# POTENTIAL USES OF USEPA'S RISK-SCREENING ENVIRONMENTAL INDICATORS MODEL FOR PRIORITIZING TOXICS USE REDUCTION AND POLLUTION PREVENTION EFFORTS

January 12th, 2001

**Prepared for:**

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January 15, 2001

ANGUS S. KING, JR.
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MARTHA KIRKPATRICK
COMMISSIONER

Senator John L. Martin, Chair
Representative Scott W. Cowger, Chair
Joint Standing Committee on Natural Resources
State House Room 437
Augusta, Maine 04333

RE: Chemical Ranking Analysis Risk Screening

Dear Senator Martin, Representative Cowger and Members of the Natural Resources Committee:

This letter and the attached report respond to the requirements in Sec. 14. 38 MRSA §2309, sub-§§7-10, "An Act to Ensure Continuous Improvement in Pollution Prevention."

The Department's Toxics Reduction staff collaborated with the Maine Bureau of Health to develop the report. On November 21,2000, we provided the report to business and environmental communities in Maine for public review. Based on the positive and strong interest we received at both meetings, and the complexity and potential significance of this information and how it might be used, we strongly recommend and encourage further public outreach as we proceed.

As background, the Toxics Reduction Law (38 MRSA §2302-2313) regulates three categories of concern: hazardous waste, toxic use and toxic releases. *Hazardous waste* consists of facility-generated wastes, that either are listed in statute or meet certain criteria including among other things corrosivity, flammability or toxicity. *Toxic use chemicals* are known as Extremely Hazardous Substances (EHS) SARA 312 chemicals. There are 358 SARA 312 chemicals on a list developed by USEPA. Quantities and location of the chemicals are reported by the facilities to the Maine Emergency Management Agency (MEMA) and Local Emergency Planning Commissions (LEPC's). *Toxic release chemicals* are known as Toxic Release Inventory (TRI), SARA 313 or Emergency Planning and Community Right-to-Know Act (EPCRA) chemicals. They are on an EPA list because of known or highly suspected toxic health effects. Facilities report their releases to EPA for public disclosure. There is some overlap between the 312 and 313 lists.

The TUR program has historically treated all chemicals as equals in regard to seeking, and quantifying reductions in these three categories. The 1999 legislation provides an opportunity to evaluate alternative approaches and options for a more strategic focus. The accompanying report identifies a series of models we have evaluated. We would like to spend time discussing some of these with you, including the EPA Risk Screening Environmental Indicators (RSEI) model that we believe has strong possibilities. In addition, for your consideration we can provide comments we received from interested parties regarding technical aspects of that model. Those comments were considered and many are already represented in the report.

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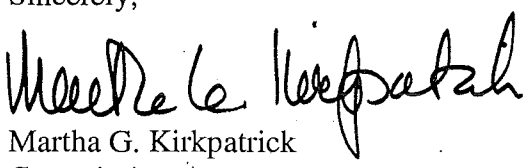
Once we choose the most appropriate model, it could be useful in number of ways as a screening tool such as:

- Focussing DEP technical assistance efforts to a targeted set of the most toxic chemicals;
- Measuring progress in new ways, taking into consideration the relative toxicity of chemicals;
- Setting new lower reporting limits based on toxicity;
- Adding chemicals to our list based on use of the model.

It is important to note that in all the models we have considered there is a need for refinement and that we recommend further analysis and fine-tuning prior to expanding the chemical list, lowering thresholds or re-aligning the program. The models appear to be useful as screening tools, but we need to do careful analysis prior to adopting any regulatory changes. As noted above, there will likely be ways to apply the screening tools in the short-run in a non-regulatory way such as offering a new means to measure progress considering relative toxicity.

I hope this background information is useful as you consider our report and recommendations. We are prepared to meet and discuss next steps with the Committee as your calendar permits. I look forward to working with you as we consider the path forward.

Sincerely,



Martha G. Kirkpatrick
Commissioner

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## EXECUTIVE SUMMARY AND RECOMMENDATIONS

The Maine Legislature enacted the Maine Toxics Use and Hazardous Waste Reduction Act, requiring the Department of Environmental Protection (DEP) to provide a report to the Legislature outlining an "assessment of and recommendations for focusing use reduction and pollution prevention efforts on the most toxic chemicals and classes of chemicals" (38 MRSA § 2309.7.B).

The idea of focusing efforts on the most toxic chemicals invokes a need to compare chemicals according to toxicity and/or risk. One way to perform such a comparison is through the use of some type of a ranking system. While the development of a chemical ranking system is fraught with difficulties, a number of organizations, including governmental agencies, environmental groups, and industries have developed methods for ranking chemicals. These methods vary greatly in overall objectives, in the information included, and in complexity. Several of these models have interesting features, and no single model has every desirable feature. Using life-cycle analysis, the European Union System for the Evaluation of Substances (EUSES) considers more chemical use patterns and release opportunities than most other models, but is specific to European terrain and weather. Imperial Chemical Industries' (ICI) developed a ranking approach called Environmental Burden to evaluate the potential environmental impacts of chemicals on a variety of environmental endpoints including human or ecological health, stratospheric ozone depletion, acidification, and smog production, but does not consider exposure. The Environmental Defense's Scorecard model is specifically developed to work with TRI data, provides output proportional to potential risks, and addresses indirect food chain exposure pathways, but does not consider much site- and facility-specific information. The USEPA's Risk Screening Environmental Indicators (RSEI) model is also specifically developed to work with TRI data, and makes greater use of site- and facility-specific information than Scorecard, but is currently limited in the scope of the release and exposure pathways considered.

The USEPA RSEI model was selected for use in evaluating how a chemical ranking system could be used to assist use reduction and pollution prevention efforts. One of the primary

reasons for selecting this model is that it appears to be on its way to becoming USEPA's standard tool for evaluating and ranking TRI release data. Consequently, there is a strong argument for becoming familiar with the capabilities and limitations of this software. The RSEI model also has several attractive features. In addition to its site- and facility-specificity, RSEI model allows greater manipulation of the model outputs (as compared to Scorecard) and thus permits the user to perform multiple analyses of the results. In addition, USEPA has indicated a willingness to provide substantial support to users of the RSEI model and will continue to do so.

The RSEI model is implemented as two basic steps: 1) the calculation of potential human exposure to a chemical using facility-specific TRI chemical release data, site-specific meteorological data (for air releases), site-specific river or stream data (for water releases), along with some additional facility-specific information and standard exposure modeling techniques; and 2) the weighting of the resulting exposure estimates by chemical toxicity and the size of the population potentially exposed. The primary model output is called a "risk-related result" and can be used to make comparisons among the chemical releases at various levels of aggregation (e.g., comparisons at the statewide level, at the county level, at the individual reporting facility level). The model does not compute health risk *per se,* because of the toxicity weighting system used to put all chemicals (carcinogens and noncarcinogens) on a common scale. The common scale is achieved by equating exposure at a noncarcinogenic threshold with an excess cancer risk of 2.5 in 10,000. Version 1.02 of the RSEI model, which is the most current version publicly available, has full risk-related results only for TRI data on air releases and chronic human health effects from inhalation exposures. Future versions of the model are intended to address TRI releases to other media (e.g., water with both fish ingestion and drinking water as exposure routes) as well as acute human and acute and chronic ecological effects.

There are several caveats that need to be borne in mind in evaluating output from version 1.02 of the RSEI model. Foremost, it needs to be remembered that the RSEI model is a screening level model. Therefore, for some chemicals the model predictions may not be as reliable as it will be for others. For example, RSEI may have difficulty with correctly assigning ranks for substances where chemical speciation is important and where physical from (gaseous versus particulate) is

important to atmospheric deposition and settling. This is because the RSEI model typically assumes the toxicity value for the most potent form of a chemical having multiple species (e.g., hexavalent chromium versus either trivalent or elemental chromium), and the air dispersion modeling is performed without deposition and gravitational settling of particulates. Persistent and bioaccumulative chemicals may not be ranked appropriately because of the absence of indirect food chain pathways for air releases. Noncarcinogens may be ranked inappropriately *if* there are significant joint occurrences of modeled exposures significantly below a toxicity threshold and large population densities. These model deficiencies are not necessarily unreasonable for a screening level model as long as they are recognized and considered in evaluating model output. Most can be addressed by more detailed site-specific assessments. Other model deficiencies (such as current absence of exposure pathways for water releases, off-site incineration, releases to publicly-owned treatment works, and consideration of toxicity endpoints other than chronic human effects) are intended to be addressed by USEPA in future model updates.

With these caveats in mind, the RSEI model results from the most recently available Maine TRI data (1998) were analyzed. A preliminary investigation was made of how a chemical ranking system could be used as an additional metric for measuring progress in reducing the release of toxicants into the environment, and how it could be used to focus use reduction and pollution prevention efforts. A limited exploration was also made of the dependency of ranking on toxicity versus quantity released.

The results were provocative, indicating clear differences in assessment of progress in reducing the release of toxicants and in assessing where to focus pollution prevention efforts when chemical toxicity information was considered. Further investigation revealed that among the top 10 ranked chemicals (ranked by risk-related result), quantity released ranged from 271 to over 700,000 pounds per year while toxicity weights ranged from 90 to 86,000. A chemical could be ranked high by having a low toxicity weight and high release quantity (e.g., sulfuric acid), a high toxicity weight and low release quantity (e.g., chromium), or various combinations of moderate release, toxicity, and/or exposure. The observations that toxicity weight is a major determinant

of chemical rank supports making some link between TRI reporting thresholds and chemical toxicity, as has recently been done by USEPA for persistent bioaccumulative toxicants (PBTs).

The RSEI model can be used to provide relative ranking of chemicals, facilities, counties, etc. Because RSEI is designed for screening purposes only (as discussed above), it is recommended that further analyses follow the identification of chemicals or facilities that are ranked high, or that have ranks contrary to experience. This is especially important for metals as noted above, where chemical speciation may have a major effect on the toxicity weight, and particle size may have a major effect of air dispersion modeling results. As the RSEI model is updated and changed, and as users become adept at the application and interpretation of the model, a number of follow-on analyses may be identified. As a starting point, these efforts are recommended for chemicals that are ranked high in the RSEI model:

- Verify that TRI data is correct (i.e., that no corrections were submitted to EPA after posting in the RSEI model);
- Evaluate existing toxicity data with special emphasis on chemical speciation issues;
- Review underlying assumptions used in RSEI exposure model to determine whether chemical degradation, transformation, deposition, partitioning, etc. might substantially alter exposure predictions;
- Compare exposure levels predicted by RSEI with risk benchmarks (e.g., RfD, RfC, risk-specific doses);
- Consider need for detailed, site-specific risk assessments.

These analyses will serve to clarify the ranking results and identify potential problems in the ranking process prior to acting on the ranks.

The analyses in this report demonstrated that the RSEI model can be used to incorporate information on toxicity, environmental fate, exposure potential, and population into a process for prioritizing chemicals for toxic use reduction and pollution prevention. The RSEI model is a powerful tool for accomplishing this task. It is important to recognize, however, that it is one of many tools for ranking chemicals. It is also important to recognize that the RSEI model, at this

time, is very much a work in progress. A Beta version is due out at any time with additional exposure pathways and other model refinements.

The analyses presented in this report provide some insight into the advantages and limitations of the RSEI model. Additional investigations are recommended to further explore the implications of the more significant limitations. To that end, the following analyses are recommended:

1. Evaluate the impact of neglecting indirect exposure pathways on the ranking of persistent bioaccumulative toxicants (PBTs). Many studies have suggested that for some PBTs such as dioxins and polychlorinated biphenyls, indirect exposure routes can be more significant than other routes. In order to determine the extent to which PBTs may be under ranked by the exclusion of these pathways, it is recommended that site-specific RSEI model concentration output be used in a multimedia exposure model that includes indirect exposure routes for PBTs. A comparison between chemical ranks using this approach and ranks excluding the indirect pathways would help to define the significance of this limitation.
2. Closely evaluate the results of the surface water release pathways scheduled to be included in the next version (2.0) of the RSEI model.
3. Investigate the impact of the RSEI model approach to ranking noncancer effects proportional to dose. As noted earlier, standard noncancer risk assessment uses a threshold approach to dose-response assessment, whereas the RSEI model's risk-related results increase linearly with dose, regardless of the relationship to the threshold. It is recommended that, for a subset of noncarcinogenic chemicals ranked high in Maine, alternative measures of noncancer hazard be employed and compared with the RSEI model approach. Specifically, a comparison between risk-related results that include only those cells where the exposure concentration is predicted to exceed the RfC (or some fraction of the RfC that accounts for other sources of exposure, e.g., 20%) with risk-related results using the model approach could be used to evaluate whether the RSEI model approach might distort the ranking of noncarcinogens.

In summary, the RSEI model is a powerful tool for ranking chemicals reported on the TRI (and potentially other databases). Among the advantages, the RSEI model's rich databases, site-specific approach, and flexibility of output permit the state of Maine to perform analyses that would otherwise require significant resources to develop independently. Based on the results presented in this report, it is clear that such analyses provide information that could be helpful in focusing use reduction and pollution prevention efforts on the most toxic chemicals. USEPA intends to use this model to rank chemical releases reported on TRI and to broadly distribute the information to the public and interested parties. In fact, USEPA plans to develop an interactive version of the model for its web site in the next few years. As such, it is to Maine's advantage to become familiar with the model and its advantages and limitations. Indeed, DEP may wish to establish a RSEI model working group consisting of appropriate state agency, public and private sector representatives to monitor the ongoing development of RSEI.

## 1.0 INTRODUCTION

Each year, the Toxics Release Inventory (TRI) provides the public with information on a substantial number of chemical releases from facilities in the U.S. The Federal Emergency Planning and Community Right-to-Know Act (EPCRA) designated a list of over 600 chemicals and chemical groups that must be reported on the TRI. Industrial facilities are required to report their releases of these designated chemicals if they a) manufacture or process in excess of 25,000 pounds or b) otherwise use in excess of 10,000 pounds of the chemical in a given year. Chemical releases from facilities that do not meet these threshold requirements are not reported or tracked. Beginning with the 2000 reporting year, the TRI reporting thresholds for several chemicals characterized as Persistent and Bioaccumulative Toxins (PBTs) have been significantly reduced (64 FR 58666)[1].

In addition to satisfying federal Right-to-Know requirements, the TRI serves as the chief tool for Toxic Use Reduction (TUR) and Pollution Prevention efforts within the state of Maine. Since 1990, TRI chemicals have served as the target list for toxic release reductions within Maine's TUR Program. The Department of Environmental Protection (DEP) collects and normalizes TRI data and uses the information to track progress in release reductions. Total pounds reported on TRI are normalized against production at the facility level, and changes over time are measured using this metric. The state of Maine has mandated progressive reductions in toxic releases over the next six years, with 40% statewide reduction in toxic releases by 2002, 50% reduction by 2004 and 60% reduction by 2006 (compared with a baseline average of the releases in 1990 and 1991; 38 MRS § 2303). In general, state resources for TUR efforts are directed to those facilities requesting assistance.

[1] Thresholds were lowered to either 10 or 100 lbs for the following chemicals: aldrin, benzo(g,h,i)perylene, chlordane, heptachlor, hexachlorobenzene, isodrin, mercury, methoxychlor, octachlorostyrene, pendimethalin, polycyclic aromatic compounds, polychlorinated biphenyls, tetrabromobisphenol A, toxaphene, and trifluralin . In addition, the following chemicals were added to the list of chemicals reported on TRI: benzo(g,h,i)perylene, fluoranthene, 3-methylcholanthrene, octochlorostyrene, pentachlorobenzene, tetrabromobisphenol A, vanadium, vanadium compounds, and dioxin and dioxin-like compounds.

The problems in relying on TRI data for pollution prevention/TUR efforts are threefold. First, the available data comprises only a subset of all chemicals used and/or released in Maine; chemicals that are not on TRI are not tracked. Second, facilities that do not meet reporting thresholds for manufacture, processing, or use do not report their releases at all. The third problem with relying on TRI data is that the use of chemical quantity alone to prioritize toxics use reduction and pollution prevention efforts means that all chemicals are implicitly considered equal with respect to their toxicity, environmental fate, and potential for exposure. For example, using quantity alone, no differentiation would be made between equal releases of methanol and arsenic, despite the fact that arsenic is much more toxic. Likewise, using the release quantity to prioritize chemical releases neglects the differences in potential public health impacts between releases in heavily populated areas versus releases in remote areas.

Recognizing that important information may not be available to the current toxics use reduction/ pollution prevention efforts, the Maine Legislature enacted the Maine Toxics Use and Hazardous Waste Reduction Act, requiring the Department of Environmental Protection (DEP) to provide a report to the Legislature outlining an "assessment of and recommendations for focusing use reduction and pollution prevention efforts on the most toxic chemicals and classes of chemicals" (Sec. 14. 38 MRSA §2309, sub-§§7B).

The idea of focusing efforts on the most toxic chemicals invokes a need to compare chemicals according to toxicity. One way to perform such a comparison is through the use of a chemical ranking system. For example, the Air Bureau of the Maine DEP has used a simple toxicity-based ranking system to set permitting fees. However, the development of a chemical ranking system is fraught with difficulties. Simple methods for ranking chemicals tend to omit information, while more sophisticated methods may suffer from data limitations or a lack of time and monetary resources. Sophisticated methods that require substantial time commitment for complicated analyses may serve only to delay efforts at reduction and prevention. In selecting a ranking system, one must balance the inclusive but conservative nature of a screening model against the data and time requirements of more refined models. Further, almost any approach must confront controversial issues such as how to weight different toxicological endpoints

including cancer, developmental toxicity, systemic toxicity, neurotoxicity, etc. A question also arises as to whether to consider only human toxicity *per se*, or to expand ranking systems to include information about environmental fate, potential for exposure, size of the exposed human population, and ecological impacts.

This report summarizes the initial efforts to evaluate available methods for ranking chemicals. It also provides a preliminary investigation of how one particular ranking system could provide an additional metric for measuring progress in reducing the release of toxicants into the environment; how it could be used to focus use reduction and pollution prevention efforts, and how it could be used to evaluate the need for reporting requirements linked to toxicity. Specifically, Section 2.0 briefly reviews several chemical ranking models currently in use. Section 3.0 describes in more detail the structure of a USEPA model specifically developed to work with TRI data. Limitations in the structure and model components are discussed. Section 4.0 provides sample analyses showing how this USEPA model can be used to focus efforts and measure progress in use reduction and pollution prevention, and to define chemical-specific reporting thresholds. Section 5.0 contains the conclusions and recommendations.

## 2.0 SELECTION OF RANKING MODEL

A number of organizations, including governmental agencies, environmental groups, and industries have developed models for ranking chemicals. These models vary greatly in overall objectives, in the information included, and in complexity. In order to identify ranking models for potential evaluation, secondary sources containing overviews of numerous ranking systems (Swanson and Socha, 1995, and USEPA, 1997) were reviewed. In addition, experts were consulted, including USEPA personnel experienced in the development and evaluation of ranking schemes, as well as academicians. Six ranking schemes available in the public domain were reviewed: the Maine Bureau of Health's Toxicity Ranking System, the Agency for Toxic Substance and Disease Registry's (ATSDR) Prioritization of Hazardous Substances for Toxicological Profile Development, the European Union System for Evaluating Substances (EUSES), Imperial Chemical Industries' (ICI) Environmental Burden Approach, Environmental

Defense's Scorecard, and the Environmental Protection Agency (USEPA) Office of Pollution Prevention and Toxics' Risk Screening Environmental Indicators (RSEI) Model. The models are described briefly below.

### 2.1 Description of Models Reviewed

*Maine Bureau of Health Ranking of Hazardous Air Pollutants.* In 1986, the Maine Bureau of Health developed a ranking system for hazardous air pollutants (ME BOH, 1986). The purpose of the ranking system was to prioritize chemicals for eventual development of ambient air guidelines. The ranking system was derived as the product of an annual air emission quantity and a toxicity score. The toxicity score was based on toxicity information derived from the Registry of Toxic Effects of Chemical Substances (RTECS)[2] for the following toxicity endpoints: carcinogenicity, mutagenicity, reproductive effects, and acute effects. For each endpoint, the chemical was ranked from either 0 to 4 or 1 to 4, with higher rankings assigned when the weight of evidence implied greater confidence that the chemical caused a certain health effect. Acute health effects were ranked higher if effects were reported to occur at lower doses. The final score for each chemical was calculated as the sum of the scores for the four individual toxicity endpoints. The product of the toxicity score and the air emission quantity was used as the metric for ultimate ranking. This ranking system did not account for environmental fate and transport or exposure potential, nor did it consider the size of the exposed population. Chronic toxicity other than these endpoints was not considered, nor was the relative potency of substances (except for acute effects).

*ATSDR Prioritization of Hazardous Substances for Toxicity Profile Development.* To prioritize chemicals for toxicological profile[3] development, ATSDR developed a ranking scheme that considered each chemical's toxicity, frequency of occurrence and concentration at Superfund sites, and human exposure potential at Superfund sites (ATSDR, 1999). Toxicity and frequency of occurrence are both scored on a scale from 1 to 600, while concentration and exposure

[2] RTECS is the National Institute for Occupational Health and Safety (NIOSH) database of toxicological data.
[3] A toxicological profile is a document summarizing the available literature on the physico-chemical properties, environmental fate, and toxicology of a particular chemical.

potential are each scored on a scale from 1 to 300. The final rank is based on the sum of the scores for these four characteristics, and ranges from 4 to 1800.

The ATSDR methodology relies on two major inputs: HazDat, a compilation of chemical concentrations and exposure information at Superfund sites; and the Reportable Quantity (RQ) methodology, a process developed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for defining the amount of chemical release that warrants notification of authorities. The HazDat database is used to obtain the frequency with which a given chemical is reported at Superfund sites nationwide. The frequency is then scaled to a maximum of 600 points. In addition, HazDat provides the concentrations of the chemicals in various media at Superfund sites, as well as anecdotal evidence of exposure status. For each chemical, the geometric mean concentration (across Superfund sites) for each medium is entered into a formula to calculate a measure of total exposure, the value of which is ultimately scaled to a maximum score of 300 points. Exposure status is grouped into three categories: exposure to the contaminant, exposure to an environmental medium containing the contaminant, and potential exposure to an environmental medium containing the contaminant. Substances are assigned to one of the three categories based on the highest category in which exposures are reported in HazDat (with exposure to the contaminant being the highest category and potential exposure to the medium being the lowest). Points within the three exposure status categories are from a) 200 to 300, b) 100-200, and c) 1 - 100. Points within a category are assigned based on the frequency of reported exposure occurrences.

The toxicity score is based on the RQ methodology. Under CERCLA, the release of a chemical in excess of its reportable quantity (RQ) must be reported to a federal, state, and local authorities. The RQ methodology is used to define the chemical-specific quantity that warrants notification of authorities. A chemical with high toxicity is assigned a low reportable quantity, and a chemical with low toxicity is assigned a high reportable quantity. In the RQ methodology, each substance is assigned to one of five RQ categories (1, 10, 100, 1000, or 5000 lbs) based on five toxicity endpoints: acute and chronic toxicity, carcinogenicity, aquatic toxicity, and ignitability/reactivity. The RQ poundage categories reflect the potency of the chemical in that

category. Each substance is ranked independently on each toxicity endpoint, and the lowest RQ value among all of the endpoints is selected as the final RQ for the chemical. The final RQ for a chemical that is biodegraded or subject to photolysis or hydrolysis (processes that diminish the amount of chemical available for exposure) is adjusted to the next highest RQ category (e.g., from 10 to 100 lbs). In the end, the toxicity points are scaled to a maximum score of 600 (for a RQ of 1) using an ordinal ranking methodology.

The final rank, as noted earlier, is calculated as the sum of the scores for the four categories: toxicity, frequency of occurrence, concentration, and exposure potential, with a maximum potential score of 1800 points.

*European Union System for Evaluation of Substances.* The European Chemicals Bureau of the Joint Research Commission of the European Commission developed the European Union System for the Evaluation of Substances (EUSES) for rapid assessment and relative ranking of risks associated with existing and new substances (EC, 1996). EUSES uses the total estimated emissions for various use patterns for the substance, ranging from processing to consumer use. Emission estimates become the inputs to a multimedia model to estimate concentrations of the chemicals in air, water, soil, etc. EUSES evaluates exposure to humans under a variety of scenarios including work, consumer use, and environmental exposures, and also evaluates exposure to ecological endpoints. To assess the toxicity of chemicals, EUSES compares dose estimates with No-Observed-Adverse-Effect-Levels (NOAELs) from laboratory studies[4]. The EUSES screening-level model appears to be quite data-rich. It uses European Union landscape and meteorological information, however, that would complicate any direct use of the full model results in the U.S. ME BOH has not obtained the EUSES model, and as such cannot comment further on whether it could be adapted to use in the U.S. However, the life cycle analysis feature in this model is very attractive.

[4] Reliance on NOAELs excludes the uncertainty factor adjustments and dose-response modeling used in the U.S. to develop toxicity benchmarks from animal bioassays. Chemical ranking based on NOAELs might be very different from ranking based on USEPA toxicity values that take into account uncertainty in extrapolating toxicological data from animal studies to humans or from subchronic data to chronic exposures, uncertainty in toxicological data for a particular chemical, etc.

*ICI's Environmental Burden Approach.* Imperial Chemical Industries (ICI) developed a ranking approach called the Environmental Burden to evaluate the potential environmental impacts of chemicals on a variety of environmental endpoints[5]. Rather than focusing exclusively on human and/or ecological health effects, ICI considers a multitude of environmental impacts: atmospheric acidification, global warming, toxicity to human health, ozone depletion, photochemical ozone (smog) creation, aquatic acidification, aquatic oxygen demand, and ecotoxicity to aquatic life. ICI's ranking metric consists of the weight of substance emitted, multiplied by a "potency factor" reflecting the capacity of the chemical to impact the particular environmental endpoint. In the case of human health impacts, ICI estimates the potency using the United Kingdom's Occupational Exposure Limit (OEL)[6]. The potency factors are unique to each environmental impact and cannot be combined across impacts. The ICI model is unusual in addressing so many environmental impacts (e.g., human health, global warming, aquatic acidification); however, it does not consider environmental fate, exposure, or population impacts when evaluating human health impacts. Further, using occupational standards for human health focuses the ranking on chemicals with acute or subchronic effects and may not give the same relative ranking obtained when using health guidelines intended to be protective of the general population, especially for carcinogens.

*ED's Scorecard.* Environmental Defense's (ED) Scorecard model is perhaps the first website[7] offering on-line access to TRI data and risk-based analyses thereof. Beginning with TRI release quantities for air and water, Scorecard uses physico-chemical characteristics of the chemical substance with generic landscape parameters to estimate the concentrations of the substance throughout various environmental media (e.g., air, water, soil, plants). Chemicals released to air or water or both are ranked together; air releases may not be ranked separately from water releases. The Scorecard model uses area-weighted mean regional parameters (such as meteorological parameters and soil properties) to predict concentrations with CalTox, a multimedia environmental fate, transport and exposure model used by California regulatory

[5] The web address is www.ici.com.
[6] Occupational Exposure Limits are comparable to U.S. Occupational Health and Safety Act (OSHA) standards and American Conference of Governmental Industrial Hygienists (ACGIH) recommended exposure limits.
[7] The web address is www.scorecard.org.

agencies. CalTox employs an equilibrium-based (fugacity) box model approach to predict steady-state concentrations throughout various compartments (air, water, soil, groundwater, etc.). Using the concentration predictions, the model estimates total daily doses (from multiple exposure pathways) to hypothetically exposed individuals using standard exposure assessment models. Scorecard calculates exposure to a hypothetical maximally exposed individual, and does not consider population impacts.

The Scorecard model couples the exposure estimates with standard risk assessment methods to calculate the risk associated with each release, and then converts each risk to a toxic equivalency potential (TEP). A TEP is an estimate of the quantity (in pounds) of the particular chemical associated with a risk equivalent to one pound of a reference compound. Cancer-causing agents (carcinogens) are ranked separately from substances that cause noncarcinogenic effects (noncarcinogens). Carcinogens are ranked relative to the known human carcinogen benzene, while noncarcinogens are ranked relative to toluene. Interestingly, part of the Scorecard website uses USEPA's RSEI model (model described below) output to estimate cancer risks on a facility-specific basis for air releases.

Scorecard uses toxicity information from a variety of sources, including USEPA, the Agency for Toxic Substances and Disease Registry (ATSDR), California's Environmental Protection Agency, and the USEPA RSEI model as well. The Scorecard model provides rankings for 345 of the 447 chemicals in the 1998 TRI database; 102 chemicals are omitted because they lack toxicological data. The top ten chemicals in Maine (1998) as ranked by Scorecard according to potential health risk are given in Table 1.

**Table 1. Environmental Defense Scorecard's Top Ranked Chemicals in Maine (1998, Water and Air Together)**

| Rank | Carcinogens | Noncarcinogens |
|---|---|---|
| 1 | Chloroform | Mercury |
| 2 | Chromium Compounds | Nickel Compounds |
| 3 | Chromium | Copper Compounds |
| 4 | Nickel Compounds | Manganese Compounds |
| 5 | Benzene | Chloroform |
| 6 | Dichloromethane | Manganese |
| 7 | Propylene Oxide | Zinc Compounds |
| 8 | Nickel | Barium Compounds |
| 9 | Acetaldehyde | Chromium Compounds |
| 10 | Formaldehyde | Copper |

*USEPA's Office of Pollution Prevention and Toxics' Risk-Screening Environmental Indicators (RSEI) Model.* Like Scorecard, the USEPA Office of Pollution Prevention and Toxics Risk-Screening Environmental Indicators Model (RSEI Model) was initially developed for application to TRI data. The RSEI model is designed to provide a screening-level method for ranking chemical releases reported to TRI. Beginning with TRI release data, the RSEI model calculates a score having some proportionality to potential health risk for each unique combination of chemical, facility, and environmental medium. Using release quantity, physical-chemical data, site-specific meteorological data (for air releases), site-specific river or stream data (for water releases) and some additional site-specific facility features, the program applies existing USEPA environmental fate and transport models to calculate an ambient chemical concentration for the medium into which the chemical is released. The RSEI model predict the movement of chemicals in the environment. The concentrations are combined with human exposure parameters to estimate surrogate doses, which are measures of the mass of a chemical entering a human body per day.

The RSEI model weights each surrogate dose by the toxicity of the chemical and by the size of the exposed population. Toxicity weights in RSEI are derived from USEPA toxicity values and employ a single proportional scale to rank both carcinogens and noncarcinogens. The common scale is achieved by equating exposure at the reference dose or reference concentration with an excess cancer risk of 2.5 in 10,000, although carcinogens and noncarcinogens may be assessed separately (except for chemicals having toxicity weights for both carcinogenic and noncarcinogenic effects[8]). Population data are derived from the U.S. Census Bureau. Version 1.02 of the RSEI model, which is the most current version publicly available, has full results only for TRI data on air releases and chronic human health effects from inhalation exposures. Future versions of the model are intended to address TRI releases to other media (e.g., water with both fish ingestion and drinking water as exposure routes) as well as acute human and acute and chronic ecological effects. RSEI is described in greater detail below in Section 3.0.

The top ten chemicals in Maine (1998) as ranked by RSEI according to risk-related result are given in Table 2. The results shown in Table 2 are not directly comparable to those given for Scorecard in Table 1. Scorecard ranked releases to air and water together on a single scale, while the results for RSEI address air releases only. Further, Scorecard considers both the carcinogenic and noncarcinogenic effects of chemicals that have toxicity values for both types of effects, while RSEI ranks chemicals using just the endpoint with the most limiting toxicity value. Note, for example, that chloroform appears among the top ten for both carcinogens and noncarcinogens on the Scorecard list (Table 1), but does not appear as a high-ranked noncarcinogen on the RSEI list (Table 2) because its RSEI toxicity weight (and risk-related result) is driven by carcinogenicity.

[8] For chemicals having both carcinogenic and noncarcinogenic EPA toxicity values (e.g., arsenic), modeling results can only be obtained for the endpoint with the most limiting toxicity value.

**Table 2. RSEI Top Ranked Chemicals in Maine (1998, Air Only)**

| Rank | Carcinogens | Noncarcinogens |
|---|---|---|
| 1 | Chromium Compounds | Sulfuric Acid |
| 2 | Chromium | Chlorine Dioxide |
| 3 | Chloroform | Manganese Compounds |
| 4 | Formaldehyde | Manganese |
| 5 | Nickel Compounds | Naphthalene |
| 6 | Nickel | Glycol Ethers |
| 7 | Benzene | Hydrochloric Acid |
| 8 | Dichloromethane | Acetaldehyde |
| 9 | * | 1,2,4-Trimethylbenzene |
| 10 | | n-Hexane |

* No other TRI chemicals reported to be released into Maine air in 1998 had RSEI toxicity weights based on carcinogenicity.

Table 3 contrasts the salient features of the five models reviewed. Each of these models has attractive features. For the purposes of the present analysis, the RSEI model was selected for further evaluation for several reasons. The RSEI model has already been applied to Maine TRI data. The model is more site-specific and facility-specific than other reviewed models. The RSEI model additionally permits access to some model inputs and outputs, and provides several options for analysis of model output data. In addition, documentation on the development, structure, function, and uses of the RSEI model is readily available. Details of the model structure and function are necessary for an in-depth understanding of the limitations of any model; thus, the transparency of the RSEI model is a key advantage. The RSEI model is publicly available as a CD-ROM. Finally, the RSEI model appears to be on its way toward becoming USEPA's standard model for the evaluation of TRI data. It is therefore appropriate that Maine develop a clear understanding of the model's capabilities and limitations. For these reasons, the RSEI model was selected for evaluating how information about toxicity, exposure, and population density could be incorporated into efforts to focus toxics use reduction and pollution prevention efforts.

## Table 3. Comparison of Significant Model Features

| Model | Model Purpose | Toxicity Scoring Approach | Environmental Fate and Transport Modeling | Exposure Pathways | Chemicals Evaluated |
|---|---|---|---|---|---|
| MEBOH | Ranking hazardous air pollutants for evaluation of human health risks | Single scale based on weight-of evidence for several toxicity categories. | Uses emissions estimates; no fate and transport modeling. | No exposure analysis included. | 75 hazardous air pollutants were ranked. |
| ATSDR | Ranking chemicals at Superfund sites for toxicological profile development | Single scale based on RQ methodology. | Uses measured media concentrations from Superfund sites; no fate and transport modeling. | Inhalation, ingestion of soil, consumption of water. | Of 815 substances found at 3 or more Superfund sites, 275 were ranked. |
| EUSES | Life cycle analysis of human health and environmental impacts of new and existing chemicals | Single scale using NOAELs. | Multimedia box-model* approach using SimpleBox. | Includes direct and indirect food chain exposures. | Information not available from resources consulted. |
| ICI Environmental Burden | Evaluation of multi-endpoint environmental impacts of chemical releases | Single scale based on European Occupational Exposure Limits. | Uses emissions estimates; no fate and transport modeling. | No exposure analysis included. | Information not available from resources consulted. |
| Scorecard | Ranking human health impacts of chemicals reported on TRI | Separate scales for cancer and noncancer using USEPA, ATSDR, and CalEPA toxicity values. | Multimedia box-model* approach using CalTox; not site-specific. Excludes releases to land. | Includes direct and indirect food chain exposures. | TRI data for 1998; 345 chemicals were ranked. |
| RSEI v. 1.02 | Ranking human health and environmental impacts of chemicals reported on TRI | Single scale based on USEPA toxicity values. Equates exposure at the RfD/RfC with cancer risk of $2.5 \times 10^{-4}$. Cancer and noncancer effects can be assessed separately. | Site-specific air dispersion approach. Currently implemented for air releases only. Future versions to add water-related pathways. | Currently inhalation only. Drinking water and fish consumption planned for later release. | TRI data from 1988- 1997; 413 chemicals were ranked. |

* Equilibrium partitioning.

## 3.0 OVERVIEW OF RSEI MODEL

The RSEI model is the product of two million dollars and more than nine years of development. USEPA regions, trade associations, environmental advocacy groups, industries, public interest groups, state health departments, community right-to-know groups, foreign countries, consultants, and environmental justice groups have had an opportunity to review and comment upon the RSEI model during the course of its development. In addition, USEPA's Science Advisory Board (SAB), a panel of independent experts who provide objective review and comment on USEPA's scientific decisions, has reviewed the RSEI model on three occasions. The current version of the model (V. 1.02) reflects revisions suggested by the USEPA SAB. USEPA continually updates and improves the RSEI model, revising the user interface, and eventually adding other media pathways and toxicity endpoints. Further, USEPA has demonstrated a willingness to try to accommodate (through model revisions) the needs of USEPA regions and state agencies for additional model capabilities. It is important to note that despite the magnitude of effort that has gone into its development, it remains a screening-level model and is not intended to supplant site-specific assessments.

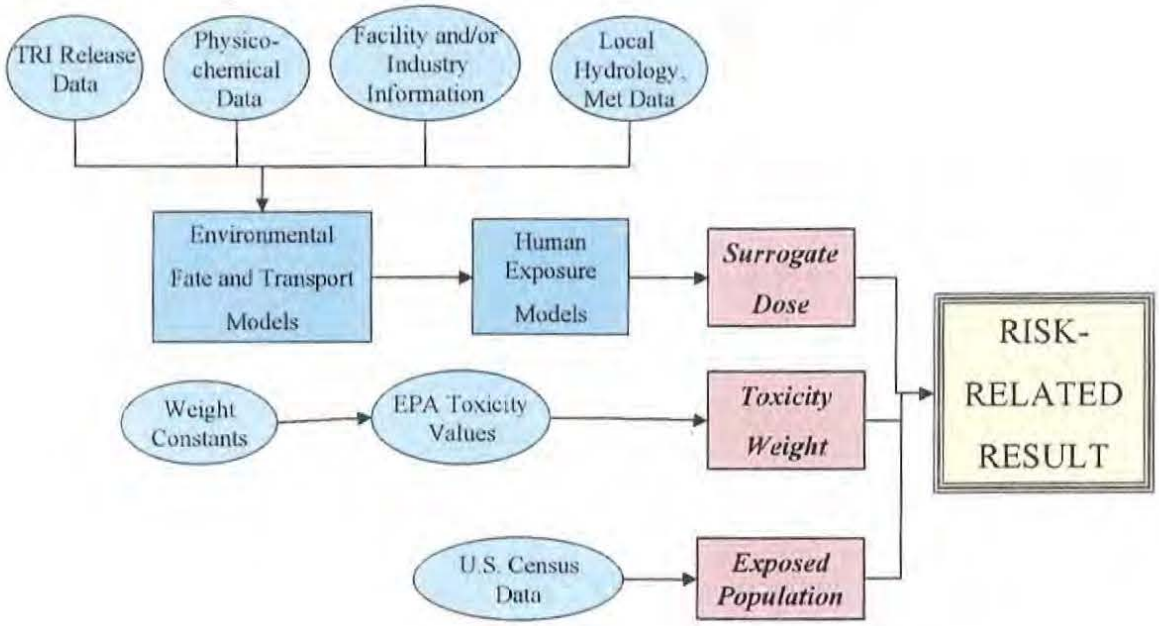
The current RSEI model bases chemical ranking on chronic human health effects. Different chemical rankings would likely result if ecological effects were considered, as some chemicals that are of low toxicity to humans may be very toxic to ecological species and vice versa. USEPA plans to develop future versions of the RSEI model to address both acute and chronic ecological effects.

### 3.1 Structure of RSEI model

The RSEI model is implemented as two basic steps: 1) the calculation of potential human exposure to a chemical using facility-specific TRI chemical release data and standard exposure modeling techniques and 2) weighting of the resulting exposure estimate by chemical toxicity and the size of the population potentially exposed. The primary model output is called a "risk-related result" and can be used to make comparisons among the chemical releases at various levels of aggregation (e.g., comparisons at the statewide level, at the county level, at the

individual reporting facility level). The model does not compute health risk *per se,* because of the toxicity weighting system used to put all chemicals (carcinogens and noncarcinogens) on a common scale. However, the risk-related result is believed to retain some proportionality to public health hazard. The general structure of the model is shown schematically in Figure 1, and these steps are described in detail below.

**Figure 1. General Structure of RSEI Model**




For every TRI-reporting facility, the model is intended to eventually perform this process for each chemical released to air, surface water, soil, etc. However, RSEI Version 1.02 currently performs these two steps for releases into air only; water and land releases have not been modeled in this version. For chemical releases to air, the RSEI model calculates inhalation exposures only. Indirect exposure pathways, where airborne chemicals are deposited to the soil and taken up into the food chain (e.g., uptake by plants and/or animals that are subsequently consumed by humans) are not included in the air model as exposure pathways, and the USEPA

does not currently plan to include such pathways[9]. For chemical releases to water, Version 2.0 of RSEI will model consumption of drinking water and consumption of fish from waterways receiving TRI releases. Finally, for chemical releases to soil, a future version of the RSEI model is intended to address transport of chemicals to groundwater and subsequent consumption of the groundwater. Volatilization of chemicals landfilled on-site is reported on TRI as a fugitive air release and is already fully implemented in Version 1.02; volatilization of chemicals from off-site landfills will be modeled separately in a future RSEI model. The USEPA does not plan to model exposure to landfilled chemicals through incidental ingestion of soil or food chain pathways.

Table 4 shows the TRI media and exposure pathways that the RSEI model is intended to address and the schedule for their release. As noted above, RSEI Version 1.02 is currently available. The beta version of RSEI Version 2.0 is scheduled for release in early 2001; changes reflected in that version are discussed later in Section 3.3.

[9] Future versions of the model will provide predicted air concentrations that could be entered into a food chain model such as CalTox.

**Table 4. TRI Media Release Pathways to be Included RSEI**

| TRI Media Release Pathway | Exposure Route | RSEI Version to Address Pathway |
|---|---|---|
| Stack Air & Fugitive Air | Inhalation | Version 1.02 (complete) |
| | Indirect Food Chain Pathways | Not currently planned |
| Direct Surface Water & Transfer to Publicly-Owned Treatment Works | Surface Water Consumption | Version 2.0 (Beta version complete) |
| | Fish Consumption | Version 2.0 (Beta version complete) |
| Off-site Incineration | Inhalation | Version 2.0 (Beta version complete) |
| | Indirect Food Chain Pathways | Not currently planned |
| On-site Landfilling | Inhalation of Volatiles | Version 1.02 (complete) |
| | Consumption of Groundwater | Planned future |
| Off-site Landfilling | Inhalation of Volatiles | Planned future |
| | Consumption of Groundwater | |
| On- or Off-site Recycling; Underground Injection | Not currently planned | Not currently planned |

### 3.1.1 Step 1: Calculating the Surrogate Dose

The term "dose" refers to the amount of chemical estimated to enter the human body per day normalized to body weight (e.g., via ingestion, inhalation, etc.). The RSEI model estimates dose as the first step in developing its risk-related results. Dose is estimated using standard USEPA environmental fate and transport models to predict the concentration of the pollutant in a particular medium (air, water, soil) at a particular location, followed by the application of standard human chemical uptake equations (e.g., inhalation, fish or water ingestion) to predict the amount of chemical entering a human body.

The RSEI model is able to perform site and facility specific modeling because it uses a grid mapping system. The RSEI model divides the U.S. and its territories into a grid of 1 km by 1 km

cells. All TRI-reporting facilities and off-site transfer facilities are mapped to specific cells in this grid system. The grid system allows the model to associate each TRI-reporting facility (and hence chemical release) with the closest weather station, river reaches, drinking water intakes, and U.S. Census population data. Using release data from TRI to represent emissions, meteorological information from nearby weather stations, flow rates from local river reaches, chemical-specific physicochemical properties[10], and other site-specific information, the RSEI model applies USEPA environmental fate and transport models to estimate the concentration of chemical in those geographic cells that the model considers to be affected by the release from that given facility. The predicted concentration in each cell is then entered into a standard human uptake model to estimate a surrogate dose for people living in that cell. The result of Step 1, then, is an estimate of a surrogate human dose (in units of mg per kg body weight per day) for each geographic cell potentially impacted by the chemical release from a given facility. As noted above, Version 1.02 of RSEI implements only fate and transport models for air releases and inhalation as the only human exposure pathway associated with these releases. Section 3.1.1.1 below provides additional detail on the air dispersion modeling performed in the RSEI model.

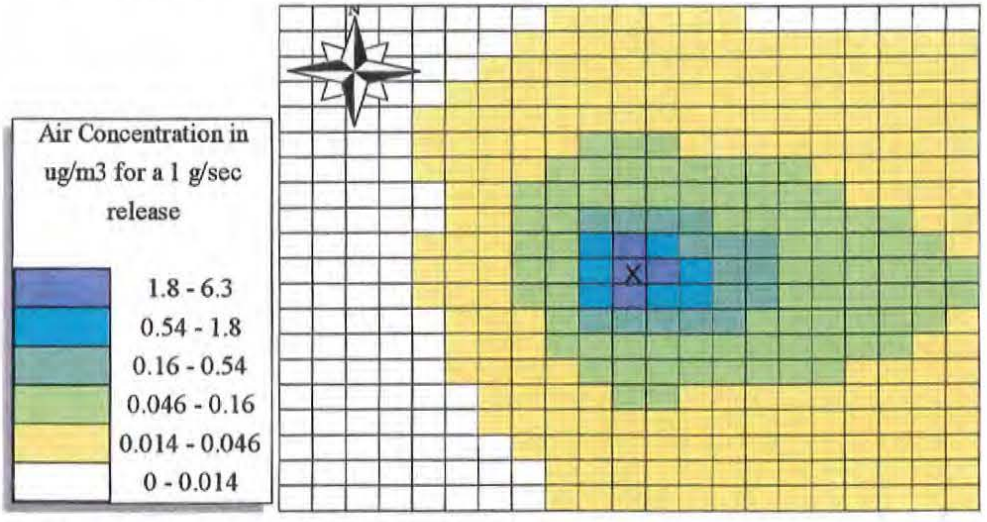
#### 3.1.1.1 Details of Air Dispersion Modeling in RSEI Model

Air dispersion modeling is used to predict the movement of chemicals emitted from a facility into the surrounding air as a consequence of meteorological factors such as wind direction, wind speed and atmospheric stability. The RSEI model implements the Industrial Source Complex Long-Term (ISCLT3) model developed by the USEPA Office of Air Quality Planning and Standards. The ISCLT3 is a steady-state Gaussian plume model (sector average) used to estimate long-term pollutant concentrations downwind from a source. The ISCLT model uses input meteorological data that have been summarized into joint frequencies of the occurrence for particular wind speed classes, wind direction sectors, and atmospheric stability categories over a monthly, seasonal or annual basis. These meteorological summaries are called STAR (for Stability Arrays) summaries, and are assembled by local weather stations.

[10] Physicochemical properties define how a chemical behaves in the environment; examples are the chemical's

When implementing ISCLT3 in RSEI, a TRI reporting facility is located on the grid system using its latitude and longitude and matched with the closest available STAR summary data. ISCLT divides the area surrounding a TRI facility into 16 sectors of equal angular width (22.5° or 0.393 radians) corresponding to the sectors of the frequency distributions for the STAR summaries. The ISCLT3 sector average model assumes a constant horizontal air concentration of a pollutant within a sector for any fixed radial distance downwind from a source. RSEI Version 1.02 uses ISCLT3 to predict air concentrations for a 21 km by 21 km block centered on the source (i.e., 10 km in each cardinal direction). Figure 2 shows a schematic representation of the corresponding 1-km by 1-km grid system and predicted air concentrations resulting from application of ISCLT3 for a hypothetical TRI reporting facility. RSEI Version 2.0 (Beta) will extend model concentrations to 50 km in each cardinal direction from the facility (a 101 km by 101 km block).

Figure 2. Illustration of results from ISCLT3 air dispersion modeling on a TRI reporting facility.




X - location of TRI facility

solubility in water, vapor pressure, molecular weight, etc.

The ISCLT3 model requires input values for a number of facility specific parameters such as chemical emission rate, stack height, stack gas velocity, and stack diameter to characterize the release of TRI chemicals. The chemical emission rate is assumed equal to the reported annual TRI release converted into a constant release in grams per second. Chemical releases to air are reported on TRI as either stack emissions or fugitive emissions. Unlike stack emissions, fugitive emissions are not released from a stack, but may be released from an area source or through leaks in equipment, etc. Stack and fugitive emissions are both modeled using ISCLT; however, different input parameters are used to predict concentrations resulting from each emission type. For stack emissions, USEPA uses either the site-specific stack height or the median stack height (when a facility had multiple stacks) and exit gas velocity information when these data are readily available.[11] Otherwise, USEPA uses the median stack height and exit gas velocity for industries sharing the same 3-digit SIC code within the databases.[12] Site-specific information detailing the characteristics of fugitive releases from TRI facilities is not readily available. Thus, for fugitive emissions in the RSEI model, USEPA adopted a screening-level approach in assuming that all fugitive releases could be represented by area sources with a fixed surface area of 10 $m^2$ and height of 3 m. Table 5 summarizes default values for air modeling parameters used in the RSEI model.

[11] USEPA derived site-specific information on these parameters from the AIRS Facility Subsystem within the Aerometric Information Retrieval System (AIRS), the National Emission Trends Database, and state-specific databases from California, New York and Wisconsin.

[12] USEPA conducted a "ground-truthing" exercise to determine the impact of using SIC-based stack parameters on air concentration predictions. In that analysis, RSEI air concentration predictions using industry-based SIC parameters were compared with predictions using a similar air dispersion model with considerably more facility-specific data. The RSEI predictions were compared with predictions of New York State's Air Guide-1 model (AG-1), a regulatory model that uses an earlier version of the ISC model. AG-1 was configured to model each stack release separately using facility specific information. Results from AG-1 were compared with those from RSEI using 1) facility specific data and 2) median SIC code-based parameters for 24 test cases in four metropolitan areas of New York. Concentration ratios (RSEI concentration/AG-1 concentration) were calculated for each cell affected by a release; a concentration ratio of one indicates complete agreement in predicted concentrations. The ground-truthing analysis showed that average concentration ratios differed by 48% or less (for facility-specific parameters) or 35% or less (for SIC code-based parameters) when computed over the cells surrounding a single facility. Average concentration ratios computed across all 24 test cases were within 2 % of unity for facility-specific parameters and within 6% of unity for SIC code-based parameters. The analysis showed further that concentration predictions in the immediate vicinity of the facility were poorer than those further away from the emission. For more detail on the groundtruthing analysis, see "Ground-Truthing of the Air Pathway Component of OPPT's Risk-Screening Environmental Indicators Model", USEPA Office of Pollution Prevention and Toxics, Washington DC, December, 1998.

**Table 5. Air Modeling Parameters Used in RSEI**

| Parameter | Value | Units |
|---|---|---|
| Area of Modeled Impact | 21 km by 21 km block* | |
| Stack Height | site- or industry-specific | m |
| Exit Velocity | site- or industry-specific | m/s |
| Stack Diameter | 1 | m |
| Exit Gas Temperature | 293 | K |
| Area Source Size | 10 | $m^2$ |
| Area Source Height | 3 | m |
| Decay Rate | varies by pollutant | |
| Pollutant Emission Rate | site-specific TRI release | lbs/yr |
| Frequency of wind speed and direction | closest STAR data | |
| Sector Width | 0.393 | radians |
| Wind Speed | closest STAR data | m/s |
| Smoothing Function | calculated | |
| Vertical term | calculated | |

* December 2000 release (Version 2.0 Beta) uses 101 km by 101 km block.

As configured for RSEI, the ISCLT model allows for pollutant decay (primarily from photooxidation, where pollutants are broken down by light). ISCLT in RSEI does not appear to allow for either dry deposition or gravitational settling of any large particles. The extent to which the omission of deposition and gravitational settling will affect concentration predictions will vary depending on factors such as the physical form of release (gaseous or particulate) and, if particulate, size and mass of particles.

Under the current version 1.02 of the RSEI model, the ISCLT equations are used to compute the average air concentration for each of the 441 cells of the 21 x 21 km grid. The concentration in each cell is entered into a standard human exposure equation for inhalation exposure to arrive at the surrogate dose. The inhalation exposure equation is:

$$Dose_{air,i} = \frac{C_{air,i} \times I_{air}}{BW}$$

Where:

| | | |
|---|---|---|
| $Dose_{air,i}$ | = | surrogate dose of TRI chemical for air concentration for cell *i* |
| $C_{air,i}$ | = | air concentration in cell *i* |
| $I_{air}$ | = | inhalation rate for adult (20 $m^3$ per day) |
| $BW$ | = | body weight for typical adult (70 kg) |

Several limitations of the surrogate dose calculation step of the current RSEI model version 1.02 should be emphasized. The reliance on TRI data to estimate a constant air emission rate introduces uncertainty for which the RSEI model does not make adjustments. TRI release quantities are estimates of the mass of chemical released into the environment, rarely empirically measured values. The quality of the release estimates is dependent upon the methods used to obtain them, and may vary across different facilities and chemicals. Using the ISCLT model without deposition and plume depletion by gravitational settling may result in the both under prediction (near the source) and over prediction (at longer distances from the source) of air concentrations for likely particle-bound pollutants such as chromium, cobalt, nickel and other metals. Finally, the RSEI model does not currently, nor does USEPA plan for RSEI to, estimate indirect air exposures associated with air releases (e.g., chemical deposition on soil and subsequent uptake by plants and animals used for human food)[13]. Exposures via food chain pathways may be particularly important for persistent bioaccumulative chemicals such as dioxins and polychlorinated biphenyls. However, future versions of RSEI may provide predicted air concentrations that can be imported into other models to estimate exposures through indirect pathways.

### 3.1.2. Step 2: Weighting the Surrogate Dose

The completion of Step 1 in the RSEI model results in surrogate dose estimates for chemical releases reported on TRI. The second step in the model is to weight the surrogate dose estimate for each geographic cell by the toxicity of the chemical and by the population exposed. The purpose of this step is to rank chemicals higher if they are more toxic and if the releases occur in densely populated areas. This step is accomplished by multiplying the surrogate dose (for each cell) calculated in Step 1 first by a quantity called the "toxicity weight" and then by the number of people potentially exposed at that dose. Each of these weighting factors is discussed below.

[13] By contrast, Scorecard, through its use of CalTox, includes indirect exposure pathways for air releases including ingestion of produce, dairy, and meat products contaminated by chemicals released into air.

### 3.1.2.1 Weighting by Toxicity

For the RSEI model, USEPA developed a system of numerical scores to characterize the toxicity of chemicals on a single proportional scale. The score, termed a *toxicity weight*, incorporates toxicity values derived by USEPA scientists (see box at right). The RSEI model converts toxicity values into toxicity weights by means of a series of constants, as shown in Table 6.

**WHAT ARE USEPA TOXICITY VALUES?**

To quantify chemical toxicity, USEPA has derived *toxicity values.* USEPA uses different toxicity values for chemicals that cause toxic effects other than cancer (noncarcinogens) and those that cause cancer (carcinogens). For noncarcinogens, USEPA uses the Reference Dose (RfD) and Reference Concentration (RfCs). A RfD or RfC is an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily oral exposure (RfD) or air concentration (RfC) that is likely to be without an appreciable risk of deleterious noncancer effects to humans (including sensitive subgroups) during a lifetime of continuous exposure. The RfD and RfC can be thought of as estimates of the population threshold for noncancer effects, below which effects would not be expected to occur. The units are milligram (mg) of chemical per kilogram (kg) body weight per day (mg/kg-day) for the RfD and microgram (µg) per cubic meter ($m^3$) for the RfC.

For carcinogens, USEPA uses the Oral Slope Factor and Inhalation Unit Risk. The Oral Slope Factor is a plausible upper-bound estimate of the probability of a cancer response per unit intake of a chemical over a lifetime. The Oral Slope Factor units are 1/mg/kg-day. The Inhalation Unit Risk is the upper-bound excess cancer risk estimated to result from continuous exposure to a chemical at a concentration of 1 µg/$m^3$ in air. The units of the latter are 1/µg/$m^3$.

These toxicity values have different meanings and different units. RfD and RfC values are smaller for more toxic chemicals, because they reflect estimate of the threshold below which no health effect should occur, and above which health effects may occur. By contrast, Slope Factors and Unit Risks increase with increasing toxicity, because they reflect the probability of contracting cancer given a fixed exposure, and a higher probability is associated with more potent carcinogens.

For more information on this topic, see USEPA (1989).

The toxicity weight constants have two functions: 1) to eliminate differences in toxicity value units (see box), resulting in a single metric (in units of inverse dose, or 1/mg/kg-day); and 2) to put different health effects on a single proportional scale. To develop a common proportional scale for toxicity weights in the RSEI model, the USEPA drew upon a previous scoring method developed for the Hazard Ranking System (HRS)[14]. For the HRS, USEPA scored the inherent toxicity of chemicals based on their cancer slope factors and reference doses. USEPA assigned order-of-magnitude scores between 1 and 1,000,000 to ranges of cancer slope factors or reference doses. The underlying basis for the ranges used in the HRS toxicity scoring system is an assumption that the hazard associated with exposure at the

[14] The Hazard Ranking System is a multipathway scoring system developed by the USEPA to "assess the threat associated with actual or potential releases of hazardous substances" at hazardous waste sites (55 FR 51532, December 14, 1990).

RfD is equivalent to the hazard associated with a cancer risk of 2.5 in 10,000[15]. USEPA adopted this assumption in developing its toxicity weight system for the RSEI model.

**Table 6. Calculation of RSEI Model Toxicity Weights from USEPA Toxicity Values**

| Chemical Type | USEPA Toxicity Value | Equation for Deriving Toxicity Weight |
|---|---|---|
| Noncarcinogen | Reference Dose (RfD) | Toxicity Weight = 0.5/RfD |
| | Reference Concentration (RfC) | Toxicity Weight = 1.8/RfC |
| Carcinogen | Oral Slope Factor | Toxicity Weight = Slope Factor/0.0005* |
| | Inhalation Unit Risk | Toxicity Weight = Unit Risk/0.00014* |

* For carcinogens classified as possible human carcinogens (USEPA Weight of Evidence Category C), the result of this equation is reduced by a factor of 10.

It can be argued that the scoring system developed for the HRS has foundations in a regulatory benchmark approach for putting chemicals with different health endpoints on a common scale. Operationally, USEPA often takes action to reduce or eliminate chemical exposures when such exposures are estimated to exceed an RfD or RfC. For carcinogens, the USEPA has historically viewed incremental lifetime cancer risk in the range of 1 in 10,000 to 1 in 1,000,000 to be *de minimus*[16]; i.e., negligible (USEPA, 1991). Thus, from a regulatory benchmark (or risk-management) perspective, the USEPA has implicitly equated chemical exposure at the RfD or RfC with exposure resulting in an incremental cancer risk of between 1 in 10,000 and 1 in 1,000,000.

There are other agency precedents for the use of this cancer risk level as the regulatory benchmark at which action is to be taken. For example, the USEPA Superfund Program made a policy decision that remedial action at Superfund sites would not be warranted where cumulative carcinogenic risks are less than 1 in 10,000 (USEPA, 1991). Likewise, two reviews of agency-wide regulatory actions show that USEPA usually takes action to reduce public health hazard

[15] For example, a chemical with an RfD of 0.5 mg/kg-day would have a toxicity weight of 1 (chemical A). A carcinogen with a slope factor of 0.0005 per mg/kg-day would also have a toxicity weight of 1 (chemical B). Given exposure to chemical B at the reference dose of 0.5 mg/kg-day, the cancer risk for chemical B would be 2.5 x 10-4.
[16] An incremental cancer risk of 1 in 10,000 is equivalent to one excess cancer for every 10,000 people exposed over a lifetime.

when cancer risk estimates exceed 1 in 10,000 ($1 \times 10^{-4}$) (Travis and Hattemer-Frey, 1988; Rodricks et al., 1987). Actions have been taken on occasion when cancer risks are smaller, but usually only when the size of the exposed population is large (Travis et al., 1987). Clearly, there are choices within the range of cancer risks, and the merits of any other risk value may be argued. Choosing a smaller cancer risk for the point of equivalence with the RfD or RfC means that greater weight in a ranking system will be given to carcinogens, and choosing a larger cancer risk for the point of equivalence means the converse will occur.

The use of a single scale based on equivalence of a threshold to a particular cancer risk to simultaneously score multiple toxic endpoints is potentially controversial, particularly if the toxicity scale is combined with exposure estimates, as it is in the RSEI model. The consequence of equating the RfD with a cancer risk of 2.5 in 10,000 is that exposure to $1/100^{th}$ the RfD is likewise equated to a cancer risk of 2.5 in 1,000,000. Similarly, an exposure 100 times higher than the RfD is equated to a cancer risk of 2.5 in 100[17]. While the regulatory benchmark argument provides some support for equating the RfD with a cancer risk in the range of 1 in 10,000, it does not support the assumptions of equivalence above and below the RfD, because these assumptions represent a departure from the traditional noncancer risk assessment paradigm. This important issue is discussed further in Section 3.2.

Of course, there are other approaches to aggregating toxicological endpoints besides equating the noncancer threshold with a particular cancer risk. In the field of medical economics, a metric referred to as *Quality Adjusted Life Years* has been extensively used as a means of comparing the cost-effectiveness of different medical interventions across conditions when the health outcomes being compared differ in terms of survival and quality of life (Gold et al., 1996). ED's Scorecard ranks carcinogens and noncarcinogens separately, and, in a separate analysis, ranks the releases of chemicals grouped by toxicological endpoint, including carcinogenicity, reproductive toxicity, neurotoxicity, developmental toxicity, etc. Segregating chemicals by toxicity endpoint obviates

[17] Peer reviewers of the draft 1992 RSEI methodology document also raised this issue. For further discussion, see USEPA, 1997. Toxics Release Inventory Relative Risk-Based Environmental Indicators: Summary of Comments Received on the Draft 1992 Methodology and Responses to Comment. Compiled by the Economics, Exposure, and Technology Division, Office of Pollution Prevention and Toxics, U.S. Environmental Protection Agency. May 1997.

the need to define a point of equivalence between cancer and noncancer effects, but complicates the allocation of resources between carcinogens and noncarcinogens. It is important to note that the RSEI model does permit users to evaluate carcinogens and noncarcinogens separately. However, for chemicals having both carcinogenic and noncarcinogenic toxicity values (e.g., arsenic), modeling results can only be obtained for the endpoint having the highest toxicity weight. In other words, the RSEI model (V. 1.02) treats chemicals as having either carcinogenic or noncarcinogenic effects but not both.

An important caveat is that toxicity data for some chemicals are very limited. Version 1.02 of the RSEI model uses toxicity values derived from USEPA sources (Version 2.0 will additionally include California EPA toxicity values). Among USEPA sources, the agency's Integrated Risk Information System (IRIS) is considered the gold standard. Toxicity values published on IRIS have undergone comprehensive review by scientists within USEPA, and enjoy agency-wide acceptance. In the absence of IRIS values, the RSEI model uses toxicity values from either the Superfund Program's Health Effects Assessment Summary Tables (HEAST) or the Office of Pesticides Program's Reference Dose and Carcinogenicity tracking reports, or values developed by OPPT specifically for the RSEI model.

Toxicity values for some chemicals are derived from extensive data sets (e.g., methylmercury, chloroform, benzene) whereas for other chemicals toxicological databases may be limited (e.g., cobalt, molybdenum trioxide). USEPA uses a simple ordinal weighting systems to describe the agency's confidence in the toxicity database for chemicals listed in IRIS, and this system is used to some extent with other agency databases. For example, carcinogens are currently graded as to the weight of evidence that a chemical is a human carcinogen, with categories of *known, probable, possible, not classifiable,* and *not a human carcinogen.* Confidence in RfDs and RfCs are reported as low, medium and high. Currently, the RSEI model (V. 1.02) makes only limited use of this information on confidence in toxicity values. As noted in Table 6, for chemicals characterized as possible human carcinogens (USEPA Weight of Evidence Category C), the toxicity weights are reduced by a factor of 10. No adjustments are made to RfDs or RfCs to reflect differences in confidence (although some RfDs and RfCs include an uncertainty factor for

limitations in the toxicological database). Variability in the quality of toxicity values in the RSEI model suggests that it will be important to consider the source of toxicity values in the model and to closely evaluate the robustness of toxicity values, especially those that are not published on IRIS.

A second important caveat stems in part from the screening-level nature of the RSEI model and its reliance on TRI data. TRI reporting does not require the speciation of inorganic elements or compounds. Thus, TRI data does not distinguish, for example, between the highly toxic hexavalent chromium and the much less toxic trivalent chromium or elemental chromium. Facilities report their releases of total chromium and total chromium compounds. In order to rank these groups of inorganic compounds, the RSEI model adopts the highest toxicity weight from among the members of the group. In other words, the RSEI model applies the toxicity weight for hexavalent chromium to all chromium and chromium compound releases reported on TRI. This approach may skew the initial rankings of some inorganic comounds if actual releases are of less toxic species. While the approach is consistent with a screening-level risk-based ranking, it underscores the need for in-depth follow-up analyses of chemicals for which speciation is likely to be an issue.

#### 3.1.2.2 Weighting by Exposed Population

In the RSEI model, the exposure estimate for each cell in the modeled grid is also weighted by the size of the exposed population. Population data are derived both from decennial U.S. Census data and county-specific census data interpolated for intervening years. Population size estimates depend upon the media pathway being evaluated. For example, the population exposed to an air release is summed across the grid cells surrounding the facility. By contrast, the population exposed to direct surface water releases through drinking water consumption (V. 2.0) is estimated as the population served by downstream drinking water intakes.

Weighting chemical releases by population means that chemical releases in heavily populated areas will rank higher than comparable releases in remote areas, all other factors being constant.

Consideration of population size in ranking chemical releases is viewed as controversial by some, though there are clear precedents for doing so. In the agency's Final Guidelines for Exposure Assessment, USEPA recommends that population risks be presented in addition to individual risks (57 FR 22888-22938). Travis et al. (1987) have shown empirically that USEPA has in the past defined acceptable or *de minimus* risk as a function of population size. In several instances, USEPA specifically cited population risk as a factor in its regulatory decision process (e.g., natural radionuclide emissions from elemental phosphorus plants; Travis et al., 1987). When population is considered, a chemical with low individual health risk and a large exposed population may rank high while a chemical with high individual health risk and a small exposed population may rank low, raising environmental justice concerns. Version 1.02 of the RSEI model does not calculate individual exposures as an output; however, future versions may permit evaluation of individual exposures through the output of modeled air and water concentrations.

### 3.2 The Risk-Related Result

Upon completion of Step 2, the model has calculated a series of risk-related results for each cell affected by a chemical release (i.e., the product of surrogate dose, toxicity weight, and population density). The risk-related results for all cells affected by the chemical release from a given facility are summed to estimate one total risk-related result for that unique combination of chemical, media pathway and facility. The risk-related results can be grouped in a variety of ways to perform different analyses. For example, risk-related results can be grouped by chemical by summing chemical-specific results across facilities statewide (this is explored further in Section 4.0). Further, the total risk-related result for each facility in the state can be calculated to rank the risk-related impacts (across all chemicals) of individual facilities. Similarly, total risk-related results can be calculated for each county to determine which county is impacted most heavily by TRI-reported releases.

The RSEI model is intended to eventually calculate risk-related results for most media-specific transport pathways reported on TRI (e.g., fugitive and stack air releases, off-site incineration, direct surface water release, etc.; see Table 3). As noted above, Version 1.02 of the model gives

full risk-related results only for stack air and fugitive air releases. Version 2.0 Beta, due to be released in early 2001, is expected to include off-site incineration, direct surface water releases, and releases to publicly owned treatment works (POTWs). For all media-specific pathways, the RSEI model offers a series of intermediate output options short of the full model, as shown in Table 7. It is important to note that none of these intermediate output options addresses environmental fate or exposure; only the full model (risk-related result) considers these. However, the intermediate output options allow the user to perform analyses to evaluate the impact of release quantity, toxicity weight, and potentially exposed population, on the final risk-related result.

**Table 7. Output Options Offered in RSEI Model.**

| Output | Description |
|---|---|
| TRI Pounds | Number of pounds released or transferred and reported on TRI |
| TRI Pounds (only chemicals with toxicity weights) | Includes only TRI pounds for chemicals with toxicity weights |
| TRI Pounds x Toxicity | TRI pounds multiplied by the higher of oral or inhalation toxicity weights |
| Modeled Pounds | TRI pounds minus pounds released to pathways not modeled by RSEI model |
| Modeled Pounds x Toxicity | Modeled pounds multiplied by toxicity weight appropriate to the exposure route being modeled |
| Modeled Pounds x Toxicity x Population | Previous variable multiplied by size of potentially exposed population. |
| Full Model (Risk-Related Result) | Product of the surrogate dose, the route-specific toxicity weight, and the exposed population |

It is important to be aware that the RSEI model risk-related result calculation implicitly treats noncarcinogenic hazards as increasing proportionate with dose, regardless of the magnitude of the dose relative to the RfD or RfC. This runs counter to the regulatory risk-assessment paradigm that the RfD or RfC is an estimate of a toxicity threshold (i.e., hazard is considered to be negligible at doses below the RfD or RfC). Because the RSEI model treats a dose below the

estimated toxicity threshold as having a small but nonzero hazard, this small hazard may be combined with a substantial population to give a high rank, even if there were no exposures above the estimated toxicity threshold. USEPA adopted this method because there is uncertainty associated with the exposure calculations (and thus exposures may be underestimated), and because some locales may be subject to exposures to the same (or like-acting) noncarcinogens from multiple sources (the combined total of which may exceed the RfD or RfC). This issue is less significant for carcinogens; the current risk assessment paradigm generally assumes that carcinogenic effects are proportional to dose even at low doses.

One way to circumvent this issue might be to examine the model's exposure predictions for noncarcinogens on a cell-by-cell basis. Using this information, it is possible to estimate the size of the population exposed to a given noncarcinogen at levels exceeding the RfD or RfC (or a specified fraction of a RfD or RfC). USEPA advocates this approach to quantifying population effects for noncarcinogenic agents in its Final Guidelines for Exposure Assessment (57 FR 22888-22938). The present version (1.02) of the model does not allow this type of analysis, but the new version (2.0) is expected to provide concentration information on a cell-by-cell basis and may permit such analysis. However, an argument can be made that such a refined analysis should only occur as part of a more detailed, site-specific risk assessment.

### 3.3 Capabilities of RSEI Version 2.0

USEPA is due to release an update (Version 2.0 Beta) to the RSEI model in early 2001. A list of the primary changes to be implemented in Version 2.0 is given as Table 8. In addition to new pathways, Version 2.0 is to have three important modifications. First, the new version will allow users to obtain the concentrations predicted by the model for each of the exposure units. This will allow more in-depth understanding of the geographic areas at issue, and may permit alternative evaluations of noncarcinogenic hazards and exposure via indirect food chain pathways as discussed above. Second, a later release of the new version will allow the use of non-TRI databases and will allow new chemicals and new facilities to be introduced into the model. The ability to add chemicals and to use non-TRI data will allow rapid updating of

emissions estimates with higher quality data (if available) and will permit consideration of a greater universe of chemical release information in the ranking of chemicals released in Maine. Finally, Version 2.0 of RSEI will account for yearly population change based on age, gender, race, and income, with appropriate exposure factors associated with each.

**Table 8. Changes Implemented in RSEI Version 2.0.**

- Overall Improvements
  - Removed exposure uncertainty adjustment factors for water and land
  - Updated physical-chemical properties
  - Added Cal-EPA final published toxicity data to hierarchy of toxicity value sources
  - Toxicity weights updated
  - Included year-by-year, county-level population modeling for U.S.
  - Modeled U.S. population by age, gender, race and income using subpopulation-specific exposure factors
  - Mapped all subpopulations within 50 km of facilities
  - Caclulated separate risk-related results for total population, children (<18) and elderly (≥65)

- Refinements to Air Pathway
  - Added air modeling of off-site incineration pathway
  - Extend air modeling to 50 km in each cardinal direction of the compass from facilities
  - High resolution air modeling of center grid cell
  - "On-the-fly" facility/chemical-specific air concentrations by grid cell
  - Added Facility- and SIC-specific stack diameters
  - Increased facility-specific air modeling parameters to ~15-20% of facilities nationwide
  - Added air hydrolysis rates to fate and decay data

- Addition of Water Pathway
  - Modeled risk-related results for direct surface water and POTWs releases
  - Mapped stream path (200 km downstream) and water intakes
  - Hand-matched important POTWs to NPDES database
  - Used harmonic stream flows
  - Used MCLs for drinking water intakes
  - Added unique database of recreational & subsistence fish ingestion populations by stream reach

- Refinements in Computing Ability
  - 32-bit operating system
  - GIS display (mapping of on- and off-site facilities)
  - Improved query language
  - Sophisticated filtering of cross tabs for complex selection and display of information
  - Geocoding for all on- and off-site facilities to improve location coordinates
  - Improved export of model results, data displays, and databases
  - Thematic mapping summaries for states & counties based on "selected" facilities and indicator elements
  - Summary trends based on "selected" facilities and indicator elements

## 4.0 APPLICATION OF RSEI MODEL TO MAINE TRI RELEASE DATA

The RSEI model was applied to Maine TRI data to explore how a toxicity ranking system might help focus toxics use reduction and pollution prevention efforts in Maine. RSEI Version 1.02 includes full risk-related results for the fugitive and stack air release pathways for TRI data from 1988 through 1997. The November, 2000 draft of this report made exclusive use of Version 1.02, as it is the only version publicly available at present. In order to use the most current data available for Maine and respond to concerns about a possible facility reporting error within the 1997 TRI data, the following analyses have been revised using output graciously provided by USEPA from RSEI Version 2.0 (Beta) using 1998 TRI data on air releases. It is important to recall that Version 2.0 contains several significant changes to the air modeling as compared to version 1.02 (see Table 6 in Section 3.3 for a complete list of changes), including:

- Extends air dispersion predictions from 10 km (Version 1.02) in each cardinal direction to 50 km in each direction from the facility,
- Performs high resolution air modeling in the center grid cell (subdividing it into 50 m x 50 m mini cells and calculating an average across all 400 mini cells),
- Adds facility- or industry SIC-specific stack diameters to the air modeling.

These changes are reflected in all of the results used in the remainder of the report.

TRI data for 1998 report air releases of 60 individual chemicals in the state of Maine. Air releases totaling more than 6 million pounds were reported, and the following ten chemicals were released in the greatest quantities (in descending order): methanol, ammonia, sulfuric acid, hydrochloric acid, n-hexane, toluene, chloroform, acetaldehyde, glycol ethers, and formaldehyde. Of the 60 chemicals released, the RSEI model provides risk-related results for 55; five were omitted due to lack of toxicological data.

Using these data and the RSEI model, several investigations were conducted. First, an analysis was performed to compare measures of progress in reducing toxic releases. The current

approach of measuring total quantity released was compared with other approaches using toxicity-weighted release quantity and risk-related results (Section 4.1). Second, chemicals released into Maine air were ranked by a variety of metrics including quantity released, toxicity-weighted quantity released, and risk-related result (Section 4.2). Third, an investigation of how RSEI chemical-specific and facility-specific information could be used to focus pollution prevention efforts was conducted (Section 4.3). This investigation explored the ability of the RSEI model to aggregate TRI data at the chemical and facility levels. Finally, the potential use of toxicity weights to modify TRI reporting thresholds was examined (Section 4.4). The question here was whether an empirical basis for reporting thresholds is apparent.

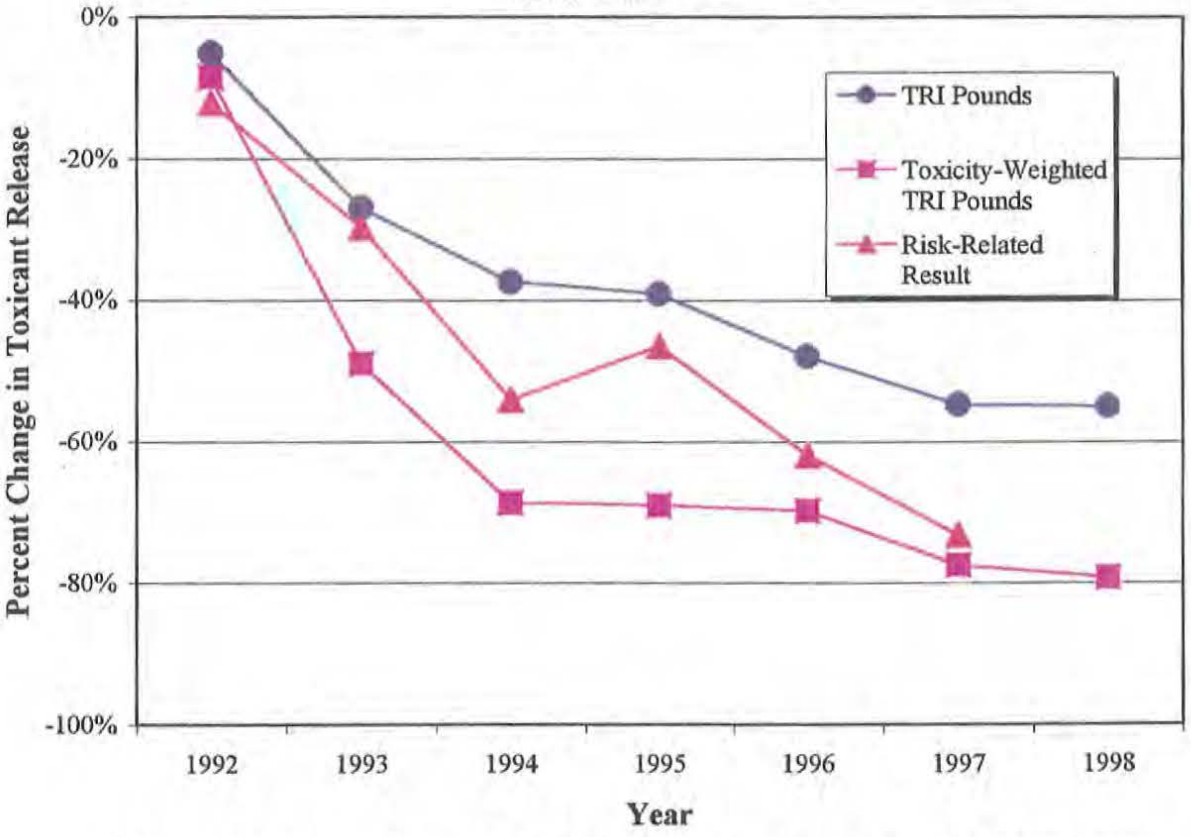
### 4.1 Tracking Progress in Use Reduction and Pollution Prevention

Currently, progress in use reduction and pollution prevention is measured as the change in total quantity of TRI chemicals released, regardless of the chemicals' toxicity or exposure potential. RSEI offers other means of measuring progress, including the toxicity-weighted release quantity (i.e., the product of toxicity weight and pounds released) or the risk-related result. An examination of the cumulative (across all chemicals) toxicity-weighted release and risk-related result from 1988-1998 gives the results illustrated in Figure 3, which are shown in comparison to the results for quantity released alone. The figure shows the percent reduction for each year when compared with a baseline average of the 1990-1991 years.

Changes in Version 2.0, as well as changes in TRI reporting requirements, dictated the removal of selected results from this analysis. Risk-related results for 1998 were not included, as changes implemented in Version 2.0 for the air pathway gave increased risk-related result values as compared with results estimated in Version 1.02, because of extending the dispersion model out to 50 km. Ammonia was removed from the analysis. The goal of the analysis was to investigate changes in chemical releases independent of changes in reporting requirements, but a change in reporting requirements for ammonia significantly changed reported releases beginning in 1994. Changes in reporting requirements for sulfuric acid and hydrochloric acid in 1995 did not result in measurable changes in reported releases; thus, these chemicals were retained. Finally, as

noted earlier, when measuring progress over time, the DEP normalizes the annual TRI release data to account for the impact of production changes. Figure 3 presents non-normalized data that are not directly comparable to past DEP measures of progress; however, the relative difference between unweighted and toxicity weighted values remains valid.

**Figure 3. Percent Change in Release Quantity, Toxicity-Weighted Release Quantity, and Risk-Related Result Over Time***



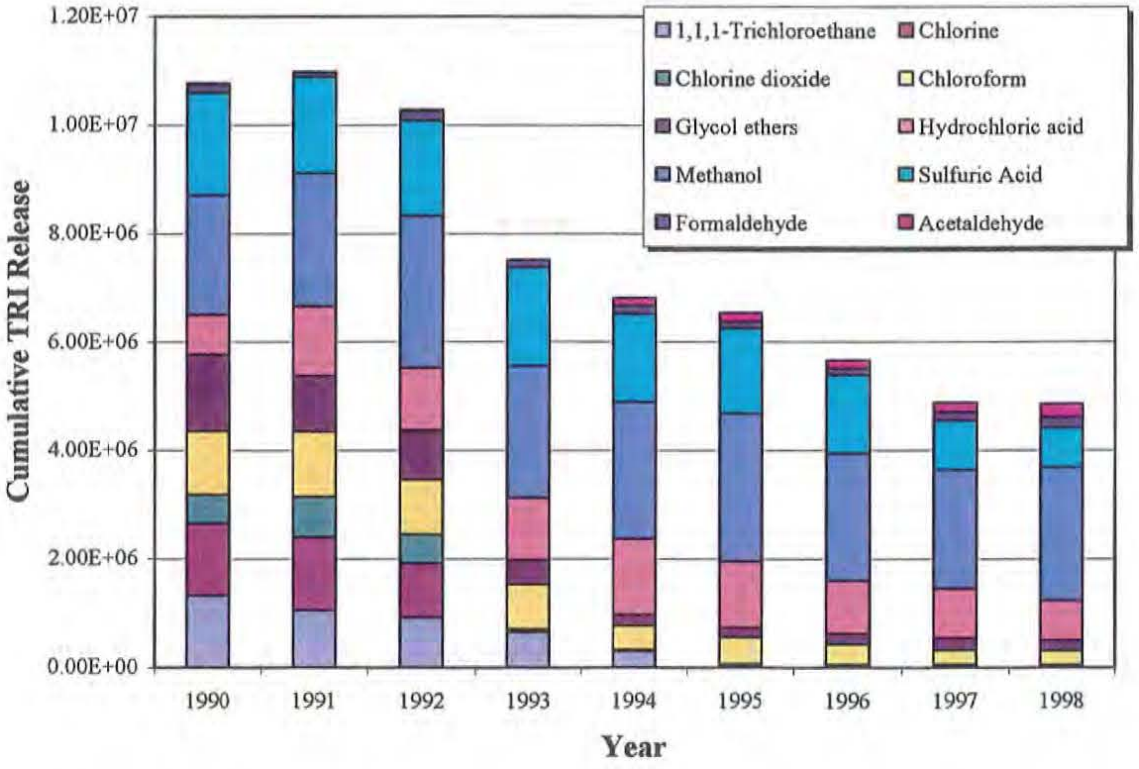

* Ammonia was not included due to changes in reporting requirements in 1995 that significantly changed reported releases.

In Figure 3, the lines show the percent reduction in release quantity or toxicity-weighted release quantity over time. The top line (circles) represents reduction in total pounds released; the bottom line (squares) shows reduction in toxicity-weighted release, and the middle line (triangles) shows reduction in risk-related result. Reductions in all three metrics were substantial between 1992 and 1994, with smaller reductions thereafter. The figure also shows that

reductions appear greater when releases are weighted by toxicity or measured by risk-related result, at least during the years from 1992 to 1994.

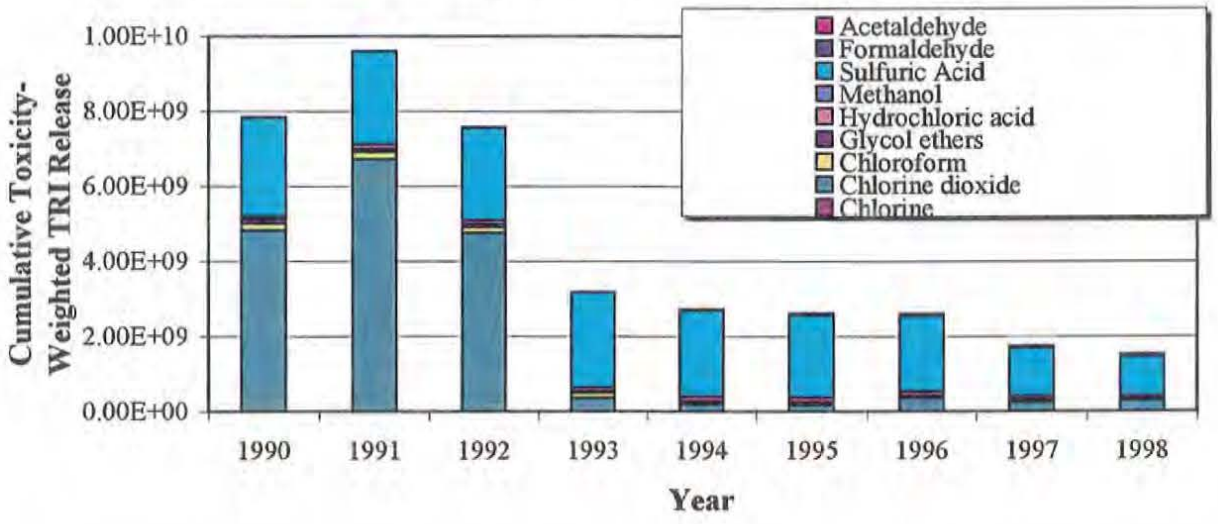
Data in the RSEI model can be summarized to examine the contribution of individual chemicals to the time-trends shown in Figure 3. Figure 4 is a stacked bar chart showing the contributions of the ten most significant chemicals to the total unweighted release. As shown in the figure, reductions in chlorine, chlorine dioxide, chloroform, glycol ethers and 1,1,1-trichloroethane releases were responsible for much of the decline in total releases between 1992 and 1994. Between 1993 and 1996, a reduction in chloroform release and the elimination of a 1,1,1-trichloroethane release caused a small reduction in the overall release quantity. Finally, between 1996 and 1997, the overall release metric dropped due to a reduction in sulfuric acid release. There was no observable change in the total quantity released metric between 1997 and 1998.

**Figure 4. Chemical Contributions to Cumulative TRI Release Over Time**



The greater reductions in toxicity-weighted release largely result from a precipitous drop in chlorine dioxide releases between 1992 and 1994. As shown in Figure 5, the toxicity-weighted release is dominated by sulfuric acid and chlorine dioxide. Prior to 1993, chlorine dioxide was released in substantial quantities. Coupled with the toxicity of chlorine dioxide, those releases represented more than half of the total annual toxicity-weighted release through 1992. Thus, with substantial reductions in chlorine dioxide releases between 1992 and 1993, the total annual toxicity-weighted releases decreased concomitantly. Between 1993 and 1996, there were very few changes in the toxicity-weighted release; both sulfuric acid and chlorine dioxide releases remained relatively constant. From 1996 to 1997, a reduction in the release of sulfuric acid resulted in a measurable change in the total toxicity-weighted release, and a small reduction in sulfuric acid occurred between 1997 and 1998.

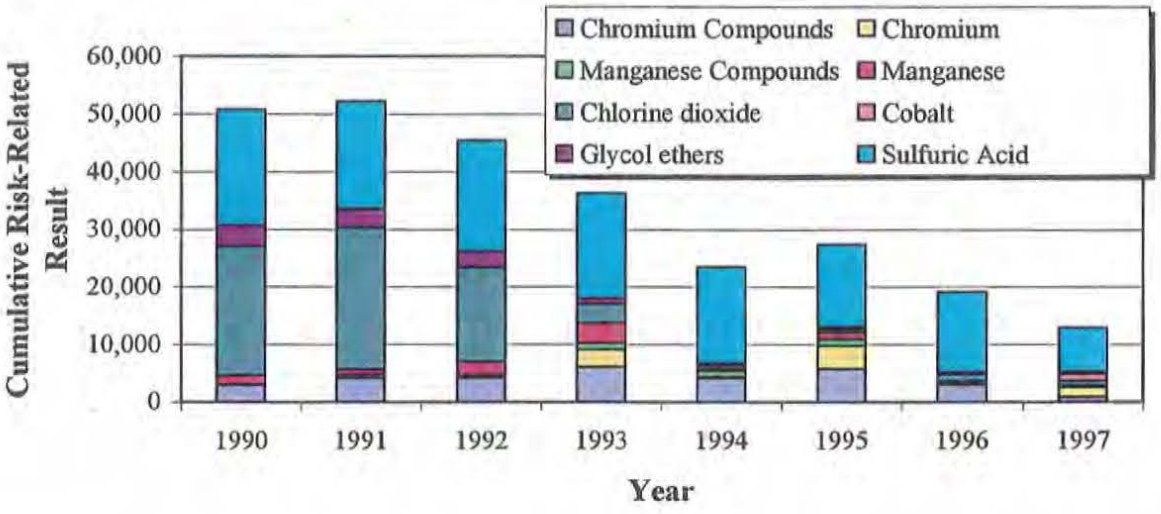
**Figure 5. Chemical Contributions to Cumulative Toxicity-Weighted TRI Release Over Time**




Like the toxicity-weighted release value, the risk-related result metric is dominated by a few chemicals, most notably sulfuric acid, chlorine dioxide, and chromium compounds, as shown in Figure 6. The risk-related result is likewise significantly reduced with decreases in chlorine dioxide emissions between 1992 and 1994. The increase in risk-related result in 1995 appears to result from a significant increase in chromium release coupled with a small increase in chromium

compounds. From 1995 to 1997, reductions in chromium and chromium compounds lead to decreases in the risk-related result.

**Figure 6. Chemical Contributions to Total Risk-Related Result Over Time**




This analysis shows that progress in use reduction and pollution prevention can be measured using not only quantity but also toxicity-weighted quantity and risk-related result metrics, and may yield different assessments about progress. It is of particular interest, for example, that only two chemicals (sulfuric acid and chlorine dioxide) dominated both the toxicity-weighted release and risk-related result metrics from 1990 to 1993, and sulfuric acid continued to dominate both metrics through 1998. Changes reflected in these figures may result from actual changes in releases, or from changes in the way releases are estimated. The reader will also note that chromium is reported separately from chromium compounds, and likewise manganese is separate from manganese compounds. USEPA specifications for TRI reporting allow facilities to report metal releases using these groupings.

### 4.2 Ranking Chemicals Based on Quantity, Toxicity, and Risk-Related Result

In this section, the ability of the RSEI model to rank individual chemicals was explored. Initially, TRI chemicals released into Maine air were ranked on a simple ordinal scale (i.e., 1st,

2nd, 3rd, ...etc) using three different metrics: TRI release quantity, toxicity-weighted release quantity, and risk-related result. Next, the model results for the top ten chemicals ranked by risk-related result were compared to evaluate differences in the magnitude of the actual risk-related results and toxicity weighted release quantity among chemicals of neighboring ordinal ranks. Finally, the magnitude of each input (release quantity, toxicity, and exposure) was examined to explore which inputs are most important in determining each chemical's rank. From these analyses, it is clear that chemical rankings based on quantity released alone differ greatly from rankings based on either toxicity-weighted releases or risk-related results. In addition, the analyses showed that chemical variation in toxicity weights appears to be a major determinant of variation in risk-related results (at least for the air pathways). Exposure modeling does exert a significant influence on the ranking for a few select chemicals, and may be more important at lower levels of aggregation (e.g., by facility or county).

### 4.2.1 Ordinal Ranking of Chemicals

Table 9 shows the top ten chemicals as ranked on a ordinal scale first by quantity released, second by toxicity-weighted release, and third by risk-related result. The ranking by toxicity-weighted release is quite similar to the ranking by risk-related result. However, the table shows a significant difference between ranking based on release quantity and ranking by either toxicity-weighted release or risk-related result. For example, when ranked by TRI pounds, methanol has the highest score. However, when methanol's low toxicity is considered, it drops to 19th in rank by toxicity-weighted pounds. Finally, when the risk-related result is used for ranking, methanol drops further to 24th. By contrast, chromium compounds, which rank 43rd in terms of pounds released, move to 6th when their high toxicity is considered, and to 2nd when exposure, toxicity, and population are considered. Results for chromium, manganese compounds, and manganese are similarly striking; each ranks low in terms of quantity released but ranks high on toxicity-weighted release and risk-related result. Recall, however, that in assigning a toxicity weight to a class of compounds (e.g., glycol ethers, chromium compounds), the RSEI model applies the highest toxicity weight available for any single member of the group. For example, RSEI assumes that all chromium and chromium compounds have the toxicity of hexavalent chromium, although environmental releases may be of the less toxic trivalent or elemental forms.

**Table 9. Ranking of Chemicals Released to Maine Air by Various RSEI Output Options**

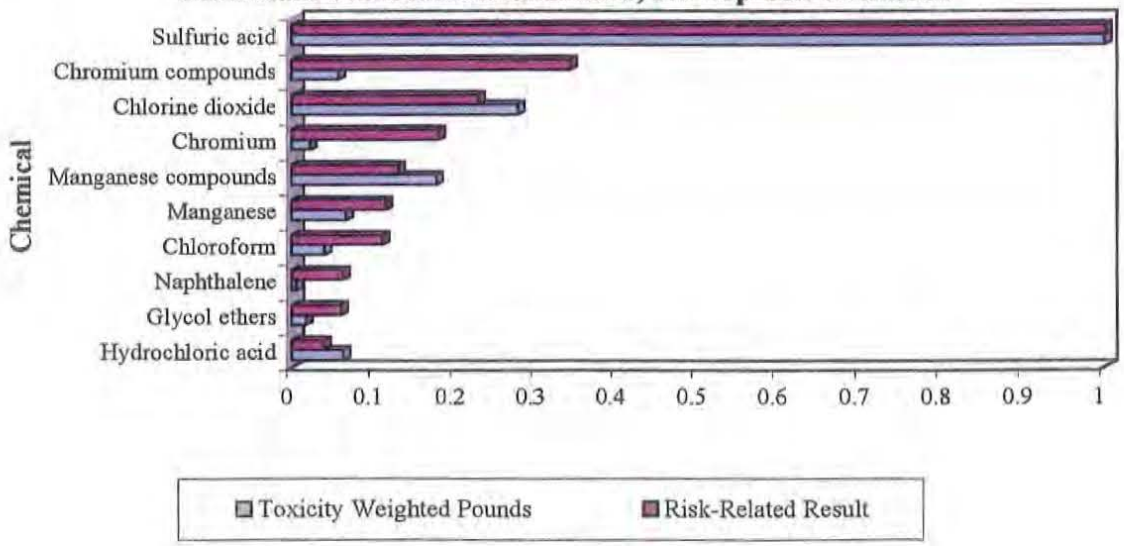
| Chemical | Rank by TRI Pounds | Rank by Pounds x Toxicity Weight | Rank by Risk-Related Result |
|---|---|---|---|
| *Ordered by Top Ten by TRI Pounds* | | | |
| Methanol | 1 | 19 | 24 |
| Ammonia | 2 | 13 | 20 |
| Sulfuric acid | 3 | 1 | 1 |
| Hydrochloric acid | 4 | 5 | 10 |
| n-Hexane | 5 | 16 | 14 |
| Toluene | 6 | 21 | 18 |
| Chloroform | 7 | 8 | 7 |
| Acetaldehyde | 8 | 7 | 11 |
| Glycol ethers | 9 | 11 | 9 |
| Formaldehyde | 10 | 12 | 13 |
| *Ordered by Top Ten by Risk-Related Result* | | | |
| Sulfuric acid | 3 | 1 | 1 |
| Chromium compounds | 43 | 6 | 2 |
| Chlorine dioxide | 13 | 2 | 3 |
| Chromium | 51 | 10 | 4 |
| Manganese compounds | 29 | 3 | 5 |
| Manganese | 38 | 4 | 6 |
| Chloroform | 7 | 8 | 7 |
| Naphthalene | 23 | 14 | 8 |
| Glycol ethers | 9 | 11 | 9 |
| Hydrochloric acid | 4 | 5 | 10 |

Hydrochloric acid is an example of a chemical for which environmental fate and exposure significantly alter ranking. Hydrochloric acid ranks 4$^{th}$ in quantity released, and 5$^{th}$ by toxicity-weighted quantity released, but drops to 10$^{th}$ when ranked by risk-related result. This table shows that the consideration of toxicity and other risk-related features may significantly alter ranks. Notably, this table does not include dioxins, which were not reported on TRI until the year 2000, or mercury, which may be under-weighted because indirect food chain exposure pathways were not assessed and water releases were not included.

### 4.2.2 Comparisons Among Risk-Related Result Values

When ranking is performed using a simple ordinal scale as above, information about the magnitude of differences in toxicity weighted release or risk-related result among chemicals is lost. Figure 7 shows a bar chart of toxicity-weighted release quantity and risk-related results (scaled relative to the chemical with the highest value) for the top ten chemicals released to Maine air as ranked by risk-related result. The bar chart shows that both the toxicity-weighted release and the risk-related result for sulfuric acid exceed the values of the next highest chemicals almost three-fold, indicating that sulfuric acid may represent a substantially greater public health concern than chemicals of neighboring ranks ($2^{nd}$ and $3^{rd}$, etc.). Further, the chart shows considerable differences between the relative magnitude of the risk-related result and the toxicity-weighted pounds for chromium compounds, chromium, chloroform, naphthalene, and glycol ethers. For example, the risk-related result for chromium is almost 40% of the maximum, but the toxicity-weighted pounds value is less than 10% of the maximum. The disparity between the risk-related result values and corresponding toxicity-weighted release values indicate that exposure modeling and population density will significantly affect the ranking for some chemicals.

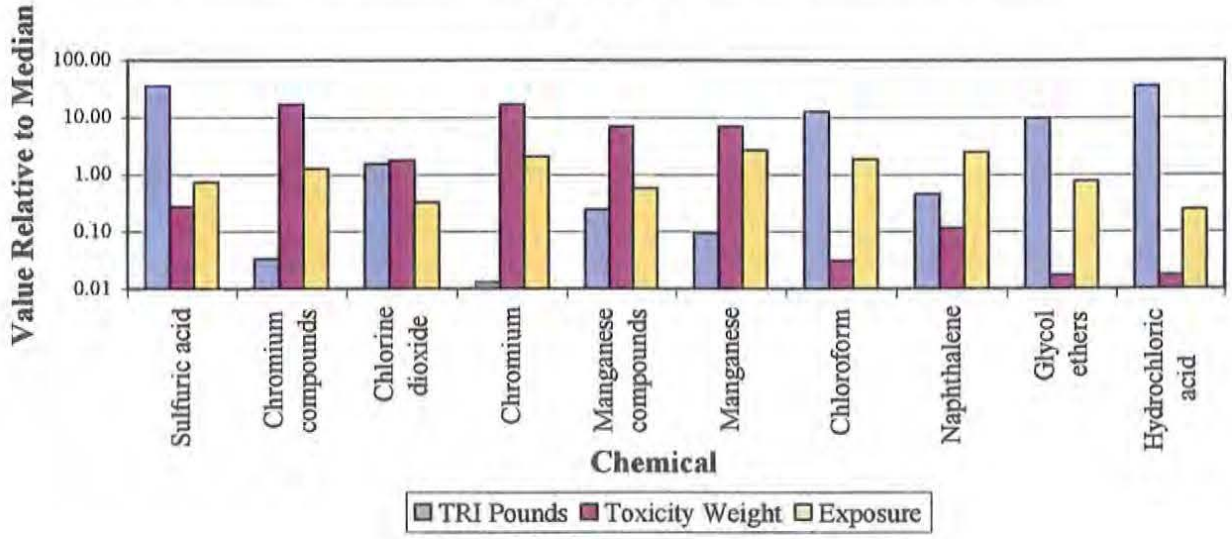
**Figure 7. Toxicity-Weighted Pounds and Risk-Related Results (Scaled to Maximum Value Across Chemicals) for Top Ten Chemicals**



### 4.2.3 Relative Contributions of Inputs to Risk-Related Results

A chemical may rank high on the risk-related scale either because it is released in large quantities, is of high toxicity, results in large population exposure, or some combination of all three factors. Indeed, this is apparent from inspection of the ordinal rankings of chemicals using the three metrics presented in Table 9. The relative contribution of these three factors (release quantity, toxicity weight, and population exposure) to the risk-related result can be explored using various input data and results from the RSEI model. For example, the risk-related result (R) can be approximated as a product of quantity released (Q), toxicity weight (T), and population exposure (E), where the latter term is back calculated as: $E = R / (Q \times T)$. To facilitate comparisons across chemicals and across these three parameters, a given chemical's value for Q, T, and E can be normalized to the median value for a group of chemicals. Figure 8 illustrates results of performing such an analysis on the 10 top ranked chemicals by the risk-related result.

**Figure 8. Magnitude of Input Compared to Median Value Across Chemicals**



The sizes of the bars in Figure 8 indicate the relative magnitude of each input as compared to the median value among the group of chemicals. For example, the median value (among the top ten) for TRI release quantity is 20,695 lbs. The release quantity bar for sulfuric acid shows that its release is 35 times greater than the median, meaning that more than 700,000 lbs of sulfuric acid were released in 1998. Because the bar for toxicity is about 5 times lower than the median value and the exposure bar is close to the median, it becomes apparent that the release quantity is the major factor contributing to its first place rank. Looking across the ten chemicals, one can group them into three categories: 1) those that rank high because of large quantities released, such as sulfuric acid, chloroform, glycol ethers, and hydrochloric acid; 2) those that rank high because of potential toxicity, such as chromium compounds, chromium, and manganese compounds; and 3) others such as chlorine dioxide, manganese, and naphthalene that rank high because of a combination of factors. Chlorine dioxide's rank results from a combination of release and toxicity; manganese's rank results from a combination of toxicity and exposure. Naphthalene is the only chemical among the top ten for which exposure appears to be driving the ranking. As the chart suggests, the differences among the exposure values are small; the range of the exposure variable over the top ten chemicals is one order of magnitude. In contrast, both release quantities and toxicity weights range over approximately three orders of magnitude (among the top ten chemicals only).

As a more formal evaluation, statistical regression analyses were performed to assess the extent to which variation in either quantity released or toxicity-weighted quantity released explains the observed variation in risk-related results for all chemicals reported released into Maine air in 1998 (n=55). Specifically, the log of the risk-related result was regressed against the log of quantity released and separately against the log of toxicity-weighted quantity released. The scatter plots are given as Figures 9 and 10. Regression analyses performed on these data show that quantity released explained only 15% of the variance in the risk-related result, and thus is a poor predictor of risk-related result on average (Figure 9) – as was indicated by the comparison of the ordinal rankings. By contrast, the toxicity-weighted pounds metric explained 88% of the variance in the risk-related result (Figure 10). Thus variation in toxicity-weighted pounds is the major source of variation in the risk-related result, at least for inhalation exposures from air

releases. Whether this result would hold for other exposure pathways, or even for the same exposure pathway in other states is unclear. For all chemicals released to Maine air in 1998, the quantity released varied over 400,000-fold, and toxicity weights varied more than 2 million-fold. By contrast, the exposed population sizes used by the RSEI model (on a facility-specific basis) varied only 30-fold.

**Figure 9. Log Risk-Related Result vs. Log TRI Pounds**

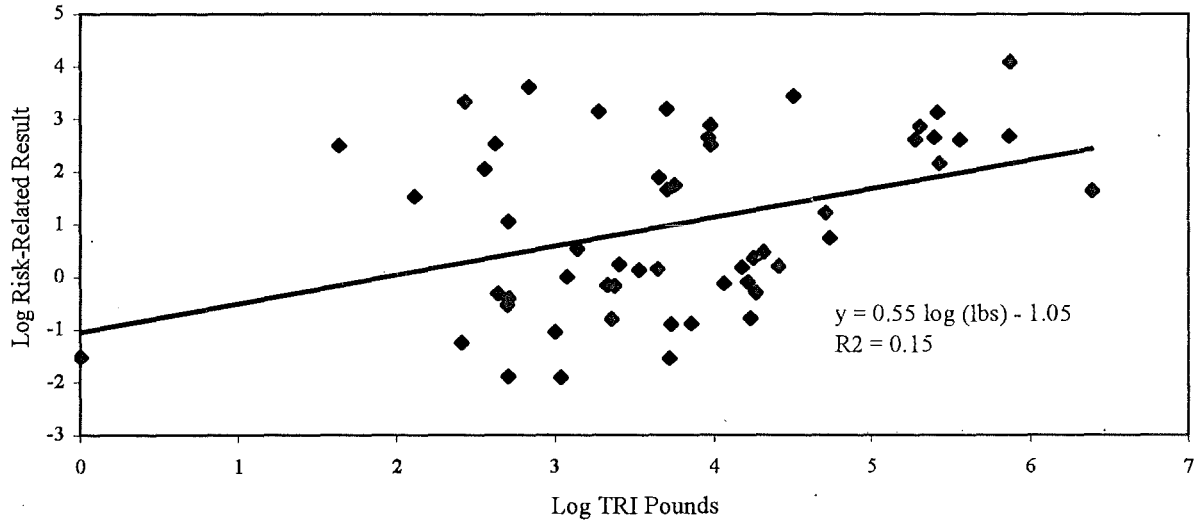
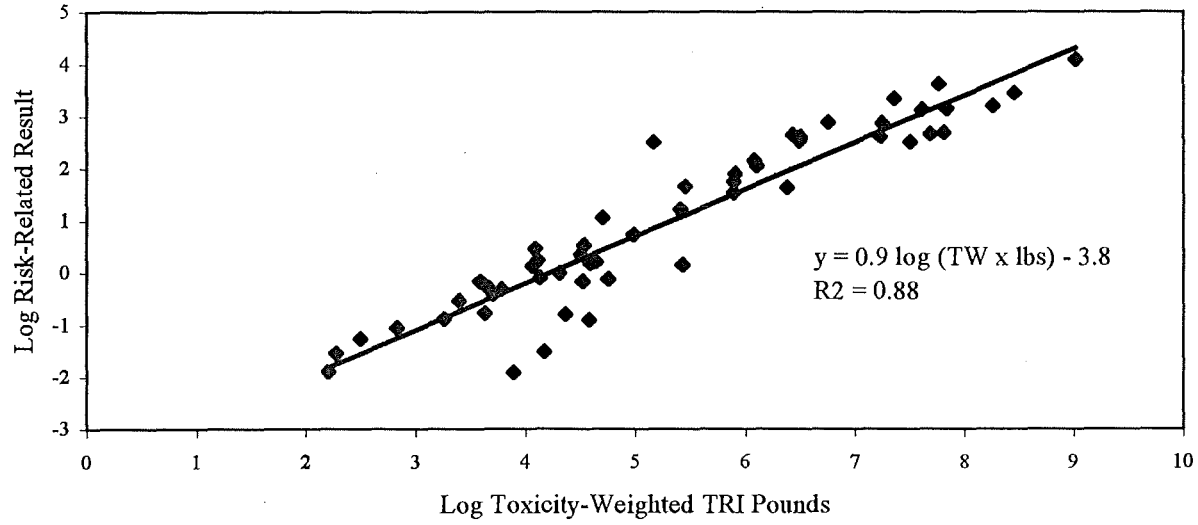



**Figure 10. Log Risk-Related Result vs. Log Toxicity-Weighted TRI Pounds**



### 4.3 Focusing Use Reduction and Pollution Prevention Efforts

Having identified the top ranked chemicals and developed some intuition about the basis for that ranking, the logical next analysis would be to identify which facilities are contributing the most toward environmental releases of these potentially high priority chemicals. The RSEI model allows the user to examine the contribution of each facility to the estimated statewide aggregated result on a chemical-by-chemical basis. To illustrate this capability, *chemical profiles* for each of the top ten chemicals were developed to show how this additional information from the RSEI model could be summarized. These 1-page chemical profiles were designed to address three fundamental questions about the top-ranked chemicals: 1) what is driving the rank – release quantity, toxicity, or exposure? 2) how confident are we in the toxicity weight used by the model? and 3) what facilities are releasing the chemical and what are their contributions to the risk-related result?

Chemical profiles for sulfuric acid, chromium, and glycol ethers are given as Figures 11, 12, and 13. Other profiles can be found in Appendix A. Each chemical profile first shows the relative magnitude of release quantity, toxicity weight, and exposure to the risk-related result in a bar chart similar to Figure 8, indicating which of these three factors drives the rank for that particular chemical. Second, the profile summarizes the toxicity information used to derive the toxicity weight. Toxicity weight information includes the toxicological endpoint driving the weight, the source of the toxicity value, a ranking of confidence in the toxicity value (for noncancer endpoints) or USEPA weight-of-evidence carcinogenicity classification (for cancer endpoints), and a qualitative discussion of confidence in the toxicity value. Finally, the profile shows a pie chart showing the facilities with air releases of the chemical and their relative contributions to the total risk-related result. It should be noted that while the RSEI model contains the raw data used to develop these profiles (with the exception of the details on the toxicological values), the program does not summarize the data in the form shown here; the data must be exported to other programs for summarization.

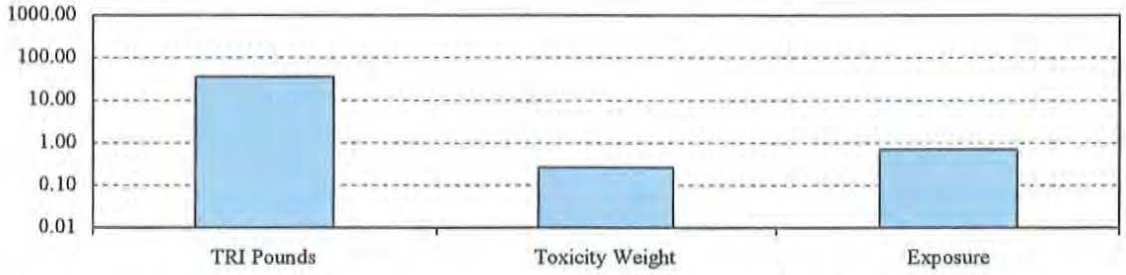
These chemical profiles, or similar data summaries, can provide the DEP and other interested parties with information helpful in focusing use reduction and pollution prevention efforts to those chemicals and facilities associated with the highest risk-related results. The inclusion of the top two sections of the chemical profiles are intended to highlight those chemicals that may warrant closer scrutiny of either toxicity values or exposure modeling because of data insufficiencies or potential chemical speciation uncertainties. For example, the chemical profile for chromium (Figure 12) includes information that should raise several red flags. The profile depicts a chemical that ranks high because of its high potential toxicity weight despite a small quantity released. But the qualitative discussion of confidence in toxicity information highlights that the assigned toxicity weight is only appropriate for the hexavalent species and results would be positively skewed if a different chemical species (trivalent or elemental) were present. Furthermore, the low TRI release quantity apparent from inspection of the bar chart should be a warning to carefully verify reported values, as these data may not have historically received the scrutiny that larger releases may have. The profile for glycol ethers (Figure 13) similarly notes that the toxicity weight is based on the most toxic member of a group of glycol ethers.

Figures 11,12, and 13 all illustrate chemicals with a few facilities identified as the primary contributors to the risk-related result. The profile for sulfuric acid (Figure 11) indicates a scenario where releases are specific to a single industry with a number of facilities contributing to the total, but just two sources contribute 60% to the risk-related result. The profile for chromium (Figure 12) indicates a more diverse group of industries contributing to the risk-related result, with four facilities contributing to more than 80% to the total. The profile for glycol ethers (Figure 13), while not exclusive, is dominated by a single industry with a single facility contributing close to 80% to the risk-related result. It should be emphasized that these chemical profiles were prepared using 1998 TRI release data and may not reflect current releases from the identified facilities.

## Figure 11. Chemical Profile for Sulfuric Acid

**CHEMICAL PROFILE: Sulfuric Acid**
**RISK-RELATED RANK (MAINE AIR 1998):** 1

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - bronchiolar epithelial hyperplasia
Source of Toxicity Value: Derived specifically for OPPTEIM

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: Although the toxicity value for sulfuric acid was developed specifically for the OPPTEIM model, there is an adequate toxicological database behind the value. Medium confidence in the toxicity value is warranted.

***Source Information***

**Facilities Contributing to Sulfuric Acid Risk-Related Result (Maine, Air, 1998)**

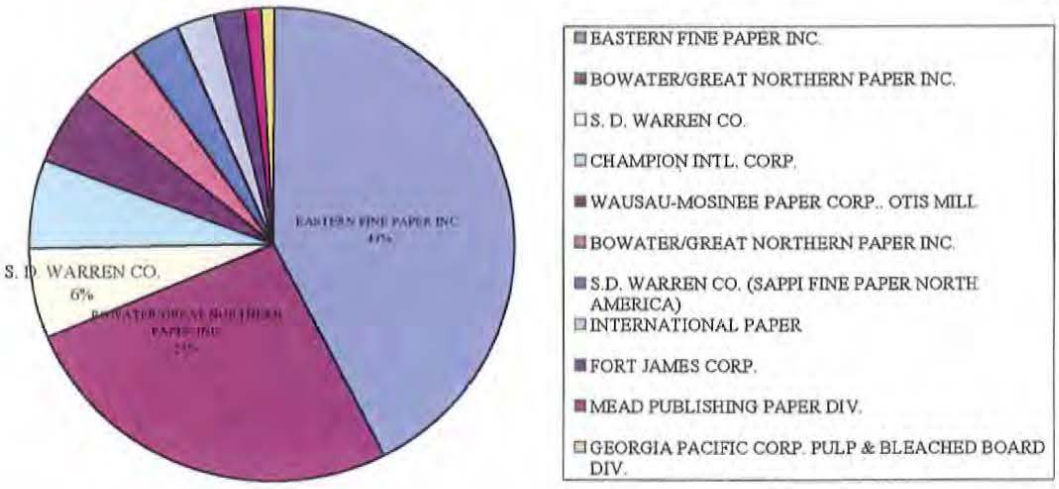
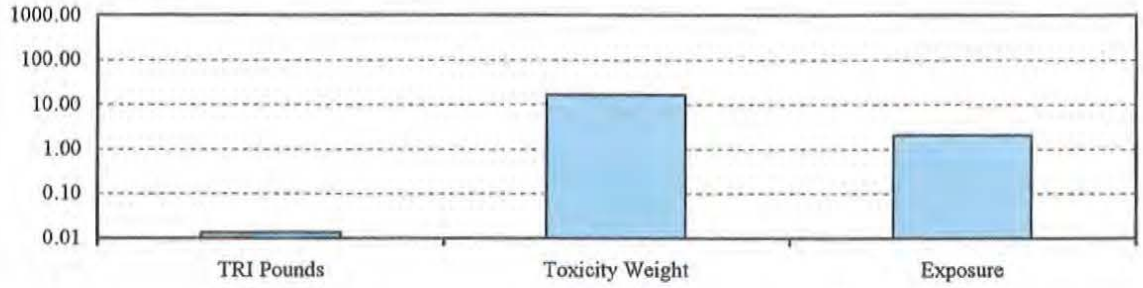


Figure 12. Chemical Profile for Chromium

**CHEMICAL PROFILE: Chromium**
**RISK-RELATED RANK (MAINE AIR 1998):** 4

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Cancer
Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | **Not Applicable** |
|---|---|---|---|
| Known Human Carcinogen | **Probable Human Carcinogen** | Possible Human Carcinogen | Not Applicable |

EPA Weight of Evidence Classification for Carcinogens

Qualitative Discussion of Confidence: The toxicity value for chromium assumes that exposures are to the Cr (VI) valence state. If actual exposures are to the Cr (III) valence state, the toxicity weight used here would be inappropriately high.

***Source Information***

**Facilities Contributing to Chromium Risk-Related Result (Maine, Air, 1998)**

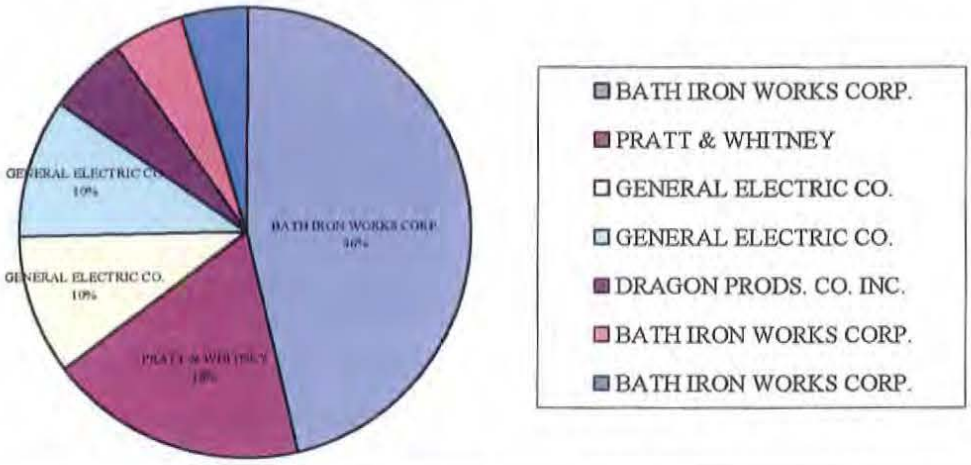
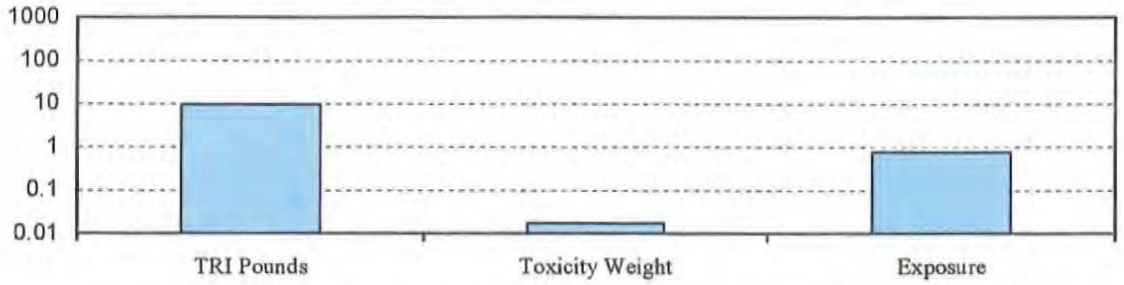


Figure 13. Chemical Profile for Glycol Ethers

**CHEMICAL PROFILE: Glycol Ethers**
**RISK-RELATED RANK (MAINE AIR 1998):** 9

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - testicular effects
Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

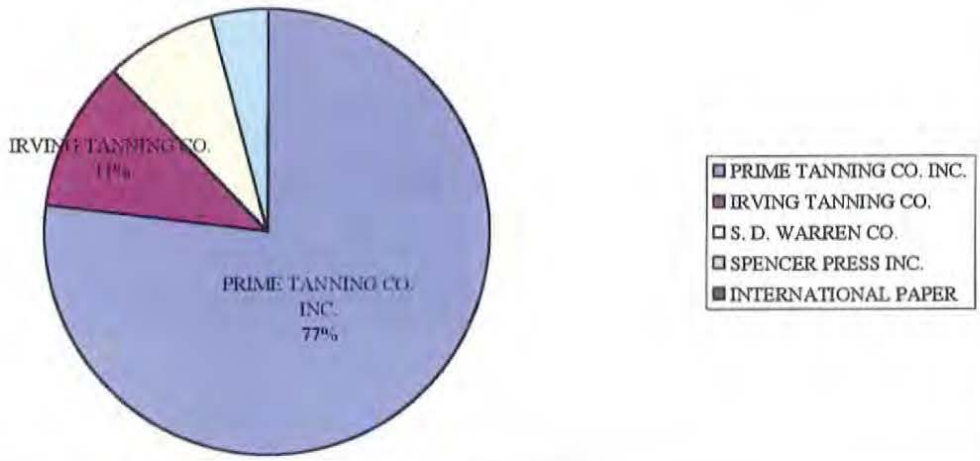
EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: The model uses the lowest RfC among a group of glycol ethers.

***Source Information***

**Facilities Contributing to Glycol Ethers Risk-Related Result (Maine, Air, 1998)**



### 4.4 Chemical-Specific Reporting Thresholds

Current TRI reporting is linked to the amount of each chemical manufactured, processed, or otherwise used by each facility. Chemical releases must be reported by facilities that manufacture or process more than 25,000 pounds or otherwise use more than 10,000 pounds of a given chemical. Facilities that manufacture, process, or otherwise use smaller quantities of chemicals do not report their chemical releases (except for PBTs beginning in the 2000 reporting year). As with ranking chemicals based solely on quantity, setting reporting thresholds based on quantity ignores differences in the chemicals' toxicity and other features.

The Maine DEP Air Bureau has implemented some linkage between toxicity and reporting requirements for air toxics. For its emissions inventory, the Air Bureau set an initial reporting threshold of 2,000 lbs (use or release quantity) for all chemicals, and from that starting point reduced the threshold for some individual chemicals based on toxicity. For chemicals carrying an USEPA weight-of-evidence carcinogen classification of A or B (indicating known human carcinogen and probable human carcinogen, respectively), the Air Bureau uses a reporting threshold of 200 lbs. Chromium and dioxin were each assigned a reporting threshold of 10 lbs because of their toxicity.

USEPA has likewise begun to consider chemical properties such as toxicity in revising reporting thresholds for TRI. The USEPA has recently adopted new, lower TRI reporting thresholds for a group of chemicals known as PBTs (Persistent and Bioaccumulative Toxins). Intrinsic chemical properties cause PBTs to remain in the environment for long periods of time and to increase in concentration through the food chain, increasing their potential effects on species at the top of the food chain (e.g., humans). The reduction in reporting thresholds is part of a larger, agency-wide initiative on PBTs. Through the use of national action plans aimed at a select group of PBTs, USEPA intends to reduce the potential for human and ecological effects from PBTs in the environment. For example, beginning in the year 2000, the reporting thresholds for mercury and polychlorinated biphenyls (PCBs) were lowered to 10 pounds (manufactured, processed, or

otherwise used) from the previous minimum of 25,000 pounds (manufactured or processed) or 10,000 pounds (otherwise used). In addition, for the first time in the 2000 TRI reporting year, USEPA will require facilities that (inadvertently) manufacture 0.1 grams of dioxin or dioxin-like compounds to report releases to the TRI (64 FR 58666-58753). Chemical-specific reporting thresholds may become more common as additional chemicals are added to the list of PBTs.

As an investigation of whether the current TRI reporting thresholds could miss a facility releasing significant quantities of a potentially toxic chemical, three chemicals' releases reported on TRI were compared with releases reported to the DEP Air Bureau under lower reporting thresholds. These chemicals, chromium (and compounds), manganese (and compounds) and cobalt (and compounds), were selected because their high toxicity results in a high risk-related rank even when releases are relatively low. Facilities report chromium releases to the Air Bureau if they use more than 10 lbs annually and report manganese and cobalt releases if they use more than 2,000 lbs. In contrast, at least 10,000 lbs must be used before TRI reporting is required. Among the facilities reporting a release to the Air Bureau but not to TRI, there was one facility whose *use* of manganese and compounds was reported to be 6,900 lbs and whose *release* of manganese and compounds was reported to be 6,537 lbs. This release quantity, which would not appear on TRI, is approximately equal to the *total* quantity of manganese compounds reported on TRI in Maine in 1998. For that TRI reporting year, a total release of 5,064 lbs resulted in manganese compounds ranking 5$^{th}$ among risk-related releases to Maine air in 1998. Similarly, a total release of only 1,913 lbs of manganese resulted in its 6$^{th}$ place rank.

The toxicity weights and quantities released for the top ten chemicals (as ranked by risk-related result) were examined to see whether an empirical basis for linking toxicity to reporting thresholds might be worthy of investigation. Table 10 reports these data and shows that the ranges both of toxicity weights and of release quantities are large, even among the top ten chemicals. Toxicity weights range from 90 to 86,000 (a range of almost 1,000-fold); release quantities range from 271 to 739,789 pounds (a range of almost 3,000-fold). The only general tendency apparent from inspection of these data is that for chemicals with high toxicity weights

(> 30,000), chemical releases well below 10,000 lbs per year were sufficient to result in high ranking.

Linking reporting thresholds to toxicity is nonetheless problematic. As noted above, most current reporting thresholds are based on the quantity of chemical *manufactured, processed, or used*, not the quantity released. The release quantity is the relevant quantity from a risk-related perspective (notwithstanding potential occupational exposures or accidental releases). The relationship between use and release is likely to be facility-specific, depending upon manufacturing and processing patterns as well as existing environmental controls. Further, many facilities that do not meet the reporting thresholds do not currently track releases. As a result, it may be difficult to empirically define a relationship between release and use. One could, of course, make assumptions about the relationship between release and use, or alternatively modify existing (use-based) reporting thresholds based on toxicity alone. Using the RSEI toxicity weight system, for example, one could develop chemical-specific reporting thresholds (based on use) that are proportional to toxicity weights. Given that significant releases of toxic chemicals are missed by existing TRI reporting thresholds, it is clear that current reporting thresholds should be revisited. However, the question remains as to the best approach for revising reporting thresholds according to toxicity.

**Table 10. Toxicity Weights and Release Quantities for Top Ten Chemicals**

| Chemical | Rank by Risk-Related Result | RSEI Toxicity Weight | Quantity Released in 1998 (lbs) |
|---|---|---|---|
| Sulfuric acid | 1 | 1,400 | 739,789 |
| Chromium compounds | 2 | 86,000 | 685 |
| Chlorine dioxide | 3 | 9,000 | 31,912 |
| Chromium | 4 | 86,000 | 271 |
| Manganese compounds | 5 | 36,000 | 5,064 |
| Manganese | 6 | 36,000 | 1,913 |
| Chloroform | 7 | 160 | 258,799 |
| Naphthalene | 8 | 600 | 9,479 |
| Glycol ethers | 9 | 90 | 201,498 |
| Hydrochloric acid | 10 | 90 | 728,062 |

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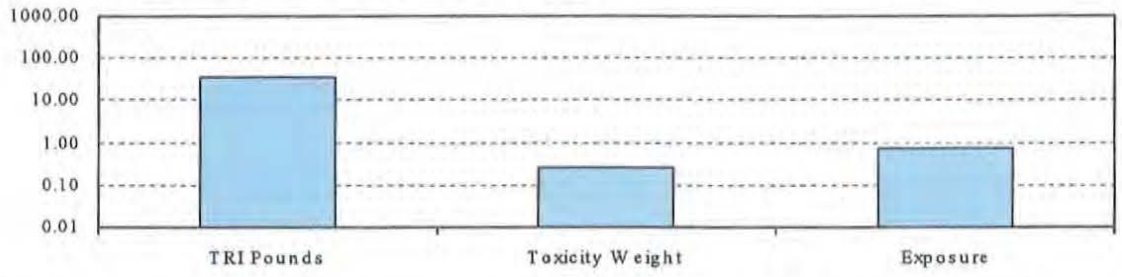
# APPENDIX A

# CHEMICAL PROFILES

**CHEMICAL PROFILE: Sulfuric Acid**
**RISK-RELATED RANK (MAINE AIR 1998):** 1

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - bronchiolar epithelial hyperplasia
Source of Toxicity Value: Derived specifically for OPPTEIM

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

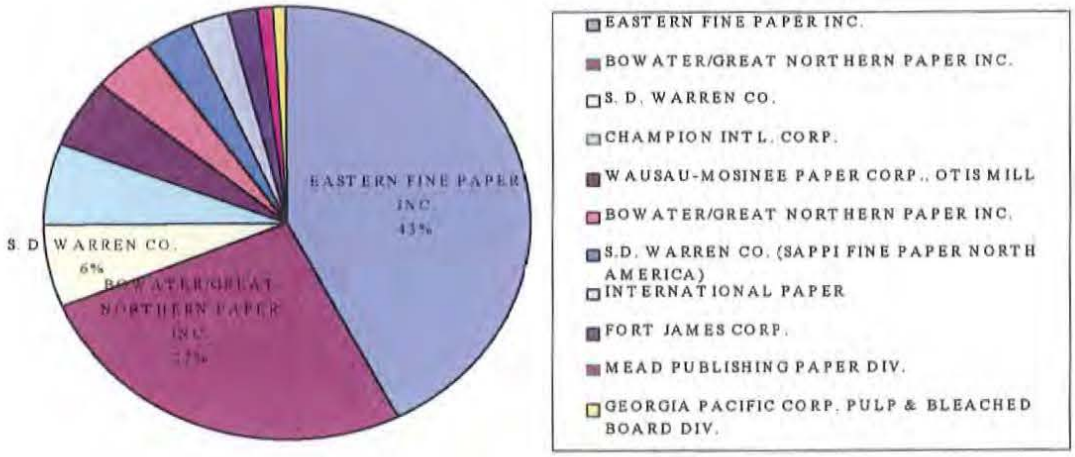
EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: Although the toxicity value for sulfuric acid was developed specifically for the OPPTEIM model, there is an adequate toxicological database behind the value. Medium confidence in the toxicity value is warranted.

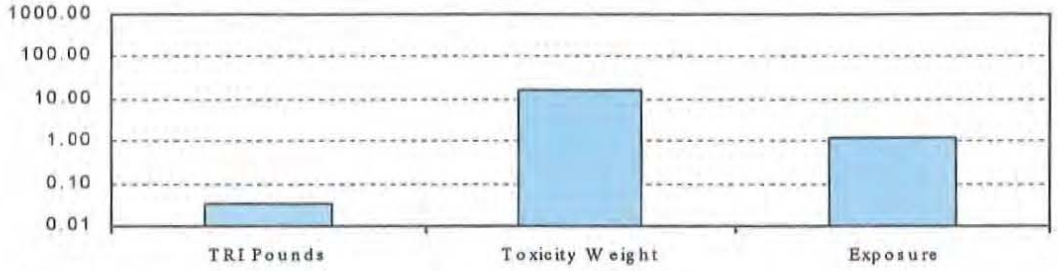
***Source Information***

**Facilities Contributing to Sulfuric Acid Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Chromium Compounds**
**RISK-RELATED RANK (MAINE AIR 1998):** 2

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Cancer
Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|
| | **Probable Human Carcinogen** | | |

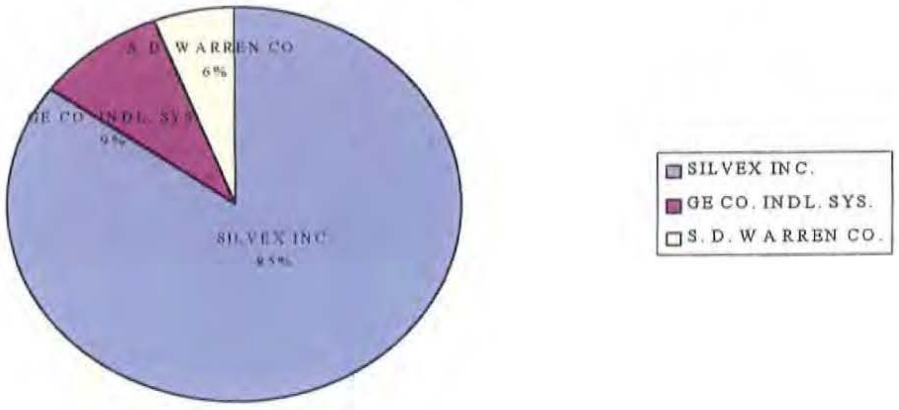
EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | Not Applicable |
|---|---|---|---|
| | **Probable Human Carcinogen** | | |

Qualitative Discussion of Confidence: The toxicity value for chromium compounds assumes that exposures are to the Cr (VI) valence state. If actual exposures are to the Cr (III) valence state, the toxicity weight used here would be inappropriately high.

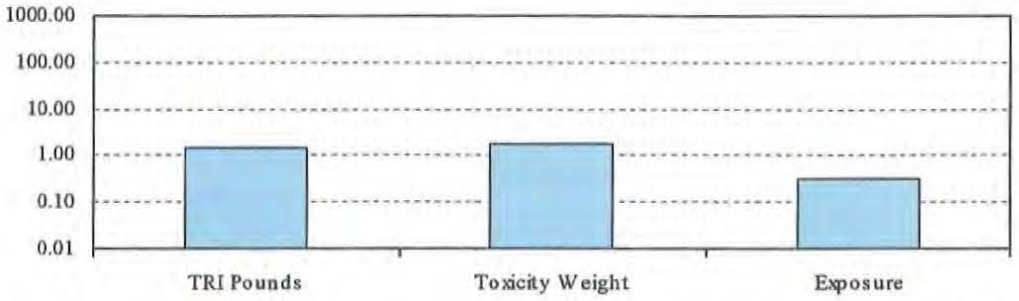
***Source Information***

**Facilities Contributing to Chromium Compounds Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Chlorine Dioxide**
**RISK-RELATED RANK (MAINE AIR 1998):** 3

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

| | |
|---|---|
| Endpoint Driving Toxicity Weight: | Noncancer - lung damage |
| Source of Toxicity Value: | IRIS |

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|

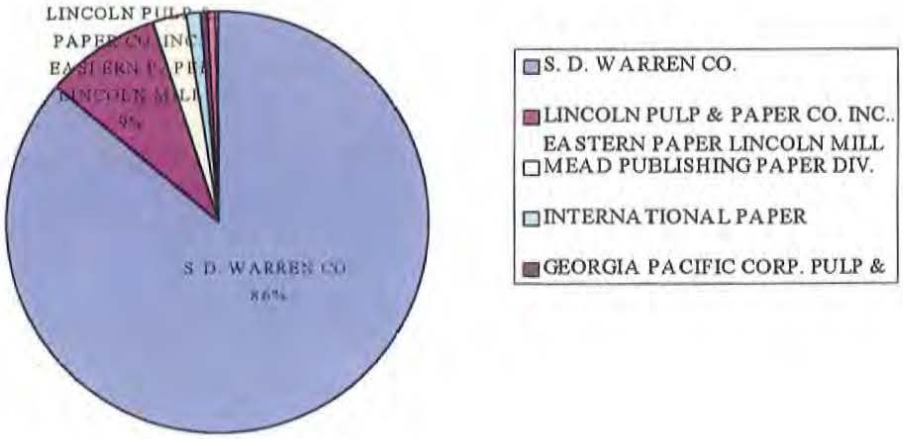
EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: No significant concerns regarding the toxicity value for chlorine dioxide were identified.

***Source Information***

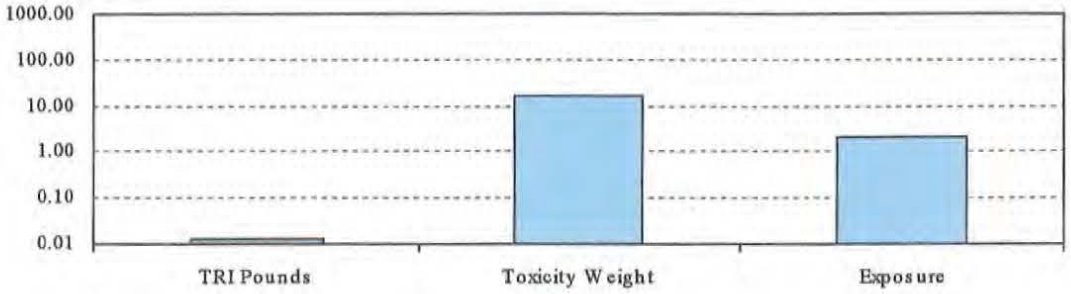
**Facilities Contributing to Chlorine Dioxide Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Chromium**

**RISK-RELATED RANK (MAINE AIR 1998):** 4

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Cancer

Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|
| | | | |

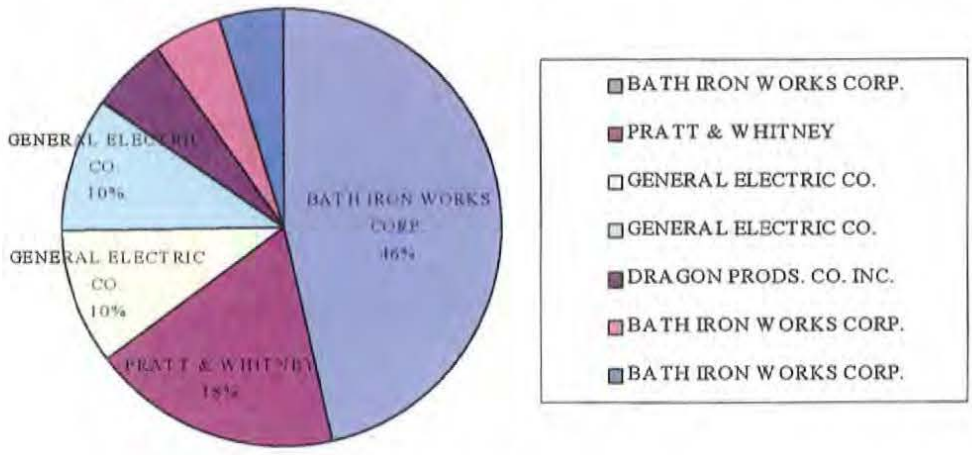
EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | Not Applicable |
|---|---|---|---|
| | | | |

Qualitative Discussion of Confidence: The toxicity value for chromium assumes that exposures are to the Cr (VI) valence state. If actual exposures are to the Cr (III) valence state, the toxicity weight used here would be inappropriately high.

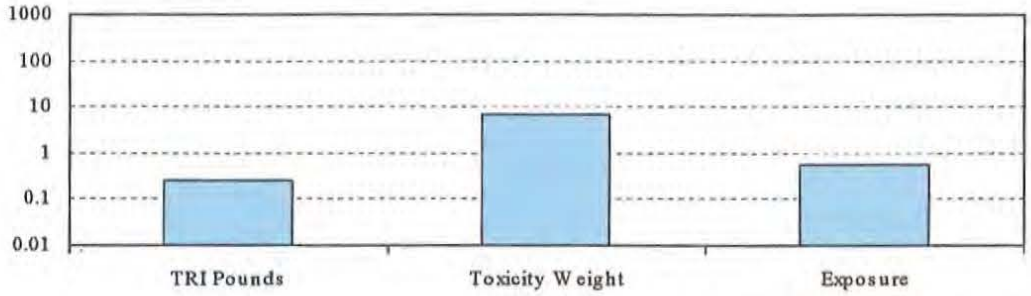
***Source Information***

**Facilities Contributing to Chromium Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Manganese Compounds**
**RISK-RELATED RANK (MAINE AIR 1998):** 5

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

| | |
|---|---|
| Endpoint Driving Toxicity Weight: | Noncancer - neurobehavioral function |
| Source of Toxicity Value: | HEAST |

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|

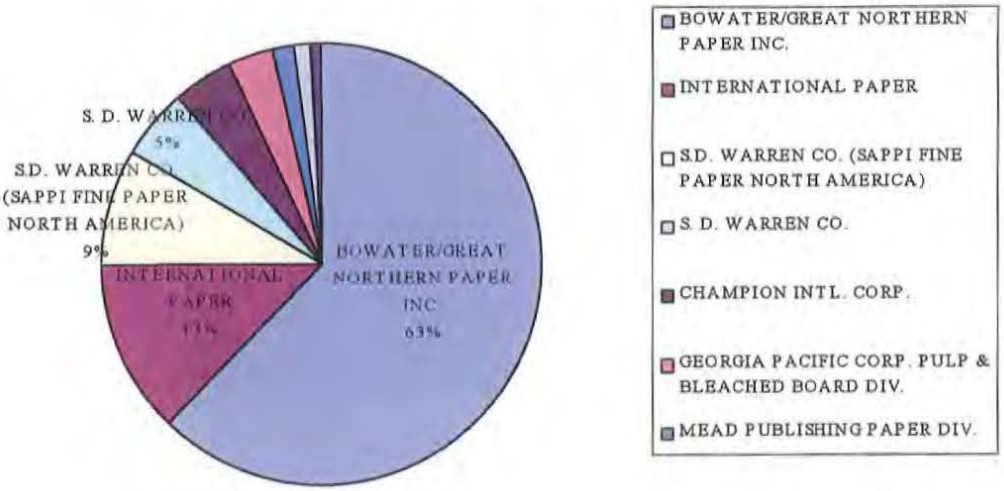
EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | Not Applicable |
|---|---|---|---|

Qualitative Discussion of Confidence: No significant concerns regarding the toxicity value for manganese compounds were identified.

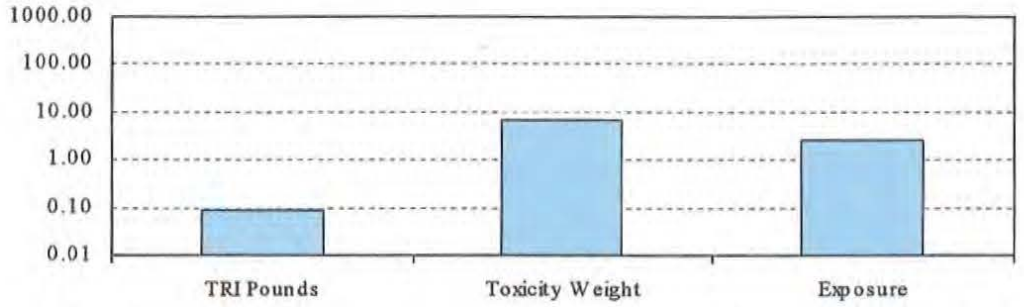
***Source Information***

**Facilities Contributing to Manganese Compounds Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Manganese**
**RISK-RELATED RANK (MAINE AIR 1998):** 6

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

| | |
|---|---|
| Endpoint Driving Toxicity Weight: | Noncancer - neurobehavioral function |
| Source of Toxicity Value: | HEAST |

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

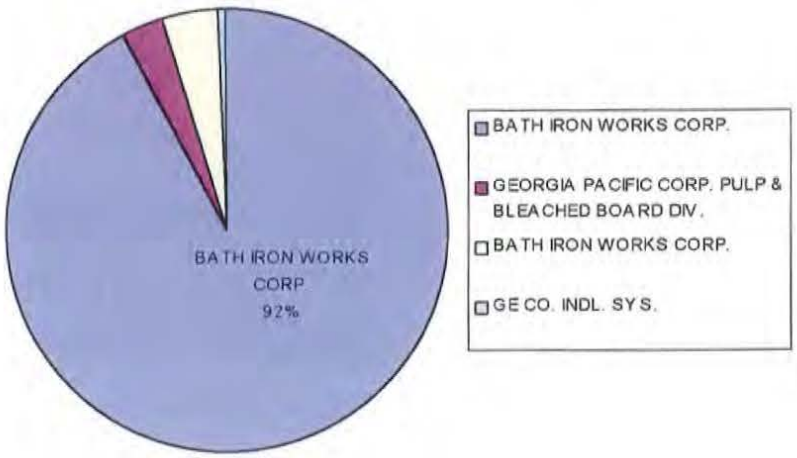
EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: No significant concerns regarding the toxicity value for manganese were identified.

***Source Information***

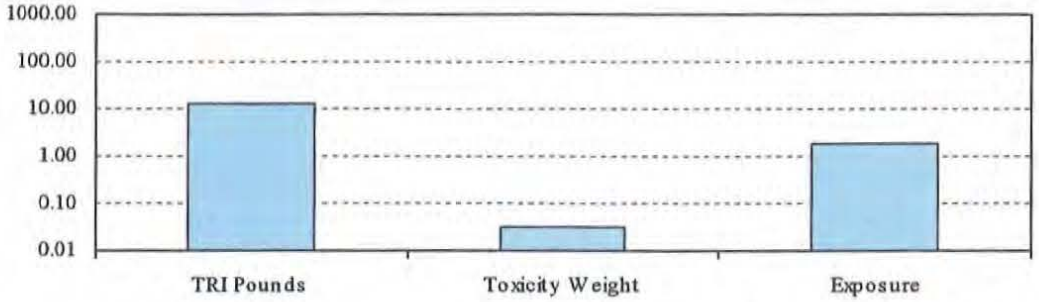
**Facilities Contributing to Manganese Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Chloroform**

**RISK-RELATED RANK (MAINE AIR 1998):** 7

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Cancer

Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|
| | | | |

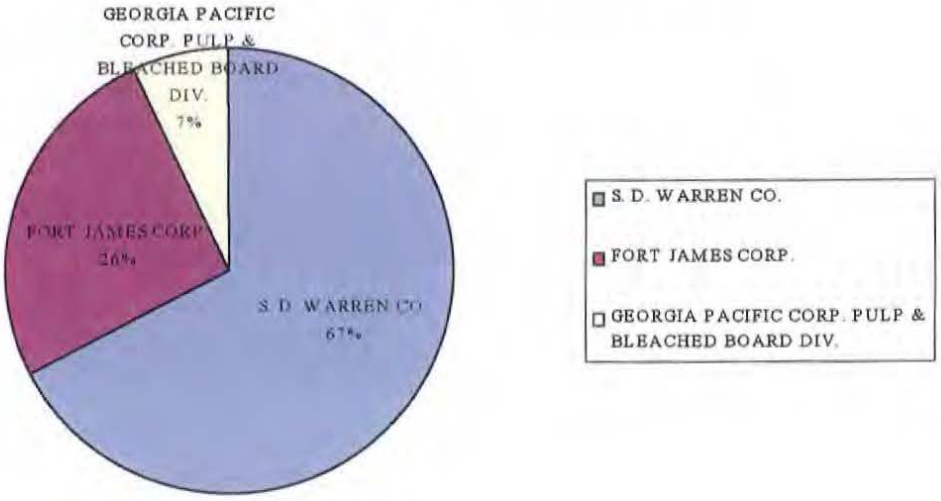
EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | **Probable Human Carcinogen** | Possible Human Carcinogen | Not Applicable |
|---|---|---|---|

Qualitative Discussion of Confidence: No significant concerns regarding the toxicity value for chloroform were identified.

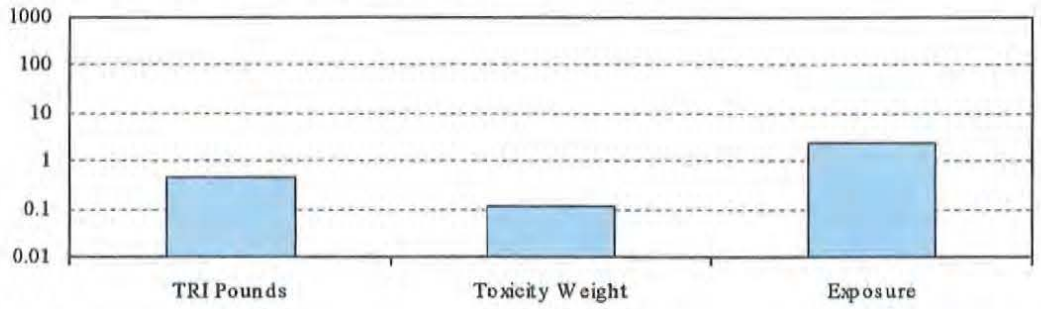
***Source Information***

**Facilities Contributing to Chloroform Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Naphthalene**
**RISK-RELATED RANK (MAINE AIR 1998):** 8

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - epithelial inflammation in respiratory passages
Source of Toxicity Value: Derived

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

EPA Weight of Evidence Classification for Carcinogens:

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

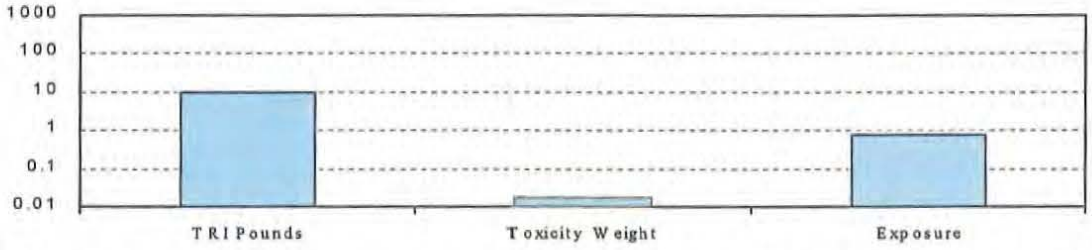
Qualitative Discussion of Confidence: The RfC for naphthalene is based on the ATSDR Minimum Risk Level derived from a 2-year National Toxicology Program study in mice. No significant issues with the study were identified.

***Source Information***

**Facilities Contributing to Naphthalene Risk-Related Result (Maine, Air, 1998)**

**CHEMICAL PROFILE: Glycol Ethers**
**RISK-RELATED RANK (MAINE AIR 1998):** 9

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - testicular effects
Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | **Medium** | Low | Not Applicable |
|---|---|---|---|

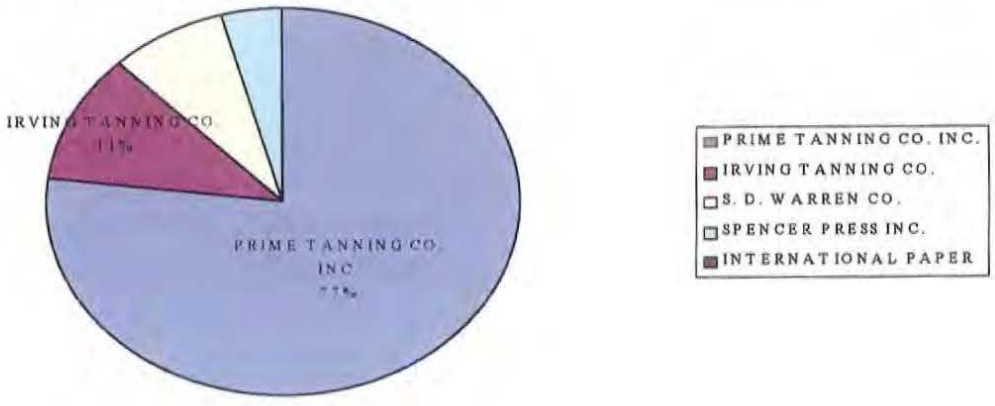
EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: The model uses the lowest RfC among a group of glycol ethers.

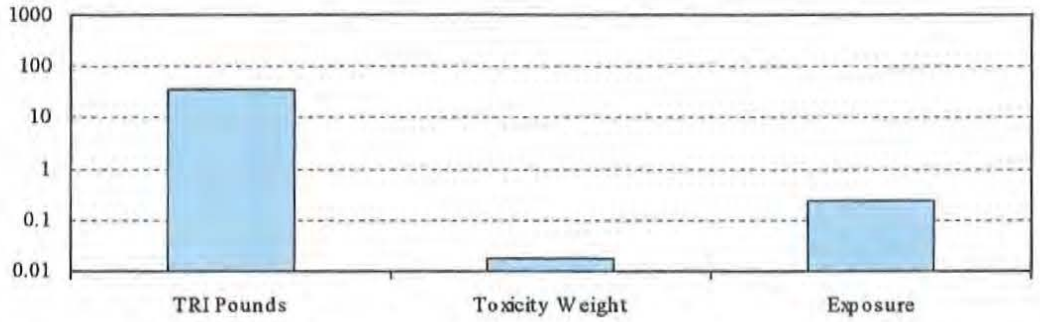
***Source Information***

**Facilities Contributing to Glycol Ethers Risk-Related Result (Maine, Air, 1998)**



**CHEMICAL PROFILE: Hydrochloric Acid**
**RISK-RELATED RANK (MAINE AIR 1998):** 10

***Magnitude of Input Relative to Median Across Chemicals***




| | | | |
|---|---|---|---|
| Median Value | 20696 lbs | 5200 per mg/kg-day | 1.12 E-10 person- mg/kg-day |

***Toxicity Weight Information***

Endpoint Driving Toxicity Weight: Noncancer - hyperplasia of respiratory passages
Source of Toxicity Value: IRIS

EPA Assessment of Confidence in Noncancer Toxicity Value:

| High | Medium | Low | Not Applicable |
|---|---|---|---|

EPA Weight of Evidence Classification for Carcinogens

| Known Human Carcinogen | Probable Human Carcinogen | Possible Human Carcinogen | **Not Applicable** |
|---|---|---|---|

Qualitative Discussion of Confidence: No significant concerns regarding the toxicity value for hydrochloric acid were identified.

***Source Information***

**Facilities Contributing to Hydrochloric Acid Risk-Related Result (Maine, Air, 1998)**