IMPLICATIONS OF THE TOXIC RELEASE INVENTORY FOR ELECTRIC UTILITIES

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Abstract

As of 1998, electric utility companies burning coal or oil are required to report their annual releases of toxic chemicals to the Toxics Release Inventory (TRI), a national compilation of multi-media (air, water, land) releases of over 600 chemicals and chemical categories designated as toxic by the U.S. Environmental Protection Agency (EPA). TRI reports for 1998 were filed by July 1, 1999, but EPA publication of the 1998 inventory is not expected before early 2000. This paper uses historical data for 1995 to estimate the magnitude of toxic releases for the electric utility sector relative to other industry groups. Releases from the electric utility industry were greater than releases from any of the twenty manufacturing industries currently reporting to the TRI. These results suggest that the addition of power plants to the TRI will significantly change the rankings of chemicals, industries and facilities listed by EPA in its annual TRI report. The implications of these changes are discussed with regard to risk communication needs and emission reduction measures potentially available to reduce toxic releases.

Introduction

The Toxics Release Inventory (TRI) was established by Section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986, and expanded by the Pollution Prevention Act of 1990. The law requires facilities in designated industry sectors to report annually the amounts of toxic chemicals released to the environment, along with information on waste management and pollution prevention activities. The TRI is a publicly available database established to provide U.S. communities with information on the presence and releases of toxic chemicals. Over 600 chemicals and chemical categories are included on the current TRI list. Published annually by EPA, and available on the World Wide Web, the TRI has become an important vehicle for identifying and quantifying the mass of chemicals released by industries and facilities at the local, state and national levels. However, the TRI provides no information on the relative toxicity or risks from the releases that are reported.

Since the TRI was established in 1986, the industries required to report toxic emissions included only the twenty major manufacturing industries identified by Standard Industrial Classification (SIC) codes 20-39. In May 1997, the U.S. Environmental Protection Agency (EPA) added seven

new industry groups to the TRI, including oil- and coal-burning electric power plants (1). Affected facilities in these industries must report TRI emissions on an annual basis, beginning with 1998 emissions. Reports for 1998 were to be filed with EPA by July 1, 1999. In the past, approximately one year has been needed for EPA to compile, analyze, and publish the results. Hence, the toxics inventory for 1998 is not expected to be available before early to mid-2000.

This paper presents an historical analysis of state-level and national estimates of TRI emissions from the electric power sector in order to obtain some perspective on the importance of this sector relative to other reporting industries. Nationally, the chemicals industry (SIC 28) and the primary metals industry (SIC 33) have had the largest total releases, as seen in Table 1. By chemical, methanol, ammonia, and zinc compounds have been the TRI chemicals emitted in greatest quantity, as shown in Table 2. A key question that motivates this paper is: how will electric utility sector releases alter the magnitude and types of chemicals reported by the TRI, and the rankings of industry groups?

To address this question, we derive estimates of TRI emissions from coal-fired plants in the U.S. for the year 1995 (the most recent year for which TRI data were available for other industry groups at the time this study was initiated). Since that time, TRI results for 1996 and 1997 also have been released by EPA (2), but as seen in Tables 1 and 2 those results are similar to the inventory for 1995 (3).

TRI Requirements

The specific requirements of the TRI have been discussed previously (4). Briefly, electric utility plants covered by TRI are in SIC codes 4911, 4931 and 4939. Any facility within a covered industry 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. Trace chemicals in air and water intake streams are excluded from TRI reporting. The TRI also exempts toxic chemicals that appear in low concentrations in products that are distributed in commerce. 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 — the quantity of chemicals in the byproduct would be exempt from TRI reporting.

For most power plants, the most relevant set of TRI chemicals are those designated as manufactured or otherwise used (4). These include the trace organics that may be found in some combustion flue gas streams, plus certain metal oxides present in flyash, bottom ash, stack emissions, and FGD wastes. Other inorganic TRI chemicals of importance are hydrochloric acid (HCl), hydrogen fluoride (HF), and sulfuric acid (H_2SO_4) "aerosol" (defined by EPA to include vapors as well as mixtures of gases and particles).

Estimating National Releases

This section summarizes the methods used in this paper to estimate chemical releases from power plants. The TRI offers substantial latitude in the methods that facilities may use to estimate toxic releases in the absence of site-specific data. Therefore, the "base case" approach

used in this study assumes that utilities will tend to use methods and assumptions that cast their facilities in the most favorable light in cases where there are reasonable uncertainties as to the best or most appropriate estimation method. Subsequently, we attempt to bound these base case estimates by developing an "upper bound" scenario that reflects more conservative assumptions.

Data Sources and Assumptions

The following section briefly discuss the data sources and assumptions used for our estimates of reportable TRI releases.

Coal Use and Power Plant Data. Power plant and fuel use data were taken from the 1995 Form 423 submitted by fossil-fuel burning power plants to the U.S. Federal Energy Regulatory Commission (FERC). The forms are submitted monthly and list the cost and quality of fossil fuels delivered to electric generating plants. The data are then merged into a large public database (5).

All coal-fired generating units with a gross capacity of 50 megawatts (MW) or more are considered in this study. Units smaller than 50 MW are excluded since FERC data do not clearly distinguish the amounts of different fuel used. Because each power plant can contain multiple units, the capacities of all units at a given facility are aggregated to determine exceedences of TRI thresholds.

The fuel source information for each facility includes the type, rank, county, state, supplier, quantity, energy content, sulfur content and ash content of fuel on an as-received basis. Table 3 shows the total coal purchased for 1995, which is assumed to equal the amount burned. For comparison, utility coal consumption for 1995 -1998 also is shown in Table 3. Net electricity generation from coal increases from 1653 BkWh in 1995 to 1807 BkWh in 1998 (6).

Oil-Fired Plants. Although oil-fired power plants are covered by the TRI, they are omitted in the present study since a scoping analysis indicated that their contribution to total national releases is relatively small. To the extent that some oil-fired plants do contribute to the TRI (principally HCl, H_2SO_4 and nickel compounds), the current estimates for coal plants may be viewed as a lower-bound for the utility sector as whole.

Trace Element Concentrations and Emission Factors. In addition to plant-level data on annual coal consumption and sulfur content, the trace element concentration of coals burned is required to calculate TRI thresholds and chemical releases. This study employs trace element concentration data compiled by Radian International for EPRI (7). The data reflect information from a literature survey plus field tests by EPRI (8), the U.S. Department of Energy (9) and others. Table 4 shows the median values for the chemical concentrations in coal averaged across the six coal supply regions used in this study. These data reflect coals actually used by utilities as opposed to coal in the ground. Because chemical concentrations are given on a dry basis, coal moisture content also must be specified to calculate chemical releases for TRI.

Trace Element Partitioning Data. The partitioning of trace chemicals between air and solids was estimated using data in the PISCES Model (10), a mass and energy balance model developed for EPRI to quantify multimedia chemical releases from power plants (4). The data

sources used in the PISCES Model are the same as those noted earlier (7-9).

Otherwise Used Chemicals. This study does not include any chemicals that are "otherwise used" since such amounts are highly site-specific and not easily estimated. A previous case study (4) suggests these amounts are likely to be small relative to the amounts that are "coincidentally manufactured" in the combustion process.

Particulate Collector Performance. Because of site-specific data limitations on particulate collector type and emission rates, an electrostatic precipitator (ESP) is assumed for all power plants, and all particulate emission rates are assumed to be below the 1979 New Source Performance Standard (NSPS) of 0.03 lb/MBtu. This assumption determines the ESP trace chemical partitioning (removal efficiency) data obtained from the PISCES Model for each coal rank. Median values are used for all plant-level estimates.

Sulfuric Acid Aerosol. One of the most poorly understood aspects of power plant toxic releases is the magnitude of H_2SO_4 vapor and aerosol formed and removed within power plant systems. Since sulfuric acid aerosol is not listed by EPA as a hazardous air pollutant (HAP), none of the recent field sampling programs conducted by EPRI or DOE included H_2SO_4 emissions in their testing. Nor do utilities commonly measure H_2SO_4 emission rates or removal efficiencies. The existing technical literature and data on this subject displays a very large uncertainty, ranging up to two orders of magnitude in emission estimates. Table 5 summarizes the range of assumptions used in this paper, drawn from EPA and industry sources (10-12).

FGD System Performance. Where the presence of a flue gas desulfurization (FGD) system is indicated in FERC 423, a wet lime/limestone system is assumed. The median value of TRI chemical concentrations in lime and limestone reagent (10) are used as additional process inputs. The median value of trace chemical removal efficiency across an FGD system (based on all fuel ranks) also is obtained from the PISCES Model (10).

Solid Waste Management. Power plants use either wet or dry ash handling systems to manage solid wastes. For plants using wet systems, some of the trace substances in the collected solids are transferred to the sluice water, and some of that amount may be released to the environment via the plant water treatment system. Because of data limitations, TRI water releases are difficult to quantify, though limited case studies suggest they are a small percentage of the total in collected solids (4). The present study thus reports only air and total releases, recognizing that the difference is predominantly a disposal to land. These land releases may occur either on-site or off-site. The TRI considers any type of landfill disposal to be a release. Exempt from TRI reporting are chemicals contained in power plant byproducts distributed in commerce. These quantities were estimated based on national average percentages for 1995, which were 33.3% for bottom ash, 25.0% for flyash, and 7.4% for FGD material (13).

Calculation Procedure

Figure 1 shows a schematic of the procedures used to estimate TRI releases. The aggregate data for each facility included the total annual coal use and the relative percentages of coal from each supply region. These percentages were applied to the trace element coal concentrations for each coal supply region and coal rank to determine the total quantity of trace chemicals manufactured

during combustion. This is the principal quantity determining whether the TRI threshold is exceeded. For plants with FGD systems, the trace chemicals in the FGD reagent also were assumed to undergo coincidental manufacture.

The TRI threshold test was applied to each trace chemical. If the threshold was exceeded, the partitioning of each trace chemical between air and solids was calculated for each plant using empirically determined removal efficiencies across the boiler, ESP and FGD system (10). Reportable releases excluded the percentages of trace metal in collected solids distributed in commerce. The final results were then aggregated to the state and national levels.

Study Results

Table 6 summarizes the total estimated releases of reportable TRI chemicals for 1995 using the base case assumptions. Hydrochloric acid aerosol (as defined by EPA) is the major TRI chemical produced by electric power plants, accounting for 56% of the total releases nationally. Combined land and water releases (most of which is landfilled solids) amount to 25% of the national total. Overall, 17 TRI chemicals exceeded the reporting threshold at one or more facilities. The power plant air releases for 1995 (Table 6) are comparable in magnitude to the combined air releases of the chemicals, primary metals and paper industries shown earlier in Table 1. Ohio had the largest total releases (Figure 2), with ten states accounting for 63% of the total utility releases from coal-fired power plants. Hydrochloric acid aerosol replaced methanol as the largest chemical release nationally in 1995 when utility emissions were included. In 17 states (Figure 2), a coal-fired power plant would have been listed by EPA as having the largest total releases in the state (14).

Uncertainty Analysis

There is substantial uncertainty in any estimate of toxic releases from power plants (15). Thus, we attempt to bound the TRI estimates in Table 6 by examining the sensitivity of those results to key assumptions affecting the largest releases. For HCl and HF releases, a bounding estimate is most easily obtained using the EPA emissions factors provided in the utility industry TRI guidance document (16). Use of the EPA factors would double the estimates in Table 6, assuming the same HCl and HF removal efficiencies used in the base case.

Uncertainty in H_2SO_4 aerosol releases stems from uncertainty in the fraction of fuel sulfur converted to SO_3 and subsequently released as H_2SO_4 (produced in the flue gas train). SO_3 production levels are known to depend upon plant parameters such as boiler type and excess oxygen levels, while emission levels (as H_2SO_4) depend also upon coal ash composition, air preheater design, and air pollution control equipment. Measurement methods also may affect reported results. The base case values in Table 5 were based primarily upon a paper by Southern Company Services (11). Other studies, however, report much higher SO_3 levels. Nonetheless, we believe it unlikely that average H_2SO_4 emissions reported to TRI will exceed the EPA emission factor estimate of 0.7% sulfur as SO_3 (12). Thus, our bounding case uses the EPA emission factor, along with a slightly lower SO_3 removal efficiency for FGD systems. These assumptions yield a national estimate of H_2SO_4 releases that is twice the base case value in Table 6.

For trace metal air releases, uncertainty estimates should consider the variability of trace element concentrations within each coal supply region, plus variations and uncertainty in the removal efficiency of particulate collectors. While a detailed analysis of these factors was not performed in this study, we estimate an emissions increase of roughly 20 to 30 percent over the base case values based on previous case studies (4, 15).

Table 7 summarizes the resulting range of TRI estimates for 1995, which vary by a factor of two (1.0 to 1.9 billion lbs). When normalized on net electricity generation, the total TRI releases range from 0.6 to 1.1 lbs/MWh. Actual releases are expected to be closer to the lower (base case) value. As noted earlier, these estimates do not include oil-fired power plants, nor coal-fired boilers less than 50 MW in size. For the power industry as a whole, the contribution of these sources was found to be small.

Study Implications

The results of this analysis show that the addition of the electric utility industry to the TRI would have significantly altered the national picture of major toxic releases and their sources for the year 1995. The electric utility industry was found to have the largest on-site and total releases nationally, with hydrochloric acid aerosol replacing methanol as the TRI chemical released in greatest quantity. Power plant releases also added to, and often dominated, the inventories of sulfuric acid aerosol, hydrogen fluoride and various metal compounds, especially barium. In many states and communities, a local power plant would have been named by EPA as the largest emitter of toxic pollutants, rather than a local industrial plant.

Since 1995, electric power plants have achieved some additional reductions in sulfur and sulfuric acid emission rates. Some additional FGD capacity, also has helped to lower releases of H_2SO_4, HCl, HF and other TRI chemicals. Nonetheless, in view of the 10 percent growth in coal use for power generation since 1995 (see Table 3), the qualitative results found for 1995 are likely to also apply to the 1998 TRI, which will report the first true estimates of power plant toxic releases. Based on the 10 percent increase in coal use, 1998 releases from electric utilities are likely to be in excess of 1.1 billion pounds. Releases from other newly-listed industries, especially the mining industry and hazardous waste disposal sites, could rival power plant releases in some regions of the country.

Risk Communication Needs

Since the TRI reports only the mass of chemical releases, and is silent on issues of toxicity or community risk, electric utilities — as well as the EPA — should be actively engaged in explaining and interpreting the new inventory numbers to the public. Indeed, a major criticism of the TRI is that the largest mass releases are not necessarily indicative of the largest environmental concerns. For example, the metal compounds in flyash and bottom ash which are now labeled as “toxics” by the TRI were previously designated as “non-hazardous” by EPA under the National Resources Conservation and Recovery Act (RCRA). Similarly, the HCl and HF releases, which dominate the power plant inventory, were found by EPA to pose “no exceedence of the health benchmarks” for inhalation exposure in a recent assessment of health risks from hazardous air pollutants (17). That same study did not even consider sulfuric acid aerosol since it is not listed by EPA as a hazardous air pollutant (though it is labeled as “toxic”

under TRI). Nonetheless, EPA notes that environmental risks from TRI chemicals may still exist at the local level. However, it is up to individual communities to assess those risks.

This potentially confusing and conflicting set of labels, perceptions and concerns regarding power plant releases undoubtedly will become prominent when the 1998 TRI results are announced. Various types of risk communication activities will therefore be important in addressing community concerns. In this regard, the use of toxicity weighting factors (18, 19) and screening risk assessments (20) are among the tools that can be helpful in putting the TRI results into perspective.

Pollution Prevention Activities

In the near to longer term, the TRI also is likely to stimulate efforts to better quantify major power plant releases, and to reduce overall emissions consistent with the pollution prevention objectives of TRI and the industry capability to respond. The following section outlines in more detail some of the options available to electric utilities to reduce TRI emissions.

Reducing TRI Emissions

Utilities interested in reducing reportable releases of TRI chemicals have a number of options. These include refinements in the methods used to estimate releases; decreased plant utilization; the use of alternative fuels; installing and/or upgrading pollution control equipment; improving plant operating practices; and finding new markets for byproducts. Each of these topics is discussed briefly.

Improved Estimation Methods

Since TRI does not require utilities to collect any new data for purposes of reporting, the method used by a utility to estimate its toxics inventory can have a pronounced influence on the results. In the absence of site-specific data, the use of a more refined site-specific estimation tool may give lower estimates of some releases than the use of more generalized emission factor estimates. This was seen earlier for the case of HCl, where EPA emission factor estimates gave values twice that of the TRI-Enhanced PISCES Model (10). That model has recently been expanded to include site-specific TRI-estimates, including summaries of TRI releases and transfers, plus technology-specific removal efficiencies for individual species (Figure 3).

Of course, improvements in the estimation method do not alter the actual emissions, nor do they necessarily lead to a reduction in the estimated releases. Nonetheless, improved estimation methods, as well as the voluntary acquisition of additional data (especially coal composition data), can establish a more realistic baseline from which to measure real changes in toxic releases.

Decreased Plant Utilization

Since annual releases are roughly proportional to the plant capacity factor, any decrease in the annual plant utilization will also reduce TRI emissions. In essence, this method would reflect the principles of environmental dispatch, as opposed to the conventional economic dispatching of power plants. Demand-side management programs that reduce the overall system load could accomplish the same objective. The feasibility of these options would have to be evaluated on a

system-wide basis for any particular company.

Fuel Switching

In many cases, substantial reductions in toxic releases can be achieved by fuel switching. Since HCl emissions dominate the toxics inventory, the use of coals with a lower chloride content yields direct benefits for TRI. Similarly, coals that are lower in sulfur nominally reduce emissions of H_2SO_4. Where technically and economically feasible, converting from bituminous coal to a subbituminous coal such as Powder River Basin can yield dual benefits from reductions in both chloride and sulfur content (see Table 4). Offsetting some of these benefits, however, would be an increase in the release of some metal compounds (e.g., barium and manganese) which tend to be more prevalent in subbituminous coals.

The use of natural gas as a supplemental fuel (including gas reburn systems for NO_x control) also can yield direct TRI benefits by reducing the amount of coal burned. In the extreme case of conversion from coal to gas, TRI emissions would be completely eliminated since gas plants are not required to report to the TRI. The site-specific availability and cost of natural gas, together with other system and station characteristics, would be key factors in evaluating these options.

Pollution Control Technology

Upgrades to existing particulate collectors can significantly lower the air releases of TRI chemicals, which often are the key factor in screening risk assessments (20). Total TRI releases are not altered, however, since substances removed from the flue gas stream are merely transferred to the land (and potentially water) streams in the absence of fly ash utilization credits.

The most substantial TRI reductions are achieved by FGD systems, which remove most of the gaseous HCl and HF along with significant amounts of H_2SO_4. In these cases, the reportable releases are destroyed rather than simply transferred to another medium. FGD units also reduce air emissions of particulate species including metal compounds, which are transferred to the FGD solid waste or byproduct. The FGD reagent, however, introduces small amounts of additional metal compounds which add to the total land releases.

Plant Operating Practices

Quantities of “otherwise used” chemicals often can be reduced by changes in plant operating practices. For example, improved operating practices may be able to reduce the amounts of chemicals used for waste treatment systems and other plant maintenance activities. At some plants, the use of listed chemicals such as hydrazine and solvents might be eliminated in favor of non-toxic substitutes. Reductions in the use of TRI chemicals should thus be a goal of all new or ongoing pollution prevention programs.

Byproduct Utilization

The concentration of metal compounds and other TRI chemicals in power plant solid wastes is typically well below the *de minimus* levels specified by EPA for exclusion from TRI reporting. Thus, any increase in the utilization of plant ash and FGD solids can reduce reportable emissions. The development of markets to productively use such materials more extensively remains a key challenge for the R&D community as well as for electric utilities.

Conclusion

The 1998 Toxics Release Inventory can be expected to focus attention on chemical releases from electric power plants, particularly coal-fired facilities. Interpreting TRI data in terms of community health and environmental risks will be the immediate challenge facing affected utilities. Experience in other industries suggests that over the longer term the TRI may also stimulate new pollution prevention activities and reductions of power plant emissions.

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Table 1.
Largest Total Releases by Industry in 1995-97 (millions of pounds per year)

SIC	Industry	1995 Releases		1996 Releases		1997 Releases	
		Air[a]	Total[b]	Air[c]	Total[b]	Air[d]	Total[d]
28	Chemicals	407	844	392	785	342	797
33	Primary Metals	138	524	145	565	132	695
26	Paper	213	238	204	228	194	234
30	Plastics	112	127	105	116	98	108
37	Transport. Equip.	109	121	103	111	91	102
All Industries		**1,562**	**2,531**	**1,452**	**2,434**	**1,332**	**2,578**

[a]From Ref. (3), Table 4-10. Figures include both fugitive and stack emissions.
[b]From Ref. (2), Table 4-6. Figures include both on-site and off-site releases to air, water and land.
[c]From Ref. (2), Table 4-2. Figures include both fugitive and stack emissions.
[d]From Ref. (2), EPA Web site.

Table 2.
Largest Total Releases by Chemical in 1995-97 (millions of pounds per year)

Chemical	1995 Releases		1996 Releases		1997 Releases	
	Air[a]	Total[b]	Air[c]	Total[b]	Air[d]	Total[d]
Methanol	210	255	206	241	194	221
Ammonia	157	195[d]	155	193	156	200
Zinc compounds	5	189	6	207	5	306
Toluene	145	147	125	127	113	116
Nitrate compounds	<1	145[d]	<1	164	<1	197
All Chemicals	**1,562**	**2,531**	**1,452**	**2,434**	**1,332**	**2,578**

[a]From Ref. (3), Table 4-19. Figures include both fugitive and stack emissions.
[b]From Ref. (2), Table 3-9. Figures include both on-site and off-site releases to air, water and land.
[c]From Ref. (2), Table 2-9. Figures include both fugitive and stack emissions.
[d]From Ref. (2), EPA Web site.
[e]From Ref. (3), Table 4-34.

Table 3.
Summary of Power Plant Coal Consumption (million tons/yr)

FERC 423 Database[a]		DOE/EIA[b]			
Coal Rank	1995	1995	1996	1997	1998
Bituminous	419				
Subbituminous	330				
Lignite	75				
Total	**823**	**829**	**875**	**899**	**911**

[a]From Ref (5).

[b]From Ref (6).

Table 4.
Mass Concentrations of Trace Chemicals in Coal (ppmw, dry basis)[a]

Chemical	Bit	Subbit	Lig
Antimony	1.0	0.57	0.74
Arsenic	10.0	5.9	8.5
Barium	94.5	196.	220.
Beryllium	1.3	0.5	1.9
Cadmium	0.53	0.83	0.1
Chloride	750.	195.	140.
Chromium	18.6	5.0	9.3
Cobalt	6.4	2.0	3.7
Copper	21.	9.3	10.5
Fluoride	69.	44.	79.
Lead	8.1	7.8	6.2
Manganese	22.4	35.5	74.
Mercury	0.12	0.10	0.22
Molybdenum	2.1	1.7	3.0
Nickel	16.1	9.5	5.9
Selenium	3.2	0.9	1.3
Silver	0.2	0.16	0.1
Thallium	1.6	2.0	0.5
Zinc	22.0	8.7	7.8

[a]From Refs (7, 10). Values for each coal rank are the median values across coal supply regions. Moisture content across regions is 5.2-10.5% (bit), 9.0-28.5% (sub) and 35.0-36.5% (lig).

Table 5.
Assumptions for Sulfuric Acid Emissions

Coal Type	wt% SO_x as SO_3[a]
Base Case[b]	
Western bituminous	0.05
All other bituminous	0.4
PRB subbituminous	0.01
All other subbituminous	0.1
All lignite	0.1
Bounding Case[c]	
All coals	0.7

[a]All SO_3 is assumed to convert to H_2SO_4.

[b]Based on Ref (11). FGD assumed to be 65% (Ref 10).
[c]From Ref (12). FGD removal assumed to be 50% (Ref 12).

Table 6.
Base Case Estimates of Total Power Plant Releases for 1995 (millions of pounds)[a]

TRI Chemical	Air	Total
Hydrochloric acid aerosol	553.5	553.5
Barium compounds	< 0.4	142.3
Sulfuric acid aerosol	129.6	129.6
Hydrogen fluoride	55.4	55.4
Manganese compounds	0.2	29.3
Zinc compounds	0.2	19.2
Copper compounds	0.1	12.2
Nickel compounds	0.1	11.7
Chromium compounds	< 0.1	9.9
Lead compounds	< 0.1	6.8
Arsenic compounds	< 0.2	6.0
Molybdenum trioxide	< 0.1	4.7
Cobalt compounds	< 0.1	3.6
Antimony compounds	< 0.1	1.5
Selenium compounds	0.3	0.7
Thallium compounds	< 0.1	0.4
Beryllium compounds	< 0.1	0.3
Total	**740.**	**987.**

[a]Figures for metal compounds refer to weight of elemental metal. Totals Include on-site and off-site releases.

Table 7.
Uncertainty Estimates for Total 1995 Releases from Coal-Fired Power Plants (millions of pounds)

Substance	Air Releases		Total Releases	
	Base[a]	Bound[b]	Base[a]	Bound[b]
HCl aerosol	553	1147	553	1147
H_2SO_4 aerosol	130	287	130	287
Hydrogen fluoride	55	135	55	135
Metal compounds	< 2	2	249	311
Total	**740**	**1541**	**987**	**1880**

[a]Base case estimates from Table 9.
[b]Upper bound estimate (see text for assumptions).

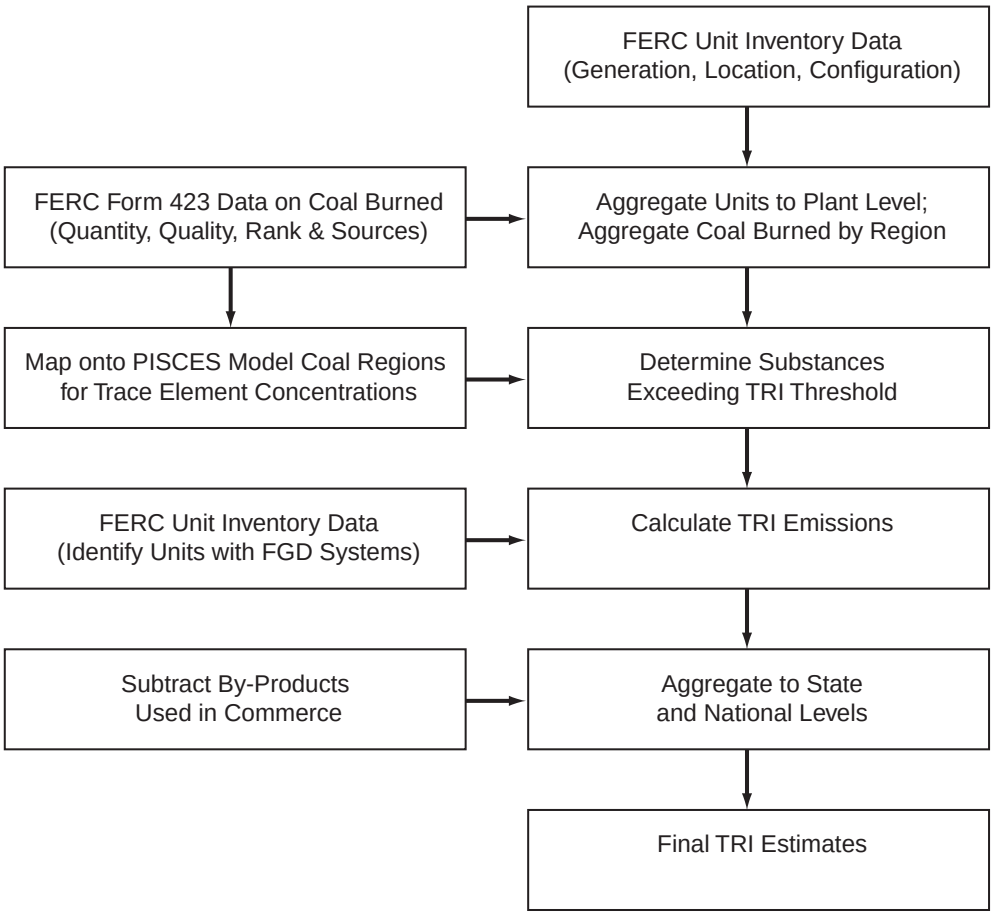


Figure 1
Schematic of Study Methodology

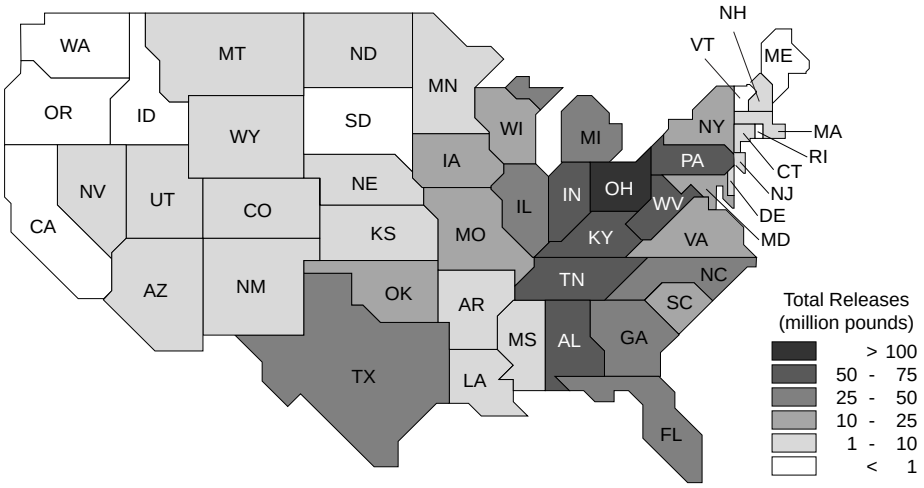
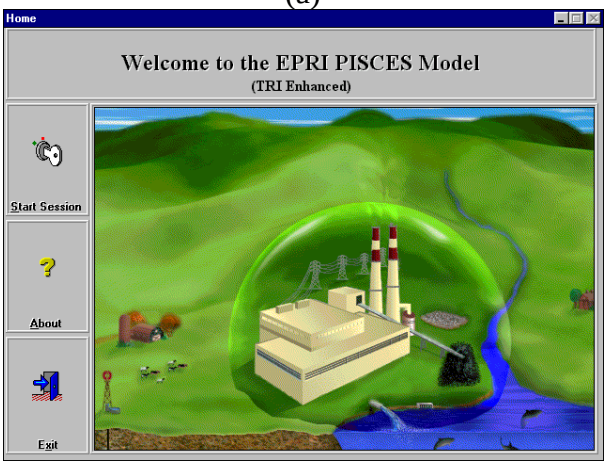
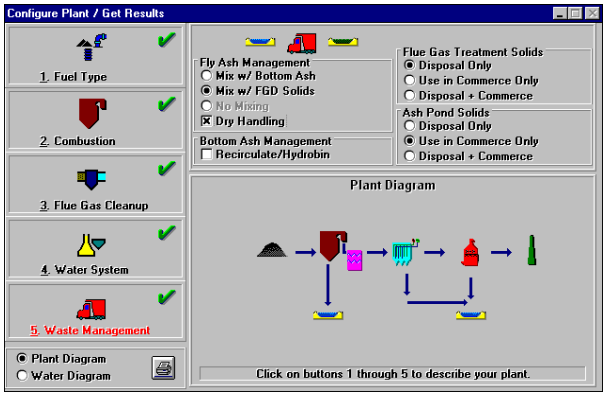


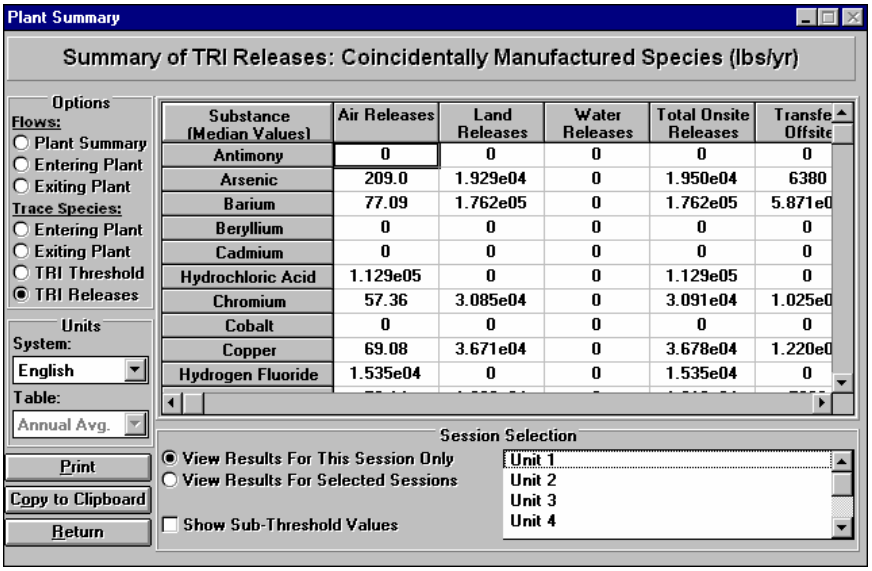
Figure 2
Base Case Estimates of TRI Releases from Coal-Fired Power Plants for 1995

(a) (b)

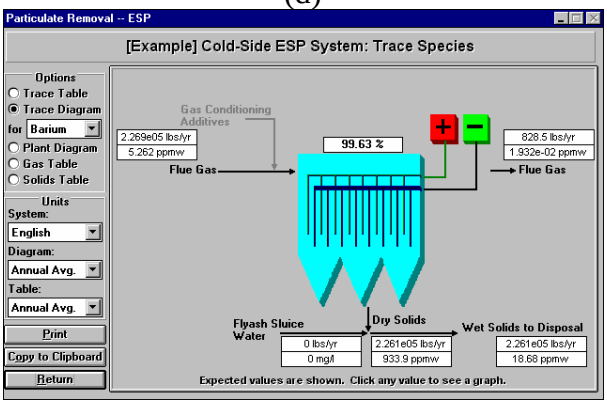




(c)



(d)



(e)

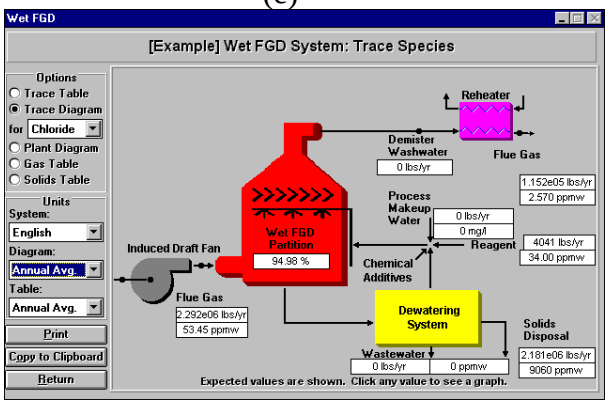


Figure 3
Sample Screen Shots of PISCES Model Version 3.03: (a) Start screen, (b) Configure Plant screen, (c) TRI Summary report, (d) ESP diagram, (e) FGD diagram.