Toxic Releases from Power Plants

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Beginning in 1998, electric power plants burning coal or oil must estimate and report their annual releases of toxic chemicals listed in the Toxics Release Inventory (TRI) published by the U.S. Environmental Protection Agency (EPA). This paper identifies the toxic chemicals of greatest significance for the electric utility sector and develops quantitative estimates of the toxic releases reportable to the TRI for a representative coal-fired power plant. Key factors affecting the magnitude and types of toxic releases for individual power plants also are discussed. A national projection suggests that the magnitude of electric utility industry releases will surpass those of the manufacturing industries which currently report to the TRI. Risk communication activities at the community level will be essential to interpret and provide context for the new TRI results.

Background

The Toxics Release Inventory (TRI) is a comprehensive public database of annual emissions to air, water, and land of over 600 chemicals and chemical categories designated as toxic by the U.S. Environmental Protection Agency (EPA) (*1*). The inventory lists releases from facilities in the 20 major manufacturing industries defined by the Standard Industrial Classification (SIC) codes of the U.S. government. TRI data also are available in electronic form, including an EPA Web site that allows users to locate and list the largest “toxic emitters” in any postal zip code area (*2*).

As of 1998, electric power plants burning coal or oil also must estimate and report their releases of toxic chemicals to the TRI. This paper examines the implications of TRI requirements for the electric utility sector and develops estimates of the toxic releases that will be reportable under TRI. The primary focus is on coal-fired power plants, which are the dominant source of U.S. power generation, accounting for 52% of electricity production in 1997 (*3*).

The Toxics Release Inventory

The TRI was established in 1986 by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA). Its purpose was to provide the public with information on the presence and release of toxic chemicals in their communities. The Pollution Prevention Act of 1990 expanded the scope of the TRI to include the reporting of waste management and pollution prevention activities. Current TRI reports summarize the quantities of on-site and off-site releases and transfers of each reportable chemical, including amounts sent to recycling, energy recovery, and waste treatment processes.

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Any facility within a listed industry sector is required to report to TRI if it has the equivalent of 10 or more full-time employees and “manufactures” or “processes” more than 25 000 pounds of any listed chemical during the reporting year or “otherwise uses” more than 10 000 pounds per year 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”. Any chemical that does not fall under the categories of manufactured or processed is considered to be “otherwise used” (*4*).

Current TRI data show the chemical industry (SIC 28) and the primary metals industry (SIC 33) have the largest nationwide releases of toxic chemicals. Methanol, zinc compounds, and ammonia are the TRI chemicals released in the greatest quantities (*1*).

Importantly, the TRI deals only with the mass of chemical releases and not with the effects or impacts of those chemicals on people or the environment. Releases of each listed chemical are reported in pounds per year (the units used in this paper), and the sum of all reported releases is used to identify and rank facilities and industries with the largest overall emissions. The question of whether, or to what extent, TRI releases pose environmental or health risks is outside the scope of EPCRA Section 313, which leaves it to individual communities to evaluate the significance of reported releases.

Application To Power Plants

Seven industry groups were recently added to the TRI, including electric utilities burning oil or coal (*4*). These newly listed facilities have until July 1, 1999 to report their TRI emissions for calendar year 1998. Typically, there is a one-year lag before EPA compiles, analyzes, and releases new TRI data. Thus, the inventory for 1998 is not likely to be available publicly until 2000.

Background studies by EPA (*5*, *6*) helped to identify some of the TRI chemicals potentially relevant to the electric utility industry (Table 1). As elaborated below, these substances are likely to be “manufactured” or otherwise used at electric power plants.

Chemicals Manufactured in Combustion. Although electric utilities do not think of themselves as a chemical manufacturing industry, TRI considers 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 found in some combustion flue gas streams but also the metal compounds 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 (*4*). 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 the 17 listed metals in Table 1 that are manufactured in amounts totaling more than 25 000 lb/yr are reportable (except for molybdenum, where only the trioxide is listed). However, affected sources are not required 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 fuels and waste streams, EPA has stated that in the absence of better site-specific information, metals that take part in

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TABLE 1. Toxic Release Inventory Chemicals Potentially Relevant to the Electric Utility Industry

metals[a]	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[c]
lead	PCBs	nitric acid
manganese	polycylic aromatics	ozone
mercury	propylene	sulfuric acid[c]
molybdenum[b]	toluene	thiourea
nickel	xylene	
selenium		
silver		
thallium		
zinc		

[a] Except for molybdenum, any compound of these metals is considered by EPA to be toxic. [b] Only molybdenum trioxide is listed as toxic. [c] Limited to acid aerosols including mists, vapors, gas, fog, and other airborne forms of any particle size.

the combustion process may be assumed to convert completely into the lowest weight metal oxide per unit of the metal possible for each metal (*4*). The Supporting Information provides additional details. If the total quantity oxidized (or otherwise converted) at a given facility exceeds the threshold amount, then *all* releases of that substance at the facility must be reported. However, trace chemicals in air and water intake streams are excluded from TRI reporting.

Additional inorganic TRI chemicals that may be manufactured during combustion include hydrochloric acid aerosol (HCl), hydrogen fluoride (HF), and sulfuric acid aerosol (H_2SO_4). HCl and HF are formed from chlorides and fluorides in fuel and emitted in gaseous form. Sulfuric acid is formed in the flue gas stream from the reaction of sulfur trioxide and water vapor and emitted either in aerosol or gaseous form, depending upon the dewpoint temperature. However, the TRI defines an aerosol to include gases and vapors (*4*). Thus, all gaseous HCl and H_2SO_4 emissions are reportable TRI releases for power plants if thresholds are exceeded.

Chemicals Otherwise Used. This category of TRI chemicals includes a variety of substances 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. It remains to be determined on a facility-by-facility basis whether the use of any listed chemical exceeds 10 000 lbs/yr, making it reportable to TRI.

De Minimus Exemptions. 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 listed carcinogens and 1.0% for all other toxic chemicals (*4*). The *de minimus* exemptions include "a listed toxic chemical manufactured during a process where the toxic chemical remains in a mixture or trade name product distributed by the facility". Thus, a power 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 for power plant byproducts—

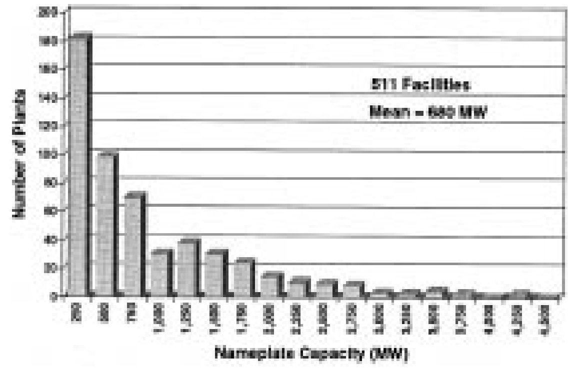

FIGURE 1. Size distribution of U.S. coal-fired power plants, 1994.

then the quantity of chemical in the byproduct is exempt from TRI reporting.

A Mass Balance Model for TRI Estimates

Most U.S. power plants do not measure emissions of trace substances, and many coal-burning plants lack data on the trace substance content of the coals they burn. To estimate TRI releases in the absence of site-specific data, a computer model has been developed by Carnegie Mellon University for the Electric Power Research Institute (EPRI). This model (called the PISCES Model) employs a fundamental mass balance approach to account for multimedia flows of chemical substances in fossil fuel power plants (*7*).

Mass and energy balance calculations are employed to track all chemical flows in to and out of a user-specified power plant configuration. All chemical substances entering in fuel, water, and reagents are tracked through the pulverizer, furnace, air pollution control devices, water treatment systems, and solid waste handling systems. An empirical database of species-specific partition factors and removal efficiencies is used to support mass conservation calculations across each plant component or environmental control unit. Data are available for a variety of component designs and fuel types commonly employed at U.S. power plants. The model database also includes empirical emission factors for organics and other substances formed within the power plant as well as extensive data 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 (*7*−*9*).

Data used to characterize the concentration and partitioning of trace chemicals in power plant streams come from the PISCES Database developed for EPRI by Radian International (*10*). Underlying data sources include the general technical literature plus recent field sampling programs conducted by EPRI (*11*) and the U.S. Department of Energy (*12*).

A TRI Case Study

The PISCES Model is used in this paper to identify and quantify reportable TRI chemical releases for a representative coal-fired power plant design. The case study plant is a 650 MW (net) facility burning an average 1995 bituminous coal (28 380 kJ/kg, 1.5% S, 9.8% ash, 6.7% moisture) in compliance with the phase I acid rain emission cap of 2.5 lbs SO_2/MBtu (1.08 g/MJ). This plant design was selected to approximate the average size of U. S. coal-fired facilities, whose size range spans nearly 2 orders of magnitude (see Figure 1) (*13*). The case study plant is equipped with an electrostatic precipitator (ESP) for flyash collection. Flyash waste is handled in a dry form and disposed of in an on-site landfill. Bottom ash is sluiced to an on-site pond or hydrobin, with all water recirculated or treated to achieve zero effluent discharge. A

TABLE 2. Trace Element Concentrations in Bituminous Coals Used for Power Generation

trace element	concn (ppmw, dry)	trace element	concn (ppmw, dry)
antimony	1.0	lead	8.1
arsenic	10.0	manganese	22.4
barium	94.5	mercury	0.12
beryllium	1.3	molybdenum	2.1
cadmium	0.52	nickel	16.1
chlorine	750.	selenium	3.2
chromium	18.6	silver	0.2
cobalt	6.4	thallium	1.6
copper	20.8	zinc	22.0
fluorine	65.0		

TABLE 3. Summary of Reportable TRI Releases (lbs/yr) for Case Study Power Plant Burning Bituminous Coal[a]

chemical[b]	air releases	land releases	total releases
hydrochloric acid	2 200 000	0	2 200 000
sulfuric acid	980 000	0	980 000
barium	830	270 000	280 000
hydrogen fluoride	180 000	0	180 000
manganese	540	65 000	66 000
zinc	290	64 000	64 000
copper	470	60 000	61 000
chromium	460	54 000	54 000
nickel	220	47 000	47 000
arsenic	750	29 000	20 900
total	3 390 000	618 000	4 010 000

[a] 650 MW net, 67% CF, zero wastewater discharge. TRI requires reporting to only two significant figures. Thus, totals may differ from sums due to rounding. [b] Quantity of each metal refers to amount in chemical compounds. Acids refer to acid aerosols.

recirculating cooling water system is used to control thermal discharges to waterways. The assumed net heat rate for this plant configuration is 10 000 Btu/kWh (*14*).

Annual mass flows were calculated based on a plant capacity factor of 67%, the recent average for U.S. coal plants (*3*). The trace element concentrations in coal were taken as the median values for all bituminous coals used for power generation (Table 2), as reflected by roughly 200 coal samples in the PISCES Model database. The partitioning of each substance between air and land streams was determined using the median removal efficiency data for all pulverized coal boiler types (tangential and wall-fired) and all ESPs with total particulate emissions less than 0.043 g/MJ (0.1 lbs/MBtu), reflecting different vintages of plants currently in operation (see Supporting Information).

All trace elements in coal are assumed to undergo coincidental manufacture as defined by the TRI. Thus, reportable species are those whose amounts in the coal feed exceed the threshold amounts.

Case Study Results. Table 3 summarizes the magnitude of combustion-related releases for the case study facility. Reportable releases include seven of the 17 metals in Table 1, plus HCl, HF, and H_2SO_4. Normalized on annual power generation, the total release of 4.0 million lbs/yr is equivalent to 1.0 million lbs/ BkWh. The dominant emissions are HCl and H_2SO_4 released at the power plant stack. HCl accounts for 56% and H_2SO_4 for 24% of the total mass emissions. Overall, air releases amount to 85% of the total plant inventory, land releases are 15% of the total, and trace metal air emissions are less than 0.1% of the total.

In general, there is substantial uncertainty and variability in the measurement of trace species emissions and in the characterization of environmental control system performance (*9*). Accordingly, the air emission rates for metals in

TABLE 4. Reportable TRI Chemicals for Coal-Fired Power Plants Based on Approximate Plant Size

net plant capacity greater than (MW)[a]	reportable compds	net plant capacity greater than (MW)[a]	reportable compds
50	HCl, H_2SO_4, Ba	1 200	Se
100	HF, Mn, Zn	1 600	Be, Mo
200	Cr, Cu, Ni	3 200	Tl
400	As	4 500	Sb
600	Pb	25 000	Ag
800	Co	40 000	Hg[b]

[a] Approximate value based on median value of trace chemical concentrations in bituminous coals (Table 2) and 67% capacity factor. [b] EPA has proposed lowering the reporting threshold for mercury to 10 lbs/yr beginning in 2000 (see Supporting Information).

Table 3 are uncertain by at least a factor of 2. A similar uncertainty applies to H_2SO_4 emissions because of uncertainty in the SO_3 content of flue gas. The case study assumes that 0.7% of the stack gas sulfur is equivalent SO_3, based on the PISCES database and EPA estimates (*15*). However, power plant SO_3 data are highly variable (*16, 17*), with most estimates ranging from roughly a factor of 2 lower or higher than the value used here. In contrast, HCl and HF emissions can be estimated more confidently for a known fuel composition since nearly all Cl and F in fuel are converted to acid gases.

Chemicals that are otherwise used at power plants are associated mainly with water and wastewater treatment processes. Based on typical usage (*18*), if chlorine were employed as a biofouling control agent at the case study plant, the annual use would be approximately 20 000 lbs/yr, making it reportable to the TRI. Estimates of hydrazine (for boiler corrosion control) and ammonia (for pH control and ion bed regeneration) are 2300 and 2900 lbs/yr, respectively. These quantities would not be reportable since they do not exceed the 10 000 lbs/yr threshold. Since the nature and amounts of otherwise used chemicals is highly site-specific, no attempt is made in this paper to estimate representative releases other than those above.

Factors Affecting TRI Releases

The case study above was intended to provide representative estimates of power plant TRI releases. However, the nature and quantity of such releases will vary significantly across the population of U.S. coal-fired plants. A number of the key factors affecting reportable releases are discussed below.

Plant Size and Operation. The size of a given facility is a key determinant of annual chemical discharges. For affected facilities, the operation of 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. Chemical releases would scale in proportion to plant size, all other factors held constant. The plant capacity factor also has a proportional effect on combustion-generated emissions. Larger plant sizes and/or higher capacity factors also can cause additional chemical species to exceed the TRI threshold and become reportable. Table 4 gives a rough estimate of the plant size needed to trigger a TRI report for trace elements in coal. This table suggests that all but the very smallest coal plants will have reportable TRI emissions.

In contrast, oil-fired power plants, which provide less than 3% of U.S. electricity, have a mean facility size roughly half that of coal (*13*). Most of these plants are operated only intermittently, with annual capacity factors averaging only 20% nationally (*3*). The combination of smaller sizes and low utilization suggests that most oil-fired plants will have few if any reportable TRI releases unless fuel impurities are relatively high.

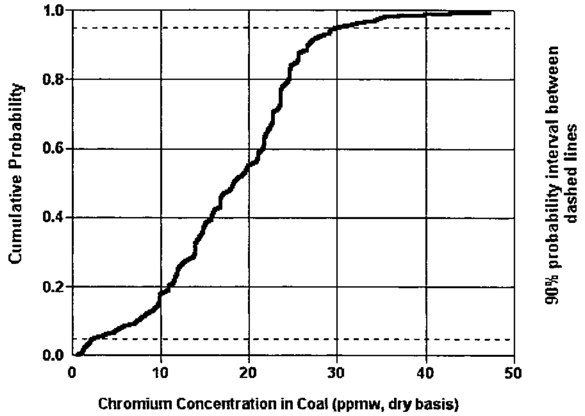

FIGURE 2. Distribution of chromium concentration in U.S. bituminous coals (based on PISCES model database).

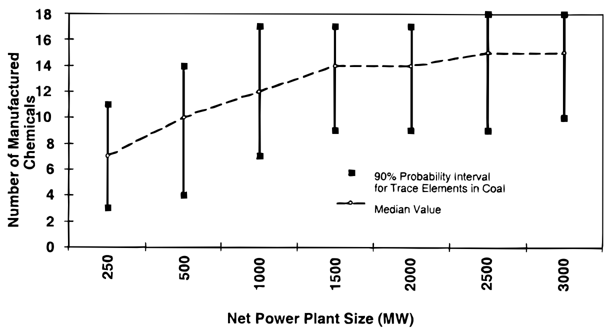

FIGURE 3. Effect of plant size and fuel composition on number of reportable TRI chemicals manufactured during combustion (based on bituminous coal and case study plant design).

Fuel Properties. Variations in coal composition across the U.S. can have a marked impact on the number of reportable TRI chemicals and the magnitude of TRI releases. For example, Figure 2 shows that the chromium concentration in power plant bituminous coals spans 2 orders of magnitude. Similar data for other trace elements (see Supporting Information) was used to construct Figure 3, which shows the number of reportable combustion-generated chemicals as a function of plant size based on a 90% probability interval for trace element coal concentration. Large facilities could be required to report as many as 18 manufactured species, while small plants may have to report as few as three. Variations in coal heating value also affect TRI estimates. As the heating value decreases, more fuel mass is needed to provide a given power output, and the mass of toxic releases increases proportionally for a given concentration in coal.

Subbituminous coals typically have lower chloride content than bituminous coals as well as lower sulfur content. These two factors alone can reduce toxic air releases by a factor of 3 or more. The generally higher alkaline content of subbituminous coals also has been reported to suppress SO_3 formation and resulting H_2SO_4 emissions (*16*). Overall, the 650 MW case study plant burning a typical subbituminous coal (19 385 kJ/kg, 0.37% S, 5.3% ash) would have a total reportable release about half that of the bituminous coal plant in Table 3. The land release component for the subbituminous plant would be about 40% greater, mainly because of higher barium and manganese compounds.

With regard to oil-fired plants, data for no. 2 fuel oil indicates that H_2SO_4 is the only combustion-generated toxic likely to exceed TRI reporting thresholds for an average size plant. For plants burning no. 6 fuel oil, HCl and some metal compounds (e.g., nickel) also may be produced in reportable amounts.

Plant Configuration. The specific configuration of a power plant can have a marked effect on the magnitude of chemical releases to different environmental media. For example, if the case study power plant described earlier were fitted with a wet lime/limestone flue gas desulfurization (FGD) system downstream of the ESP, emissions of HCl, H_2SO_4, and HF would be reduced by approximately 95%, 65%, and 92%, respectively, based on the PISCES dataset. Atmospheric emissions of the seven metallic compounds in Table 3 would be reduced by approximately 84%. Offsetting these reductions, chemical releases to land would increase slightly as a result of increased solid waste generation, including trace metals (primarily barium and manganese compounds) originating in lime and limestone FGD reagents. Overall, however, the total TRI release for the case study plant with FGD would be 1.1 million lbs/yr, a quarter of the Table 3 value. Of the major air releases, the most uncertain is H_2SO_4 since its removal in wet FGD systems is not commonly measured. Industry experience indicates that removal efficiencies for the fine sulfuric acid mist particles formed in the FGD absorber vary widely from less than 50% to as high as 90% depending on the scrubber design and inlet SO_3 concentration (*19*).

Configuration of the plant cooling water system and wastewater treatment technologies also are important. The case study plant assumed dry flyash handling and zero wastewater discharge. Many U.S. power plants have wet ash handling systems and a nonzero discharge with allowable effluent limits specified under the National Pollutant Discharge Elimination System (NPDES). 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. The PISCES model includes preliminary estimates based on recent data for plants mixing bottom ash and flyash in a single ash pond (*20*). For the case study plant, these data indicate that approximately 4.5% of the total land release in Table 3 would be diverted to a water release for a mixed wet ash configuration. Barium compounds would be the dominant water discharge. Overall, water releases would constitute approximately 1.5% of total releases for the case study facility.

Plant Operating Practices. Plant operating practices can influence the types and quantities of TRI chemicals that are otherwise used since utilities may have a choice of chemicals employed for water treatment processes and plant maintenance activities that contribute to TRI releases. In this regard, comprehensive pollution prevention programs can yield benefits for TRI reporting. For example, elimination of listed chemicals such as hydrazine or solvents may be possible at some facilities. The commercial use of plant byproducts such as flyash, bottom ash, and FGD-generated gypsum also can substantially reduce the quantities of reportable TRI chemicals where markets for such byproducts exist.

Policy Implications

The analysis presented in this paper suggests that trace chemical emissions from most coal-burning power plants in the U.S. will exceed the reporting thresholds for the Toxics Release Inventory (TRI). Some oil-fired facilities also may have reportable emissions. The largest toxic releases from power plants will be air emissions of HCl and H_2SO_4 arising from chloride and sulfur impurities in fuels. The next largest release will be barium compounds, which occur predominantly as a land release in landfilled flyash, along with other trace metal compounds. The types and magnitudes of TRI releases will vary significantly with facility size, design, fuel composition, and plant operation.

A National Perspective. Emissions from the electric utility industry will substantially alter the national picture of toxic releases currently portrayed by the TRI. A simple "back of the envelope" estimate of national releases from power plants can be derived from the results in this paper. The case study plant in Table 3 had a total TRI emission rate of 1.0 million lbs/BkWh burning bituminous coal. The rate with FGD was 0.3 million lbs/BkWh, and for a subbituminous coal without FGD it was 0.5 million lbs/BkWh. Applying these three rates to the 1996 generation mix, when coal-fired plants produced 1738 BkWh of electricity (*3*), yields a rough estimate of 1.3 billion pounds of TRI releases (including off-site transfers) from coal plants in 1996. This zero-order estimate assumes no credits for byproducts distributed in commerce and neglects otherwise used chemicals and releases from oil-fired plants. A more refined analysis for 1995, based on actual coal use at every U.S. power plant, and allowing for byproduct credits, estimated coal plant releases at 0.99−1.88 billion lbs/yr, depending on the estimation method used (*21*).

For comparison, the total 1996 release for the U.S. chemical industry was 785 million lbs and for the primary metals industry 564 million lbs (*1*). These have been the top two industry groups on the TRI list in recent years. The estimated utility release substantially exceeds either of these industries and could be as large as the two combined. Similarly, the top three TRI chemical releases in 1996 were methanol (241 million lbs), zinc compounds (207 million lbs), and ammonia (193 million lbs). The estimated power plant releases of HCl alone is two to four times these values (see Supporting Information).

These historical estimates of national power plant releases suggest that the electric utility industry will be prominent when the TRI results for 1998 are issued by EPA. Both the major TRI chemicals and the largest emitting industry can be expected to change relative to past TRI reports. In many communities, an electric power plant will head the EPA list of local facilities with the largest toxic releases (*21*). Other newly listed industries, such as the mining industry and hazardous waste disposal sites, also are likely to report large releases to the 1998 TRI, especially metal wastes disposed in landfills. It remains to be seen how the magnitude of such releases will compare to those of the electric utility industry.

Interpreting the Numbers. The magnitude and prominence of power plant toxic releases anticipated for the 1998 TRI will place increasing pressure on the electric utility industry and EPA to explain and interpret TRI results. For example, what are the health and environmental risks of HCl, which is likely to emerge as the largest toxic air release nationwide? How does one reconcile the designation of metal compounds in landfilled flyash as "toxic" under TRI, whereas flyash was declared "nonhazardous" by EPA under the Resource Conservation and Recovery Act (RCRA)? These are but two of the many questions likely to be raised as a result of the 1998 Toxics Release Inventory.

Given the potentially confusing and conflicting set of labels, perceptions, and concerns regarding power plant releases, various types of risk communication activities will be the most immediate consequence of the new TRI reporting requirements. Electric utilities will likely cite a recent EPA study of hazardous air pollutants (*22*) which found that risks from power plant emissions of HCl, HF, and other TRI substances were typically well below levels of concern. At the same time, EPA can be expected to emphasize that TRI data are intended to be evaluated in the context of site-specific and community-level situations and that designations such as "nonhazardous" under RCRA do not necessarily imply the absence of site-specific risks or toxicological effects on environmental organisms, such as from coal ash effluents.

To aid public understanding, the use of toxicity weighting factors (*23*) and screening risk assessments (*24*) are among the tools that can help improve the usefulness of TRI results. In the near to longer term, the TRI also is likely to stimulate efforts to better quantify power plant releases and to reduce toxic emissions consistent with the pollution prevention objectives of TRI and the industry capability to respond.

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Supporting Information Available

Text and tables of compounds manufactured in combustion, formation of acid aerosols, trace element removal efficiency, trace element variability in coal, reportable TRI compounds, and national estimates. This material is available free of charge via the Internet at http://pubs.acs.org.

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