochloric Acid	2,000,000	0	2,000,000
Hydrogen Fluoride	160,000	0	160,000
Manganese	190	60,000	60,000
Nickel	200	43,000	43,000
Sulfuric Acid	890,000	0	890,000
Zinc	470	58,000	59,000

[a]TRI requires reporting to only two significant figures. Totals may differ from sum due to rounding.

Table 6. 90 Percent Probability Intervals for the Manufacture of TRI Chemicals for the Case Study Power Plant (650 MW net, 65% capacity factor) (all figures in thousand lbs/yr)

Chemical	90% Range for All Bituminous Coals	TRI Threshold[a]
Antimony	0.6 - 8	21
Arsenic	3 - 160	19
Barium	75 - 860	22
Beryllium	0.8 - 7	9
Cadmium	0.1 - 16	22
Chromium	7 - 81	17
Cobalt	3 - 43	20
Copper	14 - 136	22
Hydrochloric Acid	66 - 7000	24
Hydrogen Fluoride	11 - 360	24
Lead	6 - 110	23
Manganese	18 - 240	19
Mercury	0.1 - 2	25
Molybdenum[b]	0.5 - 37	17
Nickel	13 - 130	20
Selenium	2 - 48	18
Silver	0.05 - 3	23
Thallium	1 - 10	24
Zinc	26 - 250	20

[a]Adjusted TRI threshold values from Table 3, rounded to nearest thousand.
[b]Multiply all values by 1.50 to get reportable molybdenum trioxide.

Figure 1. Size Distribution of U.S. Coal-Fired Power Plants, 1994.

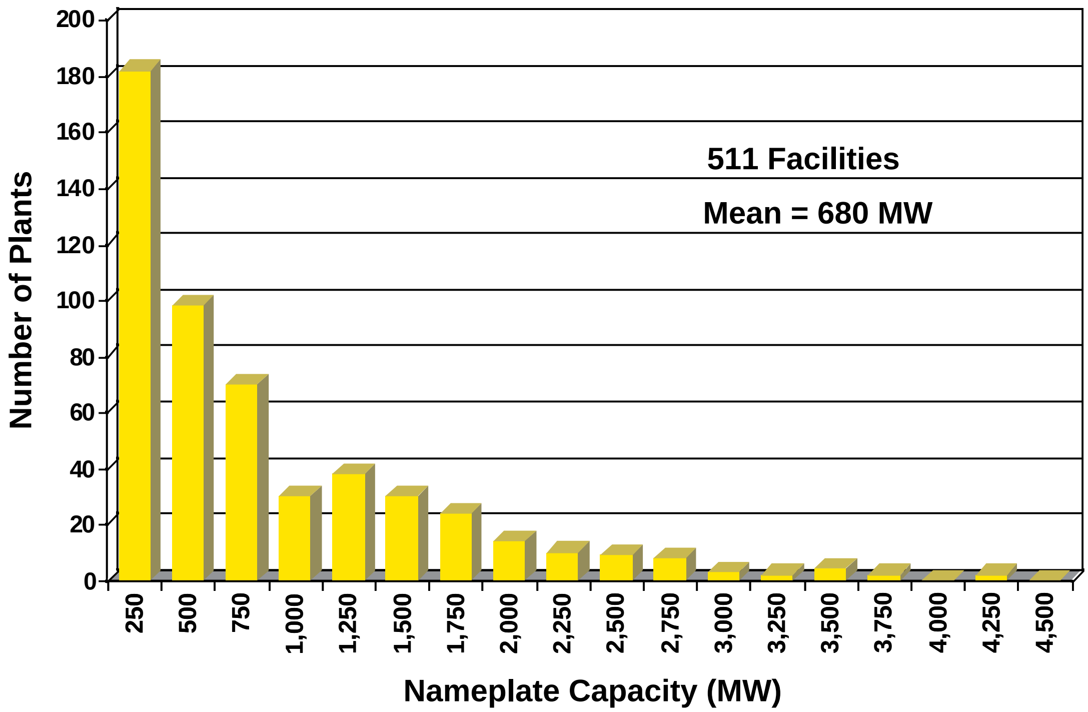

Figure 2. Schematic of the Case Study Plant.

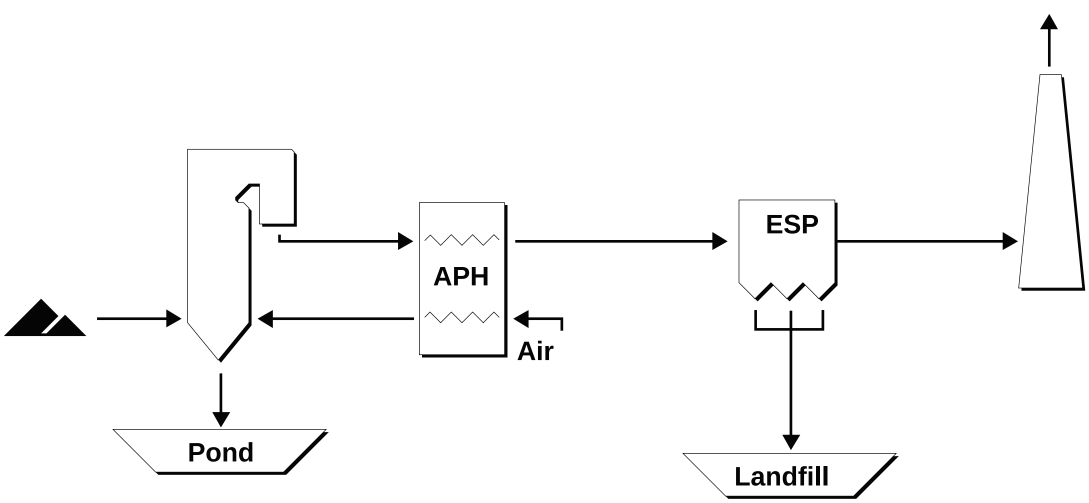

Figure 3. Distribution of Chromium Concentration in U.S. Bituminous Coals (Based on PISCES Model Database)

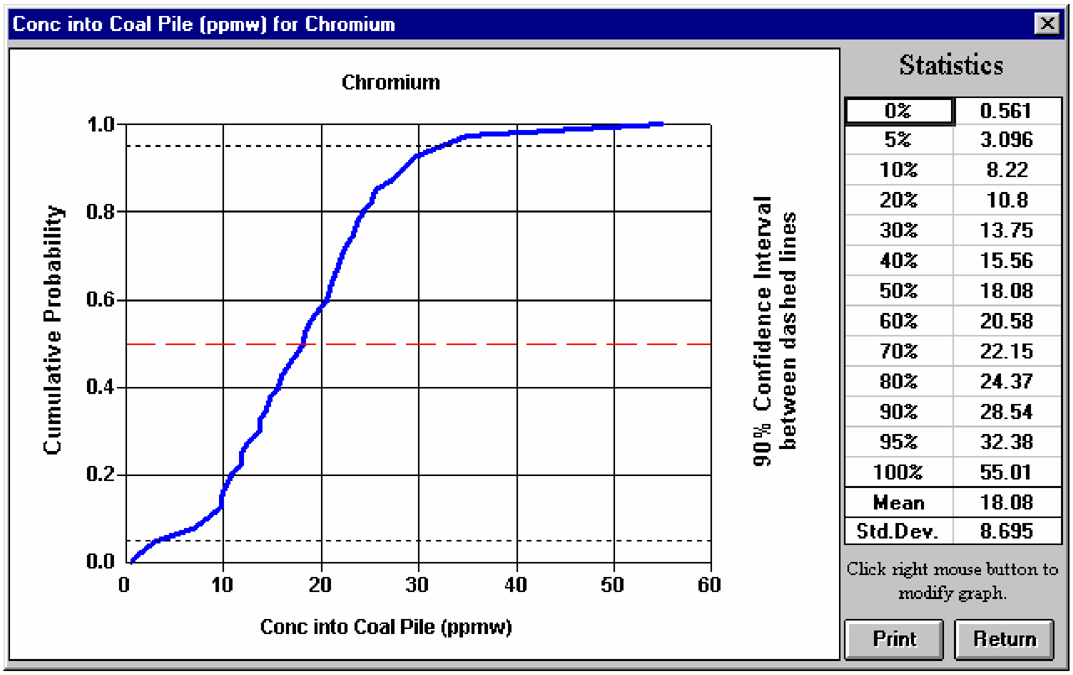

Figure 4. Effect of Plant Size and Fuel Composition on Number of Reportable TRI Chemicals Manufactured During Combustion (based on bituminous coal and case study plant design)