A Market-Based Approach to Managing Industrial SPM Emissions in India's Jamshedpur Region

A model for optimizing air pollution abatement efforts

Market-based approaches to environmental protection aim to improve environmental performance through market signals rather than through explicit mandates regarding pollutant-control methods.

These policy approaches, which can include instruments such as tradable permits or pollution charges, are often described as "harnessing market forces." If they are well-designed and implemented, market-based approaches encourage firms and individuals to undertake pollution prevention and control efforts that are in their own interests, while also collectively meeting policy goals.

About This Article

This article describes an analytical model developed for managing industrial air emissions. The model calculates optimum suspended particulate matter (SPM) abatement levels at a variety of selected emitting sources, with the objective of determining how abatement can be achieved at minimum cost. The model offers a basis for establishing market-based instruments, such as emissions trading credits, that could allow facilities to optimize their abatement of air pollutants.

Although the model described here was developed for use in a specific region of India, the authors anticipate that it could have wider applicability to other areas as well.

Background: Command-and-Control versus the Market

Command-and-control regulatory concepts form the basis of environmental policy around the world. However, a growing number of countries are beginning to supplement traditional regulations with market-based approaches.

The use of market-based solutions could be a particularly attractive option in developing coun-

V. B. Gupta, Vinay Kumar, H. K. Gupta, Arvind Kumar Gupta, and C. V. C. Rao

Published online in Wiley InterScience (www.interscience.wiley.com).
DOI: 10.1002/tqem.20015

tries, where environmental policies can be difficult to implement, but where environmental pollution often has a significant impact on the living standards of the population (Paulus, 1995).

Defining Market-Based Instruments

Market-based instruments have been defined as comprising "all price-related and/or regulatory provisions which mobilize the economic self-interest of resource users and polluters" in order to further environmental policy purposes (Paulus, 1995).

Market-based approaches attempt to inject more flexibility into environmental protection laws by allowing organizations a wider range of choice in how they satisfy their legal pollution control responsibilities. Such approaches offer polluters economic incentives to implement more efficient pollution prevention or control measures.

Market-based instruments have been found to be effective in managing air quality.

Emissions trading, which is only one such market-based device, is sometimes used as a generic term for a variety of market-based policy options. Other mechanisms include impact fees, emission offsets, licenses, and deposit systems.

Market-based instruments have been found to be effective in managing air quality (Paulus, 1995).

Implementing Effective Market-Based Approaches

Global experience to date with the application of market-based instruments in environmental management suggests that, in order to be effective, these approaches must be region-specific.

Introduction of these approaches should be undertaken in a phased/co-evolutionary manner, while ensuring that:

- they are compatible with existing legislation, in order to avoid double penalties;
- the market-based instruments are economically effective (this can be an issue when rates for resources such as water and energy are subsidized);
- revenue proceeds from use of market-based instruments will be reinvested to cover any negative impacts they are perceived to have on industrial competitiveness; and
- key stakeholders participate in the design of the market-based instruments.

Growth of Interest in Market-Based Approaches

A survey of the recent literature in this field reflects widespread interest in the use of market-based instruments—particularly emissions trading or tradable permits systems—to address air pollution, rather than the traditional command-and-control approach of setting emission and technology standards.

While much of the early experience with tradable permit systems was confined to the United States (Hahn, 1989; Tietenberg, 1985), a few less-developed countries (LDCs) are now beginning to experiment in different forms with emissions trading (Shah, Nagpal, & Brandon, 1997).

Knowledge developed from such efforts could be particularly valuable at the present time since the concept of a global emissions-trading system, with some type of voluntary participation from LDCs, is at the center of current negotiations on dealing with climate change by curbing emissions of carbon dioxide and other greenhouse gases (Jacoby, Schmalensee, & Sue Wing, 1999).

Our Research Focus

India's Jamshedpur region was identified as the test area for our study because the total industrial emissions in this region are perceived to exceed the assimilative capacities of the environmental media. In addition, most of the data required for the research were considered likely to be available.

The study focused on inter-firm trading of SPM in Jamshedpur region. Research was limited to five major companies that form part of the Tata Group, a large Indian conglomerate. It is believed that SPM trading among these companies would most likely enjoy the same administrative ease and convenience as the inter-firm trading being practiced by companies such as Royal Dutch/Shell and British Petroleum.

In a 1992 policy statement, India's Ministry of Environment and Forests emphasized financial incentives for preventing pollution. In addition, international experience over the past few years offers examples of successful application of an approach that combines regulatory, market, and social instruments for environmental management.

As part of our research, we sought to develop market-based instruments that would be suitable for regional air quality management in India. The two market-based instruments we pursued—the "environmental bubble" and emissions offsets—were designed specifically for managing regional industrial air emissions in Jamshedpur region, although they also have wider potential applicability. We also developed an analytical model to evaluate the two market-based instruments.

Jamshedpur Region

Jamshedpur is located in India's state of Jharkand and is linked with important cities and capitals by rail and roadways. It covers an area of 64 square kilometers; an estimated population of 570,000 lives in the city (Census of India, 2001). Two important rivers, the Subarnarekha and Kharkai, flow through the region.

The climate of Jamshedpur can be characterized as tropical. It is warm and humid, with three main seasons—winter, summer, and the rainy season. Temperatures reported in the majority of localities in the region range from a maximum of 44.1˚C to a minimum of 8.6˚C. Average annual rainfall reported for the region is around 1,331 millimeters.

SPM Concentrations in the Study Area

At the time of our study, SPM concentrations in the core sector zone of Jamshedpur ranged from 30 to 1,879 micrograms per cubic meter (μg/m^3) during the post-monsoon period, 15 to 1,118 μg/m^3 during the winter, and 87 to 677 μg/m^3 during the summer.

Average concentrations recorded in the study area indicated that the highest SPM concentration occurred in the core sectors, followed by zones where other types of industries are located. Concentrations were lowest in rural areas (National Environmental Engineering Research Institute, 1995).

The data revealed that the urban industrial area in particular is experiencing high levels of air pollution.

During the post-monsoon and winter seasons in the core sector zone, maximum SPM concentrations frequently exceeded 500 μg/m^3, the limit that India's Central Pollution Control Board recommends for the industrial and mixed-use category. In summer, a smaller number of SPM values exceeded the standard.

Frequency distribution levels of SPM in urban, semi-urban, and rural areas showed that the highest number of values fell in the range of 200–400 μg/m^3 during all seasons. The data revealed that the urban industrial area in particular is experiencing high levels of air pollution. SPM levels below 100 μg/m^3 are rare in this area, and high values of industrial origin are persistent in the ambient air.

The Analytical Model

Different industrial facilities generally have different pollutant abatement costs. Thus, some can reduce pollutants more cost-effectively than others.

The environmental bubble concept allows the various polluters within a geographical region (or "bubble") to reduce their emissions of pollutants in the aggregate, rather than imposing predetermined limits on each individual emissions source.

This allows facilities to achieve greater pollution control at sources where abatement is more cost-effective, in exchange for reduced controls on other sources where abatement is more expensive, as long as overall emissions are reduced by the required amount.

Under such a scheme, those facilities within the bubble area that can reduce their emissions most cost-effectively are encouraged to make the greatest reductions. This approach allows organizations to reduce a predetermined quantity of pollutants in the least expensive manner.

At the companies we studied, emitting sources are distributed in a small area and, hence, can be treated as a single source.

For purposes of our study, the most cost-effective abatement of a non-uniformly mixed assimilative pollutant is defined as being that which minimizes the cost of pollution control, subject to the constraint that the target level of the pollutant's concentration in the ambient air is met at all receptors in the airshed (Montgomery, 1972). This definition is expressed as follows in (1) and (2):

$$\text{Minimize } Z = \sum_j C_{ij}\, r_{ij} \tag{1}$$

Subject to:

$$\sum_j d_{jk}\,(e_{bij} - r_{ij}) \leq A_{ik} \tag{2}$$

$$r_{ij} \geq 0$$

Where

i Pollutant

j Emission source

k Receptor location

C_{ij} Per-unit abatement cost of pollutant i at source j

r_{ij} Abatement of pollutant i at source j

d_{jk} Contribution that one unit of emission from source j makes to the pollution concentration at point k

e_{bij} Emission of the pollutant i at source j before treatment

A_{ik} Desired level of pollutant i at receptor k

At the companies we studied, emitting sources are distributed in a small area and, hence, can be treated as a single source. For this reason, the model was modified from an ambient-based to an emissions-based system. The sum of present emissions of pollutant i from all selected companies was considered as the allowed level for the pollutant in the airshed of the selected companies.

The proposed model for the study can be stated as follows:

$$\text{Minimize } Z = \sum_j C_{ij}\, r_{ij} \tag{3}$$

Subject to:

$$r_{ij} \leq \frac{E_{ij}}{100} * e_{bij} \tag{4}$$

$$\sum_j (e_{bij} - r_{ij}) = \sum_j e_{ij}$$

$$r_{ij} \geq 0 \tag{5}$$

Where

E_{ij} Efficiency (%) of the best available technology for abatement of pollutant i at source j

e_{ij} Present emissions of pollutant i at source j after treatment

The cost-effective abatement schedules were evaluated with the same model by readjusting

$$\sum_j e_{ij}$$

for different offsets. The TORA software package was used to run the model.

Data Collection and Analysis

A survey was conducted to gather data on the costs and efficiencies of existing and alternate SPM abatement measures in five Tata Group companies—TISCO, TCIL, Tata Pigments Ltd., Telco, and Tata Rayerson Ltd.—in Jamshedpur region.

The annual abatement costs were calculated by adding annualized capital costs and operating costs for each abatement device. Data on gas volume and SPM concentrations at device inlets and outlets were used to estimate annual abatements of SPM through existing measures.

We determined annual SPM abatements with alternate technologies through multiplying inlet SPM load by the efficiency of the device. The per-unit abatement cost for each existing and alternate abatement measure was calculated and used to determine the best available technology (BAT) for each emitting source.

The collected data show that TISCO is the largest company in the region. TISCO generates 7.267 kg/s of SPM before abatement, while all the selected companies collectively generate 7.308 kg/s. Thus, our data show that TISCO generates 99.44 percent of the SPM in the sample.

Capital costs were annualized using a discounted cash flow technique (European Environment Agency, 1999). The present value of the capital cost was multiplied by a capital recovery factor (CRF) to arrive at an annualized capital cost. The method of computing the CRF is given by equation (6).

$$CRF = r \frac{(1+r)^T}{(1+r)^T - 1} \qquad (6)$$

Where

r is the discount rate

T is the lifetime in years

For $r = 0.10$ and $T = 15$ years, the capital recovery factor is 0.131474.

The annual total abatement cost was calculated for each existing and alternate technology by adding annual operating costs to annualized capital costs.

Abatements of SPM through existing technologies were evaluated by using data on gas volume and SPM concentrations before and after treatment. SPM abatements from alternate technologies were evaluated using the inlet load of SPM and the efficiency of the device.

Per-unit abatement costs were calculated for all the technologies (existing and alternate) for each emitting source. The best available technology for each of the emitting sources was selected from among the existing and alternate technologies for that source, based on the least per-unit abatement cost. Further analysis was then carried out with best available technologies.

The annual abatement costs were calculated by adding annualized capital costs and operating costs for each abatement device.

Development of Market-Based Instruments

In our research, we focused on two market-based instruments: the environmental bubble and emission offsets.

The Environmental Bubble

The companies studied abate SPM based on the levels of emissions allowed by the Central Pollution Control Board. In terms of emissions and costs, the current situation for the selected companies can be collectively summarized as follows:

Emissions of SPM before treatment	230.46 MT per year
Abatement	213.22 MT per year
Abatement cost	Rs. (rupees) 346,300,000
Net emissions after treatment	17.24 MT per year

Exhibit 1. Optimum Pollutant Abatements and Costs in All Selected Companies with Best Available Technologies

Company	Location (j)	Abatement Device	Optimum Abatement (tpa) r_{ij}	Abatement Cost (Rs. ,000)
TISCO	1. Boiler House	ESP (T)	18179.80	5112.16
TISCO	2. LD#2 Secondary Emission	ESP (B)	37295.70	18401.70
TISCO	3. Sintering Plant 2 Waste Gas	ESP (B)	9592.32	4747.24
TISCO	4. Sintering Plant 2 Dedusting Unit	Bag Filter (B)	18645.40	10366.84
TISCO	5. Sintering Plant 1 Waste Gas	ESP (B)	2722.02	850.36
TISCO	6. Sintering Plant 1 Dedusting Unit	Bag Filter (T)	6060.02	5260.10
TISCO	7. Coke Oven Waste Gas Stack	Scrubber (B)	10362.40	10041.17
TISCO	8. Power House #3	ESP (T)	61206.73	77628.51
TISCO	9. Power House #4	ESP (T)	40608.80	34355.05
TISCO	10. Blast Furnace Stove Chimney	Scrubber (B)	0.00	0.00
TISCO	11. Refractory Material	Scrubber (B)	7904.12	8309.60
TCIL	12. Boiler	Bag Filter (T)	0.00	0.00
Tata Pigments	13. Calciner and Roasting Furnace	Scrubber (T)	642.69	73.85
TELCO	14. Wartshilla DG-1	Scrubber (B)	0.00	0.00
TELCO	15. Wartshilla DG-3	Scrubber (B)	0.00	0.00
TELCO	16. Forge Stack #5	Bag Filter (B)	0.00	0.00
TELCO	17. Forge Stack #11	Bag Filter (B)	0.00	0.00
TELCO	18. Wartshilla DG-2	Scrubber (B)	0.00	0.00
TELCO	19. TP-15 Themopac Boiler	Scrubber (T)	0.00	0.00
TELCO	20. Nilgata DG	Scrubber (B)	0.00	0.00
TELCO	21. Forge Stack #9	Scrubber (T)	0.00	0.00
Tata	22. Hot Water Generator	Scrubber (B)	0.00	0.00
TOTAL			**213220**	**175146.58**

In order to optimize abatement costs, we developed an environmental bubble encompassing the multiple companies studied. We assumed that total SPM emissions within the bubble would be limited to the existing level of 17.24 MT, thus requiring a total abatement from different sources of 213.22 MT.

We calculated the optimum abatement schedule with best available technologies using the proposed model, equations (3), (4), and (5). The optimum pollutant abatements and associated costs are shown in **Exhibit 1.**

The optimum abatement schedule reveals that cost-effective abatements are possible at TISCO and Tata Pigments only. All other companies are using comparatively cost-intensive abatement technologies.

Tata Pigments is not in a position to abate more emissions. Hence, even though its abatement is cost-effective, we did not use it for offset calculations.

In our calculations, we assumed that TISCO alone would make the necessary abatements. Based on this assumption, optimum pollutant abatements and costs were evaluated with the model discussed in this article. The results are shown in **Exhibit 2.**

It is clear from Exhibits 1 and 2 that the same amount of SPM abatement achieved today could be achieved at half the current cost by using the best available technologies. It would cost slightly more if TISCO alone did the required abatement.

The selected companies currently abate 213.22 MT per year of SPM at a cost of Rs. 346,300,000. TISCO alone could handle this abatement with best available technologies at a cost of approximately Rs. 175,900,000, for a net saving of Rs. 170,400,000.

Under this scheme, other companies for which SPM abatement is more costly could simply stop abating SPM, and instead purchase abatement credits from TISCO.

Exhibit 2. Optimum Pollutant Abatements and Costs in TISCO with Best Available Technologies

Company	Location (j)	Abatement Device	Optimum Abatement (tpa) r_{ij}	Abatement Cost (Rs. ,000)
TISCO	1. Boiler House	ESP (T)	18179.80	5112.16
TISCO	2. LD #2 Secondary Emission	ESP (B)	37295.70	18401.70
TISCO	3. Sintering Plant 2 Waste Gas	ESP (B)	9592.32	4747.24
TISCO	4. Sintering Plant 2 Dedusting Unit	Bag Filter (B)	18645.40	10366.84
TISCO	5. Sintering Plant 1 Waste Gas	ESP (B)	2722.02	850.36
TISCO	6. Sintering Plant 1 Dedusting Unit	Bag Filter (T)	6060.02	5260.10
TISCO	7. Coke Oven Waste Gas Stack	Scrubber (B)	10362.40	10041.17
TISCO	8. Power House #3	ESP (T)	61849.42	78443.62
TISCO	9. Power House #4	ESP (T)	40608.80	34355.05
TISCO	10. Blast Furnace Stove Chimney	Scrubber (B)	0.00	0.00
TISCO	11. Refractory Material	Scrubber (B)	7904.12	8309.60
TOTAL			**213220**	**175887.84**

Emission Offsets

The "emission offset" concept allows polluters to receive credit for reducing emissions below certain specified levels. Such credits can then be traded to other entities or used to offset emissions elsewhere.

We calculated offset costs for SPM abatements in increments of 5 MT and 10 MT, based on use of best available technologies at TISCO.

An offset of 5 MT in abatements (bringing the total abatement to 218.22 MT per year) would cost approximately Rs. 184,900,000. An offset of 10 MT would cost approximately Rs. 200,000,000. Details on the location of potential pollutant abatements and their related costs are shown in **Exhibit 3.**

Conclusion

With respect to the companies studied in our research, Tata Pigments and TISCO currently employ the most cost-effective SPM abatement measures. By contrast, the abatement measures adopted by the other companies are more cost-intensive.

TISCO is the only company in the selected group that could achieve additional SPM emissions reductions at comparatively lower cost. If TISCO achieved permanent emissions reductions

Exhibit 3. SPM Abatements and Costs for Creating Offsets of 5 and 10 MT at TISCO

Location (j)	For offset of 5 MT		For offset of 10 MT	
	Optimum Abatement r_{ij} (tpa)	Cost (z) (Rs., 000)	Optimum Abatement r_{ij} (tpa)	Cost (z) (Rs., 000)
1. Boiler House	18179.80	5112.16	18179.80	5112.16
2. LD #2 Secondary Emission	37295.70	18401.70	37295.70	18401.70
3. Sintering Plant 2 Waste Gas	9592.32	4747.24	9592.32	4747.24
4. Sintering Plant 2 Dedusting Unit	18645.40	10366.84	18645.40	10366.84
5. Sintering Plant 1 Waste Gas	2722.02	850.36	2722.02	850.36
6. Sintering Plant 1 Dedusting Unit	6060.02	5260.10	6060.02	5260.10
7. Coke Oven Waste Gas Stack	10362.40	10041.17	10362.40	10041.17
8. Power House #3	65293.00	82811.12	65293.00	82811.12
9. Power House #4	40608.80	34355.05	40608.80	34355.05
10. Blast Furnace Stove Chimney	1556.42	4692.93	6556.42	19768.93
11. Refractory Material	7904.12	8309.60	7904.12	8309.60
TOTAL	**218220**	**184948.3**	**223220**	**200024.3**

above what is required, the company could earn emission reduction credits (ERCs) for such additional abatements. The other companies in the environmental bubble could then purchase these credits from TISCO based on their emission reduction requirements.

Cost savings of up to 50 percent are possible if the environmental bubble concept and emissions trading are introduced in the Jamshedpur region.

It is likely that inter-firm emissions trading would also result in cost savings in any region where many large companies operate.

Acknowledgments

The authors of this article are grateful to the Environmental Economics Research Committee, at the Indira Gandhi Institute of Development Research in Mumbai, for providing financial assistance for this study under the World Bank's Environmental Management Capacity Building Technical Assistance Project (EMCaB: India).

References

Census of India. (2001). Office of the Registrar General, http://www.censusindia.net

European Environment Agency. (1999). Guidelines for defining and documenting data on costs of possible environmental protection measures. Copenhagen: EEA Technical Report 27.

Hahn, R. W. (1989). Economic prescriptions for environmental problems: How the patient followed the doctor's orders. Journal of Economic Perspectives, 3(2), 95–114.

Jacoby, H. D., Schmalensee, R., & Sue Wing, I. (1999, May). Toward a useful architecture for climate change negotiations, Report No. 49, MIT Joint Program on the Science and Policy of Global Change.

Montgomery, W. D. (1972). Markets in licenses and efficient pollution control programs. Journal of Economic Theory, 5(3), 395–418.

National Environmental Engineering Research Institute. (1995). Regional environmental impact assessment studies for Jamshedpur region, 1 & 2. Nagpur: National Environmental Engineering Research Institute.

Paulus, S. (1995). Market-based instruments in environmental policy in developing countries—Framework for policy planning and institutional development in the environment. Bonn/Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit.

Shah, J. J., Nagpal, T., & Brandon, C. J. (Eds.). (1997). Urban air quality management strategy in Asia—Guidebook (URBAIR). Washington, DC: World Bank.

Tietenberg, T. H. (1985). Emissions trading: An exercise in reforming pollution policy. Washington, DC: Resources for the Future.

V. B. Gupta, PhD, has served on the faculty at the School of Futures Studies and Planning, Devi Ahilya University, Indore, since 1990. His research interests focus on systems modeling and simulation, environmental management, and planning and forecasting. He can be reached at vbgupta.fsp@dauniv.ac.in or guptavb@hotmail.com.

Vinay Kumar is affiliated with the Centre for Advocacy and Research in Environment, Mumbai. His area of expertise is environmental management.

H. K. Gupta is associated with the School of Futures Studies and Planning, Devi Ahilya University, Indore, as a research scholar. His research interests include air quality modeling and environmental management.

Arvind Kumar Gupta is associated with the Centre for Energy Studies, Indian Institute of Technology, Hauz Khas, New Delhi. His area of expertise is market-based instruments in environmental management.

C. V. C. Rao, PhD, works as a scientist in the air pollution control division, National Environmental Engineering Research Institute, Nehru Marg, Nagpur. His areas of expertise include air quality modeling, carrying capacity, and environmental management.