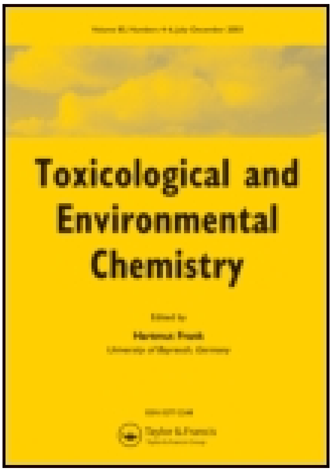

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Industrial pollution load assessment by industrial pollution projection system (IPPS)

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Growing awareness of the harmful effects on the environment caused by industrial activities has led to increasing pressure from local communities, groups, environmental organizations, and government regulators on industries to reduce their pollutant emissions. The need for industrial pollution assessment in the developing countries (where necessary information to set priorities, strategies, and action plans on environmental issues are lacking) has led to the development of the Industrial Pollution Projection System (IPPS) by the World Bank. IPPS is a cheap and rapid environmental management tool for pollution load estimation towards the development of appropriate policy formulation for industrial pollution control.

Keywords: Industrial Pollution Projection System; pollution load; pollution intensity; developing countries; industrial pollution

Introduction

Industrial activities cause a lot of damage to the three main receiving media, i.e. land, air, and water; and living things, which are the main constituents of the environment. Industries generate industrial wastes, which contain harmful chemicals, particulates, and toxic heavy metals such as lead. When these are released into air, they can cause respiratory problems. Toxic chemicals and heavy metals can collect in animal tissues and harm many living things along the food chain. Thus, environmental pollution is the contamination of the principal components of the environment, which includes air, water, and soil, as well as the discharge of solid and hazardous wastes, all which have a direct impact on humans and their environment (Ademoroti 1996).

In the United States, industry is the greatest source of pollution, accounting for more than half the volume of all water pollution and for the most deadly pollutants. The situation is not different in the developing countries, where there is usually weak monitoring and enforcement. Increased industrial activities have led to urbanization and pollution stress on the environment. Industrialization is considered by humans as the best and quickest way to development. Thus, development and industrialization have both positive and negative impacts. Developing countries are increasingly concerned about the growing pollution levels in cities (Pandey 2005). Also, government regulators and environmental organizations globally are concerned about environmental issues and put pressure on industries to reduce their pollutant emissions.

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Environmental monitoring for the purpose of industrial pollution assessment and control by conventional sampling and chemical analysis is resource intensive, time consuming, tedious, expensive, and usually unaffordable by most of the developing countries. Industries in these countries are often said to have no incentives to invest in pollution control because they lack funds on one hand and poverty on the other hand. In these countries, population growth is greater, and the current living standard is lower; and there is more pressure on environmental resources. Also, the developing countries lack the necessary information to set priorities, strategies, and action plans on environmental issues. Plant-level monitoring of air, water, and toxic emissions is at best imperfect: monitoring equipments are not available and where available are obsolete; data collection and measurement methodology are questionable, and there is usually lack of trained personnel on industrial sites. In the absence of these data, the World Bank has created a series of datasets that have given the research community the opportunity to better understand the levels of pollution in developing countries, and therefore issue policy advice with more clarity (Aguayo, Gallagher, and Gohzalez 2001; Oketola and Osibanjo 2007).

The industrial pollution projection system (IPPS) is being developed as a comprehensive response to this need for estimates of industrial pollution. The estimation of IPPS parameters is providing a much clearer, more detailed view of the sources of industrial pollution (Hettige et al. 1995). 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 the production. IPPS combines data from industrial activities (such as production and employment) with data on pollution emissions to calculate the pollution intensity factors based on the International Standard Industrial Classification (ISIC) (Hettige et al. 1994; Oketola and Osibanjo 2007). The IPPS has been estimated from a massive United State (US) database developed by the Bank's Policy Research Department, Environment, Infrastructure, and Agriculture Division, in collaboration with the Center for Economic Studies of the US Census Bureau and the US 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 the 200,000 US factories. The IPPS covers about 1500 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 toxic and ecotoxic effects (Hettige et al. 1995). The results have been used in various countries where insufficient data on industrial pollution proved to be an impediment to setting-up pollution control strategies and prioritization of activities (Faisal, Shammiu, and Junaid 1991; Arpad et al. 1995; Oketola and Osibanjo 2007).

Most developing countries have little or no industrial data; many of them have relatively detailed industry survey information on employment, value added, or output. IPPS was 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 sectoral estimates of pollution intensity, or pollution per unit of activity. Although technology, production process, and emission vary across different countries, the sheer size of the IPPS database reasonably accounts for such variations and provides a means of pollution projection at the sector and national levels (Faisal, Shammiu, and Junaid 1991). Pollution intensities or emissions per unit of activity have been estimated using all three economic variables, which are commonly available in the developing countries (i.e. employment, output, and value added). For individual pollutants, high correlation across intensities based on output value, value added, and employment was found (Hettige et al. 1994; Aguayo, Gallagher, and Gohzalez 2001; Benoit and Craig 2001).

IPPS had already been applied in several World Bank analyses, most notably: Carter Brandon and Ramesh Ramankutty, Asia: 'Environment and Development' (1993) (Carter and Ramesh 1993); and Indonesia: 'Environment and Development' (1994) (Richard et al. 1994). Sector reports for Mexico, Malaysia, and several Middle Eastern countries have also used IPPS-based estimates. IPPS had been used to produce the first comprehensive cross-country estimates of toxic pollution in World Resources (1994–1995) published by the World Resources Institute. Recent work on trade and the environment by Roland–Holst and Hiro Lee: 'International Trade and the Transfer of Environmental Costs and Benefits' (OECD 1993) have also been based on IPPS. Thus, industrial pollution can be estimated in terms of the pollution loads in tons per year for selected group of water, air, and land pollutants using IPPS. Pollution load refers to the total amount of a pollutant or a combination of pollutants released into the environment (directly or indirectly through municipal sewers or through the municipal waste collector and treatment network) by an industry or a group of industries in a given area during a certain period of time (Faisal, Shamiu, and Junaid 1991; Hettige et al. 1994; Oketola and Osibanjo 2007). It has also been used in Lagos, Nigeria (Oketola 2007).

Pollution intensity index

Pollution intensity is expressed as a ratio of pollution per unit of manufacturing activity, i.e.

$$\text{Pollutant output intensity or pollution intensity index} = \frac{\text{pollutant output}}{\text{total manufacturing activity}}.$$

Although pollution intensity estimation is conceptually straightforward, 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 (Hettige et al. 1994). The calculation of pollution intensity required merging the Environmental Protection Agency (EPA) and Longitudinal Research Database (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 Standard Industrial Classification (SIC) codes.

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. The Toxic Release Inventory (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 wastewater facilities. Initially, pollution across all media was used, aggregating all releases and transfers of a given chemical from each facility. 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 coefficient. A better alternative for the comparison of risks is provided by the multi-index categorization of toxic potency in the USEPA's Human Health and Ecotoxicity Database (HHED). This index does not rank total sectoral releases. It is quite possible for a highly pollution intensive sector to have little impact on the total level of releases and transfers.

When linearly weighted index was compared with exponential weighting, the same exponential distribution of values was observed for both measures and the two most intensive sectors were the same. Therefore, subsequent work focused solely on medium-specific pollution output intensities. 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. Medium-specific indices are used 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.

IPPS had drawn on plant-level pollution information from all of the previous mentioned USEPA pollution databases such as 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, as shown in Table 1. These intensities were calculated as pounds of pollutants released per unit of production in each industrial sector.

The choice of a denominator

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

- Physical volume of output;
- Shipment value;
- Value added;
- Employment.

The most 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 is 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. This has obvious relative price problems, particularly in the international context. It has the advantage of relatively complete coverage and the usual benefits of the dollar metric in allowing inter-sectoral comparison.

Total output value was judged superior to value added because energy and material 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 was estimated. Intensities were calculated for manufacturing sectors

Table 1. Pollution intensities in IPPS (Hettige et al. 1994).

1. Toxic and bio-accumulative pollution intensities by medium:
    - Toxic pollution to air.
    - Toxic pollution to water.
    - Toxic pollution to land.
    - Bio-accumulative metal pollution to air.
    - Bio-accumulative metal pollution to water.
    - Bio-accumulative metal pollution to land.
2. Criteria air pollution intensities:
    - Sulphur dioxide (SO_2).
    - Nitrogen dioxide (NO_2).
    - Carbon monoxide (CO).
    - Volatile Organic Compounds (VOC).
    - Particulates less than 10 µm in diameter (PM10).
    - Total Particulates (TP).
3. Water pollution intensities:
    - Biological Oxygen Demand (BOD).
    - Total Suspended Solids (TSS).

defined according to the 2-, 3-, and 4-digit International Standard Industrial Classification (ISIC). However, basic economic reasoning does suggest that employment-based intensities may be preferable for pollution projection in the developing countries. The logic is as follows:

- Effective environmental regulation is thought to be income-elastic, although careful empirical work on cross country data are yet to be done;
- Sectoral pollution is thought to be quite responsive to effective environmental regulation in many cases;
- Most cross-country econometric studies of sectoral labor demand find relatively high wage elasticity.

It was concluded that both sectoral pollution and sectoral labor demand would 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. Preliminary tests on Indonesian sectoral data and the US for water pollution provide support for this hypothesis, showing much higher variation for value-based intensities than for employment-based estimates (Hettige et al. 1994; Oketola 2007).

Fluctuation in employment-based criteria, which are caused by rapid decreases or increases in employment in the manufacturing industries in the developing countries (e.g. power shedding, casual labor or declining trend in employment reflecting rising wages) can be regarded as contributing to reduced pollution intensity through changes in formal and informal regulatory pressure and through saving of materials. It is clear that many country specific factors will affect the accuracy of prototype IPPS projections outside the United States of America.

Factors affecting IPPS pollution load

IPPS Pollution load depends on a number of factors, which include:

(1) The source size: an expanding industrial sector affects the pollution load in two ways. The first is to increase the total volume of pollutants in the short and

medium terms. In the long term, total pollutants may decline if dramatic shifts into cleaner industries take place, or if the share of the industrial sectors itself falls (neither is imminent) (Richard et al. 1994). The second is to change the pollution intensity of industrial output, defined as the amount of pollution generated per unit of output. In some developing countries, e.g. Asia, both the growth and the intensity effects are leading towards heavier pollution loads in the short and medium term. Almost always, a few large industries contribute a large proportion of total pollutants.

(2) Energy efficiency: the list of conventional air pollutants from industry includes: SO_x, NO_x, Total Suspended Particulate (TSP), CO_2, CO, and hydrocarbons (such as methane, CH_4). Industrial air pollution is primarily derived from energy use. Industry consumes over 40% of all commercial energy (which includes all sources of energy except for traditional fuels such as wood and dung) in China, India, Korea, Malaysia, Myanmar, Vietnam, and Bangladesh. As a result, energy efficiency is one of the most important, and least cost investments, that industrial firms can make to reduce air pollution. Energy efficient technologies are implicit in most investments in clean technologies, which reduce pollution through reduced inputs and lower pollution intensities.

(3) Source type: this is the kind of pollution generating activity and the procedure in the industry. The sub-sectoral composition, the level of technology and the status of environmental control will vary from industry to industry and nation to nation. However, these toxic intensity indicators can be used as a first-cut approximation of how shifts in national industrial output have affected the relative level of toxic releases.

(4) Change in work force: power shedding, casual labor or declining trend in employment reflecting rising wages can be regarded as contributing to reduced pollution intensity through changes in formal and informal regulatory pressure and saving of material, i.e. rapid decrease or increase in employment in the manufacturing industries in the developing countries also affect the pollution intensity.

(5) Technology employed: changing from obsolete technology to new and modern technology reduces pollution intensity, since waste minimization and reduction at source is employed.

(6) Raw material characteristics: use of raw material that will reduce the amount of waste generated will reduce pollution intensity.

(7) Efficacy of facility: change in procedure from non-conservative to conservative type will conserve both raw materials and energy and at the same time minimize the amount of waste generated and consequently reduce the pollution intensity.

(8) Product grades: the types and grades of product produced in an industry also affect pollution intensity.

Procedures for pollution load estimation by IPPS

Pollution loads can be estimated with respect to employment and total output separately for air, water, and land pollution using IPPS pollution intensities. Pollution load estimation using IPPS is possible using two different variables:

(i) Productivity or total output
(ii) Employment

Procedure for total output

Industrial production data or total output (or product produced per annum) can be used for pollution load estimation using the formula:

$$\text{Pollution load} = \text{Pollution intensity factor} \times \text{Unit of output.}$$

Procedure for employment

The total number of employees in an industry can also be used to estimate pollution load using the formula

$$\text{PL} = \frac{\text{PI} \times \text{TEM}}{1000},$$

where

$$\begin{aligned} \text{PL} &= \text{Pollution load for a sector or industry in ton/year} \\ \text{PI} &= \text{Pollution intensity per thousand employees per year} \\ \text{TEM} &= \text{Total number of employees in that sector or industry.} \end{aligned}$$

Procedure for emission projection

Linear growth rate, using equation of line can be employed for pollutants emission projection. This can be calculated based on the previous employment and output data from industries (Oketola 2007; Oketola and Osibanjo 2007).

IPPS and the developing countries

Though IPPS was developed by the Development and Research Group of the World Bank, it has been used in various developing countries, among other places, in Brazil, Latvia, India, Vietnam, Central and Latin America (Aguayo, Gallagher, and Gohzalez 2001). It is yet to gain popularity in the developing countries of Africa. IPPS has been employed to estimate pollution load in Lagos, which is the most industrialized state in Nigeria (Oketola 2007; Oketola and Osibanjo 2007). Pollution loads have been estimated with respect to two economic variable, employment, and total output. In Bangladesh, IPPS was employed using employment-based emission factors (Faisal, Shammiu, and Junaid 1991). Estimates of industrial air pollution, toxic and metal pollution, and conventional industrial water pollution in Thailand were carried out using the IPPS approach (Benoit and Craig 2001). In 1988, IPPS approach was applied to industrial output in Asia. Industrial pollution in Thailand, Philippines, and Indonesia gave indicative trends for six pollutants as indicators each of water pollution (BOD_5 and suspended solids), air pollution (SO_x and particulate), and toxic wastes (a composite index of various toxic emitted into air, water, or in solid wastes, and heavy metals). The estimates of toxic releases for Indonesia (based on value of shipment intensity), Thailand, and the Philippines (based on output intensity) show a 4- to 10-fold increase in the total volume of toxic wastes.

In Indonesia, a different building block for IPPS was also used. The pollution intensity index from the EPA and LRD data was developed to match the two sets of information at the facility level. This matching was necessary to ensure that the sectors-specific intensities were calculated using emissions and production data from the same set of facilities (Richard et al. 1994). Conceptually, the most appealing choice was physical volume of output, but the information relating to output volume in the United Nation Industrial Development Organization (UNIDO) data (Hettige et al. 1994), the main source for international comparisons, was not comprehensive. Consequently, value of shipments as a measure of manufacturing activity in the denominator of the pollution intensity index was used in Indonesia. Although, this statistic has obvious relative price problems particularly in the international context, it has the advantages of a relatively complete UNIDO coverage and the usual benefits of the dollar metric in allowing inter-sectoral comparison.

Though considerable international variation in the pollution load from various sectors is expected, the relative ranking of intensities across sectors may be expected to remain the same. The IPPS pollution intensity figures are developed from a sample of USA manufacturing facilities, and so constitute an estimate of the USA conditions. However, even with the accurate USA intensities, a number of sources of variation will be content to affect the reliability of the IPPS pollution estimates in the developing countries. At the 4-digit ISIC level of aggregation, there may be significant variation between the developing countries and the USA in the product mix within each sector.

Conclusion

The Industrial Pollution Projection System is a model, which can give regulators and monitoring agencies in the developing countries the knowledge about pollutant emission and pollution loads of industries. This will no doubt enable them to focus on the most polluting industries, thus reducing cost and time while increasing the level of enforcement. Consequently, more time can be spent on these few polluting industries (Oketola and Osibanjo 2007). IPPS is cheaper and less time consuming when compared to running scientific monitoring data gathering and analysis. Adopting waste minization strategies, which include cleaner production processes, by industries in developing countries, will not only reduce the cost of controlling pollution, it will also make manufacturing more efficient, thereby increasing profits while reducing pollution load in the long run. This is a win–win situation.

IPPS therefore offers a cheap environmental management tool and directional basis for rapid policy intervention by government regulatory agencies. It will enhance pollution control in the identified most polluting industries in the developing countries, where funding for environmental protection is lacking or at best grossly inadequate. The effectiveness of the intervening measures would significantly reduce the overall pollution load, improve citizens' quality of life and enhance poverty alleviation. Hence, IPPS is recommended as a rapid environmental management tool for pollution load assessment, and for providing a scientific rational basis for future policy direction to halt industrial pollution in the developing countries.

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