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The Industrial Pollution Projection System

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Summary findings

The World Bank's technical assistance work with new environmental protection institutions stresses cost-effective regulation, with market-based pollution control instruments implemented wherever feasible. But few environmental protection institutions can do the benefit-cost analysis needed because they lack data on industrial emissions and abatement costs. For the time being, they must use appropriate estimates.

The industrial pollution projection system (IPPS) is being developed as a comprehensive response to this need for estimates. The estimation of IPPS parameters is providing a much clearer, more detailed view of the sources of industrial pollution. The IPPS has been developed to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity, by its sectoral composition, and by the type of process technology used in production.

Most developing countries have little or no data on industrial pollution, but many of them have relatively detailed industry-survey information on employment, value added, or output. The IPPS is designed to convert this information to a profile of associated pollutant output for countries, regions, urban areas, or proposed new projects. It operates through sectoral estimates of pollution intensity, or pollution per unit of activity.

The IPPS is being developed in two phases. The first prototype has been estimated from a massive U.S. data base developed by the Bank's Policy Research Department, Environment, Infrastructure, and Agriculture Division, in collaboration with the Center for Economic Studies of the U.S. Census Bureau and the U.S. Environmental Protection Agency. This database was created by merging manufacturing census data with Environment Protection Agency data on air, water, and solid waste emissions. It draws on environmental, economic, and geographic information from about 200,000 U.S. factories. The IPPS covers about 1,500 product categories, all operating technologies, and hundreds of pollutants. It can project air, water, or solid waste emissions, and it incorporates a range of risk factors for human toxins and ecotoxic effects.

The more ambitious second phase of IPPS development will take into account cross-country and cross-regional variations in relative prices, economic and sectoral policies, and strictness of regulation.

This paper — a product of the Environment, Infrastructure, and Agriculture Division, Policy Research Department — is part of a larger effort in the department to study the determinants of industrial pollution as an aid to cost-effective regulation in developing countries. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Angela Williams, room N10-015, extension 37176 (77 pages). March 1995.

IPPS

THE INDUSTRIAL POLLUTION PROJECTION SYSTEM

by

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Executive Summary

The World Bank's technical assistance work with new environmental protection institutions (EPI's) stresses cost-effective regulation, with implementation of market-based pollution control instruments wherever this is feasible. At present, however, few EPI's can do the requisite benefit-cost analysis because they lack data on industrial emissions and abatement costs. For the foreseeable future, appropriate estimation methods will therefore have to be employed as complements to direct measures of environmental parameters at the firm level. We are developing the Industrial Pollution Projection System (IPPS) as a comprehensive response to this need. Estimation of IPPS parameters is also giving us a much clearer and more detailed view of the sources of industrial pollution. In this paper, we report on our findings to date.

IPPS has been developed to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity, its sectoral composition, and the process technologies which are employed in production. Although most developing countries have little or no industrial pollution data, many of them have relatively detailed industry survey information on employment, value added or output. IPPS is designed to convert this information to the best feasible profile of the associated pollutant output for countries, regions, urban areas, or proposed new projects. It operates through sector estimates of pollution intensity, or pollution per unit of activity.

We are developing IPPS in two phases. We have estimated the first prototype from a massive U.S. data base, developed by PRDEI in collaboration with the Center for Economic Studies of the U.S. Census Bureau and the U.S. Environmental Protection Agency. This data base was created by merging Manufacturing Census file data with US EPA data on air, water and solid waste emissions. It contains complete environmental, economic and geographic information for approximately 200,000 factories in all regions of the United States. The first prototype of IPPS spans approximately 1,500 product categories, all operating technologies, and hundreds of pollutants. It can separately project air, water, and solid waste emissions, and incorporates a range of risk factors for human toxic and ecotoxic effects. It can also project emissions of some greenhouse gases and several compounds which are hazardous to the ozone layer. Since it has been developed from a database of unprecedented size and depth, it is undoubtedly the most comprehensive system of its kind in the world.

We recognize, however, that this is only the beginning. Although much more detailed empirical research is needed on the sources of variation in industrial pollution, it is already clear that great differences are attributable to cross-country and cross-regional variations in relative prices, economic and sectoral policies, and strictness of regulation. The second phase of IPPS development will, therefore, have to be even more ambitious than the first. We are now undertaking an econometric research project which will use plant-level data from many countries to quantify the major sources of international and interregional variation in industrial pollution. This project should help identify the policies which have reduced industrial pollution most cost-effectively under different conditions. By quantifying the effect of country- and region-specific policy and economic variables, it should also provide the basis for adjusting IPPS to conditions in a wide variety of national and regional economies.

We have learned a number of valuable things from first-phase development and application of IPPS:

- Industrial pollution problems vary substantially across countries, and across regions within countries. We have therefore estimated intensities for a large number of air, water and toxic pollutants. To illustrate, at the broadest level of pollutant aggregation, IPPS intensity estimates are available for the sum of all toxic pollutants released to all media (air, water, land). At the narrowest level, separate intensities have been estimated for air, water and land release of over 100 toxic pollutants.

- Complementary economic data for developing countries can be somewhat randomly available by variable and level of aggregation. We have therefore found it useful to estimate IPPS parameters at the 2-, 3-, and 4-digit levels of aggregation in the International Standard Industrial Classification (ISIC). At each ISIC level, we have estimated pollution intensities, or emissions per unit of activity, using all three economic variables which are commonly available: Value of output, value added and employment. For cases where extremely detailed data are available, we have also estimated sectoral parameters at the U.S. 4- and 5-digit SIC levels. In the latter case, the estimates include some information for over 1,000 industry sectors.

- For individual pollutants, we find generally high correlations across intensities based on output value, value added and employment. At a purely 'mechanical' level, we therefore find little to distinguish the three sets of intensity measures as bases for pollution projection. However, basic economic reasoning does suggest that employment-based intensities may be preferable for pollution projection in developing countries. The logic is as follows: (1) Effective environmental regulation is thought to be quite income-elastic, although careful empirical work on cross-country data has yet to be done; (2) Sectoral pollution is thought to be quite responsive to effective environmental regulation in many cases; (3) Most cross-country econometric studies of sectoral labor demand find relatively high wage elasticities; (4) From (1)-(3), we can conclude that both sectoral pollution and sectoral labor demand will rise substantially as we move from richer (high-wage, high-regulation) to poorer (low-wage, low-regulation) economies. Since pollution and employment vary in the same direction, the variation in pollution intensity with respect to employment (P/E) may well be less than variation in pollution per unit of output. Very preliminary tests on U.S. and Indonesian sectoral data for water pollution provide support for this hypothesis, showing much higher variation for value-based intensities than for employment-based estimates.

- We have uncovered what looks like an "iron law" of pollution intensity for all pollutants and levels of aggregation: Sectoral intensities are always exponentially distributed, with a few highly intensive sectors and many which have very low intensities. High-intensity sectors differ markedly across pollutants (see below), but the exponential pattern persists. The implication for applied work is clear: Pollution projections should always be done with the most disaggregated data available. The resulting gains in accuracy are often quite striking.

- Although the phrase "pollution intensive" is commonly applied to industry sectors, it can be quite misleading. We find a very diverse pattern of sectoral intensity correlations across pollutants. Intensity correlations are sometimes high within similar classes (e.g., nitrogen dioxide and sulphur dioxide among air pollutants; biological oxygen demand and suspended solids among water pollutants). Across classes, however, intensity correlations are sometimes quite low.

- IPPS parameters can be estimated differently, depending on the types of complementary data which are available. For the present purposes, we have used our U.S. factory sample to compute three basic types of indices. The first, or Upper Bound, estimates are computed from the subsample of factories which we have succeeded in matching between the EPA and Census data bases. Since no common ID codes are available, this has been a difficult process and inevitably entailed the loss of information from many plants. EPA files are kept only on firms which are significant pollutors, so we know that our matched sample provides an upward-biased estimate of general sectoral pollution intensity. Developing-country factories tend to be more pollution-intensive, however, so these estimates provide at least a partial correction.

- We have produced complementary Lower Bound estimates for U.S. plants by summing all EPA-recorded pollution by sector and dividing by all Census-recorded output or employment. This makes maximum use of the EPA sample (the Census data cover the whole population of firms), but implicitly counts pollution from all non-EPA-recorded firms as zero. This is an underestimate, so the Lower Bound intensities should be conservative. In both Upper and Lower Bound cases, we know that the presence of large outliers in the data can have an important impact on sector-specific results. As an alternative, we have computed pollution intensities for all plants separately using the subsample of matched data, and then estimated Interquartile Mean intensities. This eliminates the possible influence of outliers and provides a robust measure of central tendency. Each set of statistics can be useful in particular contexts, as discussed in the paper.

IPPS has already been applied in several World Bank analyses, most notably in two recent World Bank publications:

Carter Brandon and Ramesh Ramankutty, Asia: Environment and Development (1993); and Richard Calkins, et. al., Indonesia: Environment and Development (1994). Inside the Bank, sector reports for Mexico, Malaysia and several Middle Eastern countries have also used IPPS-based estimates. IPPS has been used to produce the first comprehensive cross-country estimates of toxic pollution in World Resources 1994-95 (Table 12.4) published by the World Resources Institute. Recent work on trade and the environment by the OECD has also been based on IPPS, most notably the paper by David Roland-Holst and Hiro Lee: "International Trade and the Transfer of Environmental Costs and Benefits" (OECD, December 1993).

During the next year, we anticipate very rapid movement on Phase II of IPPS development: adjustment to conditions in other economies. At the conclusion of Phase I, we can offer a massive database of pollution parameters which are immediately usable for environmental planning and analysis. Complete 2-, 3-, and 4-digit ISIC pollution intensities are available on diskette from the authors.

The Industrial Pollution Projection System

1. Introduction

The Industrial Pollution Projection System (IPPS) is a modeling system which can use industry data to estimate comprehensive profiles of industrial pollution for countries, regions, urban areas, or proposed new projects. It is apparent that there is a huge potential demand for IPPS among environmental and industrial planners, particularly those working on issues related to developing countries. Most developing countries have little or no reliable information about their own pollution. Rapid environmental progress in the near future will depend on estimating pollution with projection systems like IPPS.

IPPS has been developed to exploit the fact that industrial pollution is heavily affected by the scale of industrial activity, its sectoral composition, and the process technologies which are employed in production. Although most developing countries have little or no industrial pollution data, many of them have relatively detailed industry survey information on employment, value added or output. IPPS is designed to convert this information to the best possible profile of the associated pollutant output.

The prototype system has been developed from a database containing environmental and economic data for approximately

200,000 facilities in all regions of the United States. IPPS spans approximately 1,500 product categories, all operating technologies, and hundreds of pollutants. It can separately project air, water, and solid waste emissions, and incorporates a range of risk factors for human toxic and ecotoxic effects. It can also project emissions of some greenhouse gases and several compounds which are hazardous to the ozone layer. Since it has been developed from a database of unprecedented size and depth, it is undoubtedly the most comprehensive system of its kind in the world.

How applicable are US-based estimates to other economies? It is clear that many country-specific factors will affect the accuracy of prototype IPPS projections outside the US. For particular sectors such as wood pulping, average pollution intensity is likely to be higher in developing countries. However, the pattern of sectoral intensity rankings may be similar. For example, wood pulping will be more water pollution-intensive than apparel manufacture in every country. **The present version of IPPS can therefore be useful as a guide to probable pollution problems, even if exact estimates are not possible.**

Our present goal is to expand the applicability of IPPS by incorporating data from developing countries. The project is therefore moving into the stage of outreach and information sharing with developing countries. Over time, new evidence will be used to develop systematic adjustments for economies with different characteristics.

The objective of the present paper is to provide a critical account of the material and methodology used for the first-generation IPPS. Section 2 provides a brief assessment of the available databases. Section 3 describes our methods for estimating pollution intensities by combining US Manufacturing Census data with the US Environmental Protection Agency's pollution databases. Section 4 focuses on estimation of toxic pollution intensities weighted by human and ecological risk factors. Section 5 describes the media-specific pollution intensities developed for the US EPA's criteria air pollutants, major water pollutants, and toxic releases by medium (air/water/land). The results are critically assessed in the final section. The complete set of IPPS intensities is available from the authors on request.

2. Building Blocks for Plant Level Databases

In order to establish a reliable picture of industrial pollution, a large cross-sectoral sample of facilities is required. Perhaps the world's largest sample is available in the databases maintained by the US Environmental Protection Agency and the US Census Bureau. Five of the databases with the greatest potential for constructing useful estimates and projections of industrial pollution are described below.

2.1 US EPA Emissions Databases

The US EPA maintains a number of databases at the national level that contain information on the environmental performance of regulated facilities across the US. Four are of particular relevance to the construction of pollution intensity indices: the Toxic Release Inventory, the Aerometric Information Retrieval System, the National Pollutant Discharge Elimination System, and the Human Health and Ecotoxicity Database.

2.1.1 The Toxic Release Inventory (TRI)

The TRI contains information on annual releases of toxic chemicals to the environment. It was mandated by the "Emergency Planning and Community Right-to-Know Act" (EPCRA) of 1986, also known as Title III of the Superfund Amendments. The law has two main purposes: to provide communities with information about potential chemical hazards; and to improve planning for chemical accidents.

The TRI reporting requirements cover all US manufacturing facilities that meet the following conditions:

- they produce/import/process 25,000 pounds or more of any TRI chemical *or* they use 10,000 pounds or more in any other manner;
- they are engaged in general manufacturing activities;
- they employ the equivalent of ten or more full-time employees.

The original TRI requirements, which applied for the 1987 reports, set a threshold of 75,000 pounds of TRI chemicals produced, imported or processed. This was lowered to 50,000 pounds the following year and to 25,000 pounds in 1989. Under the 1987 definition, some 20,000 facilities filed TRI reports. These were subsequently reduced to 18,846 as a result of the de-listing of six major chemicals (see below), and increased again to 19,762 facilities following the lowering of the reporting threshold.

The list of chemicals covered by the TRI is subject to an on-going review by the EPA. In the first year of reporting (1987) 328 individual chemicals and chemical categories were included, but this was adjusted to 322 the following year when the EPA determined that six chemicals were not sufficiently toxic to warrant reporting. The exclusion of three chemicals in particular - sodium sulfate, aluminum oxide and sodium hydroxide - had a dramatic impact on overall TRI totals, since they were respectively the first-, second-, and sixth-ranked chemicals. As a result, the total amount of releases and transfers reported was cut by two-thirds. The pollution intensities calculated in this paper do <u>not</u> include the chemicals de-listed up to 1989.

The TRI chemicals are drawn from lists developed independently by the states of Maryland and New Jersey, and vary widely in toxicity. No non-toxic substances or other environmental parameters, such as chemical or biological oxygen demand (COD/BOD), are recorded. TRI facilities must report annually all releases of TRI substances to air, water, or land, whether routine or accidental, and all transfers of TRI substances for off-site disposal. Although the identity of a particular substance may be claimed as a trade secret if justified in advance, only 23 of more than 70,000 TRI reporting forms submitted in 1988 included trade secret claims. Quantitative estimates in pounds must be provided for the mass of the TRI chemical released (not the total volume of the waste stream containing the chemical) in each of a range of categories, including:

- fugitive or non-point air emissions;
- stack or point air emissions;
- discharges to streams or receiving water bodies;
- underground injection on-site;
- releases to land on-site;
- waste-water discharges to publicly-owned treatment works;
- transfers to off-site facilities for treatment, storage or disposal.

For the purposes of inter-media analysis these seven categories can be aggregated under the three standard headings of releases to air, land and water.

The national repository for TRI data submitted to the EPA is the TRI Reporting Center in Washington, D.C. The information is computer-accessible through the National Library of Medicine's TOXNET database. The National Technical Information Service of the US Government Printing Office is also able to provide the data on tape, disk, CD-ROM and microfiche.

2.1.2 Aerometric Information Retrieval System (AIRS)

AIRS is the management system of the US national database for ambient air quality, emissions, and compliance data. It is divided into three subsystems:

- the Geographic/Common Subsystem, a database of necessary codes;
- the Air Quality Subsystem, containing ambient air quality data;
- the Air Facility Subsystem (AFS).

The AFS contains the emissions and compliance data mandated by the Clean Air Act that are provided by individual facilities monitored by the EPA and state agencies. There is some overlap with the TRI, because the AFS data include emissions of some chemicals listed in TRI, but the AFS also includes a number of additional substances and parameters. The most important are the US EPA's six criteria air pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), particulate matter (TP), fine particulates (PM10), and volatile organic compounds (VOC). Although air emissions data have been collected since 1973, we have only used the data from 1984 onwards. Access to information from years prior to this is more difficult.

2.1.3 National Pollutant Discharge Elimination System (NPDES)

The US EPA's NPDES database contains the self-monitored reports of facilities with NPDES permits for discharges of waste water. Both the permits and the monitoring are mandated by the Clean Water Act. Some 60,000 facilities file reports on monitoring that they perform on a monthly basis. In the database as a whole, over 2,000 parameters are reported, leading to considerable overlap with the substances reported for the TRI. Some of the more important additional parameters are Biological Oxygen Demand (BOD, a measure of the amount of oxygen consumed in the biological processes that break down organic matter in water), Total Suspended Solids (TSS), pH and temperature. The length of the time series varies regionally, the longest being about ten years. However the data are most complete from 1987 onwards, following the most recent modification of the database.

2.2 The Human Health and Ecotoxicity Database (HHED)

The EPA's HHED contains a number of indices of toxicological potency. No single index is considered sufficient to characterize all the factors relevant to a chemical's toxic potential under different circumstances, so different indices have been developed for specific applications. For example the Reportable Quantity (RQ) index is designed to guide the reporting of accidental releases required under CERCLA, whereas the Threshold Planning Quantity (TPQ) index was developed to meet the emergency response planning requirements of SARA Title III, Section 2.

For the purposes of risk-screening the HHED aggregates the toxicity values for ten indices into three toxicological potency groups. Table 2.1 indicates the mapping of threshold figures onto toxicological potency groups for four of the ten indices. In a number of cases the differences in the criteria used to develop the indices cause the same chemical to be rated in a different potency group according to the choice of index. For example, the RQ and TPQ potency categorizations may differ because TPQs are based on a chemical's potential for becoming airborne as well as its toxicity. Furthermore, a number of TRI chemicals have yet to be assigned an RQ and are not listed under any other index. Consequently these substances are listed in the HHED without being assigned a potency group ranking.

Table 2.1: **Mapping of EPA Threshold Values onto Toxicological Potency Groups**

Toxicity Index	**Toxicological Potency**		
	Group 1	Group 2	Group 3
Threshold Planning Quantity (TPQ) -acute only (pounds)	1, 10, 100	500	1,000, 10,000
Reportable Quantity (RQ) - pounds	1, 10, 100	1,000	5,000
Reference Doses (RfD) - mg/kg/day	<0.01	0.01-1.0	>1.0
Water Quality Criteria (WQC) - mg/L	<1	1-10	>10

2.3 The Longitudinal Research Database (LRD)

The LRD is an establishment-level database constructed from information contained in the Census of Manufactures (CM) for the years 1963, 1967, 1972, 1977, 1982 and 1987, and the Annual Survey of Manufactures (ASM) from 1973 to 1989. It is administered by the Center for Economic Studies (CES), which was set up within the Census Bureau in 1982 to develop the database, to use the data for the improvement of Census Bureau operations, and to make the data available to outside users.

The CM is a complete enumeration of all manufacturing establishments, as classified by the Census Bureau according to the Standard Industrial Classification System (SIC). In contrast to the CM, the ASM is a sample of establishments, selected after each census for data collection over the following five years. The annual data available in the LRD for all establishments from 1972 to 1989 include:

- the establishment name, address, four and five digit SIC codes;
- payroll statistics, including total salaries and wages;
- cost of materials and energy;
- capital expenditures;
- total value added.

In addition the LRD contains some variables that are only available for ASM establishments, and others that are only collected in census years. The additional ASM information relates to capital assets, rents, depreciation, retirements and repair. The data available only for census years include:

- the quantity and cost of material goods consumed;
- the quantity and value of product shipped;
- employment.

The product information collected by the CM (product quantity produced, product quantity shipped and product value shipped) is recorded at the 7-digit SIC level, which is so detailed that on average each facility reports under three or four product categories.

Because establishment-level data are collected by the Census Bureau under the authority of Title 13 of the US Code, the Bureau prohibits the release of information that could be used to identify or closely approximate the data for an individual establishment or enterprise. Consequently, only a limited number of researchers working as Special Sworn Employees (SSEs) and Census Bureau staff have direct access to the LRD.

3. Pollution Intensity Index Construction

3.1. The Conceptual Goal

Access to the emissions, risk and economic data described above presents a unique opportunity to develop a comprehensive picture of the environmental and human health risks associated with industrial development. The US EPA's databases and the LRD contain samples of facility-level information of an unmatched size and detail, enabling a reasonable estimate to be made of the pollution associated with any given level of activity, in any specified industrial sector. Conceptually, such estimates can be presented as an index of "pollution intensity", expressed as a ratio of pollution per unit of manufacturing activity:

$$\text{pollutant output intensity} = \frac{\text{pollutant output}}{\text{total manufacturing activity}}$$

Initially, this project focused on the generation of all-media toxic pollution intensity indices from the data contained in the TRI and the LRD. This was combined with the HHED to develop additional risk-weighted indices. The TRI was chosen for analysis before the AIRS and NPDES databases, both because of its ready availability and because of the importance of toxic release information for the analysis of risk. The analysis draws only on the first year of TRI data (1987), chosen largely because it was a census year with consequently detailed LRD data.

In the next stage of the project the AIRS and NPDES databases, and the information on media-specific releases in the TRI, were used to construct a wide range of pollution output intensities by medium (air/land/water). In addition to disaggregating the toxic pollution intensities by medium, indices were obtained for the US EPA's six criteria air pollutants (SO_2, NO_2, CO, TP, PM10, VOC,) and two water pollutant indicators, (BOD and TSS).

3.2. Operational Complexities

Although pollution intensity estimation is conceptually straight forward, several practical problems had to be confronted in actual calculation of the indices. An understanding of their resolution is important if the indices are to be correctly interpreted and applied.

3.2.1 Merger of the EPA and LRD files.

The calculation of pollution intensity required merging the EPA and LRD data at the facility level. Unfortunately, no common code numbers link the same establishments within the EPA databases or between the EPA and LRD databases. This necessitated a complex matching process which used the facility names, addresses and SIC codes. Of some 20,000 plants reporting TRI information in 1987, about 13,000 were matched to the corresponding LRD data for that year. For medium-specific intensities, data from all 200,000 plants in the LRD, 20,000 plants in the TRI, 20,000 plants in the AIRS database, and 13,000 facilities in the NPDES were combined to the extent possible.

3.2.2 The Choice of a Numerator

A number of options existed for the choice of total pollutant risk to be used as the numerator. First, a decision had to be made regarding the choice of disposal medium. As noted above, the TRI data identify a range of releases and transfers, including emissions to air, water, land, underground injection, and off-site disposal in both landfill and public waste-water facilities. Initially pollution across all media was used, aggregating all releases and transfers of a given chemical from each facility.[1]

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[1]In this regard, it is worth noting that there is little comprehensive analysis of the impact environmental regulation has had on total pollution at the plant level. Both regulation and research have generally focused on particular media, especially stressing releases to air and water. It is therefore unclear how much total "pollutant intensity" has been reduced in the US. Consider, for example, the

Second, a mechanism was needed to derive estimates of risk from the TRI data. Conceivably it would be possible to combine the TRI information on the quantity of particular chemical releases with the LRD data on quantity of inputs, thus developing a picture of cross-sectoral chemical input-output coefficients. While this might provide useful insight into the flow of specific chemicals within the economy, the wide range of environmental and health risks associated with different chemicals would restrict inter-sectoral comparisons of pollutant risk. A better alternative for the comparison of risks is provided by the multi-index categorization of toxic potency in the US EPA's HHED.

Our initial results indicated a high rank correlation between pollution risk intensity and pollution output intensity (see section 4.4). Therefore, subsequent work focused solely on medium-specific pollution output intensities (see section 5.3). These intensities were calculated at varying degrees of sectoral disaggregation, and with a number of different denominators, so that pollution projections could be made using the manufacturing data which are readily available in many developing countries.

3.2.3. The Choice of a Denominator

The LRD provides a number of options for the measure of manufacturing activity to be used as a denominator in calculating pollutant intensity. Four of the most obvious are:

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implications of concentrating trace toxins from waste water into highly toxic solid waste for shipment to a landfill.

- physical volume of output;
- shipment value;
- value added;
- employment.

The most immediately appealing choice is physical volume of output, since pollution is associated with the volume of physical residuals from production. However, the use of physical output volume poses several practical difficulties. First, a wide range of units are used to report output quantities in the LRD even within a given sector, severely complicating inter-facility analysis. Second, many facilities report output volumes in special samples not included in the main LRD, significantly reducing the sample size available for analysis. Finally, the information relating to physical output volume in developing countries is generally very sparse.

Consequently, first-round estimation focused on shipment value as the measure of manufacturing activity for estimating toxic pollution risk intensities. Although this statistic has obvious relative price problems, particularly in the international context, it has the advantage of relatively complete coverage and the usual benefit of the dollar metric in allowing inter-sectoral comparison. Total output value was judged superior to value added because energy and materials inputs are critical in the determination of industrial pollution.

To allow the system to be applied in a wider range of circumstances, pollution intensities with respect to value added and employment were also estimated in the second round of work.[2] In addition, intensities were calculated for manufacturing sectors defined according to the 2-, 3- and 4-digit International Standard Industrial Classification (ISIC).

3.2.4 Alternative Estimates of Sectoral Pollution Intensities

The EPA data used in the study only cover facilities releasing pollutants in quantities over a threshold level of emissions. Consequently, pollution intensity estimates based on these data (as in Table 4.3) may be upwardly biased, by exclusion of cleaner facilities. To correct for this, alternative intensities were estimated, by grouping data from manufacturing facilities into three classes. Facilities reporting emissions to the EPA were classified as group (1) if they could be matched to the LRD, and group (2) if this was not possible. Those facilities which did not report emissions to EPA, but were in the LRD, were defined to be group (3).

The pollution intensities derived from group (1) data were presumed to give an "upper bound" estimate for each industrial sector because of their inherent upward bias. For the matched group an intensity estimate defined as the Upper Bound Weighted Mean (known as Upper-Bound (UB) hereafter) was calculated by weighting each plant's pollution intensity by its

[2]We have noted in the Executive Summary, it is possible that employment-based intensities are more stable across countries than the value-based measures.

scale of activity[3].

The Upper-Bound estimates can be heavily affected by the presence of some extreme outliers in the matched group. To eliminate this impact, Upper Bound Inter-Quartile Mean intensities (known as Inter-Quartile Mean (IQ) hereafter) were calculated for the matched group. This involved calculating the unweighted mean of the plant intensities after dropping those which are below the first quartile or above the third quartile.

The ratio of total EPA emissions reported in a sector (from groups (1) and (2)) to the total level of economic activity in that sector reported by the LRD (from all three groups) was calculated as the Lower Bound Weighted Mean pollution intensity (known as Lower-Bound (LB) hereafter). This intensity measure assumes an emissions level of zero for group (3) plants (those which report to the LRD but not to the EPA). To the extent that these facilities have some emissions, this LB estimate is biased downward)[4].

All three intensity measures were compiled with respect to each of the denominators - total value of output, value added and employment. We recommend the use of LB intensities (especially for non-toxic air and water pollutants) because of

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[3]This intensity is equivalent to:
[total pollution in group (1)]\[total activity in group (1)]

[4]If the plants in the matched data set had lower than average sectoral pollution intensities compared to all the plants in the entire EPA dataset, IQ for those sectors could be lower than the LB.

the larger sample used for this measurement compared to the matched sample. However, depending on the circumstances in which the projections are made any one of the three measures may be used.

3.2.5. Remapping US Facilities to 4-digit ISIC

Having matched the TRI data to the LRD information at the facility level, it was necessary to select a suitable level of aggregation of industrial activity for international comparisons of pollutant intensity. The 4-digit ISIC level, comprising about 80 sub-sectors, was selected, since it is the most detailed and comprehensive level of reporting used by UNIDO.[5]

A standard US Department of Commerce concordance was used to assign a 4-digit ISIC code to each sector. Difficulties arose in dealing with those facilities reporting under more than one 5-digit SIC code when the facility's SIC codes matched more than one ISIC classification. The standard procedure for dealing with this problem was to assign each facility the 4-digit ISIC code with the greatest shipment value. Although this was generally 80% or more of the total shipment value, this approach inevitably lent some inaccuracy to the final estimates of pollutant intensity.

[5]Pollution intensity estimates were also derived for other levels of disaggregation: 2-digit, 3-digit and 4-digit US Standard Industrial Classification (SIC) sectors, which have respectively 9, 39, and 1500 sub-sectors.

4. Construction of a Toxic Pollution Risk Intensity Index

4.1. Calculation of Risk-Weighted and Unweighted Releases and Transfers

This section describes how toxic pollution intensity weighted by risk was calculated using the TRI, HHED and LRD databases. This measure enables the comparison of inter-sectoral environmental and health-related risks. Using the multi-index categorization of HHED, each chemical's rating under each index was assigned to one of three toxicological potency groups, Group One being the most hazardous (see Table 2.1). Each of the indices is also assigned to one of four higher levels of aggregation as follows:

- acute human health and terrestrial ecotoxicity;
- chronic human health and terrestrial ecotoxicity;
- acute aquatic ecotoxicity;
- chronic aquatic ecotoxicity.

For our purposes two of these categories were chosen to characterize pollutant intensity, these being acute human health and terrestrial ecotoxicity and acute aquatic ecotoxicity. Human and terrestrial ecotoxicity are distinguished from aquatic ecotoxicity because of the significant variation between the toxicological potency of many chemicals to mammalian and fish life. Chronic toxicity was ignored, largely because the evidence for low-dose, long-term effects is contentious. Since the HHED contains more than one index within each of these categories, the most hazardous toxicological potency rating was selected as a conservative estimate of the risk associated with a release of each chemical.

A difficulty arose in converting the ordinal scale ranking of toxicological risk associated with particular chemicals to a measure of the total risk posed by all releases from a facility. The approach adopted in this study was to multiply the quantity of each TRI chemical reported by a facility by its toxicological potency ranking, and then to sum the risk-weighted quantities for all chemicals released by the facility. Acknowledging the questionable validity of using an ordinal scale in an arithmetic procedure, two forms of weighting were used to test the sensitivity of the results. First, the EPA toxicological potency ratings were simply reversed, giving a linear weighting scale from 1 to 4. Four weights were used, although there are only three toxicological potency ratings, because those TRI chemicals yet to be assigned a toxicological rating (see section 3.2.2 above) were grouped together with the lowest weighting. Second, an exponential weighting was used for the four groups, rising by orders of magnitude from 1 to 1,000. This methodology generated four measures of risk-weighted releases and transfers for each facility:

- linear acute human health and terrestrial ecotoxicity;
- exponential acute human health and terrestrial ecotoxicity;
- linear acute aquatic ecotoxicity;
- exponential acute aquatic ecotoxicity.

In addition, two TRI totals unweighted for risk were calculated for each facility:

- total quantity of TRI chemicals released or transferred;
- total quantity of metals released or transferred.

A separate figure was calculated for metals and their compounds because of the specific risks associated with their accumulation in the environment and concentration as they are passed up the food-chain. The TRI metals are listed in the Annex and follow the same definition as those in "Toxics in the Community" (1989), published by the US EPA.

With each facility assigned a 4-digit ISIC code and six TRI release and transfer parameters, sectoral totals for each parameter were calculated by summing across all facilities falling within the same ISIC category.

4.2. Scaling by Shipment Value to Give Pollution Intensity

The final element in the creation of risk-weighted measures of pollutant intensity was the scaling of all six TRI parameters by shipment(output)value. This was achieved by summing facility shipment values within the 4-digit ISIC sectors in the matched TRI-LRD dataset, and dividing the result into the TRI totals. This produced the Upper Bound (UB) estimates discussed in the previous section. Of the six pollutant intensity estimates for each sector, four are dimensioned as risk-weighted pounds of TRI chemicals released and transferred per $1000 of gross output, and two are unweighted pounds of TRI chemicals per $1000 of output. It should be noted that this set of six sectoral pollutant intensity indices is probably unique. Not only is the TRI database relatively new and unique in itself, but the massive plant-level matching undertaken in this study has not previously been possible.

4.3. Results

As an indication of results obtained using the methodology described above, Figure 4.1 charts the linearly-weighted acute human and terrestrial ecotoxicity index across the seventy-four 4-digit ISIC codes for which TRI data are available. The units of the pollution index are linearly risk-weighted pounds of TRI releases and transfers per $1,000 of shipment value. Table 4.1 presents the same information, together with the ISIC sector names.

Figure 4.1 clearly illustrates the extreme sectoral variation in pollutant intensity, ranging from Fertilizers and Pesticides (ISIC 3512) with 105.3 risk-weighted pounds of TRI releases and transfers per $1,000 of product shipped, to Soft Drinks and Carbonated Water (ISIC 3134), with only 0.22 pounds per $1,000. Despite a few surprises, such as the fifteenth ranking of the Musical Instruments sector, Table 4.1 generally confirms the intuition that the most intensive sectors in terms of toxic waste per dollar of output are industrial chemicals, plastics, paper and metals. The middle-ranked sectors are associated with consumer products such as electrical appliances, textiles, and cleaning preparations, followed by the high shipment value (and consequently relatively low intensity) machine-tool industry, with the food and drink sectors filling the least intensive rankings. The shape of the distribution of pollutant intensities is also of interest. Almost perfectly exponential, it provides some hope that problems associated with toxic releases can be ameliorated by measures targeted at only a few sectors. However, it should be borne in mind that this index does not rank total sectoral releases, so that it is quite possible for a highly pollution intensive sector to have little impact on the total level of releases and transfers. Nor does the index incorporate any abatement cost considerations.[6]

Table 4.1: **Four Digit ISIC Codes and Descriptions in Descending Order of Linear Acute Human Toxic Intensity Index**
(Risk Weighted Pounds/1987 US $ Million Output Value)

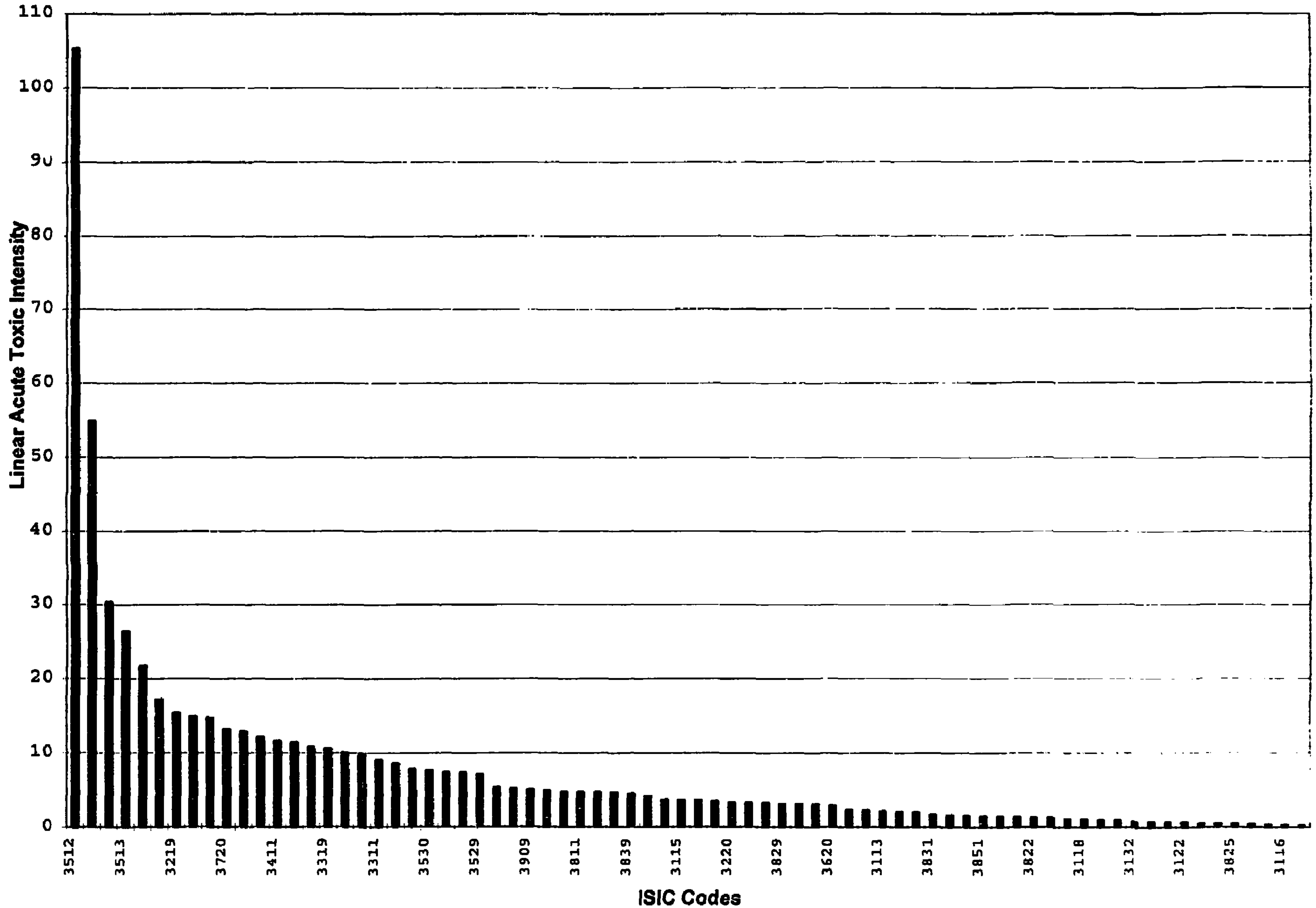
Four Digit ISIC Description	ISIC Code	Linear Acute Human Toxic Intensity	Rank
FERTILIZERS & PESTICIDES	3512	105.30	1
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	54.92	2
TANNERIES AND LEATHER FINISHING	3231	30.40	3
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRES	3513	26.44	4
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	21.83	5
PLASTICS PRODUCTS, N.E.C.	3560	17.31	6
TEXTILES, N.E.C.	3219	15.50	7
PRINTING & PUBLISHING	3420	14.93	8
PULP, PAPER & PAPERBOARD ARTICLES	3419	14.77	9
NONFERROUS METALS	3720	13.23	10

[6]See Hartman, Raymond; Wheeler, David and Singh, Manjula, "The Cost of Air Pollution Abatement," Policy Research Department Working Paper, The World Bank, Washington, D.C. 1994, for information on abatement cost by industry sector.

Four Digit ISIC Description	ISIC Code	Linear Acute Human Toxic Intensity	Rank
IRON AND STEEL	3710	12.93	11
RUBBER PRODUCTS, N.E.C.	3559	12.21	12
PULP, PAPER, & PAPERBOARD	3411	11.72	13
FABRICATED METAL PRODUCTS	3819	11.50	14
MUSICAL INSTRUMENTS	3902	10.86	15
WOOD & CORK PRODUCTS, N.E.C.	3319	10.65	16
FURNITURE & FIXTURES, NONMETAL	3320	10.06	17
PAINTS, VARNISHES, & LACQUERS	3521	9.82	18
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	9.09	19
STRUCTURAL METAL PRODUCTS	3813	8.62	20
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	7.88	21
PETROLEUM REFINERIES	3530	7.67	22
DRUGS AND MEDICINES	3522	7.42	23
SPINNING, WEAVING, & FINISHING TEXTILES	3211	7.40	24
CHEMICAL PRODUCTS, N.E.C.	3529	7.23	25
POTTERY, CHINA, & EARTHENWARE	3610	5.48	26
METAL & WOOD WORKING MACHINERY	3823	5.31	27
MANUFACTURING INDUSTRIES, N.E.C.	3909	5.05	28
MADE-UP TEXTILES EXCEPT APPAREL	3212	4.91	29
MISC. PETROLEUM & COAL PRODUCTS	3540	4.78	30
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	4.75	31
KNITTING MILLS	3213	4.74	32
WATCHES AND CLOCKS	3853	4.73	33
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	4.50	34
JEWELRY AND RELATED ARTICLES	3901	4.20	35
SHIPBUILDING AND REPAIRING	3841	3.74	36
OILS AND FATS	3115	3.72	37
FURNITURE & FIXTURES OF METAL	3812	3.70	38
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	3.52	39
WEARING APPAREL	3220	3.34	40
FOOTWEAR	3240	3.32	41
SPORTING AND ATHLETIC GOODS	3903	3.30	42
MACHINERY & EQUIPMENT, N.E.C.	3829	3.16	43

Four Digit ISIC Description	ISIC Code	Linear Acute Human Toxic Intensity	Rank
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	3.14	44
ENGINES AND TURBINES	3821	3.13	45
GLASS AND GLASS PRODUCTS	3620	2.89	46
ELECTRICAL APPLIANCES & HOUSEWARES	3833	2.32	47
DAIRY PRODUCTS	3112	2.25	48
PRESERVED FRUITS & VEGETABLES	3113	2.14	49
AIRCRAFT	3845	2.10	50
FOOD PRODUCTS, N.E.C.	3121	2.02	51
ELECTRICAL INDUSTRIAL MACHINERY	3831	1.74	52
RAILROAD EQUIPMENT	3842	1.67	53
PHOTOGRAPHIC AND OPTICAL GOODS	3852	1.59	54
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	1.55	55
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	1.47	56
STRUCTURAL CLAY PRODUCTS	3691	1.40	57
AGRICULTURAL MACHINERY & EQUIPMENT	3822	1.32	58
CARPETS AND RUGS	3214	1.31	59
MOTOR VEHICLES	3843	1.19	60
SUGAR FACTORIES & REFINERIES	3118	1.12	61
CEMENT, LIME, AND PLASTER	3692	0.98	62
TOBACCO MANUFACTURES	3140	0.98	63
WINE INDUSTRIES	3132	0.77	64
TIRES AND TUBES	3551	0.74	65
BAKERY PRODUCTS	3117	0.73	66
PREPARED ANIMAL FOODS	3122	0.70	67
DISTILLED SPIRITS	3131	0.57	68
CONFECTIONERY PRODUCTS	3119	0.48	69
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	0.45	70
MEAT PRODUCTS	3111	0.43	71
MALT LIQUORS AND MALT	3133	0.37	72
GRAIN MILL PRODUCTS	3116	0.28	73
SOFT DRINKS & CARBONATED WATER	3134	0.22	74

Figure 4.1 - Linearly Weighted Acute Human Toxic Intensity Index



4.4 Variation Across Indices

Sectors may have very different toxic significance, depending on the toxic index or weighting employed. To test this, Table 4.2 presents Pearson rank correlation coefficients for all six indices. Correlations are very high for the five all-toxic measures. The linearly-weighted human (LinHum) and aquatic (LinAq) indicators have rank correlations of .99 with total toxic intensity (TotTRI), while correlations of the latter with exponentially-weighted human (ExpHum) and aquatic (ExpAq) indicators are respectively .88 and .80. The pairs of linear/exponential indices for humans and aquatic life are also highly correlated. The high correlation (.91) between the two human indicators is illustrated in Figure 4.2.

The implications of exponential weighting can be seen in a comparison of Figure 4.3 and Table 4.3 (ExpHum) with Figure 4.1 and Table 4.1 (LinHum). Although the same exponential distribution of values is observed for both measures and the two most intensive sectors are the same [Fertilizers and Pesticides (ISIC 3512), followed by Industrial Chemicals Except Fertilizer (ISIC 3511)], a number of other sectoral rankings have shifted. For example the Iron and Steel sector (ISIC 3710) rises from eleventh place in the linearly weighted index to fourth place in the exponentially weighted index, while Paper and Paperboard Containers and Boxes (ISIC 3412) falls from fifth to twelfth place.

These undeniable differences between the linearly and exponentially weighted rankings indicate that some caution is warranted when the indices are applied. However, the results do show that total toxic intensity is a good proxy for all the total toxic measures.

Table 4.2: **Rank Correlation Analysis for Six Indices of Pollution Intensity**

Pearson Rank Correlation Coefficients

	TotTRI	LinHum	ExpHum	LinAq	ExpAQ	TotMet
TotTRI	1	0.99	0.88	0.99	0.8	0.51
LinHum	0.99	1	0.91	0.99	0.83	0.49
ExpHum	0.88	0.91	1	0.89	0.82	0.46
LinAq	0.99	0.99	0.89	1	0.84	0.45
ExpAQ	0.8	0.83	0.82	0.84	1	0.23
TotMet	0.51	0.49	0.46	0.45	0.23	1

Key:

ToTTRI - Total pounds of TRI substances released
LinHum - Linearly weighted acute human toxicity
ExpHum - Exponentially weighted acute human toxicity
LinAq - Linearly weighted acute aquatic toxicity
ExpAq - Exponentially weighted acute aquatic toxicity
TotMet - Total pounds of TRI metallic compounds released

Table 4.2 also shows that the total toxic measures have much lower rank correlations with intensity in releases of bioaccumulative metals. The rank correlations do not rise above 0.51 and fall as low as 0.23. Clearly, the metals-generating sectors are not a random draw from all toxic sectors. Applications should therefore distinguish between general toxic releases and releases of bioaccumulative metal compounds.

Figure 4.2 - Plot of Sectoral Ranks for Linearly Weighted Acute Human Toxicity against Sectoral Ranks for Exponentially Weighted Acute Human Toxicity

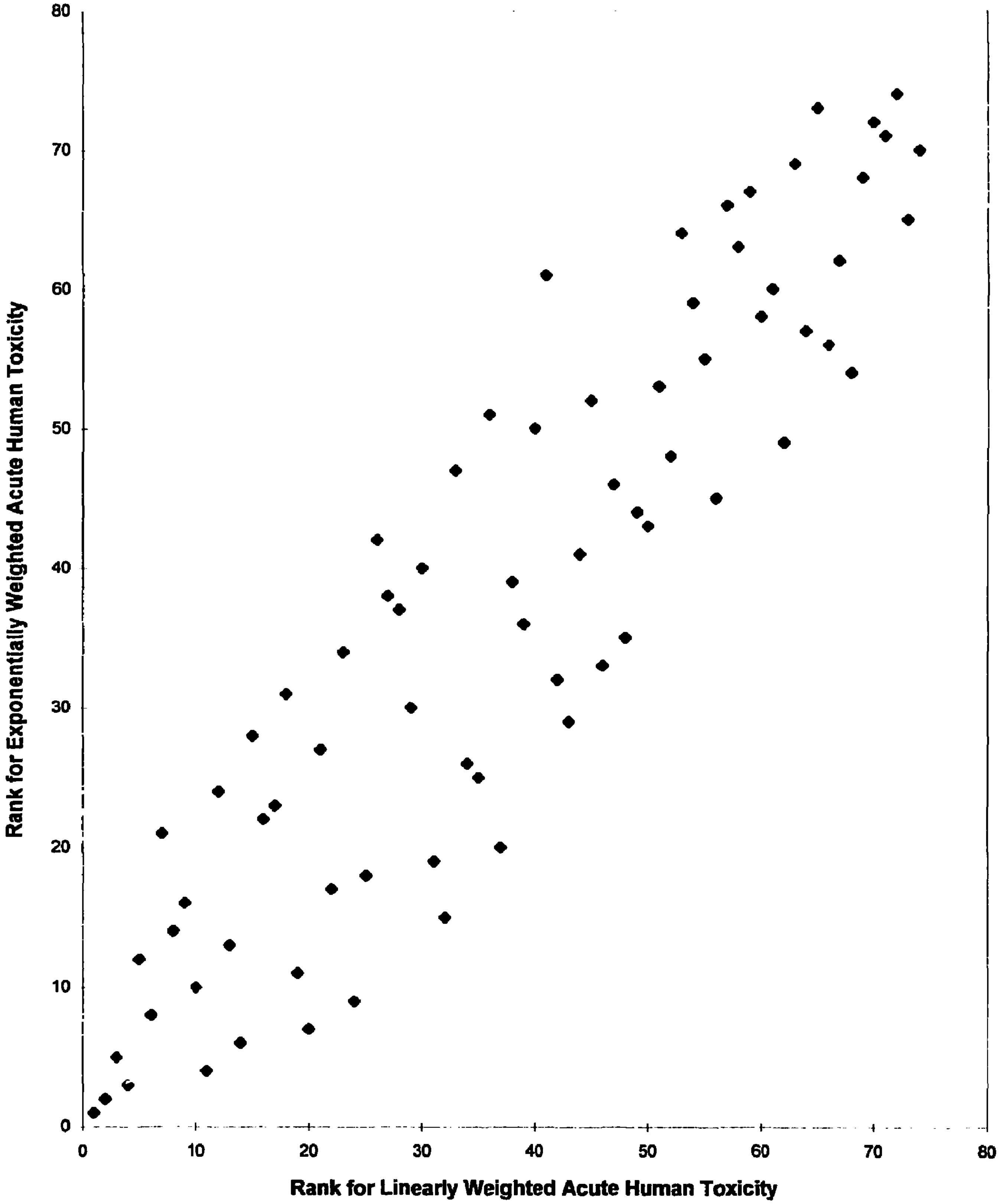


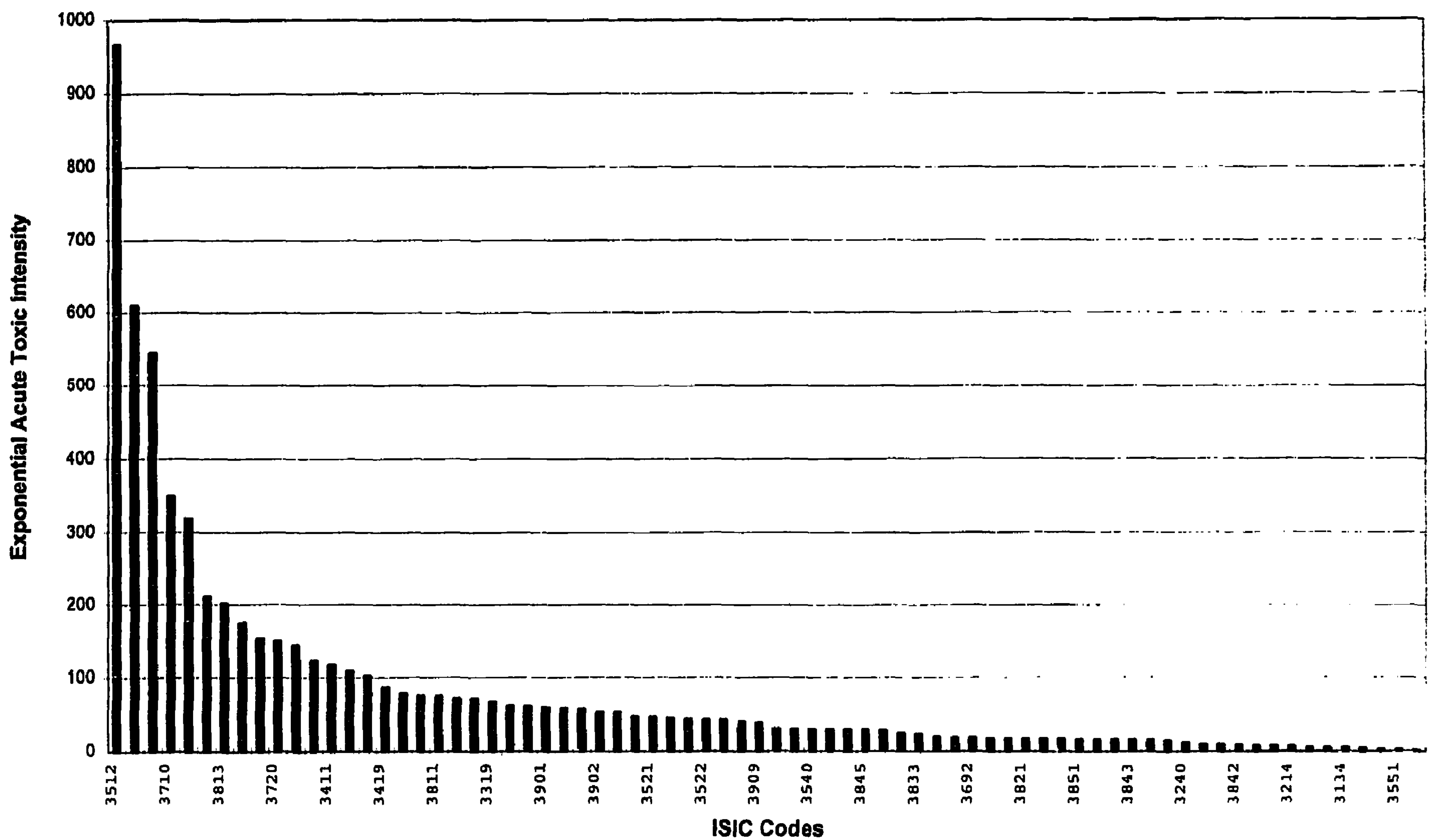
Table 4.3: **<u>Four Digit ISIC Codes and Descriptions in Descending Order of Exponential Acute Human Toxic Intensity Index</u>**
(Risk Weighted Pounds/1987 US$ Million Output Value)

Four Digit ISIC Description	ISIC Code	Exponential Acute Human Toxicity Intensity	Rank
FERTILIZER & PESTICIDES	3512	966.60	1
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	609.77	2
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRES	3513	544.60	3
IRON AND STEEL	3710	349.90	4
TANNERIES AND LEATHER FINISHING	3231	318.93	5
FABRICATED METAL PRODUCTS	3819	212.82	6
STRUCTURAL METAL PRODUCTS	3813	201.71	7
PLASTICS PRODUCTS, N.E.C.	3560	175.56	8
SPINNING, WEAVING, & FINISHING TEXTILES	3211	154.38	9
NONFERROUS METALS	3720	151.22	10
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	144.69	11
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	122.87	12
PULP, PAPER, & PUBLISHING	3411	116.90	13
PRINTING & PUBLISHING	3420	109.25	14
KNITTING MILLS	3213	102.28	15
PULP, PAPER & PAPERBOARD ARTICLES	3419	87.44	16
PETROLEUM REFINERIES	3530	78.63	17
CHEMICAL PRODUCTS, N.E.C.	3529	75.92	18
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	75.45	19
OILS AND FATS	3115	72.28	20
TEXTILES, N.E.C.	3219	72.21	21
WOOD & CORK PRODUCTS, N.E.C.	3319	67.91	22
FURNITURE & FIXTURES, NONMETAL	3320	61.29	23
RUBBER PRODUCTS, N.E.C.	3559	60.76	24
JEWELRY AND RELATED ARTICLES	3901	59.12	25

Four Digit ISIC Description	ISIC Code	Exponential Acute Human Toxicity Intensity	Rank
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	57.62	26
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	56.60	27
MUSICAL INSTRUMENTS	3902	52.07	28
MACHINERY & EQUIPMENT, N.E.C.	3829	51.90	29
MADE-UP TEXTILES EXCEPT APPAREL	3212	46.88	30
PAINTS, VARNISHES, & LACQUERS	3521	46.29	31
SPORTING AND ATHLETIC GOODS	3903	44.92	32
GLASS AND GLASS PRODUCTS	3620	43.58	33
DRUGS AND MEDICINES	3522	42.82	34
DAIRY PRODUCTS	3112	42.74	35
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	39.96	36
MANUFACTURING INDUSTRIES, N.E.C.	3909	38.03	37
METAL & WOOD WORKING MACHINERY	3823	30.30	38
FURNITURE & FIXTURES OF METAL	3812	30.10	39
MISC. PETROLEUM & COAL PRODUCTS	3540	29.44	40
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	29.21	41
POTTERY, CHINA, & EARTHENWARE	3610	29.16	42
AIRCRAFT	3845	28.71	43
PRESERVED FRUITS & VEGETABLES	3113	28.32	44
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	25.10	45
ELECTRICAL APPLIANCES & HOUSEWARES	3833	23.42	46
WATCHES AND CLOCKS	385[illegible]	19.48	47
ELECTRICAL INDUSTRIAL MACHINERY	3831	18.71	48
CEMENT, LIME, AN PLASTER	3692	18.47	49
WEARING APPAREL	3220	17.52	50
SHIPBUILDING AND REPAIRING	3841	17.43	51
ENGINES AND TURBINES	3821	17.13	52
FOOD PRODUCTS, N.E.C.	3121	17.07	53
DISTILLED SPIRITS	3131	16.80	54
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	16.21	55
BAKERY PRODUCTS	3117	15.96	56
WINE INDUSTRIES	3132	15.88	57

Four Digit ISIC Description	ISIC Code	Exponential Acute Human Toxicity Intensity	Rank
MOTOR VEHICLES	3843	15.73	58
PHOTOGRAPHIC AND OPTICAL GOODS	3852	15.37	59
SUGAR FACTORIES & REFINERIES	3118	14.62	60
FOOTWEAR	3240	11.70	61
PREPARED ANIMAL FOODS	3122	9.35	62
AGRICULTURAL MACHINERY & EQUIPMENT	3822	9.24	63
RAILROAD EQUIPMENT	3842	8.46	64
GRAIN MILL PRODUCTS	3116	8.14	65
STRUCTURAL CLAY PRODUCTS	3691	7.90	66
CARPETS AND RUGS	3214	7.18	67
CONFECTIONERY PRODUCTS	3119	5.53	68
TOBACCO MANUFACTURES	3140	5.32	69
SOFT DRINKS & CARBONATED WATERS	3134	5.26	70
MEAT PRODUCTS	3111	5.04	71
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	3.16	72
TIRES AND TUBES	3551	2.89	73
MALT LIQUORS AND MALT	3133	1.99	74

Figure 4.3 - Exponentially Weighted Acute Human Toxic Intensity Index



5. Alternative Estimates, Choice of Denominators, and Medium-Specific Indices of Pollution Intensities

This section describes three major extensions of the IPPS indices introduced in sections 3 and 4. First, Upper Bound (UB) estimates are broadened to include Lower Bound (LB) and Interquartile Mean (IQ) estimates. Second, the intensity estimates are extended to value added and employment as denominators. Finally, intensities for toxic pollution by medium (air, water, land) and many non-toxic air and water pollutants are developed. Box 1 provides brief descriptions of all pollutants incorporated in IPPS.

An additional consideration is the level of sectoral disaggregation to be used for IPPS, which could have been constructed at the enormously detailed seven-digit SIC used in the LRD. However, given that measures of corresponding economic activity in developing countries are most widely available at the four-digit ISIC level, the project has remained focused at this level of aggregation.

BOX 1: MAJOR AIR, WATER AND TOXIC POLLUTANTS

Industrial emissions to air and water pose a variety of hazards to human health, ecosystems, and economic activity.

Air Pollutants

- **Total Suspended Particulates (TP) and Fine Particulates (PM10):** Particulates are fine liquid or solid particles such as dust, smoke, mist, fumes or smog found in air emissions. In heavy concentrations, airborne particulates interfere with proper functioning of the human respiratory system. High levels of ambient TP in urban/industrial areas are therefore associated with greater morbidity and mortality from respiratory diseases. Particulate coatings on leaves inhibit plant growth. High TP concentrations may also force the use of high-cost filtration equipment by manufacturers. Fine particulates (PM10) are less than 10 micron in diameter. They pose the greatest respiratory hazard.

- **Sulphur Dioxide (SO_2):** Sulphur dioxide is a heavy, pungent, colorless, gaseous air pollutant formed primarily by fossil fuel combustion. It is associated with morbidity and mortality from respiratory disease. In addition, SO_2 is a prime source of the acid rain which has damaged huge forest tracts in the OECD and several transitional socialist economies. Acid rain and runoff have raised the acidity in numerous lakes beyond the point where indigenous fish species can survive. Acid rain also degrades concrete, mortar, marble, metals, rubber and plastics.

- **Nitrogen Oxides (NO_x):** Nitrogen dioxide (NO_2) and nitric oxide (NO) are oxides of nitrogen, often collectively referred to as "NO_x." The primary source of NO is thermal combustion of fossil fuels, which emits NO. Higher combustion temperatures, sometimes recommended to reduce emissions of Volatile Organic Compounds (VOCs), are associated with higher production rates of NO_x. NO_x emissions have important ecological impacts, since they are integral to the formation of acid rain and tropospheric ozone. Inhalation of concentrated NO_2 damages the respiratory tract, resulting in a range of effects from mild reductions in pulmonary function to life-threatening pulmonary edema.

- **Carbon Monoxide (CO):** Carbon Monoxide is a colorless, odorless, and tasteless poisonous gas produced by incomplete fossil fuel combustion. CO binds with hemoglobin in human blood 200 times faster than oxygen. Thus, the blood's ability to carry oxygen to tissues is significantly impaired after exposure to only small concentrations of CO. High doses of CO can result in heart and brain damage, impaired perception and asphyxiation, and low doses may cause weakness, fatigue, headaches and nausea.

- **Volatile Organic Compounds (VOC):** The term volatile organic compounds, describes a class of thousands of substances used as solvents and fragrances. VOCs are particularly important in the petrochemical and plastics industries. Human exposure to VOCs is mainly via inhalation, although some VOCs appear as contaminants in drinking water, food, and beverages. Many VOCs are suspected carcinogens. Acute effects from industrial exposures include skin reactions and central nervous system effects such as dizziness and fainting. Recently, sick-building syndrome (SBS) and multiple chemical sensitivity (MCS) have been linked to the relatively low (part per billion) concentrations of VOCs which are more typical of ambient environments. In addition, VOCs may form photochemical oxidants which have been identified as eye and lung irritants.

Water Pollutants

- **Biological Oxygen Demand (BOD):** Organic water pollutants are oxidized by naturally-occurring micro-organisms. This 'biological oxygen demand' removes dissolved oxygen from the water and can seriously damage some fish species which have adapted to the previous dissolved oxygen level. Low levels of dissolved oxygen may enable disease causing pathogens to survive longer in water. Organic water pollutants can also accelerate the growth of algae, which will crowd out other plant species. The eventual death and decomposition of the algae is another source of oxygen depletion as well as noxious smells and unsightly scum. The most common measure for BOD is the amount of oxygen used by micro-organisms to oxidize the organic waste in a standard sample of pollutant during a five-day period (hence, '5-day BOD').

- **Suspended Solids (SS):** Small particles of non-organic, non-toxic solids suspended in waste water will settle as sludge blankets in calm-water areas of streams and lakes. This can smother plant life and purifying micro-organisms, causing serious damage to aquatic ecosystems. The loss of purifying micro-organisms enables pathogens to live longer, raising the risk of disease. When organic solids are part of the sludge, their progressive decomposition will also deplete oxygen in the water and generate noxious gases.

Toxic Pollutants

- **Toxic Chemicals:** Many chemicals in industrial emissions are poisonous to humans, either on immediate exposure or over time, as they accumulate in human tissues. Humans can ingest severely damaging or fatal quantities through repeated exposure, or by consuming plants or animals in which these compounds have accumulated. Toxic chemicals may cause damage to internal organs and neurological functions; can result in reproductive problems and birth defects; and can be carcinogenic. Quantities and length of exposure necessary to cause these effects vary widely. Benzene and asbestos are known carcinogens linked to leukemia and lung cancer.

- **Bioaccumulative Metals:** In bioaccumulation, relatively low concentrations of contaminants in air, water, soil and plants become far more concentrated further up the food chain. Some metals can be converted to organic forms by bacteria, increasing the risk that they will enter the food chain. Bioaccumulative metals are particularly dangerous because they are dissipated very slowly by natural systems. They may cause both mental and physical birth defects. Metals can also become rapidly oxidized and converted to soluble form when sediment is exposed to oxygen. Some of the metals which are commonly measured and particularly dangerous are mercury, lead, arsenic, chromium, nickel, copper, zinc and cadmium.

5.1 Alternative Estimates of Sectoral Pollution Intensities

The impact on industrial sector rankings of different intensity measures is best illustrated by their rank correlation coefficients. As described in section 3.2.4, a range of intensity measures can be calculated for each industrial sector. Table 5.1 presents the rank correlation coefficients across these measures for toxic air pollution intensity.

Table 5.1: **Rank Correlation Coefficients Between Different Intensity Measures: Toxic Air Pollution Intensity With Respect to Total Value of Output**

Type of Measurement	Upper Bound	Inter-Quartile Mean	Lower Bound
Upper Bound	1.00	0.79	0.82
Inter-Quartile Mean	0.79	1.00	0.72
Lower Bound	0.82	0.76	1.00

The toxic air correlations are quite high, as are the corresponding correlations for toxic land pollution (not shown). For water and non-toxic air pollution, however, the results are not so clear. The water pollution intensity measures are not very robust for a few sectors because of the presence of large outliers in the EPA database. The rankings differ considerably across intensity measures, with correlation coefficients typically around 0.5. The presence of extreme outliers suggests reliance on LB or IQ estimates. For water pollution LB estimates may be optimum for most uses, because they are based on the largest sample of available data and provide the most conservative estimate. Outliers also haunt the AIRS data for some criteria air pollutants, like fine particulates. Therefore, for PM10, LB is the most conservative intensity estimate available.[7]

5.2 Different Measures of Activity

Medium-specific intensities were calculated for each of the following measures of activity:

- total value of shipment (TVS) in millions of 1987 US $;
- value added (VA) in millions of 1987 US $;
- total employment (TE) in thousands of persons.

The advantages and disadvantages of each measure have already been discussed in section 3.2.3. By developing all three, we provide more options for areas where data are scarce. Table 5.2 shows that the intensity rankings are almost perfectly correlated in any case. Therefore, the choice of measure should be driven by the availability, reliability, coverage and detail of the corresponding production data. The more disaggregate the available information, the more robust the intensity measure will be, irrespective of which scaling variable is used.

[7]The LB air pollution intensity estimates incorporate all the AIRS observations in the numerator; total ativity levels from the 1987 LRD were used in the denominator.

Table 5.2: **Rank Correlation Coefficients Between Intensity Measures Using Different Scales of Activity: Lower-Bound Toxic Water Pollution Intensity**

Scale of Activity	Total Value of Shipments	Value Added	Employment
Total Value of Shipments	1.00	0.99	0.98
Value Added	0.99	1.00	0.98
Employment	0.98	0.98	1.00

5.3 Medium-Specific Intensities

Medium-specific indices are useful for two reasons. First, they provide a better indication of the ecological stress and health risks imposed by pollution than estimates which do not distinguish the medium of discharge. Second, they allow analysis of the extent to which inter-medium substitution of waste disposal is possible within a given sector, an important consideration in comprehensive pollution control.

Current development of IPPS has drawn on plant-level pollution information from **all** of the previously mentioned US EPA pollution data bases: Toxic Release Inventory (TRI), Aerometric Information Retrieval System (AIRS) and National Pollutant Discharge Elimination System (NPDES). Using the corresponding economic data from the LRD, intensities have been calculated for 14 different pollutants. These intensities, calculated as pounds of pollutant released per unit of production in each industrial sector, are listed in Table 5.3.

Full sets of intensities by three-digit or four-digit ISIC sector are available from the authors upon request.

Table 5.3: **Pollution Intensities in IPPS**

1. Toxic and Bio-Accumulative Pollution Intensities by Medium:*

1. Toxic Pollution to Air
2. Toxic Pollution to Water
3. Toxic Pollution to Land
4. Bio-Accumulative Metal Pollution to Air
5. Bio-Accumulative Metal Pollution to Water
6. Bio-Accumulative Metal Pollution to Land

2. Criteria Air Pollution Intensities:

7. Sulphur Dioxide (SO2)
8. Nitrogen Dioxide (NO2)
9. Carbon Monoxide (CO)
10. Volatile Organic Compounds (VOC)
11. Particulates less than 10 um in diameter (PM10)
12. Total Particulates (TP)

3. Water Pollution Intensities:

13. Biological Oxygen Demand (BOD)
14. Total Suspended Solids (TSS)

* Since all risk-weighted indices are highly correlated with total toxic intensity, we have standardized on the latter. See Section 4.4.

5.3.1 Total Toxic Pollution Intensities by Medium

Extreme sectoral variation in toxic pollution intensity within each medium is indicated by Figures 5.1 and 5.2, which focus on sectors with output-based intensities greater than 3000 lbs/$1 million (US 1987). As before, pollution intensities by medium show an exponential distribution when arranged in descending order. However, it is clear that there is little correspondence between the most pollution-intensive sectors across media (see Figure 5.2). For example, Pulp, Paper, and Paperboard (3411) is relatively intensive in toxic water and air pollution; Iron and Steel (3710) is prominent in land and water; Textiles n.e.c. (3219) is mostly air pollution intensive.

Figure 5.1- Toxic Pollution Intensity by Medium for Selected Sectors

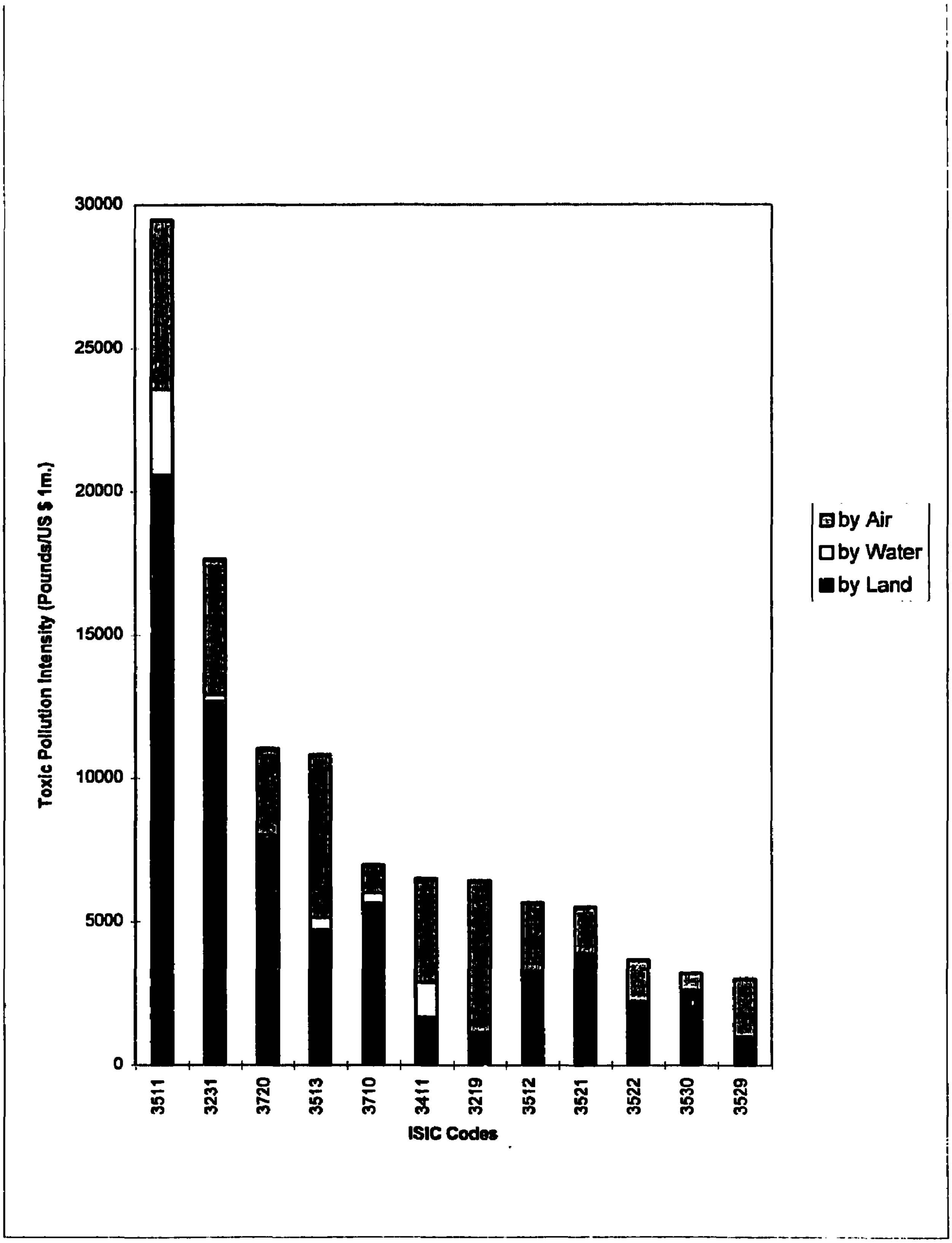
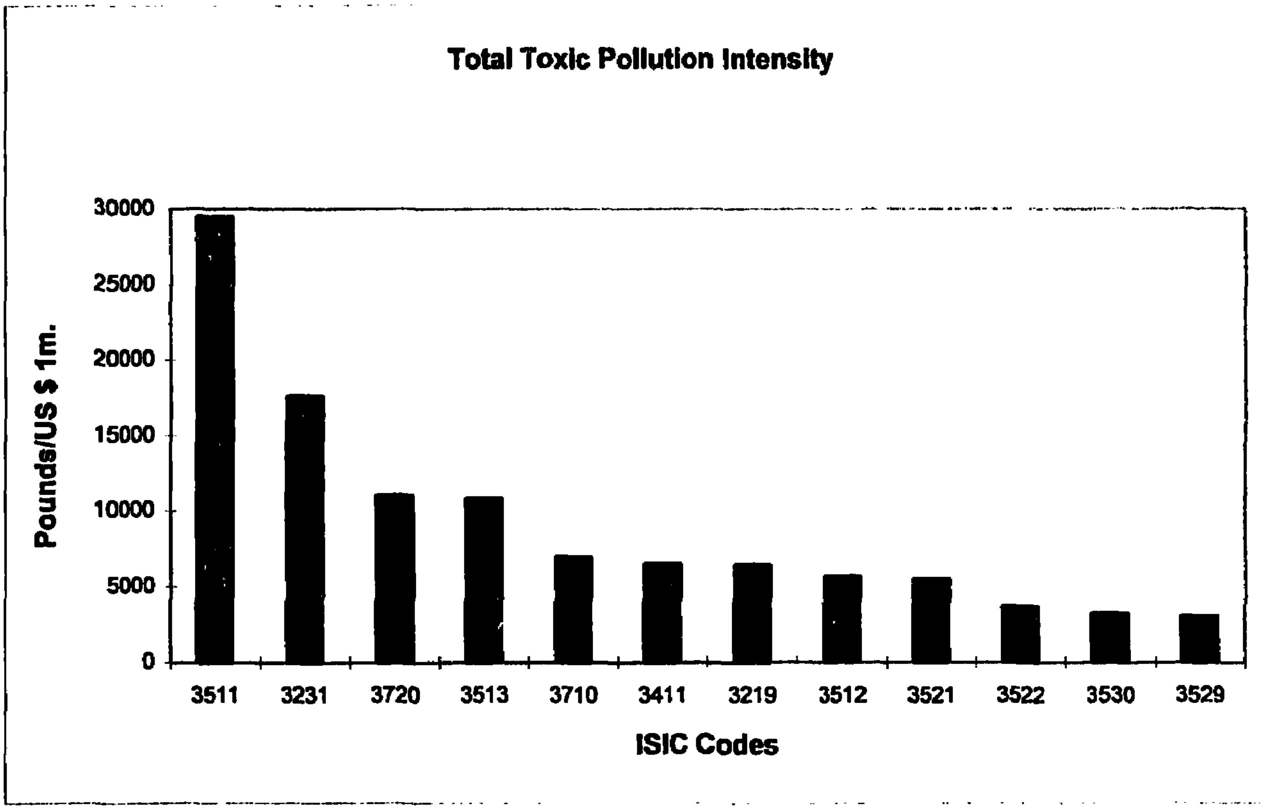


Figure 5.2 - Toxic Pollution Intensity by Medium for Selected Sectors



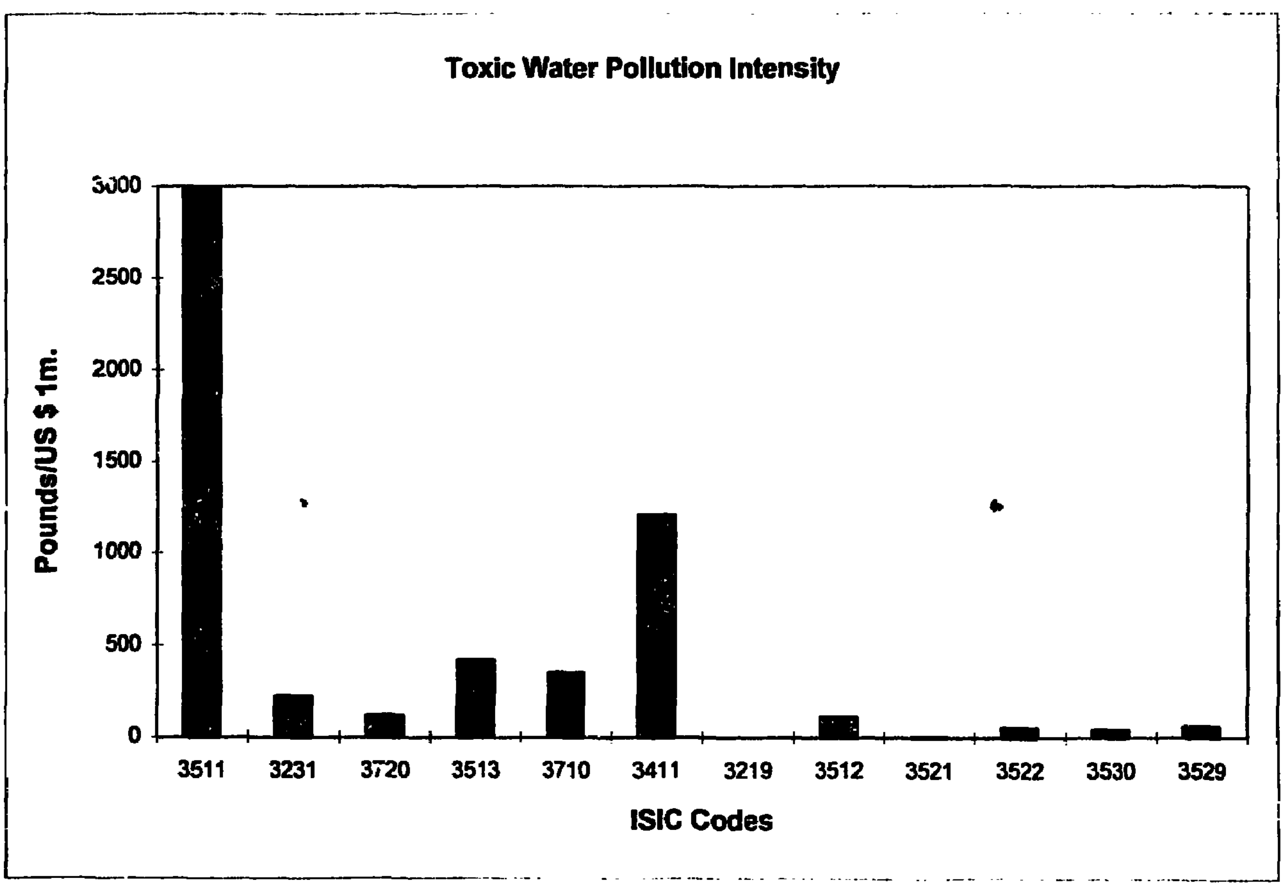
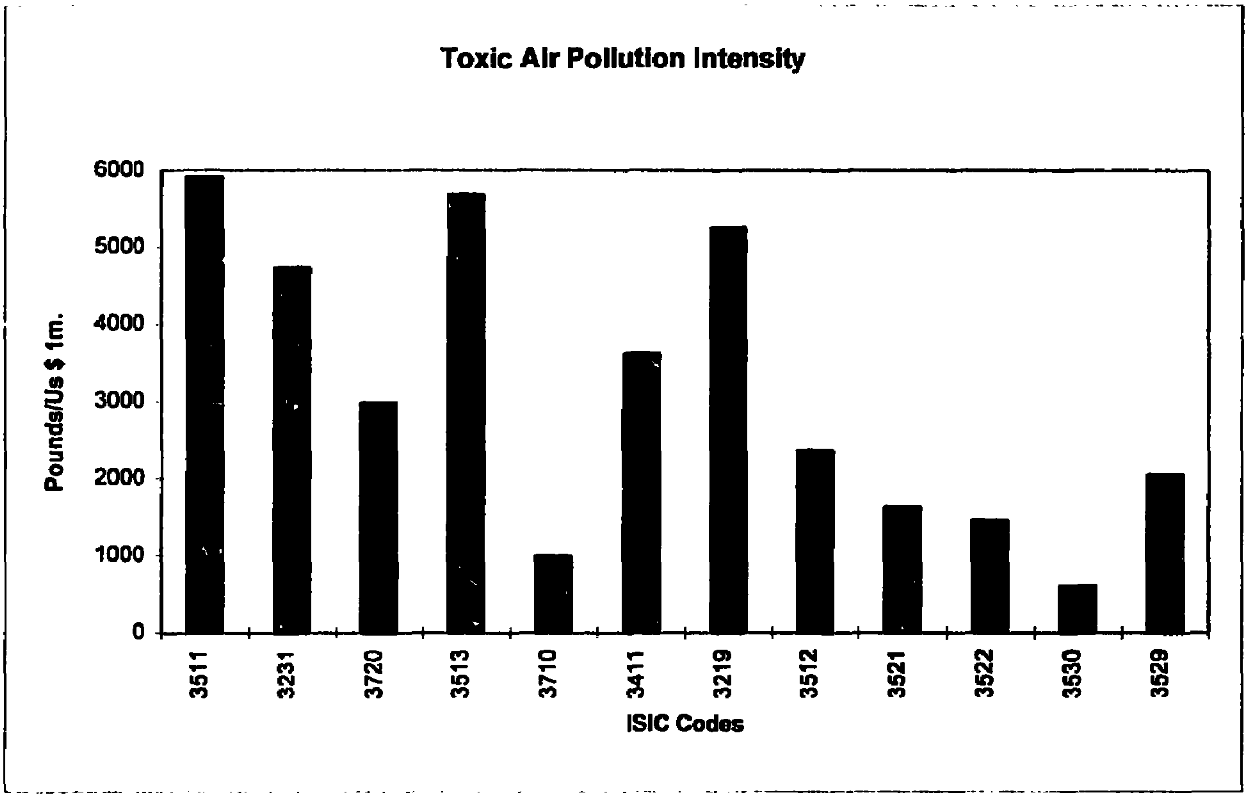
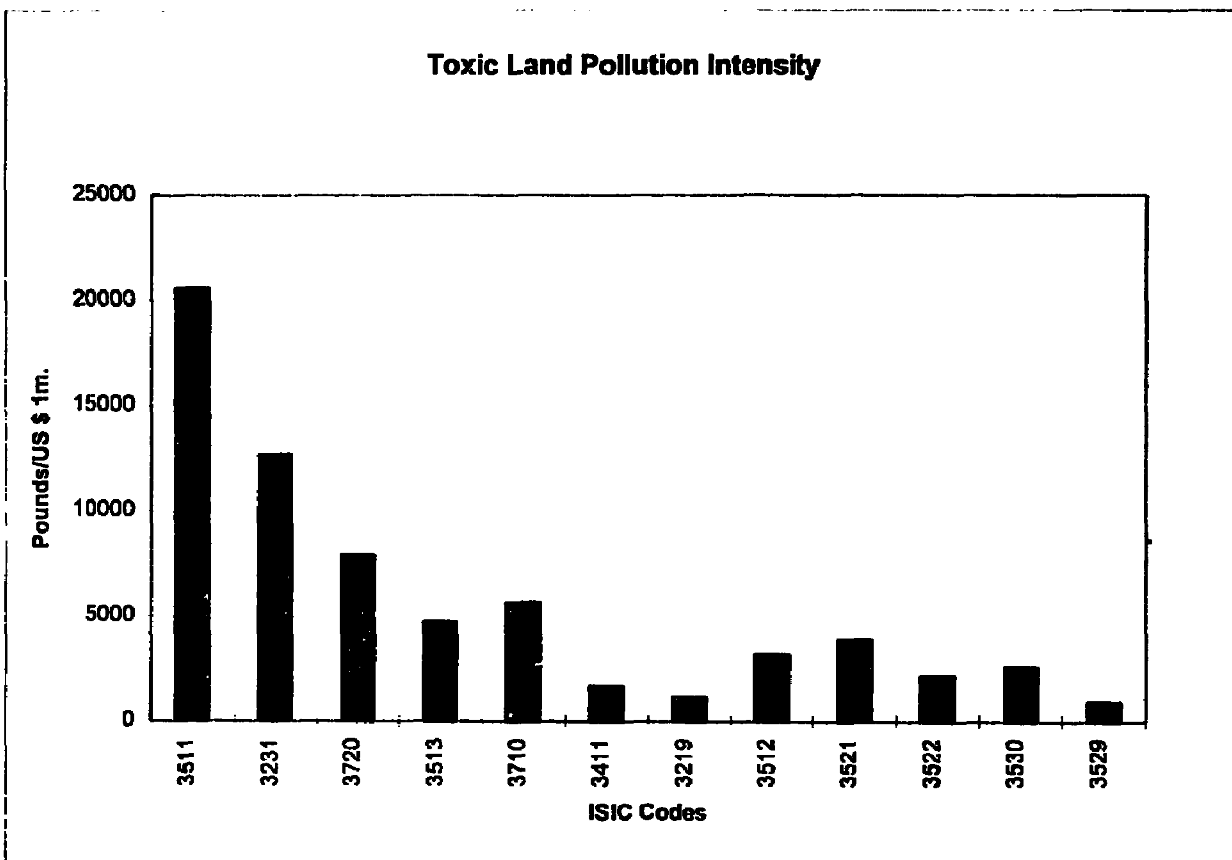


Figure 5.2 - Toxic Pollution Intensity by Medium for Selected Sectors





The results displayed in Table 5.4 confirm that there is little correlation between the rankings of sectors discharging toxics by water and air. In fact, when Inter-Quartile Mean intensities are compared, the air rankings are negatively correlated with land and water rankings. These low correlations also suggest that inter-medium substitutability may be a second-order problem for toxic waste.

Table 5.4: **Rank Correlation Coefficients Between Toxic Pollutants by Different Media: Lower-Bound Toxic Pollution Intensity with Respect to Value Added**

Discharge Medium	Air	Land	Water	All Media
Air	1.00	0.70	0.32	0.93
Land	0.70	1.00	0.60	0.87
Water	0.32	0.60	1.00	0.46
All Media	0.93	0.87	0.46	1.00

There are, however, a few industries which are highly toxic pollution intensive in all three media (See Table 5.5). These are Industrial Chemicals Except Fertilizer (3511), Plastics and Man-made Fibers (3513), Tanneries and Leather Finishing (3231), and Non-Ferrous Metals (3720). The least toxic pollution-intensive manufacturing sectors with respect to air, water and land are food-processing industries such as Bakery Products (3117), Grain Mill Products (3116), Fish Products (3114); and other industries such as Wearing Apparel (3220).

Table 5.5 <u>Toxic Pollution Intensity by Medium</u>
(Pounds/1987 US $ Million Output Value)

Four Digit ISIC Description	ISIC	By Air		By Land		By Water	
	Code	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile
MEAT PRODUCTS	3111	47.47	91.88	44.34	7.91	7.11	0.00
DAIRY PRODUCTS	3112	31.03	11.66	254.19	464.37	22.35	0.00
PRESERVED FRUITS & VEGETABLES	3113	64.61	55.92	225.98	56.57	18.17	0.00
FISH PRODUCTS	3114	11.20		12.79		0.00	
OILS AND FATS	3115	161.59	50.33	944.13	33.55	52.26	0.00
GRAIN MILL PRODUCTS	3116	5.73		2.42		0.00	
BAKERY PRODUCTS	3117	4.79		5.83		0.00	
SUGAR FACTORIES & REFINERIES	3118	55.35	16.98	264.45	307.94	1.54	0.00
CONFECTIONERY PRODUCTS	3119	29.55		36.81		0.00	
FOOD PRODUCTS, N.E.C.	3121	49.02	24.43	87.30	12.62	3.49	0.00
PREPARED ANIMAL FOODS	3122	20.31	76.66	26.68	16.88	1.72	0.00
DISTILLED SPIRITS	3131	1.43		14.92		48.94	
WINE INDUSTRIES	3132	61.06		154.87		0.00	
MALT LIQUORS AND MALT	3133	109.91		59.29		6.23	
TOBACCO MANUFACTURES	3140	271.80		26.93		1.85	
SPINNING, WEAVING, & FINISHING TEXTILES	3211	350.96	353.79	326.21	155.89	178.85	0.32
MADE-UP TEXTILES EXCEPT APPAREL	3212	244.02		41.15		3.31	
KNITTING MILLS	3213	139.68	75.38	273.27	588.20	12.87	0.04
CARPETS AND RUGS	3214	192.69	247.46	347.53	415.11	46.26	0.00
CORDAGE, ROPE & TWINE	3215	2123.56		5.82		0.00	
TEXTILES, N.E.C.	3219	5253.30	3413.19	1183.45	286.33	0.47	0.00
WEARING APPAREL	3220	12.70		4.79		0.00	
TANNERIES AND LEATHER FINISHING	3231	4733.22	2332.36	12687.84	5278.62	220.02	0.00
FUR DRESSING AND DYEING	3232	692.88		861.93		20.08	
LEATHER PRODUCTS	3233	81.70		4.84		0.00	
FOOTWEAR	3240	472.39		13.96		0.06	
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	226.97	556.97	71.31	54.94	1.09	0.00
WOODEN & CANE CONTAINERS; SMALL CANE WARE	3312	8.50		0.60		0.00	

Four Digit ISIC Description	ISIC	BY Air		By Land		By Water	
	Code	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile
WOOD & CORK PRODUCTS, N.E.C.	3319	1490.24		138.85		0.13	
FURNITURE & FIXTURES, NONMETAL	3320	1390.62	4446.51	125.28	104.35	1.00	0.00
PULP, PAPER, & PAPERBOARD	3411	3627.03	1028.90	1671.80	45.36	1209.31	38.52
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	435.38	1746.46	79.59	191.73	6.61	0.00
PULP, PAPER & PAPERBOARD	3419	1589.12	4709.00	400.67	420.21	6.00	0.00
PRINTING & PUBLISHING	3420	413.12	1546.91	55.79	164.80	0.02	0.00
IND. CHEM. EXCEPT FERTILIZER	3511	5923.99	813.65	20577.03	903.72	2992.90	0.59
FERTILIZERS & PESTICIDES	3512	2363.89	243.21	3204.00	138.83	110.89	0.00
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRES	3513	5692.07	1383.88	4718.77	527.61	416.18	0.27
PAINTS, VARNISHES, & LACQUERS	3521	1621.59	746.57	3891.10	416.51	4.22	0.00
DRUGS AND MEDICINES	3522	1451.39	802.73	2172.40	359.78	56.08	0.00
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	363.94	144.87	616.05	102.11	5.23	0.00
CHEMICAL PRODUCTS, N.E.C.	3529	2042.06	601.86	927.63	238.58	61.18	0.00
PETROLEUM REFINERIES	3530	607.86	281.50	2574.07	49.70	45.84	8.91
MISC. PETROLEUM & COAL PRODUCTS	3540	398.09	43.70	117.18	50.51	11.66	0.00
TIRES AND TUBES	3551	137.76	100.23	237.89	154.84	2.85	0.00
RUBBER PRODUCTS, N.E.C.	3559	1757.17	1943.34	671.38	339.74	0.43	0.00
PLASTICS PRODUCTS, N.E.C.	3560	1896.01	4141.55	561.73	132.58	4.63	0.00
POTTERY, CHINA, & EARTHENWARE	3610	456.27	310.82	746.58	652.42	0.97	0.00
GLASS AND GLASS PRODUCTS	3620	211.54	147.36	136.09	13.64	17.15	0.00
STRUCTURAL CLAY PRODUCTS	3691	949.03	40.54	418.32	142.85	1.88	0.00
CEMENT, LIME, AND PLASTER	3692	27.95	25.53	79.76	40.42	43.17	0.00
NONMETALLIC MINERAL PROD.N.E.C.	3699	417.88	842.35	687.98	354.27	2.08	0.00
IRON AND STEEL	3710	985.15	393.59	5647.07	1454.03	350.16	0.16
NONFERROUS METALS	3720	2988.29	391.40	7920.98	350.57	116.07	0.00
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	726.01	942.34	397.16	324.35	2.50	0.00
FURNITURE & FIXTURES OF METAL	3812	602.41	966.42	308.07	299.83	1.30	0.00
STRUCTURAL METAL PRODUCTS	3813	289.96	709.63	326.82	186.37	72.85	0.00
FABRICATED METAL PRODUCTS	3819	1226.97	1246.20	1498.62	645.46	41.14	0.00
ENGINES AND TURBINES	3821	565.63	705.07	497.01	326.01	6.87	0.00
AGRICULTURAL MACHINERY & EQUIPMENT	3822	250.49	540.32	69.07	34.33	9.32	0.00

Four Digit ISIC Descritption	ISIC	BY Air		By Land		By Water	
	Code	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile	Lower-Bound	Inter Quartile
METAL & WOOD WORKING MACHINERY	3823	154.24	353.16	338.54	110.35	3.55	0.00
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	148.61	320.63	245.51	60.58	2.67	0.00
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	111.20	262.44	39.46	25.78	0.08	0.00
MACHINERY & EQUIPMENT, N.E.C.	3829	472.39	636.59	212.51	128.54	14.95	0.00
ELECTRICAL INDUSTRIAL MACHINERY	3831	381.77		188.64		1.97	
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	732.25	638.96	660.59	525.21	6.47	0.00
ELECTRICAL APPLIANCES & HOUSEWARES	3833	203.56		117.99		0.04	0.00
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	414.90	254.13	858.69	237.32	10.33	0.00
SHIPBUILDING AND REPAIRING	3841	1970.26	5291.43	284.00	36.46	0.28	0.00
RAILROAD EQUIPMENT	3842	413.34		221.70		0.24	
MOTOR VEHICLES	3843	445.62	465.61	201.48	154.76	2.21	0.00
MOTORCYCLES AND BICYCLES	3844	236.54		171.69		95.74	
AIRCRAFT	3845	607.54	854.20	314.53	247.51	1.35	0.00
PROFESSIONAL & SCIENTIFIC	3851	306.97	508.07	149.92	106.22	1.09	0.00
PHOTOGRAPHIC AND OPTICAL GOODS	3852	773.23		420.85		0.07	
WATCHES AND CLOCKS	3853	531.95		275.08		0.00	
JEWELERY AND RELATED ARTICLES	3901	136.69		49.22		13.57	
MUSICAL INSTRUMENTS	3902	779.85		590.22		0.00	
SPORTING AND ATHLETIC GOODS	3903	381.74	1228.02	117.42	155.47	0.28	0.00
MANUFACTURING INDUSTRIES,	3909	496.12	1089.30	226.19	250.08	4.10	0.00

5.3.2 Metals Intensities

As previously mentioned, metals pose a particularly serious problem because they bioaccumulate. The natural distribution of metals is progressively altered by industrial activity, giving rise to focal concentrations. The potential consequences for exposed populations were demonstrated by

Japan's Minamata crisis in the 1960's: Hundreds of people were killed or severely damaged by poisonous levels of industrial mercury in fish. Separate attention to metals is clearly warranted, since the rank correlations of metals intensity with the toxic intensity measures are low (See Table 4.2). Separate IPPS intensities for toxic metal emissions to air, water and land are presented in Table 5.6.

As expected, Non-Ferrous Metals (3720), and Iron and Steel (3710) have very high metals intensities. Other sectors whose toxic intensity is high are also metals-intensive (e.g., Industrial Chemicals Except Fertilizer (3511); Tanneries and Leather Finishing (3231)). In contrast, Fertilizer & Pesticides (3512), Synthetic Resins and Plastics (3513) and Pulp and Paper (3411) are toxic-intensive but not particularly metals-intensive.

Table 5.6: **Toxic Metal Pollution Intensity by Medium**
(Pounds/1987 US$ Million Output Value)

Four Digit ISIC Description	ISIC Code	By Air	By Land	By Water
MEAT PRODUCTS	3111	0.00	0.03	0.37
DAIRY PRODUCTS	3112	0.02	0.00	0.00
PRESERVED FRUITS & VEGETABLES	3113	0.00	0.56	0.13
FISH PRODUCTS	3114			
OILS AND FATS	3115	0.06	19.33	0.01
GRAIN MILL PRODUCTS	3116	0.06	1.53	0.00
BAKERY PRODUCTS	3117			
PREPARED ANIMAL FOODS	3122	0.41	0.52	0.00
WINE INDUSTRIES	3132	0.00	0.67	0.00
MALT LIQUORS AND MALT	3133	0.08	26.77	0.01

Four Digit ISIC Description	ISIC Code	By Air	By Land	By Water
TOBACCO MANUFACTURES	3140			
SPINNING, WEAVING, & FINISHING TEXTILES	3211	2.89	58.52	0.20
MADE-UP TEXTILES EXCEPT APPAREL	3212	2.36	6.81	0.00
KNITTING MILLS	3213	0.00	1.29	0.00
CARPETS AND RUGS	3214			
CORDAGE, ROPE & TWINE	3215	8.73	0.00	0.00
TEXTILES, N.E.C.	3219	1.08	22.19	0.20
WEARING APPAREL	3220	0.01	0.84	0.00
TANNERIES AND LEATHER FINISHING	3231	1.61	854.36	1.30
FUR DRESSING AND DYEING	3232	0.54	528.66	0.22
FOOTWEAR	3240			
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	2.32	30.83	0.05
WOODEN & CANE CONTAINERS; SMALL CANE WARE	3312	0.00	0.60	0.00
WOOD & CORK PRODUCTS, N.E.C.	3319	0.06	0.66	0.00
FURNITURE & FIXTURES, NONMETAL	3320	0.87	1.84	0.00
PULP, PAPER, & PAPERBOARD	3411	0.34	17.19	7.84
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	0.00	0.07	0.00
PULP, PAPER & PAPERBOARD ARTICLES,	3419	9.58	12.30	0.46
PRINTING & PUBLISHING	3420	0.02	1.37	0.00
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	29.32	929.58	27.23
FERTILIZERS & PESTICIDES	3512	3.96	276.53	0.68
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE	3513	1.58	245.86	5.14
PAINTS, VARNISHES, & LACQUERS	3521	13.76	105.97	0.09
DRUGS AND MEDICINES	3522	0.25	28.16	0.14
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	0.34	25.82	0.23
CHEMICAL PRODUCTS, N.E.C.	3529	1.05	16.39	3.40
PETROLEUM REFINERIES	3530	4.95	45.76	1.96
MISC. PETROLEUM & COAL PRODUCTS	3540	0.72	23.08	0.23
TIRES AND TUBES	3551	5.35	208.28	0.27
RUBBER PRODUCTS, N.E.C.	3559	3.32	310.72	0.28
PLASTICS PRODUCTS, N.E.C.	3560	0.44	16.99	0.36
POTTERY, CHINA, & EARTHENWARE	3610	3.27	281.45	0.54
GLASS AND GLASS PRODUCTS	3620	21.93	27.89	0.06
STRUCTURAL CLAY PRODUCTS	3691	13.56	357.62	0.96
CEMENT, LIME, AND PLASTER	3692	0.98	40.25	0.00
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	6.90	48.66	0.05

Four Digit ISIC Description	ISIC Code	By Air	By Land	By Water
IRON AND STEEL	3710	169.11	3728.58	25.57
NONFERROUS METALS	3720	206.75	6849.73	4.12
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	12.40	142.40	0.18
FURNITURE & FIXTURES OF METAL	3812	1.42	20.86	0.01
STRUCTURAL METAL PRODUCTS	3813	6.44	99.01	1.45
FABRICATED METAL PRODUCTS	3819	9.96	447.75	3.43
ENGINES AND TURBINES	3821	32.09	90.69	0.25
AGRICULTURAL MACHINERY & EQUIPMENT	3822	1.31	10.99	0.09
METAL & WOOD WORKING MACHINERY	3823	2.84	237.88	0.02
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	1.04	34.06	0.03
MACHINERY & EQUIPMENT, N.E.C.	3829	3.38	107.63	0.20
ELECTRICAL INDUSTRIAL MACHINERY	3831	9.42	68.94	1.12
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	0.85	73.06	0.16
ELECTRICAL APPLIANCES & HOUSEWARES	3833	0.13	15.64	0.03
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	12.36	468.82	0.44
SHIPBUILDING AND REPAIRING	3841	45.04	30.34	0.15
RAILROAD EQUIPMENT	3842	10.10	41.55	0.00
MOTOR VEHICLES	3843	1.94	40.61	0.04
MOTORCYCLES AND BICYCLES	3844	4.56	33.20	1.82
AIRCRAFT	3845	0.46	39.16	0.09
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	0.15	16.51	0.02
PHOTOGRAPHIC AND OPTICAL GOODS	3852	0.07	37.03	0.00
WATCHES AND CLOCKS	3853	1.27	0.21	0.00
JEWELERY AND RELATED ARTICLES	3901	0.26	10.35	0.24
MUSICAL INSTRUMENTS	3902	4.26	42.44	0.00
SPORTING AND ATHLETIC GOODS	3903	0.31	17.52	0.28
MANUFACTURING INDUSTRIES, N.E.C.	3909	7.70	82.68	0.29

5.3.3 Air Pollution Indicators

The major air pollution intensities compiled in this paper can be grouped into 5 distinctly different categories. The first group, consisting of SO2, NO2, CO and total Particulates, exhibit consistently high rank correlations (see Table 5.7). The sector rankings for volatile organic compounds (VOCs), PM10, total toxic air pollution and toxic metals are correlated neither with each other nor with any of the other air pollution intensities, so they form distinct categories.

Table 5.7 <u>**Rank Correlations between Major Air Pollutant Intensities: Inter-Quartile Mean Intensities per Unit of Total Output**</u>

Inter-Quartile Intensity	SO2	NO2	CO	TP	PM10	VOC	All Toxics by Air	Toxic Metals by Air
SO2	1.00	0.89	0.8	0.85	0.65	0.58	0.21	0.27
NO2	0.89	1.00	0.86	0.81	0.67	0.56	0.19	0.24
CO	0.8	0.86	1.00	0.76	0.63	0.62	0.28	0.33
TP	0.85	0.81	0.76	1.00	0.75	0.59	0.17	0.18
PM10	0.65	0.67	0.63	0.75	1.00	0.45	0.15	0.08
VOC	0.58	0.56	0.62	0.59	0.45	1.00	0.57	0.47
All Toxics	0.21	0.19	0.28	0.17	0.15	0.57	1.00	0.53
Toxic Metals by Air	0.27	0.24	0.33	0.18	0.08	0.47	0.53	1.00

Figure 5.3 displays high-intensity sectors for all the air pollutants analyzed in this paper. In group 1 (SO_2, NO_2, CO and Total Particulates), high intensity sectors include: Cement, Lime and Plaster (3692), Pulp, Paper and Paperboard (3411), Iron and Steel (3710), Miscellaneous Petroleum and Coal products (3540), and Structural Clay Products (3691). Toxic Air and VOC intensities are high in: Synthetic Resins, Plastics and man-made Fibers (3513), Textiles n.e.c. (3219), and Industrial Chemicals except Fertilizer (3511). Inter-quartile intensities of PM10 are recorded in only three of the four-

digit ISIC sectors. This reflects the relatively small matched sample for this pollutant compared to the other air pollutants. The lower bound intensities for PM10 however, are more robust and exhibit a pattern similar to that of Total Particulates.

Table 5.8: Air Pollution Intensity for Selected Air Pollutants
(Pounds/1987 US$ Million Output Value)

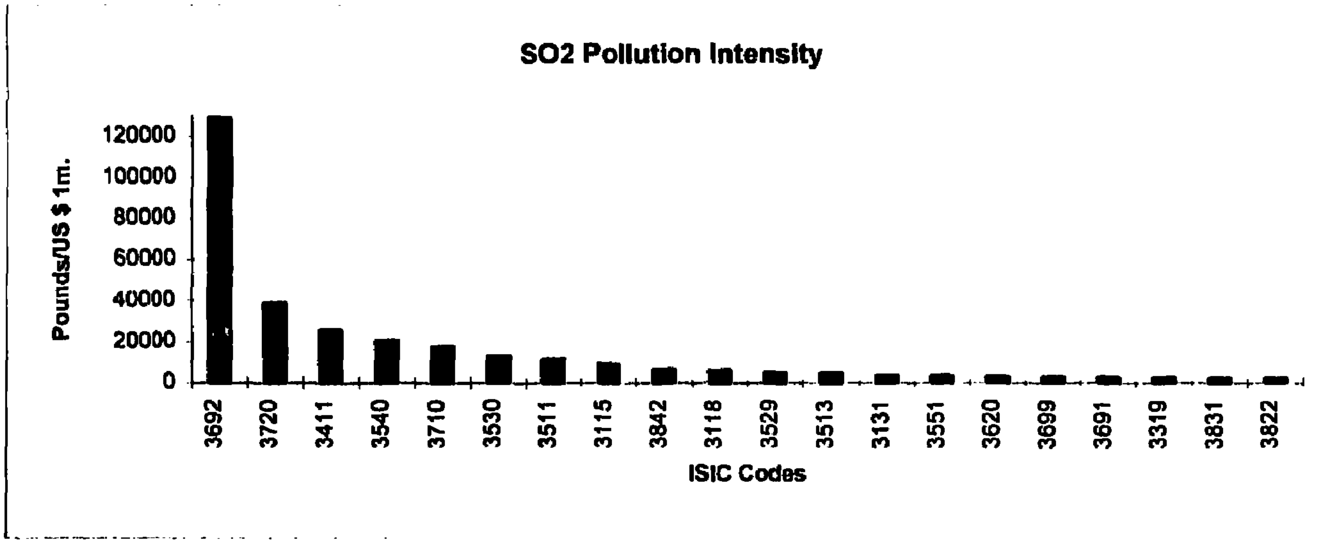
Four Digit ISIC Description	ISIC Code	SO2	NO2	CO	VOC	PM10	TP
MEAT PRODUCTS	3111	195	1997	499	10	6	56
DAIRY PRODUCTS	3112	141	198	35	9	0	73
PRESERVED FRUITS & VEGETABLES	3113	736	375	72	136	5	73
FISH PRODUCTS	3114	173	76	5	2	2	32
OILS AND FATS	3115	9387	3360	750	2572	5901	9615
GRAIN MILL PRODUCTS	3116	328	262	51	277	542	1616
BAKERY PRODUCTS	3117	16	36	5	179	0	16
SUGAR FACTORIES & REFINERIES	3118	6428	6171	3306	1094	135	4258
CONFECTIONERY PRODUCTS	3119	97	20	3	2	0	10
FOOD PRODUCTS, N.E.C.	3121	432	439	94	132	12	196
PREPARED ANIMAL FOODS	3122	745	205	56	24	308	1341
DISTILLED SPIRITS	3131	3887	1351	253	13355	170	325
WINE INDUSTRIES	3132	462	70	6	1	0	48
MALT LIQUORS AND MALT	3133	2146	1690	105	176	3	118
TOBACCO MANUFACTURES	3140	1265	766	100	252	10	24
SPINNING, WEAVING, & FINISHING TEXTILES	3211	2422	3342	448	917	65	433
MADE-UP TEXTILES EXCEPT APPAREL	3212	18	11	3	126	0	26
KNITTING MILLS	3213	217	90	37	73	13	136
CARPETS AND RUGS	3214	0	0	0	0	0	0
CORDAGE, ROPE & TWINE	3215	2075	648	904	1261	0	1094
TEXTILES, N.E.C.	3219	748	309	56	5938	0	445
WEARING APPAREL	3220	32	12	3	8	0	1

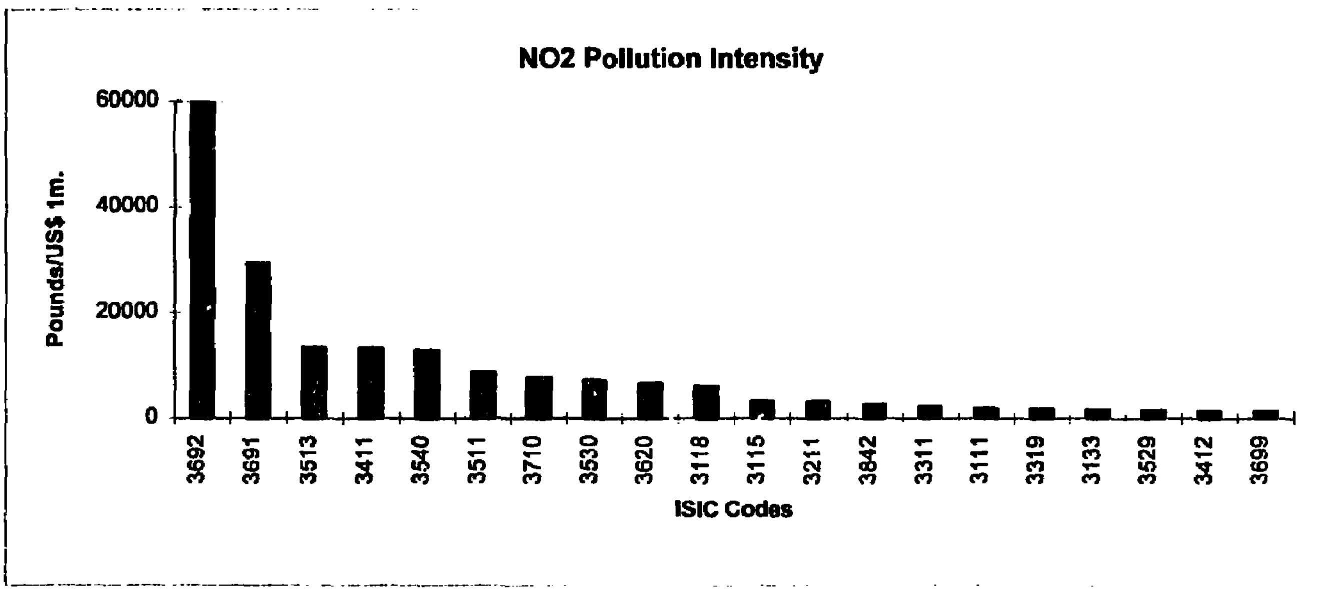
Four Digit ISIC Description	ISIC Code	SO2	NO2	CO	VOC	PM10	TP
TANNERIES AND LEATHER FINISHING	3231	1299	343	126	3819	41	157
FUR DRESSING AND DYEING	3232	932	219	52	584	21	788
LEATHER PRODUCTS	3233	0	16	3	285	0	10
FOOTWEAR	3240	16	2	0	134	0	1
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	1036	2342	5901	2509	92	3258
WOODEN & CANE CONTAINERS; SMALL CANE WARE	3312	1	2	8	41	18	268
WOOD & CORK PRODUCTS, N.E.C.	3319	2968	1923	4293	5818	1755	4373
FURNITURE & FIXTURES, NONMETAL	3320	243	172	182	5510	160	547
PULP, PAPER, & PAPERBOARD	3411	25585	13349	29203	4043	1453	5028
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	201	1472	341	446	8	46
PULP, PAPER & PAPERBOARD ARTICLES,	3419	417	128	39	700	0	10
PRINTING & PUBLISHING	3420	26	34	129	862	0	14
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	11656	8658	6687	6766	395	1873
FERTILIZERS & PESTICIDES	3512	1106	1065	212	1008	47	307
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRES	3513	5185	13477	1993	9862	4	792
PAINTS, VARNISHES, & LACQUERS	3521	246	217	31	1819	74	146
DRUGS AND MEDICINES	3522	1825	775	91	908	13	345
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	476	567	196	184	193	255
CHEMICAL PRODUCTS, N.E.C.	3529	5291	1652	53782	4098	1361	1847
PETROLEUM REFINERIES	3530	12664	7285	6579	6705	128	1117
MISC. PETROLEUM & COAL PRODUCTS	3540	20866	12982	9828	3259	641	8004
TIRES AND TUBES	3551	3797	1312	161	3844	54	420
RUBBER PRODUCTS, N.E.C.	3559	1	5	1	384	1	2
PLASTICS PRODUCTS, N.E.C.	3560	56	12	4	676	12	17
POTTERY, CHINA, & EARTHENWARE	3610	295	148	103	1151	0	349
GLASS AND GLASS PRODUCTS	3620	3378	6721	1810	862	142	1348

Four Digit ISIC Description	ISIC Code	SO2	NO2	CO	VOC	PM10	TP
STRUCTURAL CLAY PRODUCTS	3691	3029	29265	6952	2378	4681	22972
CEMENT, LIME, AND PLASTER	3692	128688	59751	7273	340	107003	62238
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	3195	1425	684	392	1953	5383
IRON AND STEEL	3710	17867	7761	27843	2392	4938	4140
NONFERROUS METALS	3720	38646	1259	17977	1406	355	3246
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	161	1035	83	260	0	45
FURNITURE & FIXTURES OF METAL	3812	43	36	14	2855	0	27
STRUCTURAL METAL PRODUCTS	3813	155	653	261	714	10	34
FABRICATED METAL PRODUCTS	3819	161	362	1850	1556	7	129
ENGINES AND TURBINES	3821	612	445	1993	663	4	163
AGRICULTURAL MACHINERY & EQUIPMENT	3822	2573	700	896	1511	0	430
METAL & WOOD WORKING MACHINERY	3823	37	8	850	535	0	7
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	497	426	75	322	1	99
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	5	4	0	64	0	2
MACHINERY & EQUIPMENT, N.E.C.	3829	479	181	399	608	2	43
ELECTRICAL INDUSTRIAL MACHINERY	3831	2865	754	118	469	1	53
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	67	34	9	408	3	5
ELECTRICAL APPLIANCES & HOUSEWARES	3833	2	15	2	696	1	0
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	391	846	1772	412	11	306
SHIPBUILDING AND REPAIRING	3841	335	150	20	1243	336	105
RAILROAD EQUIPMENT	3842	6814	2729	486	1698	1	1812
MOTOR VEHICLES	3843	279	141	189	1298	12	140
MOTORCYCLES AND BICYCLES	3844	264	154	44	7430	0	160
AIRCRAFT	3845	106	87	222	329	3	16
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	14	23	3	34	0	4

Four Digit ISIC Description	ISIC Code	SO2	NO2	CO	VOC	PM10	TP
PHOTOGRAPHIC AND OPTICAL GOODS	3852	84	130	3	157	0	32
WATCHES AND CLOCKS	3853	0	0	0	0	0	0
JEWELERY AND RELATED ARTICLES	3901	189	63	16	52	0	61
MUSICAL INSTRUMENTS	3902	80	599	142	1870	52	132
SPORTING AND ATHLETIC GOODS	3903	9	13	2	553	53	66
MANUFACTURING INDUSTRIES, N.E.C.	3909	29	14	11	408	0	7

Figure 5.3 - Air Pollution Intensity for Selected Sectors





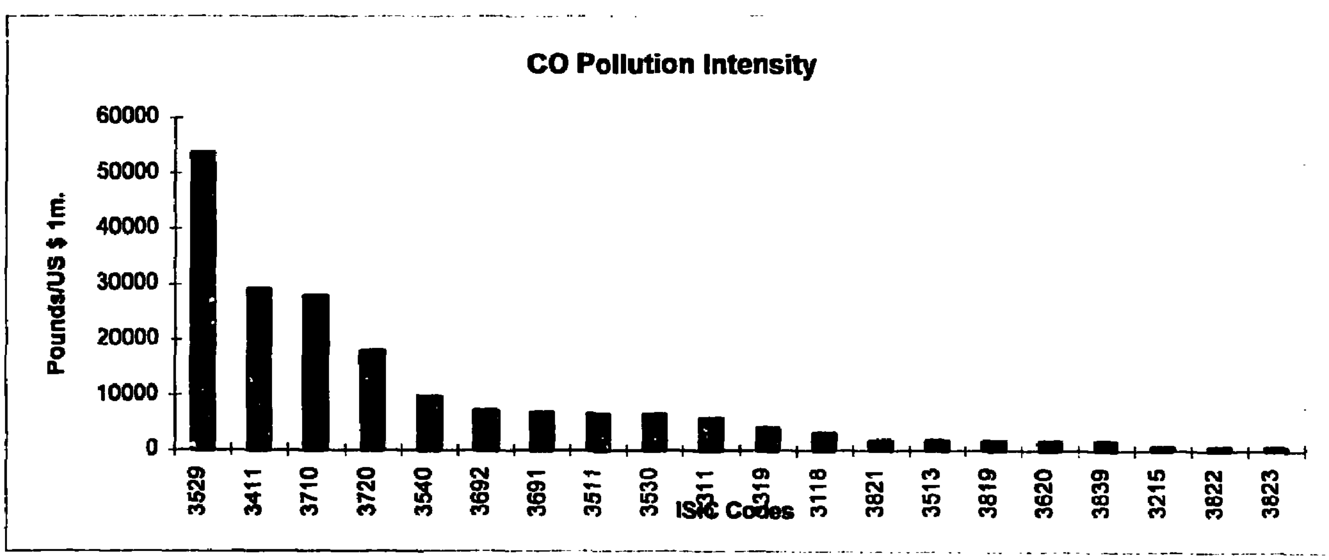
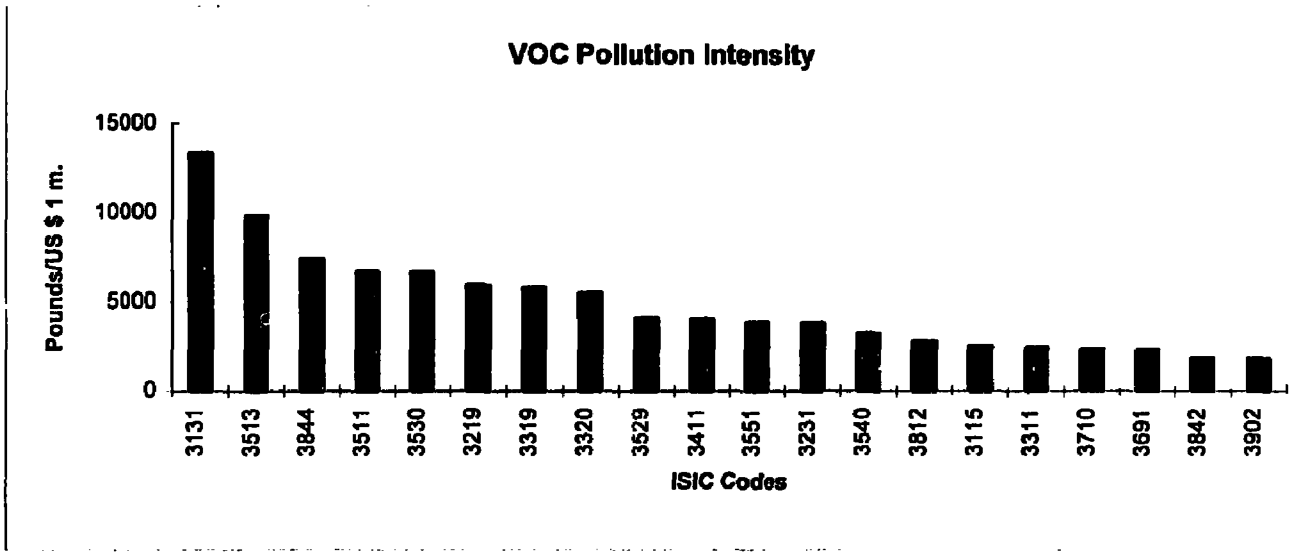
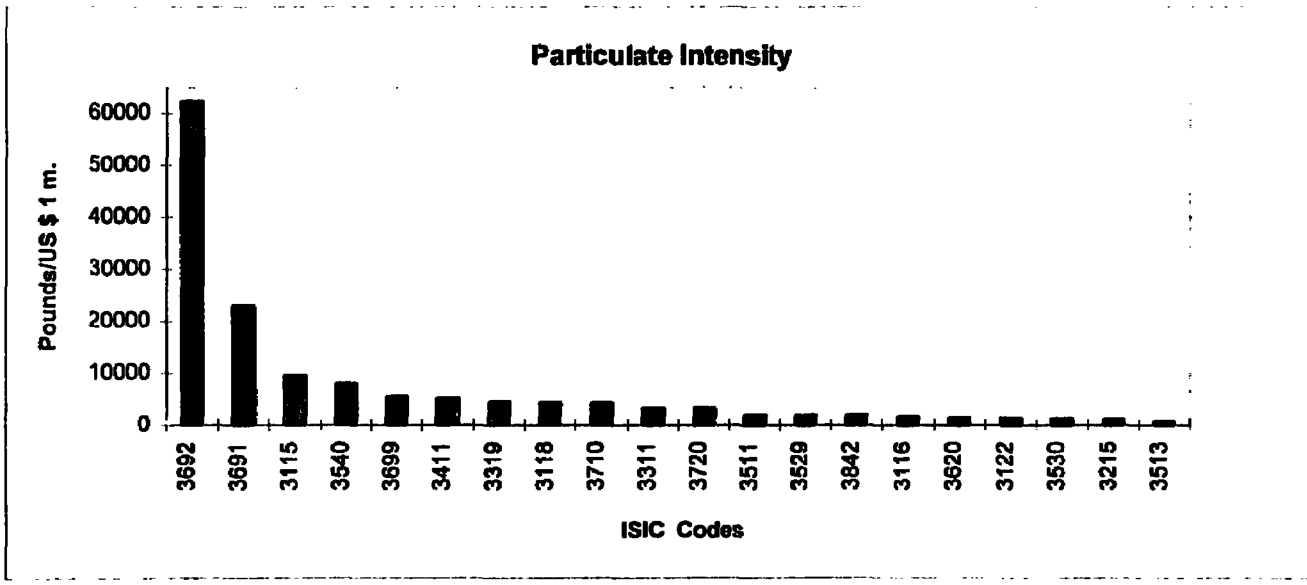
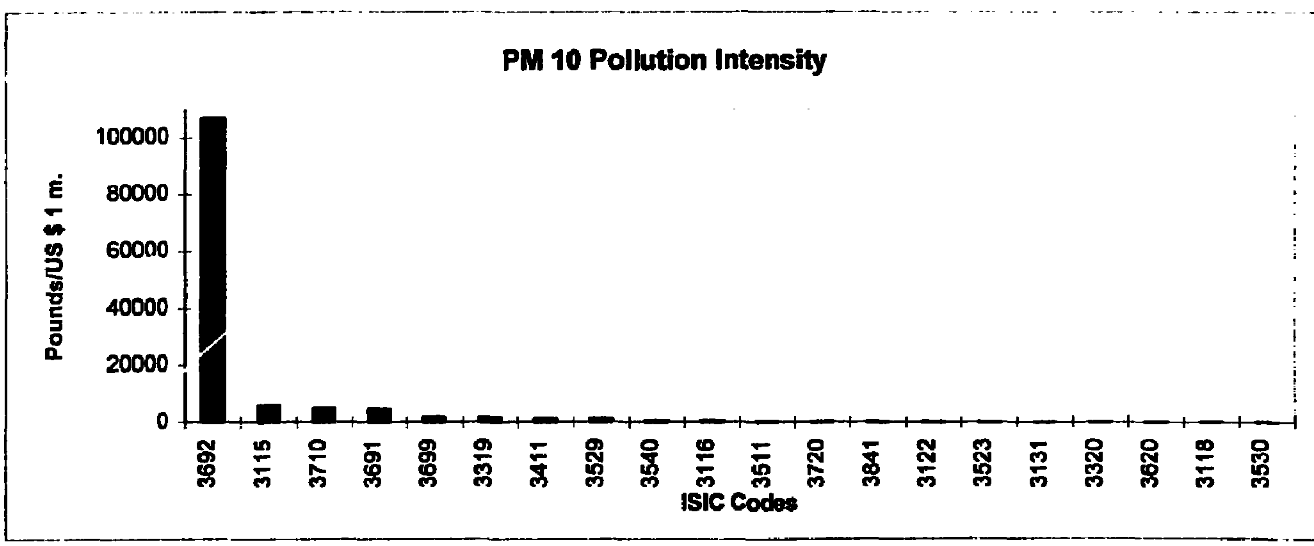


Figure 5.3 - Air Pollution Intensity for Selecter :tors







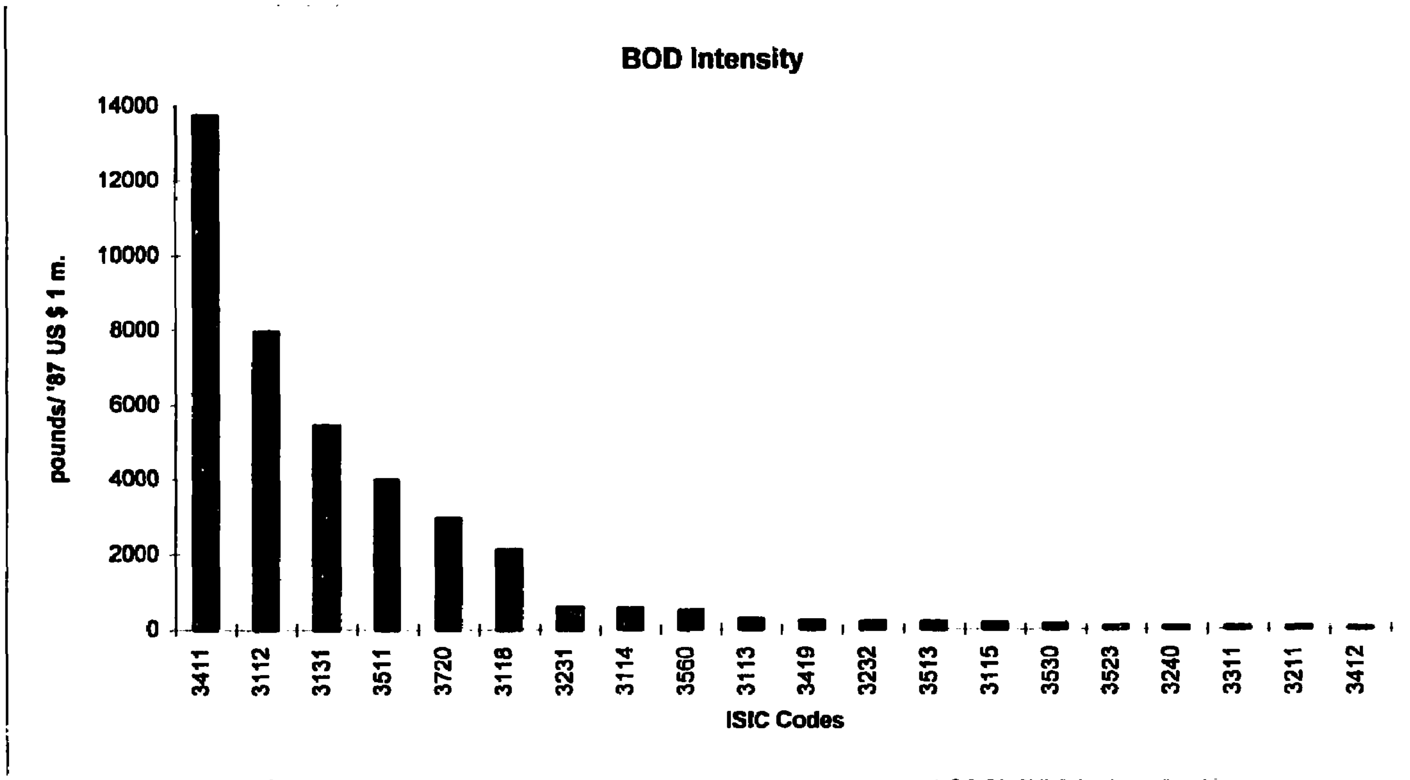
5.3.4 Water Pollution Indicators

The main water pollutants in IPPS have similar sector rankings. Rank correlations between BOD intensity, TSS intensity and Toxic effluent are all 0.6 or more, with the exception of the correlation between metals and other pollutants (see Table 5.9). Pulp, Paper and Paperboard Industries (3411), Non-ferrous Metals (3720), Industrial Chemicals except Fertilizer (3511) and Distilled Spirits (3131) are high in both BOD and TSS intensities (see table 5.10).

Table 5.9 __Rank Correlations between Major Water Pollution Indicators: Lower-bound Intensities__

Lower Bound Intensity	BOD	TSS	Toxics by Water	Toxic Metals by Water
BOD	1.00	0.71	0.57	0.37
TSS	0.71	1.00	0.62	0.46
Toxics by Water	0.57	0.62	1.00	0.67
Toxic Metals by Water	0.37	0.46	0.67	1.00

Figure 5.4 - Water Pollution Intensity for Selected Sectors



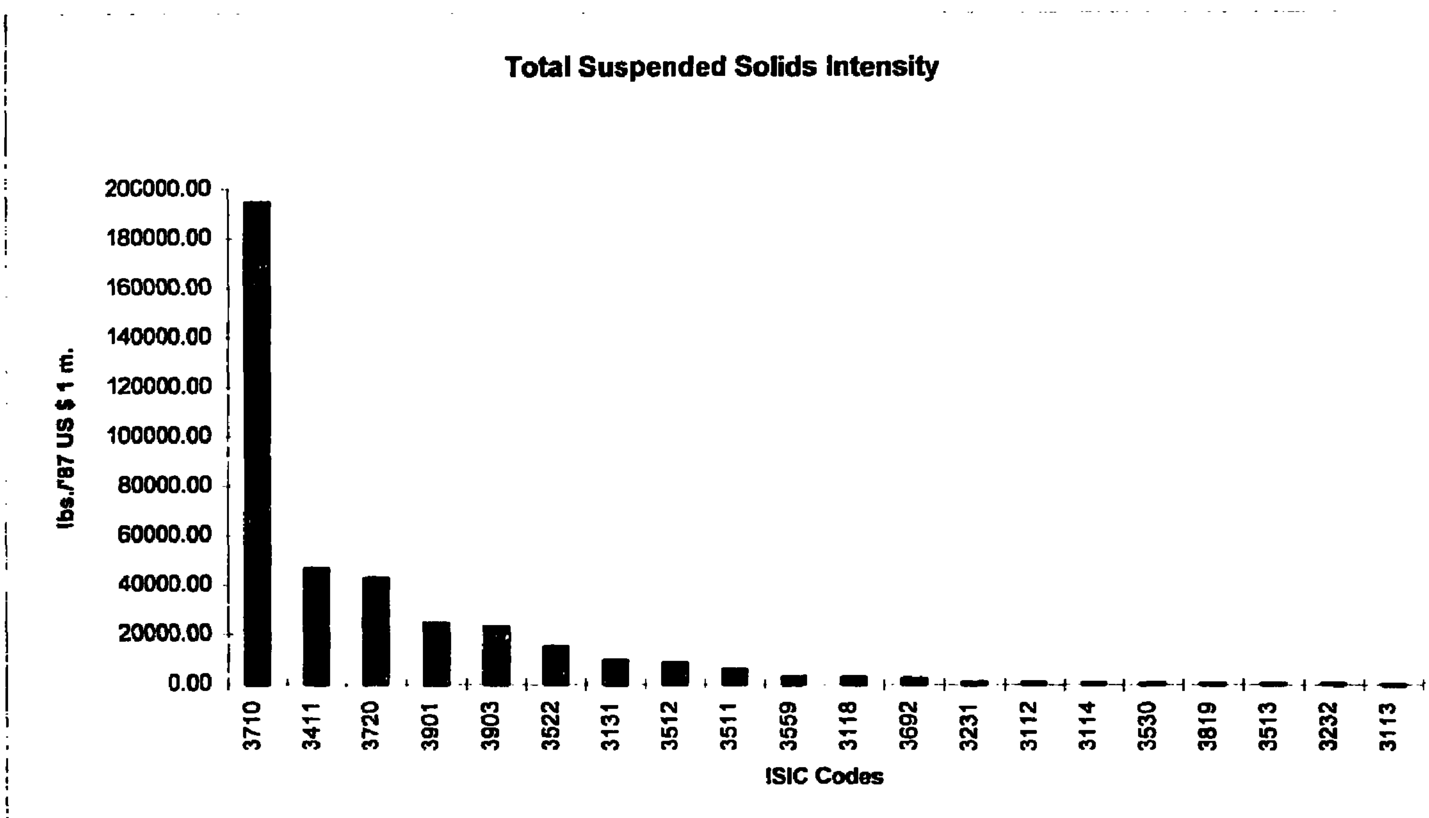


Table 5.10: Water Pollution Intensity for Selected Water Pollutants (Pounds/1987 US$ Million Output Value)

Four Digit ISIC Description	ISIC	BOD Pollution		Total Suspended Solids	
	Code	Lower-Bound	Inter-Quartile	Lower-Bound	Inter-Quartile
MEAT PRODUCTS	3111	31.52	102.18	39.09	129.61
DAIRY PRODUCTS	3112	7948.66	140.73	1144.90	120.40
PRESERVED FRUITS & VEGETABLES	3113	300.80	657.42	474.51	1284.59
FISH PRODUCTS	3114	574.42	0.00	979.27	344.55
OILS AND FATS	3115	175.31	315.58	198.08	577.26
GRAIN MILL PRODUCTS	3116	0.01		0.12	
BAKERY PRODUCTS	3117	0.12		0.14	
SUGAR FACTORIES & REFINERIES	3118	2130.73	3131.23	3054.97	769.79
CONFECTIONERY PRODUCTS	3119	18.26		8.77	
FOOD PRODUCTS, N.E.C.	3121	2.75		1.09	
PREPARED ANIMAL FOODS	3122	1.16		1.68	
DISTILLED SPIRITS	3131	5451.00	219.30	9797.25	479.78
WINE INDUSTRIES	3132	24.37		13.37	
MALT LIQUORS AND MALT	3133	28.92		66.84	
TOBACCO MANUFACTURES	3140	1.53		1.87	
SPINNING, WEAVING, & FINISHING TEXTILES	3211	98.18	587.45	152.47	1097.95
MADE-UP TEXTILES EXCEPT APPAREL	3212	0.00		0.00	
KNITTING MILLS	3213	1.82		3.67	
CARPETS AND RUGS	3214	11.62		19.54	
CORDAGE, ROPE & TWINE	3215				
TEXTILES, N.E.C.	3219	0.00		3.20	
WEARING APPAREL	3220	0.00		0.00	
TANNERIES AND LEATHER FINISHING	3231	607.39		1147.01	
FUR DRESSING AND DYEING	3232	213.45		652.40	
LEATHER PRODUCTS	3233	0.00		1.08	
FOOTWEAR	3240	100.63		98.67	
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	100.09		471.96	
WOODEN & CANE CONTAINERS; SMALL CANE WARE	3312	4.49		8.05	

Four Digit ISIC Description	ISIC	BOD Pollution		Total Suspended Solids	
	Code	Lower-Bound	Inter-Quartile	Lower-Bound	Inter-Quartile
WOOD & CORK PRODUCTS, N.E.C.	3319				
FURNITURE & FIXTURES, NONMETAL	3320	0.00		0.03	
PULP, PAPER, & PAPERBOARD	3411	13751.36	6417.93	46704.84	7717.40
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	83.55		143.45	
PULP, PAPER & PAPERBOARD ARTICLES,	3419	237.85		234.61	
PRINTING & PUBLISHING	3420	4.06	2881.17	2.23	1291.93
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	3988.90	33.03	6165.59	443.58
FERTILIZERS & PESTICIDES	3512	44.88	7.81	8732.58	206.30
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRES	3513	211.78	74.19	684.35	174.15
PAINTS, VARNISHES, & LACQUERS	3521	0.26		1.08	
DRUGS AND MEDICINES	3522	61.09	13.96	15314.74	67.16
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	110.23	60.54	155.69	83.79
CHEMICAL PRODUCTS, N.E.C.	3529	13.04		18.81	
PETROLEUM REFINERIES	3530	158.28	76.72	794.37	102.11
MISC. PETROLEUM & COAL PRODUCTS	3540	21.96	3.45	26.96	68.54
TIRES AND TUBES	3551	0.02		9.43	
RUBBER PRODUCTS, N.E.C.	3559	0.70		3277.07	
PLASTICS PRODUCTS, N.E.C.	3560	518.30	14.79	11.20	39.36
POTTERY, CHINA, & EARTHENWARE	3610	44.74		111.03	
GLASS AND GLASS PRODUCTS	3620	1.47		10.38	
STRUCTURAL CLAY PRODUCTS	3691	0.56		9.92	
CEMENT, LIME, AND PLASTER	3692	1.18		2587.58	
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	23.43	2.95	34.37	341.50
IRON AND STEEL	3710	13.22	0.00	194732.90	308.05
NONFERROUS METALS	3720	2963.03	0.00	42830.90	101.05
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	0.00		0.47	
FURNITURE & FIXTURES OF METAL	3812	0.00		0.78	
STRUCTURAL METAL PRODUCTS	3813	1.25	0.00	1.72	37.04

Four Digit ISIC Description	ISIC	BOD Pollution		Total Suspended Solids	
	Code	Lower-Bound	Inter-Quartile	Lower-Bound	Inter-Quartile
FABRICATED METAL PRODUCTS	3819	26.86	0.00	773.24	75.52
ENGINES AND TURBINES	3821	1.71			
AGRICULTURAL MACHINERY & EQUIPMENT	3822	0.00		4.99	
METAL & WOOD WORKING MACHINERY	3823	0.17		152.21	
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	6.63		5.42	
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	0.00		0.56	
MACHINERY & EQUIPMENT, N.E.C.	3829	1.63	0.10	38.49	9.46
ELECTRICAL INDUSTRIAL MACHINERY	3831	0.93	0.00	5.15	11.13
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	40.49	0.02	56.03	10.69
ELECTRICAL APPLIANCES & HOUSEWARES	3833				
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	0.36	1.20	2.19	10.93
SHIPBUILDING AND REPAIRING	3841	0.15		0.48	
RAILROAD EQUIPMENT	3842	0.00		3.73	
MOTOR VEHICLES	3843	0.23	0.00	1.17	10.14
MOTORCYCLES AND BICYCLES	3844	4.26		25.33	
AIRCRAFT	3845	1.03	0.48	8.99	11.89
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	0.69		0.77	
PHOTOGRAPHIC AND OPTICAL GOODS	3852	0.61		0.37	
WATCHES AND CLOCKS	3853	0.00		0.00	
JEWELERY AND RELATED ARTICLES	3901	0.00		24548.94	
MUSICAL INSTRUMENTS	3902				
SPORTING AND ATHLETIC GOODS	3903	0.00		23236.49	
MANUFACTURING INDUSTRIES, N.E.C.	3909	0.09		0.52	

6. Critical Assessment and Plans for Further Work

6.1. Sources of Bias

The methodology used in this study contains several possible sources of bias. The imposition of thresholds for reporting pollution to the EPA causes two obvious sampling biases, the net outcome of which is unclear. First there is no record of the cleanest plants, which will tend to move Upper Bound calculations toward overestimates of average sectoral pollutant intensities. In an effort to correct for this bias, the Lower Bound intensities assign all non-reporting facilities a pollution intensity of zero. The second bias arises because there may be a number of small facilities with very high pollutant intensities which do not reach the reporting thresholds. The Lower Bound estimates falsely assign these plants a zero pollution intensity. An attempt was made to avoid both sources of bias by calculating Inter-Quartile Mean estimates of intensities.

The differences between the Upper Bound, Lower Bound and the Inter-Quartile Mean estimates highlight the difficulty of selecting an appropriate level of sectoral aggregation. At the four-digit ISIC level, the confidence interval defined by the Upper and Lower Bound estimates will be wider than if more finely detailed decomposition is used. But the more detailed the data required, the less likely they are to be readily available.

Beyond the unavoidable inaccuracies of estimating pollution intensities at the four-digit level, a further bias may arise out of the standard procedure used to aggregate the 5-digit US-SIC data to the 4-digit ISIC level. Under this procedure, those facilities with US-SIC codes that matched more than one ISIC code were assigned the ISIC code with the highest shipment value. As a result all releases and transfers from such facilities were attributed to a single ISIC code, although in reality some proportion were associated with other activities. This approximation might lead to some overstatement of pollutant intensities, since there are frequently scale economies in pollution control for individual activities. However, this problem is probably minimized by the random occurrence of different assignments.

6.2. International Applicability

Cross-country variations in regulatory, economic and technological conditions clearly impose limitations on the international applicability of the pollutant intensity indices derived in this study. To the extent that pollution control measures merely move waste from one medium to another, the estimates of total toxic pollution intensity will be more robust than medium-specific intensities. Nevertheless, high waste disposal costs provide strong incentive for waste minimization, so US pollution intensities are likely to be lower than in less-regulated settings

Even if there is considerable international variation in the absolute level of sectoral pollutant intensities, the relative ranking of intensities across sectors may be expected to remain more constant. Thus, one might reasonably expect the Fertilizers and Pesticides sector to be found near the top of all national rankings of toxic release intensity indices, and the Soft Drinks & Carbonated

Waters sector to be found near the bottom.

6.3. Plans for Further Work

Clearly there remains huge scope for further development of IPPS. We are now assembling plant-level databases from several developing countries. Our future econometric work will quantify the effects on pollution intensity of national or regional differences in regulatory regimes, factor prices and availability of technology. Using these estimates, we will develop simple procedures which can adjust IPPS parameters for conditions in developing countries.

TRI Chemicals, 1989		
Chemical	Chemical Name	Metals
71556	1,1,1-TRICHLOROETHANE	
79345	1,1,2,2-TETRACHLOROETHANE	
79005	1,1,2-TRICHLOROETHANE	
57147	1,1-DIMETHYL HYDRAZINE	
120821	1,2,4-TRICHLOROBENZENE	
95636	1,2,4-TRIMETHYLBENZENE	
106887	1,2-BUTYLENE OXIDE	
96128	1,2-DIBROMO-3-CHLOROPROPANE	
106934	1,2-DIBROMOETHANE	
95501	1,2-DICHLOROBENZENE	
107062	1,2-DICHLOROETHANE	
540590	1,2-DICHLOROETHYLENE	
78875	1,2-DICHLOROPROPANE	
122667	1,2-DIPHENYLHYDRAZINE	
106990	1,3-BUTADIENE	
541731	1,3-DICHLOROBENZENE	
542756	1,3-DICHLOROPROPYLENE	
106467	1,4-DICHLOROBENZENE	
123911	1,4-DIOXANE	
82280	1-AMINO-2-METHYLANTHRAQUINONE	
95954	2,4,5-TRICHLOROPHENOL	
88062	2,4,6-TRICHLOROPHENOL	
94757	2,4-D	
615054	2,4-DIAMINOANISOLE	
39156417	2,4-DIAMINOANISOLE SULFATE	
120832	2,4-DICHLOROPHENOL	
105679	2,4-DIMETHYLPHENOL	
95807	2,4-DIAMINOTOLUENE	
51285	2,4-DINITROPHENOL	
121142	2,4-DINITROTOLUENE	
606202	2,6-DINITROTOLUENE	
87627	2,6-XYLIDINE	

Chemical	Chemical Name	Metals
53963	2-ACETYLAMINOFLUORENE	
117793	2-AMINOANTHRAQUINONE	
532274	2-CHLOROACETOPHENONE	
110805	2-ETHOXYETHANOL	
109864	2-METHOXYETHANOL	
88755	2-NITROPHENOL	
79469	2-NITROPROPANE	
90437	2-PHENYLPHENOL	
91941	3,3'-DICHLOROBENZIDINE	
119904	3,3'-DIMETHOXYBENZIDINE	
119937	3,3'-DIMETHYLBENZIDINE	
101804	4,4'-DIAMINODIPHENYL ETHER	
80057	4,4'-ISOPROPYLIDENEDIPHENOL	
101144	4,4'-METHYLENEBIS (2-CHLOROANILINE) (MBOCA)	
101611	4,4'-METHYLENEBIS (N,N-DIMETHYL) (BENENAMINE	
101779	4,4'-METHYLENEDIANILINE	
139651	4,4'-THIODIANILINE	
534521	4,6-DINITRO-O-CRESOL	
60093	4-AMINOAZOBENZENE	
92671	4-AMINOBIPHENYL	
60117	4-DIMETHYLAMINOAZOBENZENE	
92933	4-NITROBIPHENYL	
100027	4-NITROPHENOL	
99592	5-NITRO-O-ANISIDINE	
75070	ACETALDEHYDE	
60355	ACETAMIDE	
67641	ACETONE	
75058	ACETONITRILE	
107028	ACROLEIN	
79061	ACRYLAMIDE	
79107	ACRYLIC ACID	
107131	ACRYLONITRILE	
309002	ALDRIN	
107051	ALLYL CHLORIDE	
134327	ALPHA-NAPHTHYLAMINE	

Chemical	Chemical Name	Metals
7429905	ALUMINUM (FUME OR DUST)	m
7664417	AMMONIA	
6484522	AMMONIUM NITRATE (SOLUTION)	
7783202	AMMONIUM SULFATE (SOLUTION)	
62533	ANILINE	
120127	ANTHRACENE	
7440360	ANTIMONY	m
7440382	ARSENIC	
1332214	ASBESTOS (FRIABLE)	
7440393	BARIUM	m
98873	BENZAL CHLORIDE	
55210	BENZAMIDE	
71432	BENZENE	
92875	BENZIDINE	
98077	BENZOIC TRICHLORIDE	
98884	BENZOYL CHLORIDE	
94360	BENZOYL PEROXIDE	
100447	BENZYL CHLORIDE	
7440417	BERYLLIUM	m
91598	BETA-NAPHTHYLAMINE	
57578	BETA-PROPIOLACTONE	
92524	BIPHENYL	
108601	BIS (2-CHLORO-1-METHYLETHYL) ETHER	
111444	BIS(2-CHLOROETHYL) ETHER	
103231	BIS(2-ETHYLHEXYL) ADIPATE	
542881	BIS(CHLOROMETHYL) ETHER	
75252	BROMOFORM	
74839	BROMOMETHANE	
141322	E"TYL ACRYLATE	
85687	BUTYL BENZYL PHTHALATE	
123728	BUTYRALDEHYDE	
4680788	C.I. ACID GREEN 3	
569642	C.I. BASIC GREEN 4	
989388	C.I. BASIC RED 1	
1937377	C.I. DIRECT BLACK 38	

Chemical	Chemical Name	Metals
2602462	C.I. DIRECT BLUE 6	
16071866	C.I. DIRECT BROWN 95	m
2832408	C.I. DISPERSE YELLOW 3	
3761533	C.I. FOOD RED 5	
3118976	C.I. SOLVENT ORANGE 7	
842079	C.I. SOLVENT YELLOW 14	
97563	C.I. SOLVENT YELLOW 3	
492808	C.I. SOLVENT YELLOW 34	
128665	C.I. VAT YELLOW 4	
81889	C.I.FOOD RED 15	
7440439	CADMIUM	m
156627	CALCIUM CYANAMIDE	
133062	CAPTAN	
63252	CARBARYL	
75150	CARBON DISULFIDE	
56235	CARBON TETRACHLORIDE	
463581	CARBONYL SULFIDE	
120809	CATECHOL	
133904	CHLORAMBEN	
57749	CHLORDANE	
7782505	CHLORINE	
10049044	CHLORINE DIOXIDE	
79118	CHLOROACETIC ACID	
108907	CHLOROBENZENE	
510156	CHLOROBENZILATE	
75003	CHLOROETHANE	
67663	CHLOROFORM	
74873	CHLOROMETHANE	
107302	CHLOROMETHYL METHYL ETHER	
126998	CHLOROPRENE	
1897456	CHLOROTHALONIL	
7440473	CHROMIUM	m
7440484	COBALT	m
7440508	COPPER	m
1319773	CRESOL (MIXED ISOMERS)	

Chemical	Chemical Name	Metals
98828	CUMENE	
80159	CUMENE HYDROPEROXIDE	
135206	CUPFERRON	
110827	CYCLOHEXANE	
1163195	DECABROMODIPHENYL OXIDE	
117817	DI(2-ETHYLHEXYL) PHTHALATE	
[illegible]303164	DIALLATE	
25376458	DIAMINOTOLUENE (MIXED ISOMERS)	
334883	DIAZOMETHANE	
132649	DIBENZOFURAN	
84742	DIBUTYL PHTHALATE	
25321226	DISCHLOROBENZENE (MIXED ISOMERS)	
75274	DICHLOROBROMOMETHANE	
75092	DICHLOROMETHANE	
62737	DICHLORVOS	
115322	DICOFOL	
1464535	DIEPOXYBUTANE	
111422	DIETHANOLAMINE	
84662	DIETHYL PHTHALATE	
64675	DIETHYL SULFATE	
131113	DIMETHYL PHTHALATE	
77781	DIMETHYL SULFATE	
79447	DIMETHYLCARBAMYL CHLORIDE	
106898	EPICHLOROHYDRIN	
140885	ETHYL ACRYLATE	
541413	ETHYL CHLOROFORMATE	
100414	ETHYLBENZENE	
74851	ETHYLENE	
107211	ETHYLENE GLYCOL	
75218	ETHYLENE OXIDE	
96457	ETHYLENE THIOUREA	
151564	ETHYLENEIMINE	
2164172	FLUOMETURON	
50000	FORMALDEHYDE	
76131	FREON 113	

Chemical	Chemical Name	Metals
76448	HEPTACHLOR	
87683	HEXACHLORO-1,3-BUTADIENE	
118741	HEXACHLOROBENZENE	
77474	HEXACHLOROCYCLOPENTADIENE	
67721	HEXACHLOROETHANE	
1335871	HEXACHLORONAPHTHALENE	
680319	HEXAMETHYLOPHOEPHORAMIDE	
302012	HYDRAZINE	
10034932	HYDRAZINE SULFATE	
7647010	HYDROCHLORIC ACID	
74908	HYDROGEN CYANIDE	
7664393	HYDROGEN FLUORIDE	
123319	HYDROQUINONE	
78842	ISOBUTYRALDEHYDE	
67630	ISOPROPYL ALCOHOL (MANUFACTURING)	
7439921	LEAD	m
58899	LINDANE	
108394	M-CRESOL	
108316	MALEIC ANHYDRIDE	
12427382	MANEB	m
7439965	MANGANESE	m
7439976	MERCURY	m
67561	METHANOL	
72435	METHOXYCHLOR	
96333	METHYL ACRYLATE	
78933	METHYL ETHYL KETONE	
60344	METHYL HYDRAZINE	
748[illegible]4	METHYL IODIDE	
108101	METHYL ISOBUTYL KETONE	
624839	METHYL ISOCYANATE	
80626	METHYL METHACRYLATE	
1634044	METHYL TERT-BUTYL ETHER	
74953	METHYLENE BROMIDE	
101688	METHYLENEBIS (PHENYLISOCYANATE)	

Chemical	Chemical Name	Metals
90948	MICHLER'S KETONE	
1313275	MOLYBDENUM TRIOXIDE	m
505602	MUSTARD GAS	
121697	N,N-DIMETHYLANILINE	
71363	N-BUTYL ALCOHOL	
117840	N-DIOCTYL PHTHALATF	
759739	N-NITROSO-N-ETHYLUREA	
684935	N-NITROSO-N-METHYLUREA	
924163	N-NITROSODI-N-BUTYLAMINE	
621647	N-NITROSODI-N-PROPYLAMINE	
55185	N-NITROSODIETHYLAMINE	
62759	N-NITROSODIMETHYLAMINE	
86306	N-NITROSODIPHENYLAMINE	
4549400	N-NITROSOMETHYLVINYLAMINE	
59892	N-NITROSOMORPHOLINE	
16543558	N-NITROSONORNICOTINE	
100754	N-NITROSOPIPERIDINE	
91203	NAPHTHALENE	
7440020	NICKEL	m
7697372	NITRIC ACID	
139139	NITRILOTRIACETIC ACID	
98953	NITROBENZENE	
1836755	NITROFEN	
51752	NITROGEN MUSTARD	
55630	NITROGLYCERIN	
90040	O-ANISIDINE	
134292	O-ANISIDINE HYDROCHLORIDE	
95487	O-CRESOL	
95534	O-TOLUIDINE	
636215	O-TOLUIDINE HYDROCHLORIDE	
95476	O-XYLENE	
2234131	OCTACHLORONAPHTHALENE	
20816120	OSMIUM TETROXIDE	m
104949	P-ANISIDINE	
120718	P-CRESIDINE	

Chemical	Chemical Name	Metals
106445	P-CRESOL	
156105	P-NITROSODIPHENYLAMINE	
106503	P-PHENYLENEDIAMINE	
106423	P-XYLENE	
56382	PARATHION	
87865	PENTACHLOROPHENOL	
79210	PERACETIC ACID	
108952	PHENOL	
75445	PHOSGENE	
7664382	PHOSPHORIC ACID	
7723140	PHOSPHORUS (YELLOW OR WHITE)	
85449	PHTHALIC ANHYDRIDE	
88891	PICRIC ACID	
1336363	POLYCHLORINATED BIPHENYLS	
1120714	PROPANE SULTONE	
123386	PROPIONALDEHYDE	
114261	PROPOXUR	
115071	PROPYLENE	
75569	PROPYLENE OXIDE	
75558	PROPYLENEIMINE	
110861	PYRIDINE	
91225	QUINOLINE	
106514	QUINONE	
82688	QUINTOZENE	
61072	SACCHARIN (MANUFACTURING ONLY, NO PROCESSOR	
94597	SAFROLE	
78922	SEC-BUTYL ALCOHOL	
7782492	SELENIUM	
7440224	SILVER	m
100425	STYRENE	
96093	STYRENE OXIDE	
7664939	SULFURIC ACID	
75650	TERT-BUTYL ALCOHOL	
127184	TETRACHLOROETHYLENE	
961115	TETRACHLORVINPHOS	

Chemical	Chemical Name	Metals
7440280	THALLIUM	m
62555	THIOACETAMIDE	
62566	THIOUREA	
1314201	THORIUM DIOXIDE	m
7550450	TITANIUM TETRACHLORIDE	m
108883	TOLUENE	
584849	TOLUENE-2,4-DIISOCYANATE	
91087	TOLUENE-2,6-DIISOCYANATE	
8001352	TOXAPHENE	
68768	TRIAZIQUONE	
52686	TRICHLORFON	
79016	TRICHLOROETHYLENE	
1582098	TRIFLURALIN	
126727	TRIS (2,3-DIBROMOPROPYL) PHOSPHATE	
51796	URETHANE	
7440622	VANADIUM (FUME OR DUST)	m
108054	VINYL ACETATE	
593602	VINYL BROMIDE	
75014	VINYL CHLORIDE	
75354	VINYLIDENE CHLORIDE	
1330207	XYLENE (MIXED ISOMERS)	
7440666	ZINC (FUME OR DUST)	m
12122677	ZINEB	m
	ANTIMONY COMPOUNDS	m
	ARSENIC COMPOUNDS	
	BARIUM COMPOUNDS	m
	BERYLLIUM COMPOUNDS	m
	CADMIUM COMPOUNDS	m
	CHLOROPHENOLS	
	CHROMIUM COMPOUNDS	m
	COBALT COMPOUNDS	m
	COPPER COMPOUNDS	m
	CYANIDE COMPOUNDS	
	GYLCOL ETHERS	
	LEAD COMPOUNDS	m

Chemical	Chemical Name	Metals
	MANGANESE COMPOUNDS	m
	MERCURY COMPOUNDS	m
	NICKEL COMPOUNDS	m
	POLY BROMINATED BIPHENYLS	
	SELENIUM COMPOUNDS	
	SILVER COMPOUNDS	m
	THALLIUM COMPOUNDS	m
	ZINC COMPOUNDS	m

NOTE: "m" denotes the metal compounds used for estimating toxic metal pollution intensity.

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