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Market Based Instruments for Regional Air Environment Management at Jamshedpur

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MOEF IGIDR WORLD BANK

MARKET BASED INSTRUMENTS FOR REGIONAL AIR ENVIRONMENT MANAGEMENT AT JAMSHEDPUR

Project Code: P-297

FINAL REPORT

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EXECUTIVE SUMMARY

Indira Gandhi Institute of Development Research, Mumbai funded the research project titled “Market Based Instruments for Regional Air Environment Management at Jamshedpur” under World Bank scheme – EMCaB through its letter no. EERC/JP-TRR/SAN/P297 dated 21/09/2001.

The report presents abatement cost curves and marginal cost curves of different SPM abatement measures. A linear programming model is developed to calculate optimum abatements for different market based instruments. The cost curves and LP model are used to evaluate proposed economic instruments.

1. OBJECTIVE OF THE STUDY:

The objective of the project was to design and assess market based instruments to improve economic and environmental performance of the industries in Jamshedpur region.

2. MARKET BASED INSTRUMENTS:

Market-Based Instruments are regulations that encourage behavior through market signals rather than through explicit directives regarding pollution control levels or method. These policy instruments, such as tradable permits or pollution charges, are often describe as “harnessing market forces” because if they are well designed and implemented, they encourage firms (and/or individuals) to undertake pollution control efforts that are in their own interests and that collectively meet policy goals.

Goals and Economic Principles of MBIs: There are three goals of MBIs:

1) Cost effectiveness.
2) Decrease externalities.
3) Revenue generation.

The two economic principles for MBI are Polluter pays and Pre-cautionary:

- The Polluter-pays (or user-pay) principle assigns rights that allow internalization of cost that would not normally be incurred by the polluter or user (externalities).

- The Pre-cautionary principle provides a mechanism for dealing with the uncertainty of imparts.

Emission Trading:

Emission trading is a general term used for the three Kyoto protocol flexibility mechanisms. It is a market-based system that allows firms the flexibility to select cost effective solution to achieve established environmental goals. With emission trading firms can meet established emission goals by:

- Reducing emission from a discreet emission unit.
- Reducing emission from another place with in the facility.
- Securing emission reduction from another facility, or
- Securing emission reduction from the market place.

Emission trading encourages compliance and financial manager to pursue cost-effective emission reduction strategies and provides incentives to emitters to develop the mean by which emission can inexpensively be reduced.

Environmental Bubble:

A bubble is a regulatory concept where by two or more emission sources are treated as if they were a single emission source. This creates flexibility to apply pollution control technologies to whichever source under the bubble has the most cost effective pollution control options, while ensuring the total amount of emissions under the bubble meets the environmental requirement for the entity. Bubbles are closed systems. It allows existing sources flexibility in meeting required emission limits, by treating multiple emission points as if they face a single, aggregate emission limit. This allows the firm to rearrange discharge points within the plant in the most cost-effective manner.

Emission Offset:

Offsets are a form of credit-based emission trading. Offset is created when a source makes a voluntary, permanent emission reduction that is in surplus to any required reductions. Existing sources that create offsets can trade them to new sources to cover growth relocation. Regulators approve each trade. Regulators normally require a portion of the offsets to be retired to ensure an overall reduction in emission.

Offsets are an open system. One offsets is an emission reduction that a pollution source has achieved in excess of permitted levels and or required reductions. The excess amount is the credit and can be sold in the market. The offset program was developed in 1976 to reduce the conflict between economic growth and progress towards air quality standard levels in non-attainment regions

In the present study two market-based instruments – environmental bubble and emission offsets - are developed and evaluated.

3. THE STUDY AREA-JAMSHEDPUR AND ITS BASELINE AIR ENVIRONMENT

Jamshedpur: An Introduction:

Jamshedpur is located in the state of Jharkhand and is linked with important cities and capitals by rail and roadways. It covers an area of 64 sq. km. The population of the city is 570,349 (Census, 2001). Maximum and minimum temperature reported in the region is 44.1^{o}C and 8.6 ^{o}C respectively and average annual rainfall reported for the region is around 1331 mm. Two important rivers viz. Subarnarekha and Kharkai are flowing in the region. TISCO, TELCO, TCIL, ISWP, TATA Tubes, INCAB, IVP, TRF, JEMCO and TATA Pigment and many other small industries are located in city. A number of Educational Institutions and hospitals are also located in the region.

Baseline Air Environmental Status:

Studies carried out by NEERI on air environment included measurement of ambient air quality within 15 km radius of the TISCO works, estimation/measurement of stack, prediction of ground level concentration (GLS) through air quality/dispersion models for existing operational levels and proposed facilities are used for the purpose of present study. SPM concentrations in core sector zone ranged from 30 to 1879, 15 to 1118 and 87 to 677 μg/m^3 during post monsoon, winter and summer seasons respectively in the study region. Average concentrations recorded in the study area indicate that highest SPM concentration occurs in core sectors followed by zone where other types of industries are located and was lowest in rural areas.

Ambient SO_2 levels observed during post monsoon, winter and summer seasons indicated wide fluctuations ranging from 6 to 398 μg/m^3. Seasonal averages of values recorded in core sector zone were in the range of 6-56, 24-99 and 26-68 during post monsoon, winter and summer seasons respectively. Ambient NO_2 levels observed during the post monsoon, winter and summer varied from 3 to 191 μg/m^3.

The mean concentrations of NO_X levels ranged from 3 to 53 µg/m^3. Winter levels were found to be higher then post monsoon and summer season values. In general concentrations were found to be less then CPCB prescribed limits of 80 µg/m^3 for residential / rural area.

The baseline environmental conditions indicate that the particulate matter ambient concentrations are exceeding the national ambient air quality standards. Reduction in particulate emission would contribute to significant improvement in the ambient environment. We estimate that additional particulate emission reduction in the range of 5 and 8 MT could bring about improved environmental conditions in critical areas of Jamshedpur.

4. METHODOLOGY:

The main task of the project has been bifurcated into following three parts:

1. Construction of abatement cost curves
2. Development of MBIs
3. Comparison of different instruments.

Construction of Abatement Cost Curves:

A cost curve is a ranking of abatement measures in terms of increasing marginal cost by size of emission reduction. Cost curves can be presented graphically or as tables or rankings. Cost curves are useful for policy analysis because they identify cost effective measures to achieve various emission reductions. The steps involved in the derivation of a cost curve for emission reduction are:

- The first step is to estimate the pollution load for each source in the selected companies. Since actual information of this nature does not exist, it is estimated by using data on volume of gas flow and pollutant's concentration in the gas.
- The second step is to identify the abatement options. A survey was conducted to identify existing abatement devices in the selected companies. During the survey information on efficiency, capital cost and operating cost of each device is also gathered.

Another survey was conducted to identify alternate abatement technologies for SPM and NOx at different sources. The data on capital cost, operating cost and efficiency are also collected for these devices.

- The annual abatement and its total cost are estimated for each device. The capital cost is annualised by multiplying it with cost recovery factor using the information of discount rate and lifetime of the device. The discount rate is taken as 10% and lifetime of 15 years.
- An abatement cost function was developed to rank the different abatement technologies.
- Abatement cost curves and marginal cost curves were drawn for all technologies existing and alternate.

The existing and alternate technologies were compared for each source as per their unit abatement cost to find out best available technologies suited for the source. The cost curves are also drawn for best available technologies.

Similar curves of all three sets of abatement devices are also drawn with operating cost of the devices.

Development of MBIs:

In the present study two MBIs were considered - bubble and offset.

It is assumed that the selected companies are making abatements as per Government regulations under CAC system. The sum of present emissions of the pollutants from the selected companies is considered as air-shed for estimating bubble's limit. The abatement cost curves for alternate measures for the selected companies were used to find out source specific optimum abatements to achieve emission limit of the bubble. The abatement cost for achieving bubble's limit by Tisco alone was also estimated using concerned cost curves. The abatement costs were also calculated for abatements through best available technologies at different sources in all companies using concerned cost curves.

A linear programming model was also developed to calculate optimum abatements to achieve the bubble's limit of pollution.

Two offsets (5 and 8 MT) are created and their additional costs are estimated with abatement cost curves of alternate and best available technologies. The cost curves were used to calculate additional cost for this additional abatement.

The proposed model was also used to calculate the optimum abatements.

Comparison of Different Instruments:

The costs are calculated under bubble policy and compared with the existing costs under CAC.

5. ANALYTICAL METHODS

The bubble concept allows various polluters in a geographical region-with varying abatement costs-to jointly reduce a predetermined quantity of pollutants. The cost effective abatement of a non-uniformly mixed assimilative pollutant is that abatement 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 air-shed. It can be expressed as:

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

Subject to:

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

$$r_{ij} \geq 0$$

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

As all of the selected companies are within 5 KM radius from Tisco, d_{jk} would not have much impact on distribution of SPM in the area. Therefore, the model was modified from ambient-based to emissions-based system and diffusion coefficients were not taken into consideration. The sum of present emissions of pollutant i from all selected companies was considered as allowed level for the pollutant in all the places of the air-shed of the selected companies, because the companies are meeting Govt. specified standards under CAC system. The proposed model for the study can be stated as follows:

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

Subject to:

$$r_{ij} \le \frac{E_{ij}}{100} * e_{bij}$$

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

$$r_{ij} \ge 0$$

where,

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

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

In designing of offsets of 5 MT and 8 MT the cost effective abatement schedules are evaluated with the same model by readjusting net after treatment emissions, $\sum_j e_{ij}$.

The TORA package is used to run the model.

6. DATA COLLECTION AND ANALYSIS:

Major air polluting industries in Jamshedpur region include iron and steel, engineering and locomotive, agricultural tools, tube manufacturing etc. A report on Tisco and carrying capacity report developed by NEERI were considered to identify potential air polluting Tata group companies. Based on field visits and gathered information the following companies were selected in the region for the study:

i. TISCO

ii. Tata Pigments Ltd.

iii. Tata Rayerson Ltd.

iv. Tata Engineering and Locomotive Company Ltd. (Telco)

v. Tinplate Company of India Limited (TCIL)

vi. Telco Constructions and Equipment Company Ltd.

vii. Tata Cummins Ltd.

The report contains a compilation of data on costs and efficiencies of abatement measures to reduce emissions – SPM and NOx. A survey was conducted to collect data on air emissions at different sources and cost and efficiency of existing abatement devices in all the selected companies. Another survey was conducted to find out possible alternate abatement devices for each emitting source. The cost and efficiency of each such device were also evaluated.

A list of best available abatement technologies was developed for each emitting source from among existing and alternate abatement technologies suited at that source on the basis of unit abatement cost of the technology. The capital cost, operating cost and efficiency data of best available technologies are also gathered.

Data Analysis:

Tisco alone generates 7.267 kg/s of SPM and 257.03 g/s of NOx before abatement. While all selected companies including Tisco generate 7.308 kg/s of SPM and 257.25 g/s of NOx. It shows that Tisco generates 99.44% of SPM and 99.91% of NOx.

The collected data from the selected companies reveal that no NOx abatement device has been installed at any source. Therefore, NOx data are not used in further calculations. The five companies have installed SPM abatement devices to check the dust emissions. Tisco is the major emitter of SPM and NOx with more than 99% in the selected group. Data on gas volume, concentration of SPM at inlet and outlet are used to estimate annual SPM emissions and abatements by existing measures at each emitting source.

Two types of analyses are carried out – one considering the capital cost and another without taking capital cost into consideration. In the first category the capital costs have been annualised using a discounted cash flow technique [EEA, 1999]. The present value of the capital cost is multiplied by the capital recovery factor, which is given by the following formula:

$$C.R.F. = r\frac{(1+r)^T}{(1+r)^T - 1}$$

where, *r* is the discount rate and *T* is the lifetime in years. For *r* = 0.10 and *T* = 15 years, the capital recovery factor is 0.131474. Annual total abatement cost is calculated for each existing and alternate technology by adding annual operating cost to the annualised capital cost.

7. DEVELOPMENT OF ABATEMENT COST CURVES AND MARKET BASED INSTRUMENTS (INCLUDING CAPITAL COST OF THE DEVICES)

Construction of Cost Curves:

An abatement cost function is developed and parameters are estimated using annual abatements and costs data for all existing pollution control devices. With the help of these parameters annual abatement costs are estimated for the same level of abatements. The abatement devices are ranked on the basis of the difference of observed and estimated annual abatement costs. The top rank (1) is given to the technology having most negative value of the difference between observed and estimated costs. The last rank is given to the technology having most positive difference. All the abatement devices are rearranged as per their ranks from top to last.

Abatement cost curves are drawn for all existing abatement technologies in the selected companies. The x-axis contains cumulative abatements and y-axis its cumulative costs. The abatement cost curves are also drawn for all the abatement measures installed at various polluting sources in Tisco. Marginal abatement cost curves are also drawn for the technologies installed in all companies as well as in Tisco. Y-axis in marginal cost curves contains marginal abatement costs while x-axis contains cumulative annual abatements.

The suppliers of alternate abatement devices were contacted to collect data on alternate devices for abatement of SPM at different sources. Data on capital cost, operational cost and efficiency were collected. Abatement cost curves and marginal cost curves are drawn for all the alternate abatement devices. Similar curves are also drawn separately for the alternate devices at different emitting sources in Tisco. Similarly marginal abatement cost curves are drawn for the alternate devices in all companies and in Tisco.

Annual abatement costs and abatements are also calculated for the best available abatement technologies as per the procedure adopted earlier. An abatement cost function is also developed for ranking all these best available technologies. Abatement costs curves are drawn for the best available technologies in all the selected companies. The similar curves are also drawn for the best available technologies for the different emitting sources at Tisco. Similarly marginal cost curves for the best available technologies in all companies and in Tisco are also drawn.

Development of Market Based Instruments:

The cost curves are used to estimate abatement costs for different target levels of abatements. A bubble with its limit equals to the sum of existing SPM emissions from all selected five companies is developed. The existing abatement cost is estimated for the bubble from abatement cost curve of existing abatement technologies in all the companies. The abatement costs are also estimated from cost curves with alternate and best available technologies for keeping limit of the bubble unchanged.

Two offsets of 5 MT and 8 MT of SPM abatements are developed and associated additional costs were estimated for alternate and best available.

8. DEVELOPMENT OF ABATEMENT COST CURVES AND MARKET BASED INSTRUMENTS (EXCLUDING CAPITAL COST OF THE DEVICES)

Construction of Abatement and Marginal Cost Curves:

The capital cost can be considered as sunk cost for such devices. In that case only annual operating cost will take part in developing cost curves and market-based instruments. Therefore, in this section market-based instruments are developed on the basis of operating costs only. The abatement technologies are ranked as per their unit abatement costs. Highest rank is given to the technology having least per unit abatement cost.

The abatement and marginal cost curves are drawn in a similar manner as done earlier in case of including capital cost. The curves are drawn for all three sets of technologies.

Development of Market Based Instruments:

The cost curves are used to estimate abatement costs for the bubble and proposed offsets.

9. DEVELOPMENT OF MARKET BASED INSTRUMENTS USING LINEAR PROGRAMMING MODEL:

Environmental Bubble:

The optimum abatements from alternate measures are calculated using the LP model. It is found that all optimum abatements are at Tisco only. As per current situation Tisco abates 212.54 MT SPM under CAC with cost of Rs. 345.92 millions (including capital cost) or Rs. 81.72 millions (operating cost). For the Bubble Tisco abates 213.22 MT of SPM with abatement cost of Rs. 205.34 millions (with capital cost) or Rs. 74.07 millions (without capital cost). It shows that there is lot of cost saving. The additional abatement made by Tisco can be rewarded as ERCs to Tisco and which can be sold in the market to other companies.

In case of best available technologies also the most of the optimum abatements are at Tisco only. Tata Pigments is the company that has cost effective abatement device but it cannot reduce more therefore, it can be allowed to make their needed abatements. TCIL has less per unit operating cost, hence, its abatement is optimum under operating cost (without capital cost) category. But if we see total cost including capital cost then its abatement is not optimum. Anyhow, the company is not in position to abate more, therefore, it cannot be considered as a candidate to earn ERCs. Tisco is the only company that has capability to reduce more and at less cost.

The annual abatement costs with BATs are much less than existing / alternate technologies. The cost saving is an intensive to the companies to adopt the bubble policy.

Emission Offsets:

The offsets of 5 MT and 8 MT of SPM abatements have been evaluated with alternate and best available technologies. For offsets of 5MT / 8MT total annual abatements would be 218.22 MT and 221.22 respectively. It is found that further abatement is possible with Tisco only. Therefore, for the proposed offsets Tisco will make the required abatements and earn ERCs.

With alternate abatement technologies:

The model results show that the optimum abatements, in addition to the required for the bubble, for developing an offset of 5MT would take place at Blast Furnace and Refractory Material units of Tisco. The refractory material unit of Tisco will abate more for the offset of 8MT. The optimum abatements are same under both the cases of cost considerations.

The cost (including capital cost) of the offsets of 5 / 8 MT will enhance by Rs. 15.28 / 24.73 millions. The operating costs for offsets of 5 MT and 8 MT will increase by Rs. 6.29 millions and Rs. 12 millions respectively.

With best available technologies:

The model results show that the optimum additional abatements for creating 5 MT offset will take place at power house # 3 (4090.3 T) and blast furnace (8859.7 T) of Tisco and boiler of TCIL (50 T). The total additional cost (including capital cost) for this offset would be Rs. 7.92 millions. For 8 MT offset further optimum abatement of

3 MT will take place at blast furnace of Tisco with additional cost of Rs. 9.05 millions. Total abatement cost for 8 MT offset would be Rs. 16.97 millions.

If we consider only operating costs of the devices to evaluate optimum abatements for creating 5 and 8 MT offsets, then the model results indicate as follows:

Additional abatements for 5 MT offset at sintering plant (4040.3 T) and blast furnace (831 T) of Tisco and Wartsilla DG 2 of Telco (28.7 T) with total additional cost of Rs. 3.6 millions. . For 8 MT offset further optimum abatement of 3 MT will take place at blast furnace of Tisco with additional cost of Rs. 2.71 millions. Total abatement cost for 8 MT offset would be Rs. 6.31millions.

10. RESULTS AND DISCUSSION:

The abatement costs calculations from cost curves and LP model for the environmental bubble indicate that the cost saving is much more with BATs. Therefore, it is suggested that if inter-firm trading is introduced the companies will focus towards cost effective measures i.e. BATs. These measures are also capable to abate more SPM emissions and the companies would try to abate more SPM with BATs and earn ERCs. As Tisco is the only company in the selected group that can abate more with less cost. Therefore, emission reduction credits will be earned by Tisco and other companies for them SPM abatement is cost intensive can purchase those credits from Tisco.

Similarly the cost saving is much more with best available technologies for both the offsets. The required abatements for the offsets are made by Tisco only in almost all the cases. Therefore, the Tisco can be allowed to earn the credits and other cost intensive companies can purchase these credits from Tisco.

The proposed LP model gives more cost effective schedules for required abatements in all the cases. The development of the model for the bubble and offset is also simple and takes less time in comparison to the development of abatement cost curves. It shows that the LP model can effectively be used for such calculations.

11. POLICY RECOMMENDATION:

The results show that there are huge cost savings in reducing the emissions with best available technologies. The cost saving is a good incentive to attract the players to adopt emission trading scheme. Two types of emission reduction trading schemes are recommended:

1. Inter-firm Emission Reduction Trading:

TISCO is responsible for more than 90% of the SPM emissions in the Jamshedpur region, and also has low cost options of reducing further the SPM emissions. Available technologies, players and their roles severely restrict an emission trading market system to operate.

We recommend, in this specific circumstance, that all the major industries in the region may be asked (by the Pollution Control Board) to reduce their emissions by 5% below the consented (in the consent to operate and establish under Air Act) SPM emission levels. They could be given two options, for complying with the additional SPM emission reductions:

1) Reduce the emissions at their own site
2) Procure Certified Emission Reduction

The industries can be allowed to bid for emission reductions based on validated proposals- baseline being the present emission permits (in the consent to operate and establish under Air Act) only. Validated emission reduction proposals can be registered and based on monitoring of emission reductions, annually, the Certified Emission Reductions can be granted. These certified emission reductions could be the basis for assessing the compliance by the industries, of the additional 5%reduction.

The institutional mechanism to implement these additional emission reductions could be led by the voluntary association of Industries or a citizens/stakeholders forum to improve the Environment in Jamshedpur. This forum could establish a registry, designating validating and monitoring entities. The operational framework could be similar to that of Emission Trading under Kyoto Protocol.

2. Intra-firm Emission Reduction Trading within Tisco:

Tisco alone has 11 emitting sources with good quantity of emissions. Total SPM emission load (before treatment) from Tisco is 229.17 MT p.a. Tisco also has separate environmental division to take care of all environment related problems. The validating and monitoring activities for emission reduction certificates will not have much extra financial burden on Tisco. A good competition can be established among the emitting sources of the company, if each emitting source is considered as an independent unit. Even we will not have large number of players to decide the market price of the ERCs, but intra-firm emission reduction trading within Tisco can improve its abatements with less cost. Therefore, intra-firm trading within Tisco is recommended for getting an experience.

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1. INTRODUCTION

1.1 Background:

Indira Gandhi Institute of Development Research, Mumbai funded the research project on Market Based Instruments for Regional Air Environment Management at Jamshedpur under World Bank scheme – EMCaB through its letter no. EERC/JP-TRR/SAN/P297 dated 21/09/2001 to Devi Ahilya University, Indore.

The objective of the project was to design and assess Market Based Instruments to improve economic and environmental performance of the industries in Jamshedpur region.

The work has comprised a combination of literature surveys, contact with industry and trade associations, and commissioned measurement programmes. This report presents cost curves of abatement technologies for the abatement of SPM emissions. A marginal cost curve is a ranking of abatement measures in terms of increasing marginal cost by size of emission reduction. The cost curves can be presented graphically or as tables or rankings. Cost curves are useful for policy analysis because they identify cost effective measures to achieve various emission reductions, or conversely how much it would cost to achieve a given reduction.

This report contains a compilation of data on costs, abatements and efficiencies of measures to reduce emissions of SPM and NOx. The abatement cost curves and marginal cost curves were drawn for different measures. The abatement costs were also calculated with alternate and best available technologies for bubble and offsets.

Three sets of abatement measures are evaluated i.e. existing, alternate and best available. The best available technologies are those technologies for specific polluting sources that make SPM abatement at least cost. These include cost effective technologies from existing and alternate technologies. Calculating the abatement costs carries out two types of analyses, first includes the capital costs of the equipments and second excludes the capital costs. The abatement cost curves and marginal cost curves are drawn for all three sets of the technologies.

A linear programming model has also been developed to calculate optimum abatements at different emitting sources under bubble and offset policies. The per unit abatement costs for each technology has been evaluated first by including the capital cost of the device and then by excluding the capital cost. The data on SPM emissions before treatment at different locations and efficiency of the abatement device suited for that location are used to evaluate maximum possible abatement of that source. The sum of existing net emissions after treatment is considered as bubble's limit. The per unit abatement cost, maximum possible abatement and bubble's limit are used as input data for the model. The optimum abatements are calculated by running the model on TORA package.

1.2 Structure of the Report:

The report has been divided into eleven sections. Section 2 gives an overview of the market-based instruments. Section 3 describes the study area. Section 4 explains the methodology adopted for the study. This section documents in detail the methodology used for calculating the costs and emission reductions; the data sources and references; and any assumptions made. Section 5 describes the analytical method used in the study. The key inputs to the quantitative analysis were capital cost, operating cost, efficiency of the devices, emission load, concentration of the pollutants at inlet and outlet. This information is taken from the companies, as described in Section 6. The same information was also collected for the alternate abatement devices and listed in section 6. Each cost curve embodies, abstracts and illustrates a great deal of information. The abatement cost curves, marginal abatement cost curves and market-based instruments are developed for all three sets of the technologies including capital cost of the devices. This underlying information is presented in full in Section 7. The same curves and MBIs are also developed with operating costs only. The curves and MBIs – environmental bubble and offsets are reported in section 8. The market based instruments - bubble and offsets - are also developed with proposed linear programming model. The optimum SPM abatements are calculated with TORA package for bubble and offsets under both cost considerations. The model results are given in section 9. The section 10 discusses the results and conclusion. The policy recommendations are mentioned in section 11. The references are reported in section 12.

2. MARKET BASED INSTRUMENTS

2.1 Introduction:

Market-based instrument approaches a wide range of potential mechanism and hundreds of individual instruments. At one extreme, they include fines or sanctions that are linked to traditional command and control (CAC) regulation. At the other extreme, they include laissez-faire approaches that depend on consumer advocacy or private litigation to provide incentives for improving environmental management. Between these extremes are the more familiar tax and subsidy approaches as well as less commonly used mechanism that rely on a traded property rights. All of these approaches, in their own fashion, attempt to internalize environmental costs.

Although the principles of polluter pays and prevention have long been established in environmental policy, in practice the emphasis has largely been on repair oriented and curative measures. This is also reflected in the worldwide predominance of command-and-control concepts in environmental policy. Experience has, however, shown that such concepts have limited reach, and this is increasingly forcing a reorientation in policy instruments and hence not least (in both institutional and instrumental terms) to greater integration of environmental policy and economic policy. In a market economy context, one of the most important requirements for this is the integration of the environmental dimension into the market mechanism in such a way that the market responds effectively to them instead of working against them. In a broad sense, the term “market-based instruments (MBI)” is used to cover all price-related and/or regulatory instruments that harness the commercial self-interest of actors (i.e. industry, farmers, transport users or the population at large) for environmental goals.

Although overshadowed by political and scientific debate, a wide range of market based instruments (MBI) have found their ways into environmental policy in a growing number of countries. In Germany this applies to the effluent charge at Federal level and, above all, to the states and local authorities. Other OECD countries are acquiring experience with MBI in environmental policy, starting with so-called "emission trading" in the USA, and going on to liability laws in Japan and the deposit on car bodies in Norway. Several developing countries are also developing approaches of this kind, e.g. different rates of duty on leaded and unleaded petrol in Thailand, pollution licenses in Chile and the environmental fund in Tunisia.

2.2 Goals and Economic Principles of MBIs:

There are three goals of MBIs:

- Cost effectiveness.
- Decrease externalities.
- Revenue generation.

The two economic principles for MBI are Polluter pays and Pre-cautionary:

- The Polluter-pays (or user-pay) principle assigns rights that allow internalization of cost that would not normally be incurred by the polluter or user (externalities).
- The Pre-cautionary principle provides a mechanism for dealing with the uncertainty of imparts.

2.3 Arguments for Using Market-Based Instruments in Environmental Policy:

In both industrialized and developing countries, the application of individual market-based instruments has always been the result of specific constellations. These generally involved a mixture of environmental and economic considerations. The difficulties in implementing "command and control" approaches, the high costs (to both private and public sector budgets) and the static nature of curative environmental policy have always been an important motivation for considering ways to introduce economic mechanisms into environmental policy. There are a number of factors at work here, such as:

- the enormous cost of monitoring;
- the disproportionate growth in waste and effluent disposal costs as the level of purification required by "end-of-pipe" technologies rises;
- free residual pollution, which leaves no incentive to reduce emissions beyond standards (and results in substantial external costs, particularly in developing countries);

- the obstacle to innovation caused by rigid technical regulations which leave little scope for integrated and possibly more cost-effective solutions and frequently go beyond the expertise of environmental agencies;
- the economic inefficiency of standards, which require each individual source of emissions to meet the same norms irrespective of the costs of compliance (which can vary very widely depending on the type of plant) and which do not permit compensatory approaches.
- other issues arise when the peculiarities of public goods and long-term developments are considered, for example arising out of distortions to price mechanisms. This type of problem is particularly frequent in developing countries. Free access to a resource where there is no possibility of excluding potential users tends to lead to overexploitation (e.g. fish stocks, water).
- where property rights are vaguely defined or uncertain (e.g. for forests, arable or grazing land), users will tend to omit or neglect maintenance measures, contributing to overexploitation.
- internationally widespread subsidies for primary fuels, fertilizers and pesticides are tending to undermine the effect of ecological regulations and hence their goals.
- besides burdening public-sector budgets, undesirable ecological effects arise where fees for public services (e.g. water supply, sewerage, and waste disposal) are too low to cover costs.

"Command-and-control" approaches generally have little impact on the (economic policy) framework for economic growth and structural change, creating the risk that higher emission and resource consumption levels will erode their initial successes. Against this background, determining the “right” set of instruments is a question that can only be answered on a case-by-case basis, i.e. depending on the nature of the environmental problems (type of pollutant or resources), their sources (e.g. number, type, geographical distribution), the impact on people, environment and economy, and with due allowance for the existing institutional structure and setting. It is, however, important to avoid giving market-based instruments an air of mystery through terminological differentiation from “other” instruments of environmental policy. The controversy over the fundamental superiority of regulatory instruments or market-based instruments has given way to a pragmatic consensus that it is normally a matter of developing an effective policy mix of different and complementary regulatory and market-based instruments which will also have a preventive effect. In considering the advantages and disadvantages of a given instrument, it is accordingly important to look at the experiences in the context of the entire range of (regulatory and market) instruments.

2.4 Experiences with Market-Based Instruments:

The environment management policies are classified by Asafu-Adjaye (2000) as given in Figure 2.1. Unlike the Command and Control (CAC) approach, market-based instruments use price or other economic variables to provide incentives for polluters to reduce harmful emissions. Market based instruments include charges, subsidies, marketable (or tradeable) permits, deposit/refund systems, ecolabelling, licenses, and property rights. Successful emission trading schemes introduced before 1997 were set out as examples for designing subsequent ones. The US trading schemes, RECLAIM trading credit programme and Acid Rain Programme were such.

There are several market-based instruments being used for improving environmental quality in different countries. The examples of such market based instruments and experiences with them are listed as follows:

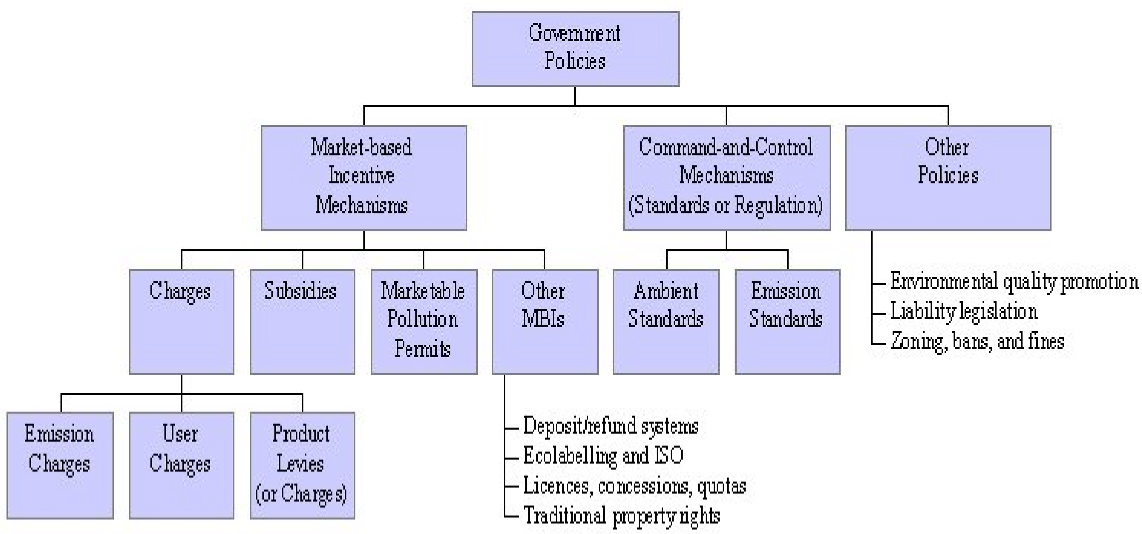

Figure 2.1: Government policies for managing environment

a. Charges

A charge or a tax is a fee that is imposed on a pollutant in proportion to the amount of the pollutant released into the environment. Charges are based on the **'Polluter Pays Principle (PPP)'**, which requires that a polluter must bear the cost of any pollution abatement necessary to maintain environmental quality.

Charges may be classified into the following categories:

Emission (or effluent) charges are based on the actual amount of the pollutant discharged.

Product charges or levies are a mark-up on the price of a pollution-generating product that is based on the amount responsible for pollution. An example of a product charge is a carbon (fuel) tax.

User charge is a fee levied on the user of an environmental resource based on the costs of treating emissions (or effluents) that affect the resource.

Administrative charge is a service fee for implementing or monitoring regulation. The advantages and disadvantages of charges system are shown in Table 2.1.

Table 2.1: Advantages and Disadvantages of Charges System

Advantages of charges	Disadvantages of charges
A charge gives consumers and firms an economic incentive to reduce pollution. Unlike standards, which are applied uniformly to all polluters, charges enable firms to adopt a cost-effective pollution abatement solution. Compared to standards, there is a stronger incentive for firms to adopt new technology in order to lower the charges they have to pay.	An 'optimum' standard is often difficult to set for certain non-market environmental commodities. Firms could pass on a portion of the tax or charge to consumers in the form of higher product prices. Imposing a tax could also lead to job losses as firms minimize their costs in order to increase pollution abatement. Costs of monitoring the compliance may be high if charges are based on the emission.

Examples

Korea: Effluent charge system:

The effluent charge system was introduced in 1983 in the Republic of Korea as a penalty for violations of the regulatory standard. The charge rate was low. Unlike command and control with penalties such as closure, relocation of firms or imprisonment, payment of the penalty was not a threat to industries. Ineffective monitoring induced polluters to attempt to avoid penalties through bribery or cheating. Computation of charges based on toxicity rather than on total volume discharged, led some polluters to dilute the wastewater to acceptable level.

Malaysia: The Malaysian Effluent Standard-Charge System

The Malaysian Effluent Charge System, instituted with the passage of the Environmental Quality Act of 1974, included provisions for using economic incentives and disincentives in the form of effluent charges, in support, rather than replacement, of regulations on discharges. The Act requires that all dischargers pay a fee to obtain a license to discharge waste into public water bodies. The fee varies according to one or more of the following factors: (i) the class of the premises; (ii) the location of the premises; (iii) the quantity of wastes discharged; and (iv) the existing level of pollution.

In 1977, the effluent charge system under the Act was combined with the discharge standards. The first discharge fees were collected in 1978. As the quantity of waste discharged increased, the standards became more stringent and the discharge fees also increased. The results of the combination of the standards with the charges were very encouraging. Despite a 50% increase in the number of palm oil mills between 1978 and 1982 and a steady increase in palm oil production, the total biochemical oxygen demand (BOD) load released in public water bodies dropped steadily from 22 tons per day in 1978 to 5 tons in 1984.

In a review of the Malaysian effluent standard-charge system, a number of problems have been identified:

- The system is considered not to be economically efficient because the charge was not set on the basis of marginal environmental damage costs but rather on the cost of capital for pollution abatement.

- The charge is based on BOD rather than on the volume of waste discharged, thus there may be an incentive for some firms to dilute their effluent in order to avoid paying the charge.
- In addition to charges for water disposal, there are also charges for land disposal that are based on volume and not concentration. The charges for land disposal are higher than those for water disposal and therefore there is an incentive for firms to shift disposal from land to water.
- The surcharge for effluents above the standard is so low that it does not act as a sufficient deterrent. Some mills find it cheaper to pay the fine than treat their effluent sufficiently to meet the standard.

Experts have concluded that despite its effectiveness in controlling palm oil pollution, the system is not economically efficient. However, despite its weaknesses, the Malaysian mixed MBI-CAC system provides valuable lessons for developing countries that are planning to introduce market-based instruments to support environmental legislation.

Pacific Island Countries: The several environmental policies are in use. The key sectors and relevant economic tools are as listed in Table 2.2:

Thailand:

In March 1992, the Government of Thailand passed the Energy Conservation Promotion Act. With regard to the Act, taxes were imposed on almost all types of fuels to finance for energy conservation measures.

b. Subsidies

A subsidy is a payment or tax concession that assists firms to reduce pollution. In that sense a subsidy is the opposite of taxes. The subsidy could be offered in proportion to the per unit reduction in pollution, or it could be offered for the purchase of pollution abatement equipment or technology.

Table 2.2: Sector wise Description of Economic Tools

Sector	Economic tools	Brief description
Waste Management	Deposit-Refund	A surcharge on the price of the product is levied, this charge is returned when the container is returned. Sometimes a small levy is also charged to cover administrative costs
	Dumping Fee	A small charge at the dump site to help cover costs. Charges must be small to discourage illegal dumping, and anti-littering laws must be in place before charges are imposed.
	Directed Lending Schemes	Capital is provided to financial institutions to offer loans for pollution abatement/environmental management investments at a reduced rate.
	Land taxes	A tax on land holdings, a proportion of which is usually allocated to waste management.
Mining/Forestry	Performance bonds	Money deposited into a government account as insurance against environmental damage. Interest is paid to developer; any environmental damage is paid for from the bond. Bonds are returned after development phase is complete and no damage has occurred.
	Resource taxes	A tax on ore extracted which can be used for environmental management, or invested in social capital such as schools and health services.
Fisheries	License/permit fees and access fees	Recoups some of the benefits from resource exploitation and can be used to finance resource management and monitoring.
Agriculture	Product taxes	Government surcharge on a product that is environmentally damaging to either decrease product demand, or raise revenue for environmental management.
	Tax rebates	Rebates to tax payers for the costs of activities which improve environmental quality.
Industry	Permits/license fees	Fees can be set in such a way to cover the administrative costs of checking monitoring and pollution control
	Environmental insurance	Insurance against the costs of damage caused by natural occurrences, e.g. cyclones
	Subsidies	Can be used to encourage waste management/treatment, or to assist new environmentally preferable industries to get established. Subsidies in this sector usually in the form of tax deductions and tax rebates.
Tourism	Environmental taxes	Can be incorporated into an existing tax scheme such as the departure tax.
Conservation	Trust funds	A large capital fund derived from a donor or the accumulation of government revenues. The interest from the fund (or proportion of the capital and interest) is used to support conservation activities.
	Entrance fees	Used on popular tourist attractions to raise revenue.

(Source: South Pacific Regional Environment Programme)

Comparison of charges and subsidies

In theory, both taxes and subsidies should result in the same optimum level of environmental quality. However, there could be the following differences:

- where there is unrestricted entry into the industry, subsidies could attract more firms and therefore aggregate pollution could increase in the long-run
- subsidizing polluters may be seen as socially unjust because some may see this as taking income away from the society

c. Marketable (or tradable) permits:

A relatively new addition to MBIs is the marketable (or tradeable) permit system that originated from the U.S. Under this system, the government issues a fixed number of permits or "rights to pollute" equal to the permissible total emissions and distributes them among polluting firms in a given area. A market for permits is established and permits are traded among firms. Firms that maintain their emission levels below their allotted level can sell or lease their surplus allotments to other firms or use them to offset emissions in other parts of their own facilities. The advantages and disadvantages of permits are listed in Table 2.3.

The concept of marketable permits may also be used to manage natural resources such as fisheries. This system is referred to as **Individual Transferable Quotas (ITQs)**. Under this system, property rights to a specified quantity of fish harvest are distributed among firms or auctioned off to the highest bidders. The holders of ITQs may use, sell or lease them to other firms. Over time, the ITQ system leads to an efficient use of effort and harvest. An example of an ITQ is given below the Table 2.3.

Table 2.3: Advantages and Disadvantages of Permits

Advantages of Permits	Disadvantages of Permits
• Allocation of permits is determined by market forces • The ability to sell permits is an incentive for firms • The system makes allowance for industrial development. • The system can generate income for the government.	• The market for permits may not be perfectly competitive. • Well-developed markets may constraint the permits' system. • Administrative, monitoring and enforcement costs may be high.

Example

Australia: Individual transferable quotas (ITQs) for the fishery industry

The Australian government introduced an ITQ for the Australian fishery in 1984. Each individual holding a quota was entitled to a proportion of the Total Allowable Catch (TAC) set by the government each year. The TACs have been reduced each year since 1984, owing to concern about the biological viability of the tuna stocks. With the introduction of the ITQ, the number of vessels operating in the Australian fleet declined by over 50 percent by 1991. Current levels could even be lower. At the same time, the harvests have remained roughly constant at 10,000 metric tons. The ITQ would seem to have achieved the objective of reducing effort in the fishery without affecting harvests.

Poland: The Polish Pilot Project in Tradeable Emissions Permits

A tradable industrial emissions demonstration project was started in Poland in 1991. The project aims to show that the economic instruments that have been successful in the U.S. also offer a significant potential for pollution abatement in the transition economies. The project involves at least six large firms and a number of small district heating plants. The program operates as follows. The regional administrator issues an emission permit to firms who then use a combination of control technology and emissions reductions credits to achieve the ambient standard. The demonstration project has already shown some promise.

Despite legal and social problems, educational efforts have achieved positive attitudes towards the experiment from potential participants. It is believed that there are also many opportunities for successful replication of the project both in Poland and in other economies in transition.

d. Other MBIs

Deposit-Refund systems

A deposit-refund system consists of a 'deposit', which a front-end payment for potential pollution and a 'refund' which is a guarantee of a return of the deposit upon proving that the pollution did not take place. Deposit-refund schemes have built-in economic incentives similar to charges. For example, the 'deposit' is an attempt to force the consumer to account for the cost of improper waste disposal by making an upfront payment. On the other hand, the 'refund ' serves as a reward for proper waste disposal given in Table 2.4.

Table 2.4: Advantages and Disadvantages of Deposit-Refund Systems

Advantages of deposit-refund systems	Disadvantages of deposit-refund systems
• It is a voluntary scheme that attempts to change environmental behaviour at least cost to the government. • Monitoring and enforcement costs are minimal because it requires limited supervision. • The system can be used to encourage recycling and more efficient use of raw materials. For example, the 'deposit' can be considered as a tax to encourage firms to use raw materials more efficiently, while the 'refund' encourages them to properly dispose of their waste products.	• If refunds are too low, the public may not have an incentive to participate in the scheme.

Example

PNG:

Refunds for returned bottle paid by PNG Bottle Industry Pty Ltd. is K1.50 for a 285ml Coke bottle, K1.70 for a 285ml Pepsi bottle and K1.20 for an SP beer bottle. The use of returnable bottles is cheaper in economic and energy terms than non-returnable bottles or cans. Therefore PNG Bottle Industry Pty Ltd has an incentive to offer refunds. The average returnable rate for bottles is 85% within the country, while in Port Moresby, it can be as high as 90%, and i.e. the same bottle is reused about 9 times.

Aluminum cans cannot be re-used but the raw material, aluminum, is valuable. The strength of the overseas aluminum market allows the recycling companies to offer reasonable refunds. PNG Recycling exported 13,000 tonnes of cans in 1997. Given a price of US$1,050 per tonne for packed cans, the company could have earned over US$13 million in foreign exchange. The high level of reuse and recycling means that resources are conserved and the waste stream reduced. Recycling also has social benefits in the form of income redistribution of sections of the population with no formal employment.

Korea: Waste Disposal Deposit-Refund System:

A waste disposal deposit-refund system failed to motivate manufacturers to collect and treat waste because the deposit was only 10-20% of the cost for collection and treatment of wastes. Ministry of Environment plans to raise the deposit rate in consultation with relevant ministries such as Ministry of Health and Welfare. Also, the government's revised provision compels management of waste by polluters. Violation of the provision would lead to severe fine or imprisonment in worst case. Introduction of such a direct regulation implies that the market based economic incentive is not effective given the low rate of penalty to violators. Development and Industry oriented ministries strongly oppose higher penalties that might encourage compliance.

Eco-Labeling and ISO Standards:

In the eco-labeling or performance rating approach, firms are required to provide information on the final end-use product. Firms are performance rated based on ISO 14000 voluntary guidelines that include the following: zero discharge of pollutants, adoption of pollution abatement technology, submission of mitigation plans. The 'eco-labels' are attached to products that are determined to be 'environmentally friendly'.

Example

***Republic of Korea:* Promotion of Eco-Labeling and ISO 14000:**

To meet the international norms and standards emerging rapidly, Korea is promoting better management of the environmental labeling system and the adoption of ISO 14000 standards.

Licenses, Concessions and Quotas:

Licenses, concessions and quotas have traditionally been used for the management of environmental resources such as forests and fisheries. For example, many Pacific island countries (PICs) use licenses and access fees to manage their exclusive economic zones (EEZ). However, due to lack of knowledge about the financial performance of foreign fishing fleets, and inadequate monitoring and enforcement capacity, most PICs are unable to capture a fair proportion of the rents from fishing.

Example

***PNG:* Foreign Fisheries Vessels:**

The PNG Government licenses foreign fishing nations who annually harvest about K200-K300 million worth of fish (mainly tuna) and receives about K15 million per annum in license fees. Papua New Guinea's capacity to monitor and regulate foreign operators is limited, and many of them avoid paying resource rent to the State. The South Pacific Commission estimates the potential tuna catch in Papua New Guinea waters to be 240,000-260,000 metric tonnes per annum. Licensed foreign vessels generally report catches of up to 150,000 metric tonnes per year. However, anecdotal evidence suggests that the actual catch is considerably higher due to poaching and under-reporting of catch statistics.

Traditional Property Rights:

In recent years, there has been a realization that traditional or customary communal rights systems can provide insights into the design of modern systems of natural resource management. In most developing, as well as developed countries, resource managers have concentrated their management efforts on licenses and quotas in order to prevent overexploitation of natural resources such as fisheries and forests. In many cases, these efforts have been unsuccessful. Customary communal rights systems, whereby local people manage their own resources through the establishment of private or communal ownership over common property resources, have better chances of success. This is because the "owners" of the resource have an interest in its current and future productivity and would be inclined to control exploitation so as to maximize the net benefits.

Example

***Sri Lanka:* Sri Lankan Coastal Fisheries System**

Sri Lankan coastal fisheries have a history of traditional property rights in the form of rights of access and closed communities. In earlier times, beach seine owners controlled access to coastal waters and had associated rights that were obtained through inheritance or marriage. While there was no limit to the number of nets that anyone holding rights to access could have constructed, the fishermen on a given beach refrained from constructing additional nets unless they could bring in a catch whose value would have been higher than the cost of the net. That is, they acted as a single unit.

Sri Lankan coastal villages tend to be 'closed' communities in the sense that outsiders are not allowed access to the fishing grounds. Outsiders are also not allowed to anchor or beach fishing boats along the shoreline of the community, and labour is not recruited from outside the village. This restriction on access may be instrumental in the observation that Sri Lankan coastal fishermen, unlike other small-scale fishermen in Asian countries, earn incomes above their opportunity costs.

OECD Find Outs and their Experiences:

In 1989 the Organization for Economic Co-operation and Development (OECD) identified 100 different type of MBIs. Examples of these include:

a) Packaging taxes

b) Effluent taxes and charges

c) Capital or operating subsidies

d) Tradable permits

e) Deposit-refund schemes

f) Performance bonds

g) Liability instrument and many others

Early OECD experiences show that relying on MBIs can

1) Decrease compliance cost by industry.
2) Decrease administration burden on the public sector.
3) Improve environmental conditions in urban air quality.
4) Decrease emission and effluent of toxic and non-toxic waste.
5) Improve human health condition, which in turn improves economic productivity and decrease health care costs.

6) Contributes to institutional sustainability by supporting cost effective public sector institution that co-operate with the private sector and non-governmental organization.

2.5 Design of Tradable Emissions Permits:

In general, the described advantages of market-based instruments are, of course, also valid for tradable emissions permits. These design possibilities are diverse and therefore an easy judgment whether permits are the superior environmental policy instrument is difficult to make. The property rights approach for environmental problems was designed as follows: there might be a market in pollution rights, where a board creates a certain number of these rights, each right giving whoever buys it the right to discharge one equivalent amount of waste into natural waters, or air, during the current year. The board would withhold 5 percent of the rights and all waste dischargers would be required to buy the number of rights they needed. There would be immediately a positive price. Some firms would reduce their emissions and sell rights. When population and industry grew there will be an increase in the demand for rights. With the price going up, there would be an incentive to reduce emissions. There would be sells and buys from old and new polluters, whose bids and offers establish the price of the rights. The price would (with fluctuations) show an upward trend. The amount of rights must be determined on scientific grounds (idlest, health standards or cost-benefits analyses). (Dales, 1968) Since a stricter standard usually results in less pollution, the demand for pollution rights would be higher than its supply, which would result in a positive price for these rights. Because plants have different costs of controlling emissions, when pollution rights are transferable, those plants that can control most cheaply would find it in their interest to control more and sell the excess. Buyers for these reductions could be found whenever it was cheaper to buy rights for use at a particular plant than to install more control equipment. Whenever an allocation of control responsibility was not cost effective, further opportunities for trade would exist. When all such opportunities had been fully exploited, the allocation would be cost effective. (Tietenberg, 1985) The structure of property rights that could produce efficient allocations in a well-functioning market economy should have four main characteristics:

1. *Universality*: All resources are privately owned and all entitlements completely specified.

2. *Exclusivity*: All benefits and costs accrued as a result of owning and using the resources should accrue to the owner, and only to the owner, either directly or indirectly by sale to others.
3. *Transferability*: All property rights should be transferable from one owner to another in a voluntary exchange.
4. *Enforceability*: Property rights should be secure from involuntary seizure or encroachment by others.

An owner of a resource with a well-defined property right (one exhibiting these four characteristics) has a powerful incentive to use that resource efficiently because a decline in the value of that resource represents a personal loss. (Tietenberg, 1980) Another very important purpose of tradable property rights is to convey to polluters appropriate price signals. (Noll, 1982)

Montgomery (1972) has formally proved that the permit system is efficient. He concludes, that even in quite complex circumstances the market in licenses has an equilibrium that achieves externally given standards of environmental quality at least cost to the regulated industries. The least-cost outcome hereby is independent of the initial allocation of permits.

2.5.1 Different kinds of pollutants trigger different designs of permit systems:

The relatively simple concept developed by Dales does not consider the effects that different kinds of pollutants have on ambient air or water quality. Therefore, it has to be determined very carefully, for which pollutant the permit system should be used. The three groups are Uniformly Mixed Assimilative Pollutants, Non-uniformly Mixed Assimilative Pollutants, and Uniformly Mixed Accumulative Pollutants. (Tietenberg, 1985). The former two are used in Montgomery's analysis. He refers to the affected permit designs as "pollution license", and an "emissions license", respectively.

2.5.2 Uniformly mixed assimilative pollutants:

These are pollutants that can easily be involved in a permit design developed by Dales. The reason is that it is unimportant for the permits where these pollutants are released in the air, or water. They do not accumulate over time and the capacity of the environment to absorb these pollutants is sufficiently large, relative to their rate of emissions. The ambient quality of the environment, therefore, depends on the total amount of pollutants released, but not on the distribution pattern of emissions. (Tietenberg, 1985) The condition for a cost-effective allocation of uniformly mixed assimilative pollutants is, as already developed for all incentive-based instruments, the equalization of marginal abatement costs throughout the industry with the permit price. It only has to be a determined number of permits, with each permit containing the right to a certain amount of emissions. (Noll, 1982) The pollutants that are applicable for this "easy" permit scheme are usually also globally effective, for example, carbon dioxide (CO_2), and chlorofluorocarbons (CFCs).

2.5.3 Non-uniformly mixed assimilative pollutants:

Most pollutants that have to be dealt with are not as "easy" to handle with as CO_2 or CFCs. They have their major impacts in local, ambient environments and, thus, a cost-effective and ecologically effective policy has to take into account that the location of sources is crucial. Examples of these kinds of chemicals and environmental conditions are, total suspended particulate (TSP), sulfur dioxide (SO_2), and biochemical oxygen demand (BOD). (Tietenberg, 1985)

The Montgomery paper analyzes two systems of marketable pollution permits: a system of “pollution licenses” that defines allowable emissions in terms of pollutant concentrations at a set of receptor points, and a system of “emission licenses” that confer directly the right to emit pollutants up to a specified rate. Montgomery demonstrates that the former system satisfies the important conditions that market equilibrium coincides with the least-cost solution for attaining any predetermined level of environmental quality and does so for any initial allocation of licenses among polluters.

However, the transactions costs for polluting firms associated with Montgomery’s system of pollution licenses are likely to be quite high. His alternative system of emissions licenses promises considerable savings in transactions extremely restrictive (and sometimes unattainable) condition is required for an initial allocation of permits to ensure that the market equilibrium is the least-cost solution. This finding is particularly disturbing on two counts. First, the environmental authority may not be able to find an initial allocation of permits that ensures efficient outcomes. And second, even should such an allocation exist, a substantial degree of flexibility in the choice of this initial allocation may be lost; such flexibility can be extremely important in designing a system that is efficient and politically feasible.

Let us assume that we have a specific region, an air shed, in which there are m sources of pollution, each of which is fixed in location. Air quality in terms of a particular pollutant is defined by concentrations at n "receptor points" in the region; we thus describe air quality by a vector Q = (q_1…., q_n) where q_j is the concentration of the pollutant at point (receptor) j. The dispersion characteristics of the problem are described in terms of a diffusion model which we represent by an m x n matrix of unit diffusion or transfer coefficients.

$$D = \begin{bmatrix} & \vdots & \\ \cdots & dij & \cdots \\ & \vdots & \end{bmatrix}$$

Where d_{ij} indicates the contribution that one unit of emission from source i makes to the pollution concentration at point j.

The environmental objective is to attain some predetermined level(s) of pollutant concentrations within the region; we denote these standards as Q* = (q^*_1,…, q^*_n). The standard needs not be the same at each point; the environmental authority could, for example, prescribe lower concentrations as the target in densely populated areas.

The problem thus becomes one of attaining a set of predominant levels of pollutant concentration at minimum aggregate abatement cost. Or, in other words, we are looking for a vector of emissions from our m sources, E = (e_1,…, e_m), that will minimize abatement cost subject to the constraint that the prescribed standards are meet at each of the n locations in the region.

The abatement costs of the i^{th} source are a function of its level of emissions: $C_i(e_i)$. So our terms, is to

$$\text{Minimize} = \sum_i c_i\,(e_i)$$

s.t. $ED \leq Q^*$

$E \geq 0.$

Montgomery has shown that such a vector of emissions exists and, moreover, that, if the sources of pollution are cost-minimizing agents, the emission vector and shadow price that emerge from the minimization problem satisfy the same set of conditions as do the vector of emission and permit prices for a competitive equilibrium in an air –permits market. In short, if the environmental authority were simply to issue q_j^* permits (defined in terms of pollutant concentrations) for each of the n receptor points, competitive bidding for these permits would generate an equilibrium solution that satisfies the conditions for the minimization of total abatement costs.

These results establish a benchmark case for a control system that minimizes abatement costs. Two properties of this outcome are noteworthy. First is the utter simplicity of the system from the perspective of the environmental agency. In particular, official need have no information whatsoever regarding abatement costs; they simply issue the prescribed number of permits at each receptor point, and competitive bidding takes care of matters from there. Alternatively, the environmental authority could make an initial allocation of these permits to existing polluters. Subsequent transactions in a competitive setting would then establish the cost-minimizing solution. As Montgomery proves formerly, the least-cost outcome is independent of the initial allocation of the permits. Second, in contrast to the models burden it places an administrators, this system can be extremely cumbersome for polluters. Note that a firm emitting waste must assemble a “portfolio” of permits from each of the receptor points that is affected by its emissions: a source at point i will have to acquire permits at each receptor j in the amount (d_{ij} e_i). There will, therefore, exist n different markets for permits, one for each receptor point, and each polluter will participate in the subset of these markets corresponding to the receptor points affected by his emissions. It would appear that the transactions costs for polluters are likely to be substantial under our benchmark system, although this expense may be justified, under certain circumstances, by the savings in abatement costs.

The scheme examined above as a prototype for an ambient-based system (APS) of pollution permits: the permits are defined in terms of pollutant concentrations at the receptor points. An alternative approach in the literature is an emission- based system (ESP) under which the permits are defined in terms of levels of emission rather than in terms of the effects of these emissions on ambient air quality. This latter approach often makes use of a set of emission zones within which emissions of a particular pollutant are treated as equivalent. The environmental authority determines an allocation of permits to each zone, and polluters within a zone trade permits on a one to one basis. There are no trades across zones: each zone is self – contained market with its own price for permits determined by the polluters' demand for permits and the supply as determined by the authority.

From this perspective, we can envision at one extreme for EPS (following Titenberg a system in which the entire region is a single market). The environmental authority issues a fixed number of permits for the region as a whole, and the subsequent bids and offers of participants generate a single market-clearing price. As we move away from this spatial case, we encounter continuity more finely divided systems of zone designed to take into account the spatial character of the air shad. However, regardless of the total number zones, each pollution source will lie only in a single zone and will consequently operate in only one permit market for a given pollutant.

It is last feature of EPS that constitutes its basic appeal. Recall that under APS the polluter must operate in a number of markets for each pollutant (in the benchmark case, one for each receptor site that his emissions affects) and is subject to a different "weighting parameter" (i.e., diffusion coefficient) in each market. The assembling of the requisite portfolio of permits could become quite complicated for firms; they might even find themselves, in some instances, buying in one market while selling in another. It is not altogether clear just how large these "transactions costs" are likely to be (more on this shortly); some well-organized brokerage operations could conceivably facilitate greatly the transfer of permits. But it would appear, nonetheless, that, from the perspective of the polluter, EPS offers a major attraction by requiring polluters to buy and sell permits within a single market and with no system of source-specific weights attached to individual firms.

However, while the EPS approach may simply life for polluters, it is a potential nightmare for the administrators of the system. Recall that under APS the environmental authority need only establish the number of permits to be offered for sale at each receptor site (so as to meet the prescribed air –quality standard) and specify the diffusion or transfer coefficient for each source of pollution. Market forces take over from there and, under competitive conditions, generate the least cost pattern of waste emissions.

In contrast, EPS will not, in general, achieve the least cost outcome, and it makes enormous demands on an administrating agency that arises to approach the least-cost solution. To do so, the agency must have knowledge of the source-specific abatement cost in addition to the air-modeling data required for APS. Moreover, EPS requires continuing readjustments among zonal stocks of permits. The reason the least-cost solution is unlikely to be achieved is straightforward; since polluters with somewhat varying dispersion coefficients are aggregated into the same zone, one-for-one trades of pollution rights will not reflect the differences in the concentrations contributed by their respective emissions. The price of emissions to each polluter will not, in short, reflect accurately the shadow price of the binding pollution constraint. Further, the system of zones may prevent one source from making beneficial trades with another source which happens to be located in a different zone.

These objections to EPS need not be serious, if the dispersion characteristics for emissions within zones are not very different (Hahn and Noll). This suggests that an increase in the number of zones can reduce the “excess abatement costs” associated with EPS. However, increasing the number of zones will tend to reduce the number of participants in the market with the undesirable repercussions from the decrease in competitiveness of markets for permits and increased uncertainty of permits prices.

A more troublesome issue that, even were there no differences in the dispersion characteristics of emissions within each zone, the environmental authority must still determine an allocation of permits to each zone. And this determination requires the complete solution by the administrator of the cost-minimization problem. To reach this solution, the administrating agency must have not only an air-quality model (to provide the dij) and the capacity to solve the programming problem. With less-than-perfect information, the agency’s zonal allocation of permits may fail to attain the ambient air – quality targets. If pollution were excessive, the authority would have to reenter the market (in at least some of the zones, where again the pattern of zonal purchase would require a fairly sophisticated analysis) and purchase or confiscate permits. Such an iterative procedure s not only cumbersome for the administrator of the system, but may create considerable uncertainty for firms as to the future course of permit prices.

We stress, moreover, that this procedure involves more that just grouping once and for all towards an unchanging equilibrium. Altered patterns of emissions resulting from the growth (or concentration) of existing firms, the entry of new firms, and changing abatement technology will generate a continually shifting least-cost pattern of emissions across zones. Under EPS, the environmental authority faces a dynamic problem that will require adjustments to the supplies of permits in each zone. We conclude that the zone approach suffers both from its inability to realize the least-cost pattern of emissions and from the formidable burden it places on the administrating agency.

2.5.4 Uniformly Mixed Accumulative Pollutants:

These are substances that accumulate in the environment because their rate of injection exceeds the assimilative capacity. The question of interest here is not only how cost-effective control responsibility is allocated among sources, but how it is allocated over time as well. The cost-effective allocation is the one that has the lowest associated present value of control costs among all those allocations that satisfy the pollution constraint (the ceiling). The model that can be used in this context is very similar to the one developed for exhaustible natural resources. In a cost-effective allocation, marginal pollution control costs rise over time (similar to the shadow price of natural resources) and the amount emitted (the amount of resources taken) declines over time. The rate of increase in permit prices would be equal to the social rate of interest. In each time period the marginal costs of control are equalized across all sources. The system is called a cumulative emission permit system. Permits themselves have no time dimension, but they do not regulate emission rates, they limit total emissions (tons rather than tons per year). (Tietenberg, 1985)

2.5.5 Trading rules:

Since none of the above approaches seems to give satisfying results in terms of cost-effectiveness, and of the "hot spot" problem, an alternative way to let firms trade, and still keep ambient pollution levels in the appropriate range, has been introduced into the literature. There have been suggested three so called Trading

Rules in the literature: (1) the pollution offset, (2) the non-degradation offset, and the (3) modified pollution offset.

1) The pollution offset is an alternative that combines certain characteristics of both systems described above (the ambient and the emissions permit system). The basic idea is to define permits in terms of emissions and to allow their sale among polluters, but not on a one-to-one basis. More specifically, transfers of emission permits are subject to the restriction that the transfer does not result in a violation of the ambient air-quality standard at any receptor point. The source of new emissions (or of expanded emissions) must purchase a sufficient number of emission permits from existing sources to "offset" the effects of the new emissions on pollutant concentrations in such a way that the pollution constraint is everywhere satisfied. (Krupnick, Oates, Van de Verg, 1983)
2) The non-degradation offset has similar properties as the pollution offset, but it allows trades among sources as long as they do not violate ambient air quality standards and total emissions do not increase. (Tietenberg, 1985)
3) The modified pollution offset allows trades among sources as long as neither the pre-trade air quality nor the concentration target (whichever is more stringent) is exceeded at any receptor. Total emissions are not directly controlled. (Oates, 1988)

2.5.6 Time as a possible design-determining aspect of pollution rights:

There are two ways in which time can have an influence on the permit design. The first one is the length of the permit life. They could be either indefinitely long or issued for a certain time period (for example, one year). They could also be valid until a formal regulatory procedure declared them invalid or changed the amount of emissions allowed by a single permit. When issuing indefinitely valid permits, the regulator might have to buy them back in order to reduce emissions further. (Noll, 1982) The second way in which time influences permit designs deals with the fact that emission rates vary over time. Sources of concentration variation include variation in emission rates (seasonal, daily patterns) and variation in meteorological conditions (for example, thermal inversions). Ambient standards based purely on annual averages can be met without worrying about the timing of the emissions. (Tietenberg, 1988) When the ambient standard is based on a short-term average, however, the timing and the quantity of emissions are both important. Because a major component of the variation in observed concentration is regular and, therefore predictable, temporal strategies are tractable. Peaks always occur during the same season or even the same time of day (for example, ozone concentrations). (Roberts, 1983) Controlling the timing as well as the flow of goods and services is a familiar activity in public policy (for example, peak-hour pricing) Thus, temporal control is not a novel concept, and normally it involves charging higher prices in peak periods. Since the emissions trading program is a quantity-based approach not a price-based approach, the control authority regulates emissions, not prices (Tietenberg, 1985).

2.5.7 Potential initial distribution methods for tradable permits:

After laying out the potential advantages and disadvantages of different permit designs, a very important practical question has to be answered. How should the permits be allocated to the sources in the system? In general, there are three different methods, Grandfathering, the Auction method, and the Hahn-Noll-Auction (or Zero-Revenue Auction). The former two are methods on opposite sides of a possibility spectrum. The latter tries to combine positive elements of both, while avoiding some of the drawbacks the pure methods contain.

2.5.8 Grandfathering the permits to existing sources:

While giving the permits to existing sources without compensation, the government transforms the already existing "right to pollute" (see Coase's reciprocity theorem) into an absolute and enforceable property right. Although the amount received will be generally less than what the firms were allowed to emit before introduction of the system, they still have an absolute cost advantage compared to new firms that might be introduced to the system at a later time. Montgomery's (1972) treatment, looking at it from efficiency grounds, it is unimportant who received the initial allocation of rights, the polluters or the sufferers. The following market transactions will ultimately lead to a Pareto Optimal allocation of all permits among market participants. Tietenberg (1985) argues that fairness, as well as political considerations, dictate using a grandfathering distribution method. The study holds against by giving society, not polluters, as primary "owners" of a clean environment, the property rights to that asset. Having Coase's argumentation in mind, this cannot be followed on theoretical grounds. Opinions though, can be linked to moral or distributional reasons, since grandfathering (but only the initial allocation, not the whole trading scheme) stands in contrast to the usually promoted polluter-pays-principle. Crucial for any kind of grandfathering scheme is the establishment of an emissions inventory for baseline calculations for the initial allocation of permits. (Hahn, Noll, 1982)

2.5.9 Auctions:

Dales' (1968) original idea of how to distribute the emission permits was to auction them off. The companies have to bid for the number of rights they need to cover their emissions. This would directly lead to the efficient allocation since the companies would use their marginal abatement costs as orientation for their bids. A unique market price could be established. It would also be quite effective because all market transactions and participants would be focused at one particular place. This reduces transactions costs compared to an open market scheme, where sellers of emission permits have to find potential buyers in a complicated process. (Tietenberg, 1985) On the other hand, auctions have the potential disadvantage of political opposition from the side of buyers. Firms would not only have to bear the costs of emissions reduction, but also the cost of permits for remaining emissions. This fact makes it quite difficult to get an auction scheme through the legislative process. Interest groups will fight off this distribution design in favor of a grandfathering approach, as it was described above. Another potential difficulty is the fact that an auction creates revenue for the government, which has to be used in some way. (Dales, 1968) This can have alocative as well as distributional consequences in the environmental, but also other policy areas. For example, when rent-seeking interest groups try to use these revenues for their purposes.

2.5.10 Hahn-Noll's zero revenue auctions:

To avoid the problems described for the auction and grandfathering schemes, Hahn and Noll (1982) developed a method that captures some of the advantages of both methods, while leaving disadvantages out. The idea is to use an auction process that redistributes auction revenues to the firms that participate in the market. In order to produce an efficient outcome, the method for determining the rebate to a firm must not depend on its actions in the auction. One possible auction process that generates no net revenue and that has attractive incentive properties is as follows: "Each firm would receive a provisional initial allocation, based upon one of the criteria [determined elsewhere]. All sources would be required to offer their entire allocation for sale. Each firm would then report its demand curve for permits, and the sum of the demand curves would be used to calculate the market-clearing price for the fixed total quantity of permits for the entire market. This price would then be used to calculate the final allocation of permits to each firm, according to its demand curve. Firms would make a gross payment to the state, equal to the market price times their final allocation, and would receive a gross revenue from the state, equal to the market price times the initial allocation. The net financial effect on each firm would be the market price times the difference between its initial and final allocation; the net financial effect on all firms taken together would be zero." (Hahn, Noll, 1982) Other advantages of this auction type are clear-cut price signals, competitive pricing, and that questions of equity can be considered. Franciosi, Isaac, Pingry, and Reynolds (1993) show, in an experimental setting, that the Hahn-Noll Auction were little different in terms of either prices or market efficiencies from the normal uniform price auctions described above. (Franciosi et al., 1993, p. 21). The drawbacks of the Zero Revenue Auction are that it is somewhat more difficult to understand than simple grandfathering and that it makes participation mandatory, rather than voluntary. (Hahn, Noll, 1983)

2.5.11 Offsets:

Offsets are a form of credit-based emission trading. Offset is created when a source makes a voluntary, permanent emission reduction that is in surplus to any required reductions. Existing sources that create offsets can trade them to new sources to cover growth relocation. Regulators approve each trade. Regulators normally require a portion of the offsets to be retired to ensure an overall reduction in emission. Offsets are an open system. One offsets is an emission reduction that a pollution source has achieved in excess of permitted levels and or required reductions. The excess amount is the credit and can be sold on the market.

The offset program was developed in 1976 to reduce the conflict between economic growth and progress towards air quality standard levels in non-attainment regions. Without this new instrument, it would be almost impossible to locate a major new plant or expand significantly a major existing plant in areas that do not meet the NAAQSs. The offset policy allows new sources or major source modifications to be sited in non-attainment areas so long as overall emission reductions were achieved within the airshed leaving the area better off than before. (Dudek, Palmisano, 1988) Potential cost-savings from redistributing the burden of pollution control were thought to be relatively large due to the highly unequal marginal control costs under the CAC regulatory regime. (Roberts, 1983) The new emissions have to be more than "offset" by the reductions at another plant. It is important to note that this is an external trading approach with companies trading ERCs among each other (although internal trading within the same plant is also allowed). Following theoretical considerations, this makes much more cost-savings possible than internal trading, where companies offset emissions from different sources within the same plant. By buying credits, new sources finance emission controls undertaken by existing sources. New sources must have LAER standards installed. This has the disadvantage that a certain amount of control is still regulated by CAC requirements. Effects on the overall trading activity are inevitable and are further analyzed below. Some states have devised innovative offset programs which use the federal regulation as a starting point.

2.5.12 Bubbles:

A bubble is a regulatory concept where by two or more emission sources are treated as if they were a single emission source. This creates flexibility to apply pollution control technologies to whichever source under the bubble has the most cost effective pollution control options, while ensuring the total amount of emissions under the bubble meets the environmental requirement for the entity. Bubbles are closed systems. Article 4 of the Kyoto protocol allows a bubble to be formed between Annex B countries. (Annex B countries are the 39 emission-capped industrialized countries and economics in transition listed in Annex B of the Kyoto protocol. Legally binding emission reduction obligation for Annex B counties range from an 8% decrease (e.g. Various European nations) to a 10% increase (Iceland) in relation to 1990 level during the first commitment period from 2008 to 2012.

The bubble system, which is considered by EPA to be the centerpiece of emissions trading, was first established in 1979. It is this component of the ETP which most closely resembles the concept addressed in the empirical and theoretical work. (Atkinson, Tietenberg, 1991, p. 18) It allows existing sources flexibility in meeting required emission limits, by treating multiple emission points as if they face a single, aggregate emission limit. Instead of holding each source at the plant to the applicable TBES, the entire plant is treated as a single source. This allows the firm to rearrange discharge points within the plant in the most cost-effective manner, that is, according to the equimarginal principle. (Hahn, Hester, 1989)

Bubbles must be approved as a revision to an applicable SIP. This policy encompasses internal as well as external trading opportunities. Bubbles can be extended not only to include emissions points within the same plant, but emission points in plants owned by other firms as well. Initially, every bubble had to be approved at the federal level as an amendment to a state's implementation plan. In 1981, though, the EPA approved a "generic rule" for bubbles in New Jersey that allowed the state to give final approval for bubbles. Since then, several other states have followed suit. (Hahn, 1989) Generic rules are classes of state regulations that describe the circumstances under which states can review and approve individual bubbles without EPA review of each transaction. A generic rule is essentially a state-delegated program. The use of generic rules allows trades that fit generic criteria to occur without a SIP revision, thereby avoiding one to two years of regulatory delay in obtaining approval for specific bubbles. Generic rules also promote greater predictability and signal industry regulators' commitment and support for trading programs. (Dudek, 1988)

2.5.13 Emission trading:

Emission trading is a general term used for the three Kyoto protocol flexibility mechanisms. It is a market-based system that allows firms the flexibility to select cost effective solution to achieve established environmental goals. With emission trading firms can meet established emission goals by:

a) Reducing emission from a discrete emission unit.

b) Reducing emission from another place with in the facility.

c) Securing emission reduction from another facility.

d) Securing emission reduction from the market place.

Emission trading encourages compliance and financial manager to pursue cost-effective emission reduction strategies and provides incentives to emitters to develop the mean by which emission can inexpensively be reduced.

2.5.14 Netting:

The development of emissions trading began with netting in 1972, when smelter operators proposed to avoid standards if the additional emissions could be netted out by other, cheaper measures at the same plant. (Roberts, 1983) This was officially allowed in 1975, but a court decision in 1978 struck down this rule. Meanwhile, it became clear that states could not meet their SIP deadlines and the offset policy was born. There are two sources of potential cost savings that may result from netting. First, netting enables firms to reduce emissions control costs when classification as a major source would subject the firm to more stringent emission limits. The second source arises from the condition that firms avoid the permitting procedures that apply to major sources. (Hahn, Hester, 1989, p. 134) The major issue here is that the firm avoids a major "New Sources Review" (NSR) process that is very burdensome and expensive and can delay building of the source for several years. Like most bubble arrangements, netting transactions are intrafirm transactions. Netting allows a firm that creates a new source of emissions in a plant to avoid the stringent emission limits that would normally apply by reducing emissions from another source in the plant. A firm using netting can only obtain the necessary emission credits from its own sources, therefore only internal trading is allowed. (Hahn, 1989)

2.5.15 Banking:

In 1979 the EPA gave states the right to create ERC banks. Firms could bank and save ERCs for future use in their own plants or for trading in offset and netting transactions. States were required to develop a system where ERCs could be deposited and to develop procedures for transferring ERCs into and out of the appropriate bank accounts. Because states were not required to establish banking programs, the ability of a firm to bank credits depends upon the existence of a state regulatory program. (Hahn, Hester, 1989) The banking of an ERC should have established a secure property right for the firm that could be used in later transactions. In theory, banking should reduce the uncertainty surrounding a firm's ability to use completed emission reductions in future emissions trading transactions. The uncertainties surrounding state behavior towards these property rights reduced the incentive to bank ERCs.

2.6 Commandment for Market Based Instruments:

1) **REALISM:** Be modest. Do not try to implement policies and instruments beyond the available institutional capacity.

2) **GRADUALISM:** National or regional projects can be implemented gradually by pilot project or experimental programs. The establishment of plausible and enforceable norms, standard, and guidelines is an important starting point.

3) **LEGAL FLEXIBILITY:** Legislation must allow for the possibility of low-cost revision.

4) **INSTITUTIONAL INTEGRATION:** Intra and inter governmental integration must be pursued to overcome barriers and capitalize on institutional strengths. Economic agencies must be included as well as representation from the legislative branch.

5) **PARTICIPATION:** Participation by stake holders is critical and must be based on open sharing of information. Issues that may paralyze the process should be avoided, and equity issues should be properly identified, evaluated and addressed.

6) **MARKET CREATION:** The growing reliance on markets must be incorporated into the design of environmental policy and MBIs. High transaction collection costs should be avoided and reforms should not outpace implementation and acceptance is market adjustment.

7) **REVENUE GENERATION:** Many MBIs can generate earmarked revenues. Although correct pricing of environmental goods and services is one objective of MBIs a cost-recovery approach may be a more effective way to build consensus, remove barriers and guarantee financing.

8) **HUMAN RESOURCE DEVELOPMENT:** Qualified human resources in the environmental field are limited and remuneration of public sector employees is generally low. Human resource profiles should be restructured to make the most of limited budgets. Given these constraints, public sector environmental units should be kept small and should rely to a significant degree on external expertise, concession, and the means for building consensus.

9) **LEADERSHIP:** Those responsible for environmental management must be leading the decision making process by identifying stakeholders, constraints, and the means for building consensus.

10) **CONTINENTALISM:** OECD experience and recommendation should not be rejected out of hand, but there is a need to increase ties among regional agencies whose economic and cultural contexts may be more familiar.

2.7 Systematic Approach towards Effective MBIs Implementation:

To operationalize the use of MBIs more effectively within this fragile institutional context requires a systematic approach. The following steps be considered by countries that are contemplating the adoption or reform of environmental management policies:

1) Clearly identify the environmental problem that the policy reforms are meant to address, and set clear goals and objectives.

2) Take stock of existing instruments, including an assessment of their flexibility and the degree to which they help internalize environmental costs.

3) Analyze existing legal mechanisms and their compatibility with MBIs, and consider the feasibility of reform that would create a more favorable legal environment.

4) Assess relevant market forces, economic agents, and the rationality of economic incentives, paying particular attention to the potential role of market-based reforms to enhance the effectiveness of environmental management.

5) Identify environmental damages whose costs are not internalized, and their relation to various economic and domestic activities e.g. pollutant emission and transportation, land degradation and natural resource exploitation, water pollution and sewerage.

6) Quantify, if possible, the social benefits (environmental improvement, social control, cost reduction, fiscal revenues) and costs (tax erosion, smaller consumer surplus, inflation) of the proposed reforms.

7) Investigate the feasibility of introducing specific MBIs in terms of their impacts on private costs, institutional costs, the marginal cost of revenue generation, and legal measures.

8) Recommend policy, institutional, or legislative action such as decentralization, or legislation based on the polluter-pays principle.

3. THE STUDY AREA-JAMSHEDPUR AND ITS BASELINE AIR ENVIRONMENT

3.1 Jamshedpur: An Introduction:

Jamshedpur is located in the state of Jharkhand and is linked with important cities and capitals by rail and roadways. It covers an area of 64 sq. km. The population of the city is 570,349 (Census, 2001). Maximum and minimum temperature reported in the region is 44.1^{o}C and 8.6 ^{o}C respectively and average annual rainfall reported for the region is around 1331 mm. Two important rivers viz. Subarnarekha and Kharkai are flowing in the region. TISCO, TELCO, TCIL, ISWP, TATA Tubes, INCAB, IVP, TRF, JEMCO and TATA Pigment and many other small industries are located in city. A number of Educational Institutions and hospitals are also located in the region.

The climate of the area conforms to general tropical climate. It is warm and humid, with three main seasons viz. winter, summer and rainy seasons. Soil is generally sandy- loam and clayey loam. The depth of the soil was found to vary considerably and nutrient status of the soil is generally low and deficiency of Nitrogen (N) and Phosphorus (P) is pronounced.

All the rivers in the region generally dry up in the summer. Subarnarekha river is impounded at several places and Kharkai river at one place to hold water during the summer, which is used for both domestic and industrial purposes. Jamshedpur region is fed by Dimna reservoir, which impounds clean water as its entire catchments are well protected from possible human interferences.

Besides the industries in the study region, there are several important industries in the city and the city gives a prestigious position to the state of Jharkhand in the country. As regards the transport facilities, there is a good network of roads maintained by TISCO, TELCO and PWD. The national highway No.33 also runs through the district and city. The Howrah-Nagpur main line of the South- Eastern Railways traverses the district from east to west for about 190 KMs. Jamshedpur has an airfield owned by the TISCO.

3.1.1 Demographic structure:

As per the 1991 census, due to increase in number of urban centers, the urban population has increased considerable confirming the trends of Urbanization. As such urban content is 94.66% of the total population. This higher increase as per census records has been attributed to industrial and mining activities and particularly phenomenal growth of Jamshedpur city. The density varies from 1562 to 10466 per sq. km.

The high level of urbanization and much greater employment potential in the towns might have resulted in migration from the rural areas where poor quality of land yield very poor crops and mining potential is low.

As per census records of 1991 in Singhbhum district, the population of the Scheduled Caste in village varies in the range of 0.69% to 4.75% and Scheduled Tribes varies in the range of 32.6% to 70.33%. The Scheduled Caste population in the urban area varies from 0.83 % to 5.97% but Scheduled Tribes fraction is in the range of 0.69% to 56.97%.

The literacy rate in the rural areas varies in the ranges of 20.51% to 37.04% with an average of 28.77% while in urban areas, literacy rates is 57.49%. This, to a large extent can be attributed to the high degree of the industrialization and consequent urbanization.

3.1.2 Cultural and aesthetics:

Jamshedpur, being an industrial town has brought together various communities belonging to differrent culture and life-styles enriching the socio-economic environment of the area. Besides benefiting to the urban centers in the area, this has also influenced the rural area bringing in improvement in quality of life of the rural and tribal people.

The area has rich cultural heritage with specific languages of the area dominated by Hindi, followed by Bihari and Bengali. The tribal speaks Santhali, Munda etc. Both the tribals and ethnic groups celebrate several festivals.

3.2 Baseline Air Environmental Status:

Studies carried out by NEERI on air environment included measurement of ambient air quality within 15 km radius of the TISCO works, estimation/measurement of stack, prediction of ground level concentration (GLS) through air quality/dispersion models for existing operational levels and proposed facilities are used for the purpose of present study.

A methodologically designed ambient air quality surveillance programme (AQSP) should form the basis to determine the impact assessment on air environment, which ultimately helps in formulating a sound environmental management plan. The basic considerations for designing such a programme include: i) representative selection of sampling locations primarily guided by the topography and micro-meteorology of the region. ii) adequate sampling frequency and iii) inclusion of all the major pollution parameters. Overall network was designed on circular grid basis to cover all directions with more emphasis on downwind locations. All these aspects were given due consideration in devising an optimal scheme for AQSP for comprehensive assessment in and around the core zone area.

The existing ambient air quality status (AAQS) within the impact zone was evaluated through in-situ monitoring whereas, GLC predictions, conditions of different emission scenarios were made through air quality/dispersion modeling taking into account the existing micrometeorological and topological characteristics of Jamshedpur region.

3.2.1 Micro-meteorology:

Two portable weather stations were installed, one on the terrace of National Metallurgical Laboratory (NML) and another at the promise factory in Adityapur industrial area to collect data on prevailing surface wind pattern during the study period; whereas long term secondary data collected from IMD were analyzed to study the geographical changes if any, in the wind pattern. Wind roses were plotted from the IMD data collected. Winds exhibited wide diurnal variation with low wind speeds during daytime and calm conditions during night and it was observed that prevalence increases during winter season. Prevailing wind directions during post monsoon and winter season were from northwesterly and westerly directions. In summer season, wind pattern fluctuated widely and prevalence of wind from southeast and east directions was found to be higher.

3.2.2 Heat island studies:

Heat island studies were carried out within the TISCO works and Jamshedpur city by measuring the dry and wet bulb thermometer readings using whirling psychrometer. Corresponding relative humidity levels were also measured and tabulated in **Table 3.1**. It is evident from the measurements that industrial area has lower relative humidity due to higher temperature than the surrounding area thereby indicating the effect of heat island.

Table 3.1: Heat Island Studies at Jamshedpur

TICSO Works	Relative Humidity %	Urban Residential Area	Relative Humidity %
West plant- first aid	55	Crisis control room	70
Main electrical power distribution center	57	Eye hospital	71
S.P No. 2 – RMBB yard	58	Modi Park	69
Near G. blast furnace	48	Tata Main hospital	71
EOF water treatment plant	50	Kadma Polic station	76
SMS-3 Draftsman office	53	Kharkai bridge and Kantilal hospital	72
R & D-Pilot Plant	50	Sewage tretment plant	75
Ring Plant	53	Veterinary Hospital	75
Strip mill	50	Lic Colony	65
I.M Section	51	Link Road	68
Power house gate	53	Guest house, soanri	68
BFIT mill office	49	Sonari Bazar	68
Bar & Rod mill water treatment plant	40	Canara Bank, Bistpur	64
Plant medical office	48	Dena Bank Bistpur	68
Sr. GM's office	48	Nildhi Flats	81
Pump house 2 & coke oven	40	Telco Colony	72
EMD lab	42	Kharangajar	72

3.2.3 Inversion height, mixing height and stability studies:

Monostatic SODAR was installed in the study area. The instrument provided useful information on temperature variation with height, inversion, and stability class band mixing height which influences pollutants dispersion/dilution.

Sodar has been set up on the terrace of the National Metallurgical Laboratory, which is located just outside the boundary of the TISCO factory. The machinery complex and Stacks are at a distance of about 500m from the Sodar. Data collected during the period from Nov. 1992 to February 1993 have been analyzed. Sodar system was operated round the clock for a period 10 days in each month.

The plots of the nocturnal inversion heights and daytime mixing heights as a function of (local) time are made. It may be seen from these plots that the plume activity ceases by 1600 hours giving rise to stable atmospheric conditions. The height of the stable boundary layer (SBL) shows a sharp increase for 2 to 3 hours from 1800 hours onwards whereas during the next few hours a little height is lost during some of the months (Nov., Dec.) And after the sharp increase, very soon a steady height is attained. During the morning i.e. 0400 to 0600 hours a sudden increase in SBL height has been observed again. It is presumed that the abnormal changes in the SBL height might be affecting the stack plume behavior during the Sodar location and developing turbulence in the atmospheric air being probed by Sodar (Heat island effect). The SBL height varied between 80 m and 300 m during these months. In all probability SBL height is likely to be around 80m in the months of Nov., Dec., and Jan., and around 100m in February, whereas the maximum SBL height of 300m has been recorded only for 5% of the time.

Morning erosion of the inversion boundary layer has been clearly seen in November only. After the erosion of the inversion, the thermal plumes grow in height attaining a maximum height by noon when it retains for the next few hours before declining in height.

Diurnal variations in the atmospheric stability have also been determined based on Sodar data. It may be seen that atmosphere is highly stable only during November and during rest of the month it is only moderately stable during night. The atmosphere is highly unstable during 1000-1600 hours in January and during 0900-1600 hours in February.

3.2.4 Ambient air quality status:

For Ambient Air Quality Monitoring (AAQM) 20 sampling stations were selected in all directions within the study area exhibiting circular grid design. The location and bearings of all 20 ambient air quality monitoring stations are projected in **Table 3.2.**

Table 3.2: Ambient Air Quality Monitoring Stations (Locations and Bearing)

Sr. No.	Location	Sampling Height (m)	Directions
1	Burma Mines, National Meteorological Lab.	12	SE
2	Jugsalai, Shankar Katra, Market / Municipal office	5	S
3	Bistupur, Maharastra Mandal	12	W
4	Kadma, TISCO girl's school, D.B.M School	15	NW
5	Mango, PHED water campus	4	NE
6	Karandih, LBSM college/ Railway colony	6	S

7	Adityapur, Sampark, Khakai river Bridge	5	SW
8	Sonari, Arya Samaj, School	5	N
9	Sakchi, Apex Sales office / Graduate college	8	NE
10	Nildih, Golmuri club	10	E
11	TELCO colony, Little flower school	12	E
12	Kharangajhar, vidya Bharti Chinmaya Mission School	12	E
13	Deoghar, Puja, Enterprise	4	NE
14	Pardih, Kali Mandir, Nh-33	5	N
15	Asanboni, Arti udyog, NH-33	10	N
16	Gamaria, Rajasthan Bhavan	9	W
17	TISCO, Adityapur Complex, Gamaria Club	5	W
18	Asangi, Promise Factory	7	SW
19	Udaipur, Nahato's Residence	4	W
20	Bara Dangar, Mukhiya's Residance	4	NE

The parameter for the AAQM includes suspended particulate matter (SPM), Sulfur dioxide (SO_2) and Nitrogen dioxide (NO_2). SPM as well as gaseous pollutants were monitored on 8 hourly averages. However in the core sector zone the averaging period was reduced and gaseous pollutant was monitored on 4 hourly averages because of high concentration. Besides additional pollutant parameters such as Carbon monoxide (CO), total oxidants, Sulphation rate and settle able particulates were also monitored whenever necessary to carryout AAQM on comprehensive basis. Different types of sampling equipment: viz. high volume sampler, gaseous monitoring unit, etc were deployed to meet the specific requirement of field conditions. The samples were collected round the clock during study period. The standard methods used for sampling / analysis of different pollutant.

CO measurements were carried out using MSA detector tubes during winter season at important heavy traffic junctions in Jamshedpur city. Total oxidants were monitored within the central core sector area during daytime.

The observed levels and ranges of SPM and NO_X frequency percentiles besides other statistical parameters for all the one season for the tidy area for winter season are presented in the **Table 3.3** and **3.4** respectively. Air Quality Status is depicted in **Table 3.5** at Jamshedpur for winter season and detailed analysis is presented in concentration forms for each pollutant as below.

Suspended Particulate Matter (SPM)

SPM concentrations in core sector zone ranged from 30 to 1879, 15 to 1118 and 87 to 677 μg/m^3 during post monsoon, winter and summer seasons respectively in the study region. Average concentrations recorded in the study area indicate that highest SPM concentration occurs in core sectors followed by zone where other types of industries are located and was lowest in rural areas.

During the post-monsoon and winter season in the core zone, SPM concentration (maximum) exceeded 500 μg/m^3 frequently, which is the CPCB recommended limit for the industrial and mixed used category. However, in summer relatively less number of SPM values exceeded the standards. Frequency distribution level of SPM in urban, semi urban and rural areas depict that maximum number of values fall in the range of 200-400 μg/m^3 during all seasons.

Data reveal that urban industrial area is under the stress of air pollution. Levels below 100 μg/m^3 are rare and high values of industrial origin are persistent in the ambient air.

Sulpher Dioxide (SO_2)

Ambient SO_2 levels observed during post monsoon, winter and summer seasons indicated wide fluctuations ranging from 6 to 398 μg/m^3. Seasonal averages of values recorded in core sector zone were in the range of 6-56, 24-99 and 26-68 during post monsoon, winter and summer seasons respectively. The 95^{th} percentiles values are higher than 120 μg/m^3 in the core sector. However, in other areas the 95^{th} percentile levels are mostly below the prescribed limit of 80 μg/m^3.

Oxide of Nitrogen (NO_X)

Ambient NO_2 levels observed during the post monsoon, winter and summer varied from 3 to 191 μg/m^3. The mean concentrations of NO_X levels ranged from 3 to 53 μg/m^3. Winter levels were found to be higher then post monsoon and summer season values. In general concentrations were found to be less then CPCB prescribed limits of 80 μg/m^3 for

Table 3.3: Cumulative Percentile Distribution of SPM: Winter

8 Hrs. Avg. time **unit: µg/m^3**

Sampling Location	Avg.	Min	Max	SD.	Cumulative Percentile				
					10	25	50	80	95
Burma Mines	407	250	596	99	262	319	391	480	587
Jugsalai	532	216	1074	208	300	343	471	701	814
Bistupur	603	385	1118	185	389	422	540	722	876
Kadma	310	186	402	58	208	253	307	359	396
Mango	465	266	651	104	305	372	451	545	628
Sakchi	461	347	624	90	368	384	423	548	620
Adityapur	464	266	826	143	298	326	408	588	730
Sonari	321	103	926	171	135	214	279	408	503
Nildih	478	341	631	86	351	389	494	565	632
TELCO colony	305	212	565	89	212	237	279	354	443
Kharangajhar	363	258	504	68	260	287	363	420	436
Deoghar	263	15	996	240	24	47	233	365	657
Pardih	309	144	534	115	176	192	284	413	518
Asanboni	161	67	259	59	72	99	169	413	248
Gamaria	305	104	588	107	108	214	312	219	449
TISCO, Adityapur Complex	287	65	812	155	127	179	239	367	491
Asangi	360	214	540	100	230	274	334	337	535
Udaipur	334	190	478	81	227	238	329	472	454
Karandih	520	306	908	170	308	334	481	422	876

Table 3.4: Cumulative Percentile Distribution of NO_2: Winter

8 Hrs. Avg. time **unit: µg/m^3**

Sampling Location	Avg.	Min	Max	SD.	Cumulative Percentile				
					10	25	50	80	95
Adityapur	17	3	40	10	5	8	13	25	34
Sonari	18	3	65	14	5	9	13	25	43
Nildih	40	7	93	25	8	16	37	53	86
TELCO colony	12	3	23	6	3	5	12	19	20
Kharangajhar	17	3	48	10	6	7	16	22	29
Deoghar	10	3	50	13	3	3	3	13	20
Pardih	11	3	31	8	3	3	9	17	20
Asanboni	25	3	98	32	3	3	8	31	95
Gamaria	7	3	17	4	3	3	6	10	15
TISCO, Adityapur Complex	4	3	12	2	3	3	3	5	9
Asangi	11	3	44	10	3	3	6	17	26
Udaipur	6	3	14	4	3	3	5	9	13
Karandih	22	3	57	15	3	8	18	35	49

Table 3.5: Air Quality Status At Jamshedpur: Winter

Location	Benzene Soluble Avg.: µg/m^3	Oxidant Avg.: µg/m^3	Sulphation Rate mg SO_3/100 Sq. Cm.	Dust Fall Rate MT/KM^2 / Month
Burma Mines	57.2	8.3	1.71	12
Jugsalai	52.2	19	0.23	25
Bistupur	94.2	18	0.25	7
Kadma	45.5	3	0.07	4
Mango	54.9	12	0.06	8
Sakchi	47.0	12	0.25	17
Adityapur	64.9	-	0.02	11
Sonari	63.3	-	0.14	9
Nildih	70.6	-	0.25	14
TELCO colony	26.5	-	0.12	13
Kharangajhar	44.6	-	0.30	11
Deoghar	75.8	-	0.06	7
Pardih	37.5	-	0.12	8
Asanboni	40.1	-	0.09	4
Gamaria	65.1	-	0.01	5
TISCO Adityapur Complex	62.5	-	0.03	1
Asangi	68.3	-	0.08	4
Udaipur	33.4	-	0.02	1
Karandih	91.9	-	-	19

residential / rural area. There is a sufficient margin to assimilate further NO_X concentration in the study area.

Oxidants

Oxidants measurement carried out during winter season in the core sector zone revealed that oxidant is not predominant at Jamshedpur.

Carbon Monoxide

Carbon monoxide (CO) measurement was carried out at all ambient air monitoring stations sites showed below detectable levels. However, CO measurement carried out at the important heavy traffic streets during peak traffic hours in the winter season in the core sector zone revealed that in most of the street the levels are below 10 ppm.

Sulphate Rate

The lead oxide candle methods have been used for the determination of sulphation rate. This method is mainly qualitative and CPCB has not prescribed any standards for this parameter. Sulphation rate level during winter season ranged between 0.01

to 1.71 mg SO_3 /100 sq. cm./day, whereas in summer the levels were measured to be in the range of 0.04 to 1.44 mg SO_3/100 sq. cm. Sites within the core sector zone especially during the summer showed higher levels.

Settleable Particulates (Dust fall):

This is measure through a simple static technique wherein settle able dust fall is measured. In case where the settle able dust is generated by localized sources, the inheritable dust fall rate s widely variable. The reported data on dust fall is qualitative. Dust fall range in between 1 to 35 MT/km^2/ month in the study area during winter and summer months. Sites in core sector zone recorded comparatively higher levels of dust fall rate.

Benzene Soluble

SPM samples from the study area were processes for benzene soluble. The benzene soluble levels ranged between 26.5 to 94.2 µg/m^3.

Implications

The baseline environmental conditions indicate that the particulate matter ambient concentrations are exceeding the national ambient air quality standards. Reduction in particulate emission would contribute to significant improvement in the ambient environment. This problem needs immediate attention because of high particulate settling rate.

We estimate that additional particulate emission reduction in the range of 5 and 8 MT could bring about improved environmental conditions in critical areas of Jamshedpur as also compliance with National Ambient Air Quality Standards.

4. METHODOLOGY

The main task of the project has been bifurcated into following three parts:

1. Construction of abatement cost curves
2. Development of MBIs
3. Comparison of different instruments.

4.1 Construction of Abatement Cost Curves:

4.1.1 Approach:

A cost curve is a ranking of abatement measures in terms of increasing marginal cost by size of emission reduction. Cost curves can be presented graphically or as tables or rankings. Cost curves are useful for policy analysis because they identify cost effective measures to achieve various emission reductions. The steps involved in the derivation of a cost curve for emission reduction are:

- The first step is to estimate the pollution load for each source in the selected companies. Since actual information of this nature does not exist, it is estimated by using data on volume of gas flow and pollution concentration in the gas.
- The second step is to identify the abatement options. A survey was conducted to identify existing abatement devices in the selected companies. During the survey information on efficiency, capital cost and operating cost for each device was also gathered.

Another survey was conducted to identify alternate abatement technologies for SPM and NOx at different sources. The data on capital cost, operating cost and efficiency were also collected for these devices.

- The annual abatement and total abatement cost were estimated for each device. The capital cost was annualized by multiplying it with cost recovery factor using the information of discount rate and life time of the device.
- An abatement cost function was developed to rank the different abatement technologies.

- Abatement cost curves and marginal cost curves were drawn for all technologies existing and alternate.

The existing and alternate technologies were compared for each source as per their unit abatement cost to find out best available technologies source-wise.

4.1.2 Information gathering process:

Emissions data are taken from the selected Tata group companies at Jamshedpur region. Information on technology in place (abatement measures) was collected from a number of sources including the published literature and from industrial contacts. Information on alternate abatement options and their costs and efficiencies was gathered from the suppliers of the technologies. The information gathering for this project took place iteratively. Published sources were consulted, and initial contacts were made with representatives of the companies and other experts. Information so gathered is written up in such a way as to contain all the information required to make a cost curve. At this stage, there are likely to be important assumptions or uncertain information, and these are documented as explicitly as possible. A second pass was then made, contacting industry sources again and inviting them to comment on the first draft, its figures and assumptions. Their comments were fed back into refined cost curves.

4.1.3 Compilation of data for the cost curves:

It has been the intention to include all possible abatement devices in the cost curves. In reality, we have been severely limited by lack of data and so the cost curves presented here give an incomplete picture of the reductions that can be achieved and their associated costs. In some cases where information is lacking, it has been possible to make reasonable enough approximations or deductions to include the measure in the cost curve.

4.1.4 Estimation of costs:

Capital costs have been annualized using a discounted cash flow technique [EEA, 1999]. The present value of the capital cost is multiplied by the capital recovery factor, which is given by the following formula:

$$C.R.F. = r\frac{(1+r)^T}{(1+r)^T - 1}$$

where r is the discount rate and T is the lifetime in years. For r = 0.10 and T = 15 years, the capital recovery factor is 0.131474. Annual operating costs (which are assumed to be constant for the lifetime of the equipment) are added to the annualized capital cost to obtain the total annual abatement cost. This methodology is consistent with the approach recommended by the Treasury Green Book and is derived by simply equating the capital cost of the equipment with the present value of T equal annual payments made in successive years, the first payment being made at the end of year 1. This annual payment is the annualized capital cost. The discount rate used is 10% by default. Plant and equipment lifetimes are generally assumed to be 15 or 20 years, in present study it is taken as 15 years. Add-on equipment used in harsh conditions may have a shorter useful lifetime, while new plant built from scratch may be expected to have a longer lifetime.

4.1.5 Ranking of abatement technologies:

The following abatement cost function was adopted to rank all categories (existing, alternate and best available) of the abatement measures:

$$TAC = K * (ABAT)^n$$

where

TAC	Total abatement cost Rs.(,000) per annum
ABAT	Annual abatement of the pollutant (tpa)
K, n	Parameters

The parameters K and n were estimated from TAC and ABAT data. Using estimated values of K and n, the abatement costs (^TAC) were estimated for known abatements for all the technologies from cost function.

The technologies were ranked by calculating (ln TAC – ln^TAC). The top rank (1) was given to the technology having largest negative value of ln TAC – ln^TAC and last rank was given with largest positive value of ln TAC – ln^TAC.

4.1.6 Abatement cost curves:

The marginal cost curves show the unit abatement cost of achieving any required level of emission abatement. The x axis shows cumulative emission abatement (tonnes) achieved by implementing different abatement measures. The y axis shows the marginal abatement cost required to achieve the level of emission abatements on the *x* axis. The technologies considered in the construction of cost curves as per their ranks. The top ranked technology is included first and lowest rank technology last.

The total abatement cost curves were also drawn for all technologies by taking cumulative abatement on the x-axis and cumulative abatement cost on the y-axis.

4.2 Development of MBIs:

In the present study two MBIs were considered - bubble and offset.

4.2.1 Environmental bubble:

A bubble is a regulatory concept where by two or more emission sources are treated as if they were a single emission source. This creates flexibility to apply pollution control technologies to whichever source under the bubble has the most cost effective pollution control options, while ensuring the total amount of emissions under the bubble meets the environmental requirement for the entity. Bubbles are closed systems.

It is assumed that the selected companies are making abatements as per Government regulations under CAC system. The sum of present emissions of the pollutant from the selected companies is considered as air-shed for estimating bubble's limit. The abatement cost curves for alternate measures for the selected companies were used to find out source specific optimum abatements to achieve emission limit of the bubble. The abatement cost for achieving bubble's limit by Tisco alone was also estimated using concerned cost curves.

The abatement costs were also calculated for abatements through best available technologies at different sources in Tisco using concerned cost curves.

A linear programming model was also developed to calculate optimum abatements to achieve the bubble's limit of pollution.

4.2.2 Emission offsets:

Two offsets (5 and 8 MT) are created and their additional costs are estimated with abatement cost curves of alternate and best available technologies. The cost curves are used to calculate additional cost for each offset.

The proposed model was also used to calculate the optimum abatements.

4.3 Comparison of Different Instruments:

The costs were calculated under bubble policy and compared with the existing costs under CAC.

5. ANALYTICAL METHOD

The bubble concept allows various polluters in a geographical region-with varying abatement costs-to jointly reduce a predetermined quantity of pollutants. The cost effective abatement of a non-uniformly mixed assimilative pollutant is that abatement 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. It can be expressed as:

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

Subject to:

$$\sum_j d_{jk}(e_{bij} - r_{ij}) \le A_{ik}$$

$$r_{ij} \ge 0$$

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

As all of the selected companies are within 5 KM radius from TISCO, d_{jk} would not have much impact on distribution of SPM in the area. Therefore, the model was modified from ambient-based to emissions-based system and diffusion coefficients were not taken into consideration. The sum of present emissions of pollutant i from all selected companies was considered as allowed level for the pollutant in all the places of the airshed of the selected companies, because the companies are meeting Govt. specified standards under CAC system. The proposed model for the study can be stated as follows:

$$\text{Minimize } Z = \sum_{j} C_{ij}\, r_{ij}$$

Subject to:

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

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

$$r_{ij} \geq 0$$

where,

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

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

In designing of offsets of 5 MT and 8 MT the cost effective abatement schedules are evaluated with the same model by readjusting net after treatment emissions, $\sum_{j} e_{ij}$.

The TORA package is used to run the model.

6. DATA COLLECTION AND ANALYSIS

Major air polluting industries in Jamshedpur region include iron and steel, engineering and locomotive, agricultural tools, tube manufacturing etc. A report on Tisco and carrying capacity report developed by NEERI were considered to identify potential air polluting Tata group companies. Based on field visits and gathered information the following companies were selected in the region for the study:

i. TISCO

ii. Tata Pigments Ltd.

iii. Tata Rayerson Ltd.

iv. Tata Engineering and Locomotive Company Ltd. (Telco)

v. Tinplate Company of India Limited (TCIL)

vi. Telco Constructions and Equipment Company Ltd.

vii. Tata Cummins Ltd.

6.1 Data Collection on Existing Abatement Technologies and Emission Loads:

Personal discussions and surveys were undertaken to gather the required information on existing abatement measures and characteristics of emissions at the selected companies. The existing emission loads of each unit are as follows:

6.1.1 TISCO:

Tisco is the largest industrial unit located in the region. Tisco is the major air polluting company in the region. Different processes of steel making are practiced at Tisco. Main processes can be divided into Blast Furnace (BF), Steel Melting Shop (SMS), Rolling Mills, Refractory Material Plant (RMP), Power House (PH) etc. The processes can be expressed as follows:

6.1.1.1 Coke-oven:

In coke-ovens, naturally found coal is converted into coke in a series of batteries. Coal is crushed and blended to give required composition. It is then pushed into the batteries and coal is heated externally. The process of coke making is completed in 16-20 hours. Large amount of carbonaceous gas is emitted through leakages in the batteries. Pollutants like SPM and NOx are emitted through seven stacks at the rate of 410.74 and 37.79 g/s respectively. No air pollution control devices are installed at these units.

There are two processes for making coke, wet quenching and dry quenching. The several studies conducted abroad reveal that dry quenching generate less emissions, use less energy and produce coke with better quality. Therefore, dry quenching is recommended for making the coke.

6.1.1.2 Ore crushing and sintering plant:

With the introduction of mechanized mining, a large percentage of fines are generated which cannot be charged in the blast furnace as such. All the fines like iron ores fines; blue dust; lime stone fines; coke breeze etc. are mixed together and heated. The sinters so formed are crushed to required size and sent to BF plant. The nature of process is such that it emits fugitive dust as well as dust through stack. ESPs have been provided to arrest the dust emissions from both SP#2 and SP#1. Multi cyclone (MC) is installed at one unit of SP#1. The total loads of pollutants - SPM and NOx - from both sintering plants are 1196.56 and 49.78 g/s respectively.

6.1.1.3 Blast furnace (BF):

Blast furnace is commonly used in the steel plants to produce molten metals, which is used for making various steel products. Iron ore, coke and limestone are charged in BF and heated to 900-1000 ^{0}C. Manganese ore, Fe/Mn slag, quartzite, scrape etc, are also added in small quantities in BF. The raw materials per day are about three times the quantity of hot metal produced. Hot metal consisting of 92-94% of iron ore is recovered from iron ore and is separated from the slag. The emitted gas contains nearly 25% CO and large amount of dust. In order to use this gas as a fuel TISCO is carrying out territory treatment of this gas and bringing down the dust concentration level to 1650 mg/Nm^3. The stack gas emissions study at one of the BFs shows that pollutant concentration of SPM and NOx are quite low but the total load from seven BFs in g/s is about 281.28 and 23.87 respectively.

6.1.1.4 Steel melting shop:

Hot metal coming out of the BF is stored in the refractory lined mixers. Light scrape along with iron ore, Mn ore and limestone is first charged into the open hearth furnace (OH) followed and heavy scrape. Introducing maximum heat melts the scrape and when the scrape starts sweating, hot metal is added through the back walls or doors. When the bath has reached the proper composition oxygen is introduced (called oxygen lancing) for refining the metal. This is one of the most important processes of most polluting nature in steel plant. The quantity of air pollutants emitted through the OH furnace was measured during O_2 lancing period. The dust emissions concentrations into selected furnaces were ranging from 3.53-9.22 g/Nm3, whereas the total loads in g/s from SPM and NOx from 11 SMS stacks are 1183.82 and 1.29 respectively. SMS units are not equipped with any control devices for controlling dust emissions. LD-1 shop having 1.1 MTPA capacities is provided with gas cleaning and pollution control facilities. The gas containing high CO is recovered and used as fuel in the steel plant.

6.1.1.5 Rolling mills:

These mills are provided with number of soaking pits where the ingots are uniformly heated to bring them to plastic stage, so that they can be rolled easily without defects. This section is equipped with blowing mill, strip bar and billet mill, structural mill and shipping arrangements. The furnaces are heated either by CO or BF gas. The total emissions from 19 such units are SPM 577.05 g/s and NO_X 47.52 g/s.

6.1.1.6 Refractory plant:

This section supplies the specially made refractory materials required to maintain and repair various units of the plant and also to facilitate adequate availability of vessels, furnaces, and ladles for optimum production.

Refractory production department consists of following three major sections:

1) Refractory manufacturing plant (RMP)

2) Lime calvining plant

3) Tar bonded dolomite brick plant

Maerz kiln and super basic kiln were studied for air pollutant emissions. During the sampling period it was found that SPM and NO_X are the major air pollutants, emissions from kiln stacks are 250.89g/s and 8.15 g/s respectively. Cyclone/bag filters have been installed in Maerz kiln whereas bag filters have been provided in super basic furnace but emissions through the stacks are much on higher side.

6.1.1.7 Power house:

Different types of boilers of varying capacities are in operation to generate required power. Coal, blast furnace, and coke oven gases are being used to produce steam. Coal fired boilers are provided with ESP to arrest dusty emission. One boiler each PH-3 and PH-4 was identified for pollutant emission studies. SPM emissions from PH-3 and PH-4 boilers are 2072.5 g/s and 1294.17 g/s while those of NOx are 57.57 and 31.06 g/s respectively.

6.1.2 Tata Pigment Ltd.:

The Tata Pigment Limited was incorporated on 2nd April, 1959. The Company which is now a wholly owned subsidiary of Tata Steel manufactures synthetic red and yellow oxides of iron, which are used as pigments in paints, plastics, rubber, building materials, paper, tiles, cosmetics leather, printing inks and other products. Tata Red, Tata black, Tata Green, and Tata Yellow Powders have also been specially developed for floors.

The raw material required for synthetics oxides making is brought from TISCO. Furnace oil is the main fuel for heating the blank inside the furnace. The furnaces are of roasting types. Studies on the Tata Pigments stacks reveal that dust emission load from common stacks attached to 3 calciner and one roasting furnace are about 20.4 g/s.

6.1.3 Tata Rayerson Ltd.:

The company is a 50:50 joint venture between Tata Steel and Rayerson International, USA. Established in 1997, it is a leading player in the steel processing and distribution business in North America, with a turnover of about US$ 3 billion.

The company undertakes the distribution and processing of industrial materials in India. It aims to become the dominant industrial materials management service provider in India, and create customer value by processing and distributing industrial plastics. The company is currently involved in buying, processing, and selling steel, as well as toll processing (conversion) for steel producers and consumers.

Emissions through stack attached to boiler include 0.13 g/s of SPM and 0.04 g/s of NO_X. At present scrubber is being used to abate the SPM.

6.1.4 Tata Engineering and Locomotive Company Ltd. (TELCO):

TELCO is one of the largest manufacturers of heavy duty trucks and their spare parts. The emission loads through all stacks are 18.2 g/s of SPM and 0.053 g/s of NOx.

6.1.5 Tinplate Company of India Limited (TICL):

The Tinplate Company of India Limited (TICL) is an associated company of Tata Steel. A pioneer in the indigenous manufacturer of tinplate sheets, TCIL, has its work in Golmuri, Jamshedpur. The work has two units – the Hot Dip Plant which has a capacity of more than 100,000 tones per annum and the Electrolytic Tinplate and Tin free steel plant with a capacity of more than 90000 tpa.

Steel sheet bars are cut and heated in a hot mill furnace. The separated sheets are then cold rolled and sent for annealing. Boiler and annealing furnaces are coal fired, whereas hot mill and galvanizing furnaces are either producer gas or fuel oil fired. One hot mill, one boiler and one galvanizing plant were studies to quantify SPM and NOx emissions. These emissions were then used for simulating emissions from other similar units. The emissions from furnace stacks are 1.98 g/s of SPM and 0.001 g/s of NO_X.

6.1.6 TELCO Constructions and Equipment Company Limited (Telcon):

The company manufactures construction equipments that are used in major infrastructure projects in India. It has remained a market leader for the past five years, despite stiff competition. It has revolutionized the Indian construction equipment industry, with the introduction of the V series of hydraulic excavators.

The company uses state-of-the-art technology to manufacture excavators and backhoe loaders. It enjoys a 90 % share of the crawler crane market in India. These are the largest machines made locally. The company was the first to introduce mini-excavators in India, and its brand EX60, is the most successful machine to be made in India so far. It is the largest manufacturer of hydraulic excavators in India, with over 6,000 machines in the market. It offers the widest available range of hydraulic excavators, eight models ranging from 2 tonnes to 60 tonnes in size. The company can indigenously design and develop products. There are no stack emissions from TELCON operations.

6.1.7 Tata Cummins Limited (TCL):

TCL is a 50-50 joint venture between Tata Engineering and Cummins Engine Co., Inc.-USA. While Tata Engineering Engine Co. is the largest 200+ HP diesel engine manufacturer in the world. The company manufacturers low emission diesel engines for use in Tata Engineering's new generation medium and heavy commercial vehicles that conform to Euro-I standards.

Air emission studies for SPM and NOx were carried out, gaseous emissions are insignificant e.g. 0.12 g/s of NO_X but SPM emissions are around 0.34 g/s. At present no control measures are adopted as the level of pollutants are within statutory limits prescribed by CPCB. Unit wise air pollution details are given in Table 6.1.

The data on existing abatement technologies at different polluting sources of selected companies were collected. It includes capital cost, operating cost, efficiency etc. No NOx abatement technology is installed at any location. Telcon and TCL have not installed any abatement measure even for SPM because emissions are very less. The collected details are listed in Table 6.2.

The data on gas volume and concentrations of pollutants SPM and NOx were collected from through field visits and discussions with dealing officials. Unit-wise concentrations of air pollutants SPM and NOx before and after abatement are listed in Table 6.3.

6.2 Data Collection on Alternate Abatement Technologies:

A questionnaire survey was undertaken to identify alternate pollution abatement technologies for abatement of SPM and NOx at the emitting source in selected companies. The data related to abatement efficiency and costs-capital and operating were also gathered for the identified abatement devices. The survey was conducted through personal discussion with the suppliers of the technologies. The relevant information is also gathered from internet surfing and telephonic interviews with suppliers and experts. The findings of the surveys are summarized in Table 6.4 for abatement of SPM at selected sources.

Abatement technologies for NOx can be installed at various locations of TISCO. Other companies are emitting very less quantity of NOx therefore, abatement of NOx is not required at these locations. Data on possible abatement technologies for NOx at Tisco is gathered and reported in Table 6.5.

Table 6.1: Company-wise Emissions of SPM and NOx

Company	Unit Process	Raw Materials	Emission Rate (g/s)	
			SPM	NOx
TISCO	Blast Furnace	Coke, Iron, Limestone	281.28	23.87
	Coke Oven	Coal	410.74	37.79
	Steel Melting Shop	Pig iron, coke, limestone	1183.82	1.29
	Sintering Plant	Coke, iron ore, limestone	1196.56	49.78
	Power House #3	Coal	2072.5	57.57
	Power House #4	Coal	1294.17	31.06
	Rolling Mills	Steel	577.05	47.52
	Refractory material	Refractory material	250.89	8.15
TCIL	Furnaces, Boiler	Coal, steel	1.98	0.001
Tata Pigments	Furnace	Furnace oil	20.4	0.0065
Telco	Furnace	Furnace oil, Steel	18.2	0.053
Tata Rayerson	Boiler	Gas	0.1294	0.04
Tata Cummins	-	-	0.34	0.12
Telcon	-	-		

Table 6.2: Data on Existing Abatement Technologies for SPM

Company	Location	Abatement Device	Efficiency (%)	No. of Devices	Costs (Rs. Lacs) Per device	
					Capital Cost	Operational cost p.a.
TISCO	Boiler House	ESP	99.5	1	1000	40
TISCO	LD#2 Secondary Emission	ESP	99.9	2	750	30
TISCO	Sintering Plant 2 Waste Gas	ESP	99.8	1	1300	50
TISCO	Sintering Plant 2 Dedusting	ESP	99.8	1	1500	60
TISCO	Sintering Plant 1 Waste Gas	MC	80	1	15	6
TISCO	Sintering Plant 1 Dedusting	ESP	99.8	1	1300	50
TISCO	Power House#3	ESP	99.6	6	1500	62
TISCO	Power House#4	ESP	99.5	4	500	20
TISCO	Blast Furnace Stove Chiminey	ESP	99.9	2	1000	40
TISCO	Refractory Material	Bag Filter	99.9	6	80	3.2
TCIL	Boiler	Cyclone	80	1	8	0.32
Tata Pigments	Calciner and Roasting Furnace	Bag Filter	99.9	1	4	0.16
Telco	Wartshilla DG-2	Cyclone	80	1	6	0.24
Tata Rayerson	Hot Water Generator	Scrubber	80	1	2	0.08

Table 6.3: Existing Abatement details of SPM and NOx

Company	Location	Abatement Device	Gas Volume (Nm^3/hr)	Concentration of SPM (mg/Nm^3)		Concentration of NO_X (mg/Nm^3)	
				Before Treatment	After Treatment	Before Treatment	After Treatment
TISCO	Boiler House	ESP	244400	8500	120	700	700
TISCO	LD#2 Secondary Emission	ESP	665900	6400	90	7	7
TISCO	Sintering Plant#2 Waste Gas	ESP	576900	1900	90	270	270
TISCO	Sintering Plant#2 Dedusting Unit	ESP	355100	6000	60	1	1
TISCO	Sintering Plant#1 Waste Gas	MC	323680	1200	300	70	70
TISCO	Sintering Plant#1 Dedusting Unit	ESP	148600	4660	120	3	3
TISCO	Power House#3	ESP	829000	9000	105	250	250
TISCO	Power House#4	ESP	931800	5000	34	120	120
TISCO	Blast Furnace Stove Chiminey	ESP	613700	1650	23	140	140
TISCO	Refractory Material	Bag Filter	225800	4000	42	130	130
TCIL	Boiler	Cyclone	1700	4200	878	2.08	2.08
Tata Pigments	Calciner Furnace	BF	22950	3200	232	1.02	1.02
Telco	Wartshilla DG-2	Cyclone	21500	190	38.16	8.86	8.86
Tata Rayerson	Hot Water Generator	Scrubber	1700	274	55	85	85

NOx concentrations are same before and after treatment because no abatement device is installed to abate NOx.

Table 6.4: Possible Alternate Abatement Technologies for SPM at Different Locations

Company	Location	Alternate Abatement Device	Supplier	Capital Cost in Lacs	Operating cost Rs. / day	Efficiency (%)
TISCO	Boiler House	ESP	Thermax	250	5000	99.9
		Scrubber	Batliboi	150	6500	80
	LD#2 Secondary Emission	ESP	Batliboi	500	7200	99.9
	Sintering Plant 2 Waste Gas	ESP	Batliboi	250	4000	99.9
	Sintering Plant 2 Dedusting Unit	Bag Filter	Batliboi	150	23000	99.9
		Bag Filter	Thermax	150	25000	99.9
	Sintering Plant 1 Waste Gas	ESP	Batliboi	120	2500	99.9
	Sintering Plant 1 Dedusting Unit	Bag Filter	Thermax	85	11350	99.9
		Bag Filter	Batliboi	80	12300	99.9
	Coke Oven Waste Gas Stack	Scrubber	Batliboi	500	9500	80
	Power House#3	ESP		700	12600	99.9
		ESP	Batliboi	800	12350	99.9
	Power House#4	ESP		700	12600	99.9
		ESP	Batliboi	800	12350	99.9
	Blast Furnace Stove Chimney	Scrubber	Batliboi	550	9500	80
	Refractory Material	Scrubber	Batliboi	100	5500	80
		Bag Filter	Thermax	125	18650	99.9
TCIL	Boiler	Bag Filter	Thermax	4	600	99.9
		Bag Filter	Batliboi	5	700	99.9
Tata Pigments	Calciner and Roasting Furnace	Scrubber	Thermax	80	3750	80
Telco	Wartshilla DG-1	Scrubber	Batliboi	7	1000	80
	Wartshilla DG-3	Scrubber	Batliboi	10	1000	80
	Forge Stack # 5	Bag Filter	Batliboi	10	1500	99.9
	Forge Stack # 11	Bag Filter	Batliboi	8	1200	99.9
	Wartshilla DG-2	Scrubber	Batliboi	7	1000	80
	TP-15 Themopac Boiler	Scrubber	Thermax	60	2500	80
	Nilgata DG	Scrubber	Batliboi	10	1000	80
	Forge Stack # 9	Screbber	Thermax	80	2500	80
Tata Rayerson	Hot Water Generator	Scrubber	Batliboi	12	350	80
		Scrubber	Thermax	15	300	80

Table 6.5: Possible Alternative Abatement Technologies for NO_X at TISCO

Location	Alternate Abatement Device	Cost Estimates in Crore	Efficiency (%)
LD#2 Secondary Emission	Combustion Modification	24.10	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Coke Oven Waste Gas Stack	Combustion Modification	21.41	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Blast Furnace Stove Chimney	Combustion Modification	22.21	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Boiler House	Combustion Modification	8.84	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Refractory Material	Combustion Modification	8.17	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Sintering Plant 2 waste gas	Combustion Modification	20.88	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%
Power House	Combustion Modification	30.00	20-40%
	SCR	3.0	45-80%
	SNCR	-	40-60%
Hot Water Generator	Combustion Modification	0.06	20-40%
	SCR	-	45-80%
	SNCR	-	40-60%

6.3 Data Analysis:

It is clear from Table 6.1 that Tisco is biggest air polluting unit at Jamshedpur. It generates 7.267 kg/s of SPM and 257.03 g/s of NOx before abatement. While all selected companies generate 7.308 kg/s of SPM and 257.25 g/s of NOx. It shows that Tisco generates 99.44% of SPM and 99.91% of NOx.

Two types of analyses are carried out – one considering the capital cost and another without taking capital cost into consideration. In the first category the capital costs have been annualized using a discounted cash flow technique [EEA, 1999]. The present value of the capital cost is multiplied by the capital recovery factor, which is given by the following formula:

$$C.R.F. = r\frac{(1+r)^T}{(1+r)^T - 1}$$

where r is the discount rate and T is the lifetime in years. For r = 0.10 and T = 15 years, the capital recovery factor is 0.131474. Annual total abatement cost is calculated for each existing and alternate technology by adding annual operating cost to annualized capital cost.

Abatement of SPM is evaluated by using available data from Table 6.3 for all existing technologies as Table 6.3 consists the information of SPM concentration before and after treatment. The calculated total abatement cost and abatement for all existing technologies source-wise are listed in Table 6.6.

Abatement from alternate technologies is calculated for their given efficiencies by assuming that the technologies would perform as per their quoted efficiencies. Using volume data of SPM from Table 6.3 and efficiency and cost data for alternate technologies from Table 6.4 possible annual abatement and annual cost are calculated and listed in Table 6.7.

The data given in Table 6.5 is not sufficient for drawing abatement cost curves for NOx.

Table 6.6: Abatement and Total Abatement Cost for All Existing Technologies

Company	Location	Abatement Device	Abatement (tpa)	TAC (Rs. 000 p.a.)
Tata Pigments	Calciner and Roasting Furnace	BF	596.6927	68.5896
TISCO	Sintering Plant 1 Waste Gas	MC	2551.893	797.211
TISCO	LD#2 Secondary Emission	ESP	36808.02	25721.1
TISCO	Power House#4	ESP	40535.31	34294.8
TISCO	Boiler House	ESP	17941.11	17147.4
TISCO	Refractory Material	Bag Filter	7828.956	8230.752
TISCO	Sintering Plant 2 Dedusting Unit	ESP	18477.42	25721.1
TISCO	Power House#3	ESP	64595.85	155526.6
TISCO	Sintering Plant 2 Waste Gas	ESP	9147.096	22091.62
TCIL	Boiler	Cyclone	49.47122	137.1792
Telco	Wartshilla DG-2	Cyclone	28.59755	102.8844
TISCO	Sintering Plant 1 Dedusting Unit	ESP	5909.881	22091.62
TISCO	Blast Furnace Stove Chiminey	ESP	8746.772	34294.8
Tata Rayerson	Hot Water Generator	Scrubber (B)	3.261348	34.2948

Table 6.7: Abatement and Total Abatement Cost for All Possible Alternate Technologies

Company	Location	Abatement Device	Abatement (tpa)	TAC Rs. 000 p.a.
TISCO	Boiler House	ESP (T)	18179.83	5111.85
TISCO	Boiler House	Scrubber (B)	14558.42	4344.61
TISCO	LD#2 Secondary Emission	ESP (B)	37295.68	18403.4
TISCO	Sintering Plant 2 Waste Gas	ESP (B)	9592.322	4746.85
TISCO	Sintering Plant 2 Dedusting Unit	Bag Filter (B)	18645.39	10367.11
TISCO	Sintering Plant 2 Dedusting Unit	Bag Filter (T)	18645.39	11097.11
TISCO	Sintering Plant 1 Waste Gas	ESP (B)	3399.122	2490.188
TISCO	Sintering Plant 1 Dedusting Unit	Bag Filter (T)	6060.024	5260.279
TISCO	Sintering Plant 1 Dedusting Unit	Bag Filter (B)	6060.024	5541.292
TISCO	Coke Oven Waste Gas Stack	Scrubber(B)	10362.38	10041.2
TISCO	Power House#3	ESP (T)	65293	82813.08
TISCO	Power House#3	ESP (B)	65293	90154.02
TISCO	Power House#4	ESP (T)	40772.03	55208.72
TISCO	Power House#4	ESP (B)	40772.03	60102.68
TISCO	Blast Furnace Stove Chiminey	Scrubber(B)	7096.336	21397.14
TISCO	Refractory Material	Scrubber (B)	6329.626	19933.44
TISCO	Refractory Material	Bag Filter (T)	7904.12	50704.05
TCIL	Boiler	Bag Filter (T)	62.48385	271.5896
TCIL	Boiler	Bag Filter (B)	62.48385	321.237
Tata Pigments	Calciner and Roasting Furnace	Scrubber (T)	514.6675	2420.542
Telco	Wartshilla DG-1	Scrubber (B)	56.74918	457.0318
Telco	Wartshilla DG-3	Scrubber (B)	60.3035	496.474
Telco	Forge Stack # 5	Bag Filter (B)	81.05398	678.974
Telco	Forge Stack # 11	Bag Filter (B)	62.97725	543.1792
Telco	Wartshilla DG-2	Scrubber (B)	28.62768	457.0318
Telco	TP-15 Themopac Boiler	Scrubber (T)	91.73408	1701.344
Telco	Nilgata DG	Scrubber (B)	23.34221	496.474
Telco	Forge Stack # 9	Screbber (T)	83.14624	1964.292
Tata Rayerson	Hot Water Generator	Scrubber (B)	3.264326	285.5188
Tata Rayerson	Hot Water Generator	Scrubber (T)	3.264326	306.711

B and T are names of the suppliers of technologies T=Thermax and B=Batliboi

7. DEVELOPMENT OF ABATEMENT COST CURVES AND MARKET BASED INSTRUMENTS (INCLUDING CAPITAL COST OF THE DEVICES)

7.1 Construction of Cost Curves:

An abatement cost curve is a ranking of abatement measures in terms of increasing marginal cost by size of emission reduction. Two types of abatement cost curves are drawn for all abatement technologies-total abatement cost curve and marginal abatement cost curve.

7.1.1 For existing abatement technologies:

The ranking of existing technologies was done as mentioned in methodology section. The parameters K and n are estimated after using abatement and total abatement cost data from Table 6.6. The estimated values are lnK=1.483 and n=0.862 with R^2=0.855. With these values of parameters estimates of total abatement costs (^TAC) were made for existing abatements as listed in Table 6.6. The values of lnTAC-ln^TAC were calculated and technologies were ranked with these values. Highest rank (1) was given to the technology which has most negative value of lnTAC-ln^TAC and lowest rank was given to the technology with most positive value of lnTAC-ln^TAC. All technologies were rearranged rank-wise (first to last).

Cumulative abatement is calculated for rearranged technologies in all the companies and shown in graph on x-axis. Similarly cumulative total abatement costs were calculated and shown on y-axis to draw total abatement cost curve. The curve is shown in Figure 7.1.

Marginal abatement costs were calculated from cumulative abatement and cost values. The graph between these marginal abatement cost and cumulative abatement was drawn and shown in Figure 7.2 for all selected companies.

As Tisco is the major air-polluting unit in the region therefore separate abatement cost curves are also drawn for the measures at Tisco. The existing abatement technologies were sorted for different locations in Tisco from rearranged list of technologies developed in section 7.1.1 without disturbing the arrangement. For the sorted list of technologies total abatement cost curve and marginal cost curves were drawn and given in Figure 7.3 and 7.4 respectively.

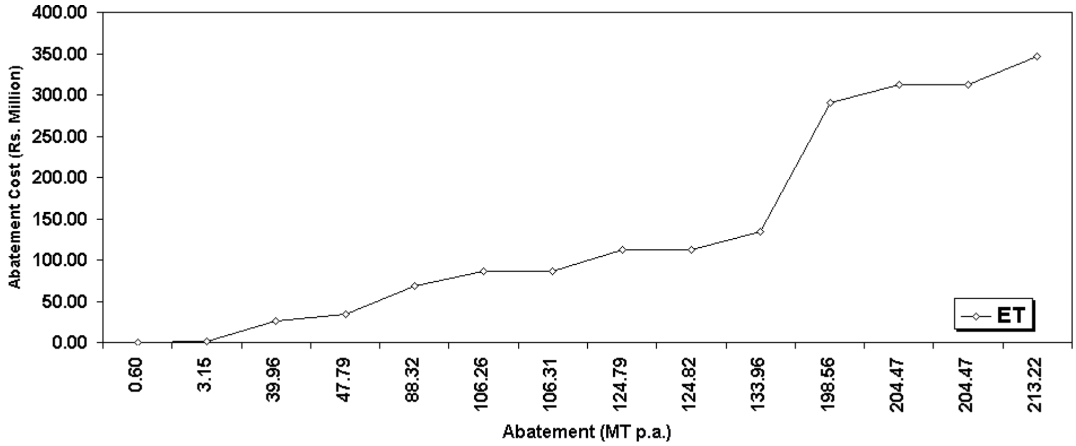

FIGURE 7.1: ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COST

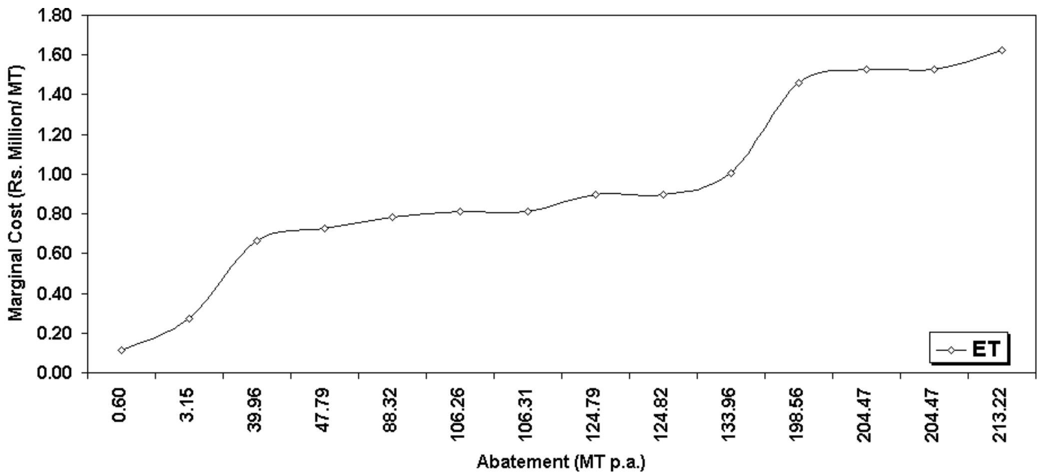

FIGURE 7.2: MARGINAL ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COST

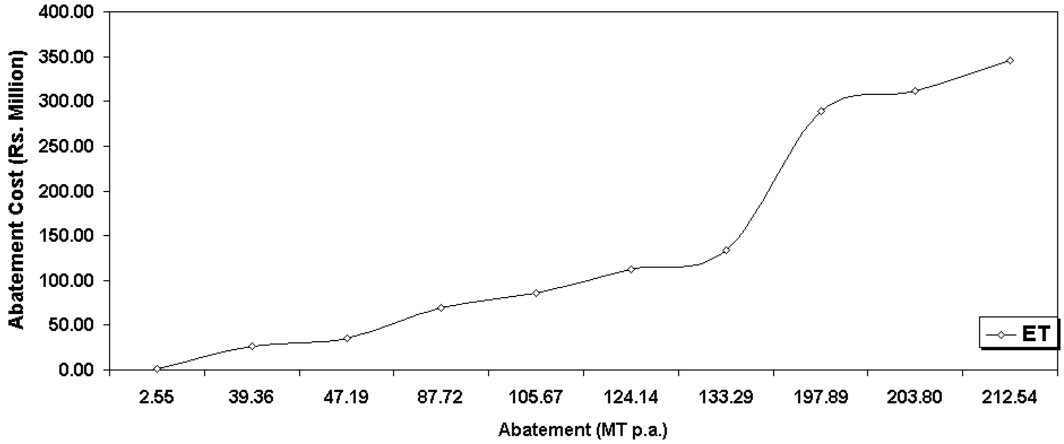

FIGURE 7.3: ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COST

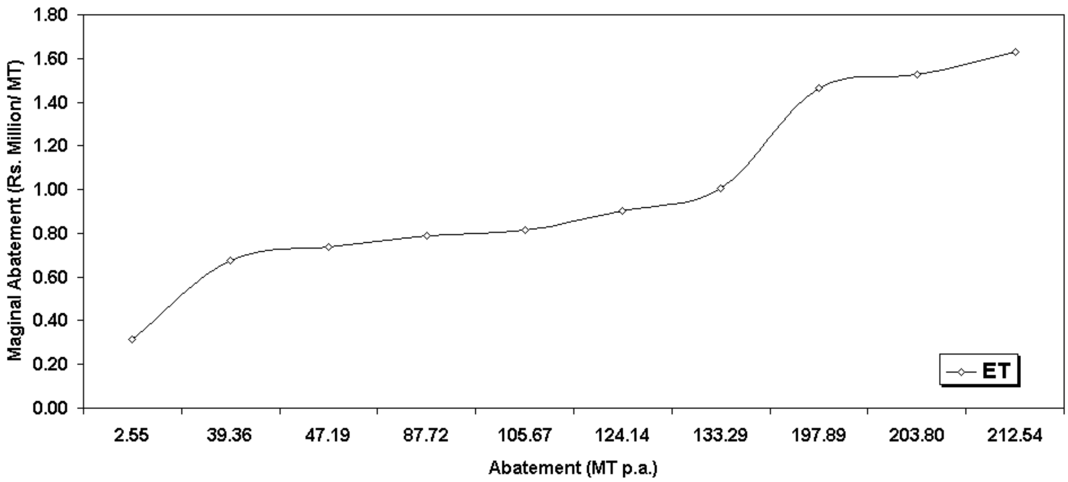

FIGURE 7.4: MARGINAL ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COST

7.1.2 For alternate abatement measures:

There are two possible alternate technologies for abatement of SPM at some locations as mentioned in Table 6.7. Unit abatement cost is calculated for all these technologies using information given in the table. For each location better alternate abatement technology was identified with less unit abatement cost. Parameters K and n were estimated with abatement and cost data of identified better abatement technologies. The estimated values are as follows:

Ln K=4.357　　　　n=0.536　　　　R^2=0.857

Using these values Ln^TAC were calculated and alternate technologies were ranked as per method discussed in section 7.1.1.

Total abatement cost curves and marginal cost curves were drawn for alternate technologies in all the selected companies and given in Figures 7.5 and 7.6 respectively. As mentioned in section 7.1.1 the alternate technologies were sorted for Tisco. Total abatement cost curve and marginal cost curve for alternate technologies for Tisco were also drawn and shown in Figures 7.7 and 7.8 respectively.

7.1.3 For best available technologies (BATs):

A list of best available abatement technologies was developed for each emitting source from among existing and alternate abatement technologies suited at that source on the basis of unit abatement cost of the technology.

The existing and alternate abatement technologies at each location were compared as per their unit abatement cost and best available technology having less unit abatement cost for the location was selected. For selected BATs annual SPM abatement and total annual cost were calculated. The calculated abatement and cost for all BATs were used estimate K and n for ranking BATs.

Total abatement cost curve and marginal cost curve were drawn for BATs in all selected companies and given in Figures 7.9 and 7.10 respectively. The same types of graphs were also drawn for BATs in Tisco and given in Figures 7.11 and 7.12 respectively.

7.1.4 Comparison of cost curves:

Abatement cost curves of all technologies (existing, alternate and best available) in the group of selected companies compared in Figure 7.13 while marginal abatement cost curves are compared in Figure 7.14.

Similarly abatement cost curves of all technologies (existing, alternate and best available) in TISCO compared in Figure 7.15 while marginal abatement cost curves are compared in Figure 7.16.

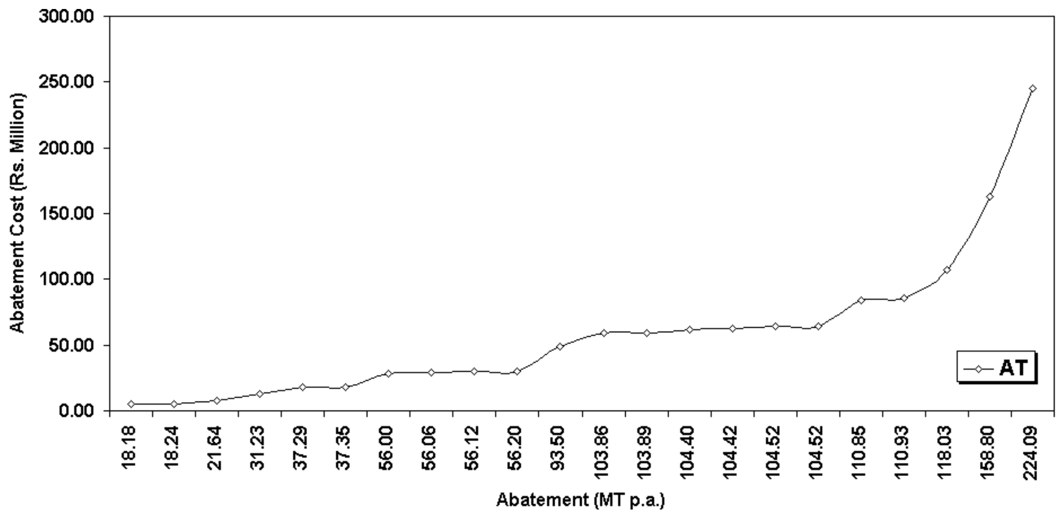

FIGURE 7.5: ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COST

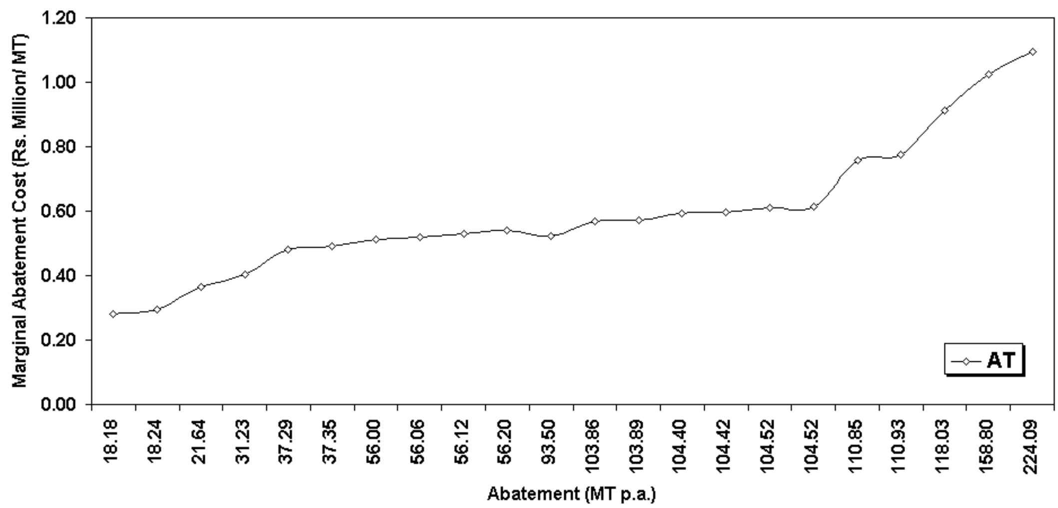

FIGURE 7.6: MARGINAL ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COST

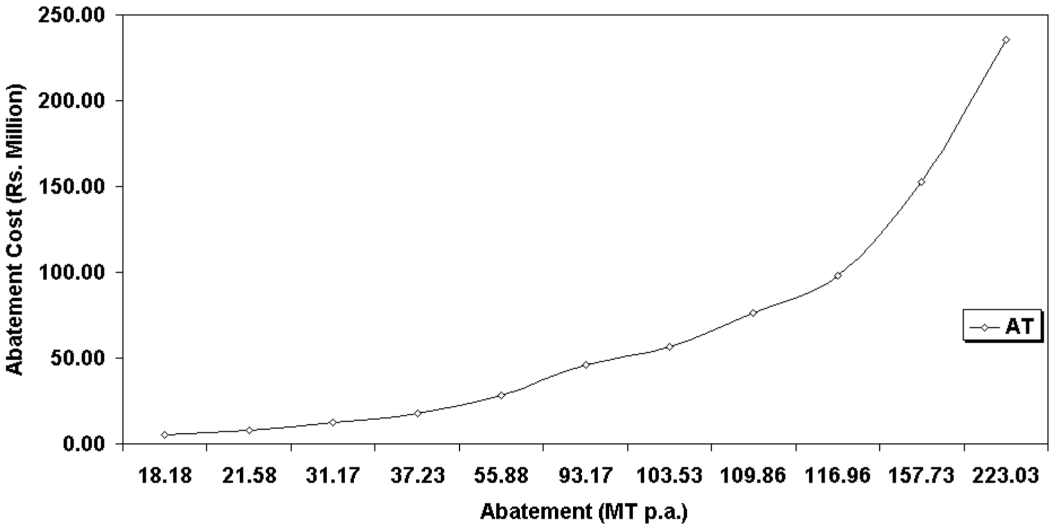

FIGURE 7.7: ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COST

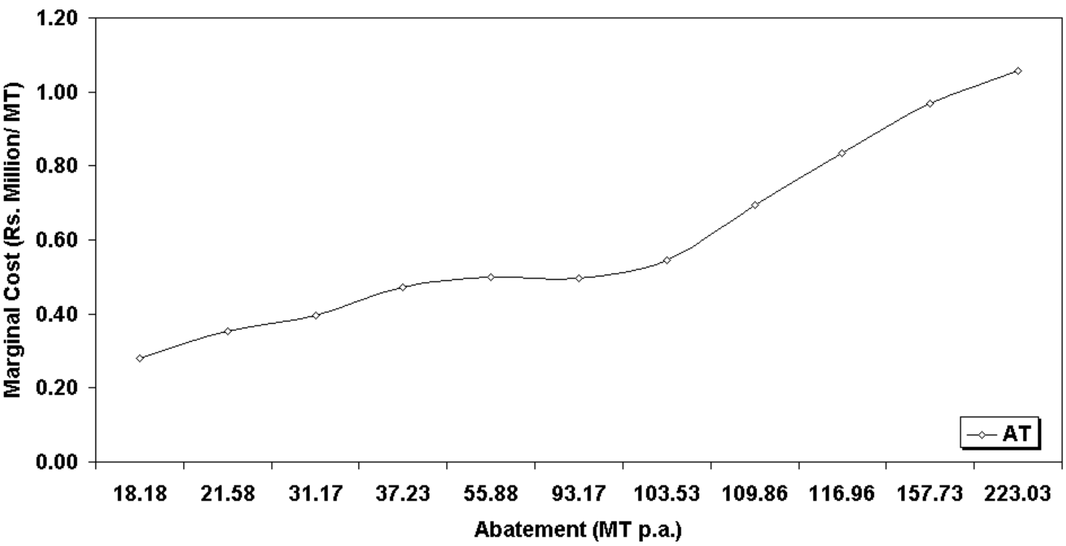

FIGURE 7.8: MARGINAL ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COST

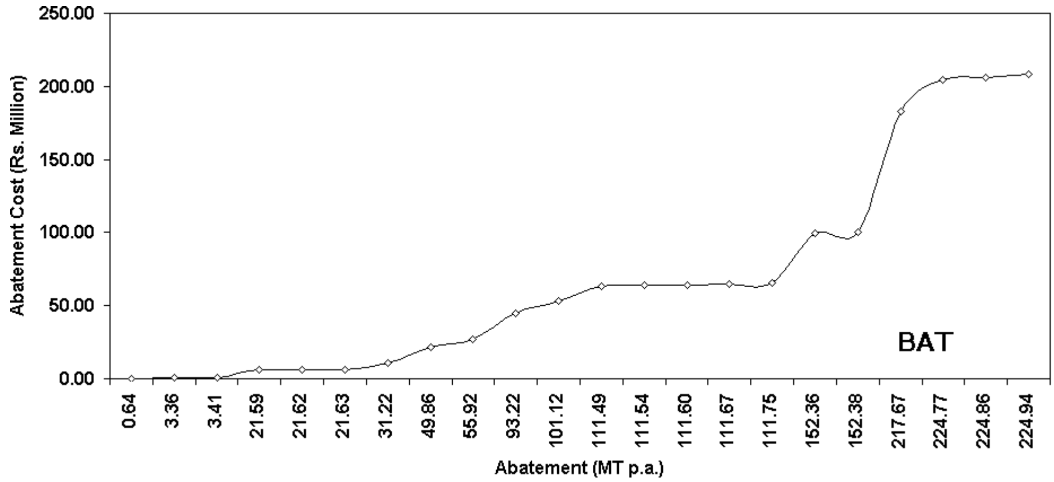

FIGURE 7.9: ABATEMENT COST CURVE OF BATs IN ALL COMPANIES CONSIDERING CAPITAL COST

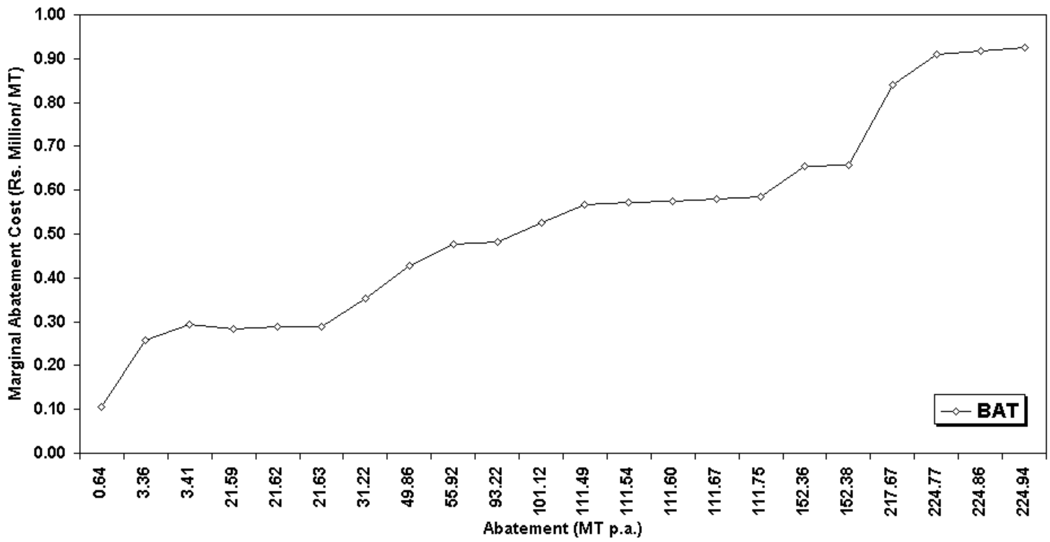

FIGURE 7.10: MARGINAL ABATEMENT COST CURVE OF BATs IN ALL COMPANIES CONSIDERING CAPITAL COST

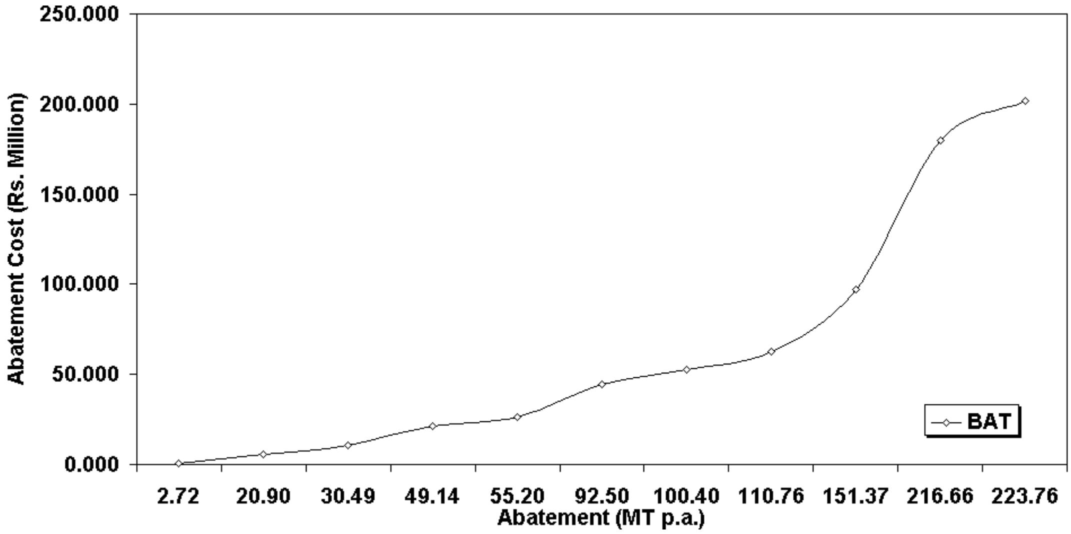

FIGURE 7.11: ABATEMENT COST CURVE OF BATs IN TISCO CONSIDERING CAPITAL COST

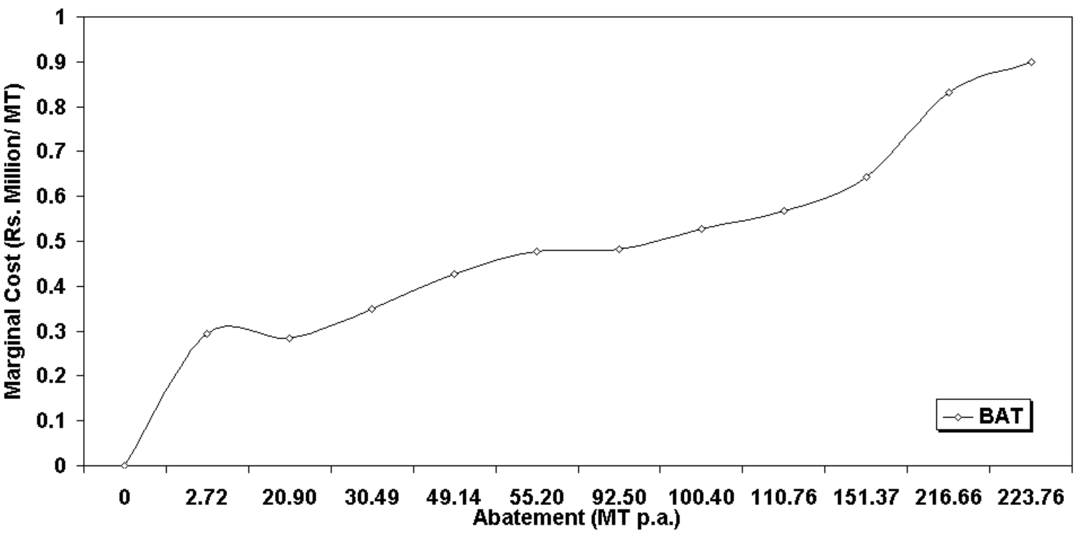

FIGURE 7.12: MARGINAL ABATEMENT COST CURVE OF BATs IN TISCO CONSIDERING CAPITAL COST

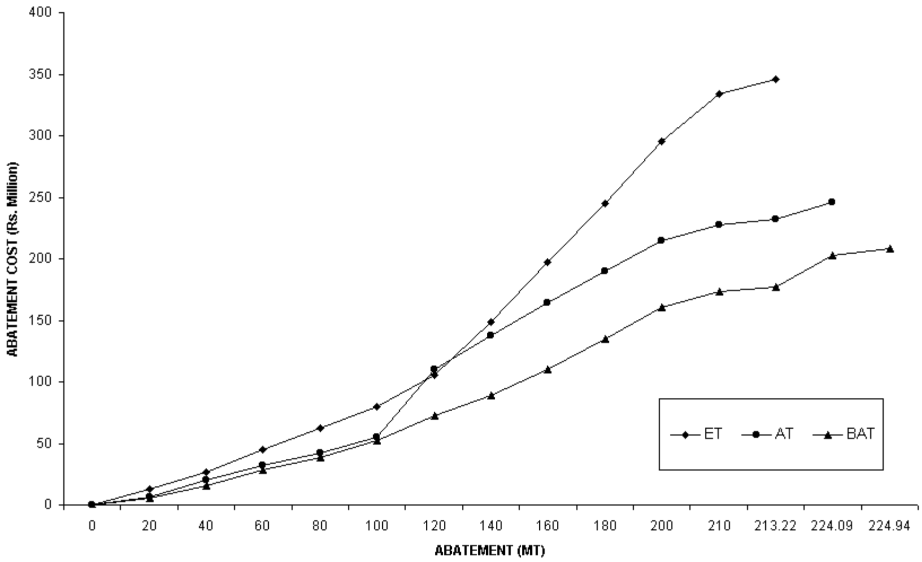

FIGURE 7.13: COMPARISON OF ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COSTS

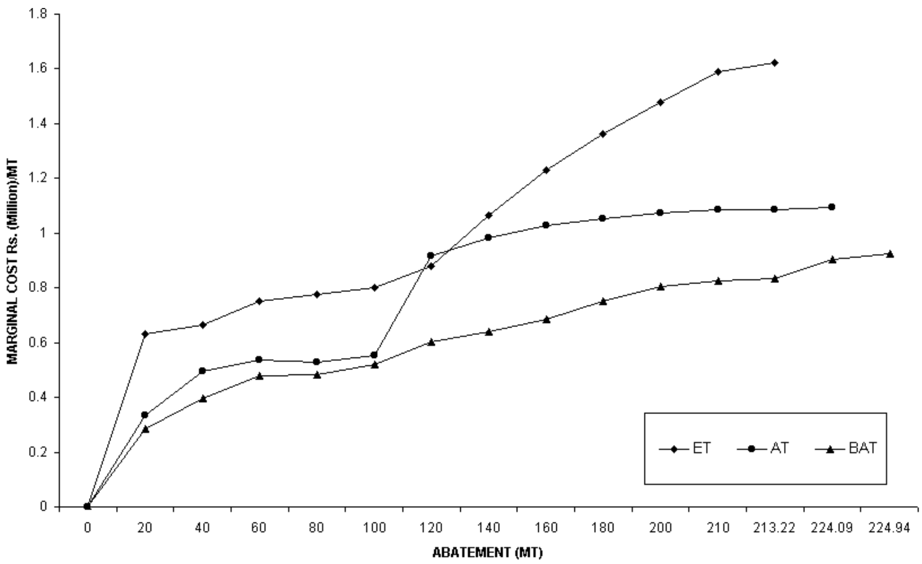

FIGURE 7.14: COMPARISON OF MARGINAL ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN ALL COMPANIES CONSIDERING CAPITAL COSTS

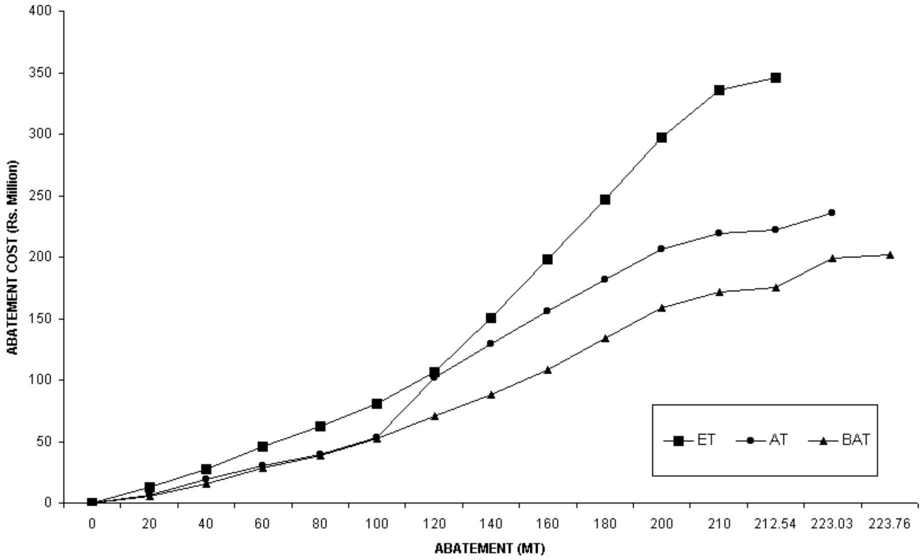

FIGURE 7.15: COMPARISON OF ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COSTS

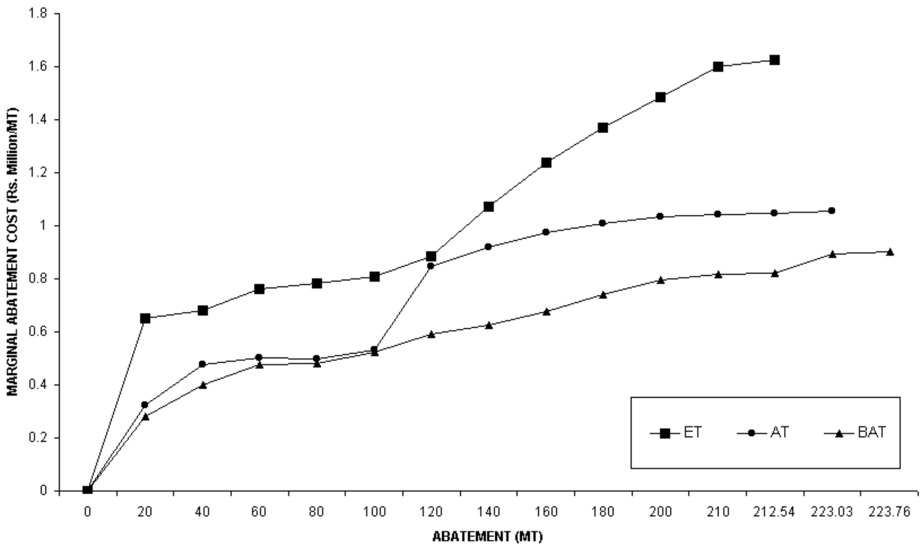

FIGURE 7.16: COMPARISON OF MARGINAL ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN TISCO CONSIDERING CAPITAL COSTS

7.2 Development of Market Based Instruments:

No MBIs could be developed for NOx due to non-availability of required data. The companies do abatements of SPM as per their requirement of emissions allowed by the pollution control board. The current situation in all selected companies is as follows:

Emission of SPM before Treatment	: 230.46 MT p.a.
Abatement	: 213.22 MT p.a.
Net Emissions after Treatment	: 17.24 MT p.a.
Abatement cost	: Rs. 346.26 millions

The abatement cost curves or marginal cost curves developed in section 7.1 are used to calculate abatement cost for desired level of abatements with alternate / best available technologies at different sources taking into consideration the capital costs of the devices.

Two market-based instruments, bubble and offset, are evaluated as follows:

7.2.1 Environmental bubble:

The present net annual emission of SPM 17.24 MT is considered as limit of the bubble. To achieve this amount of net annual emission the companies are paying a sum of Rs. 346.26 millions by making SPM abatement of 213.22 MT. The associate cost for this abatement with alternate technologies is calculated as Rs. 231.75 millions from Figure 7.5. The same level of abatement with best available technologies can be achieved with cost of Rs. 177.43 millions only (Figure 7.9). Therefore, it is clear that the cost of Rs.114.51 millions and Rs. 168.83 millions can be saved in making same amount of abatement using alternate and best available technologies respectively. The results can be summarized as follows:

Bubble's limit of SPM emissions: 17.24 MT

To keep the bubble's limit same the target annual SPM abatement = 213.22 MT

Abatement costs to achieve the annual target of SPM abatement by all companies:

(i) with existing abatement measures:	Rs. 346.26 millions (under CAC)
(ii) with alternate abatement measures:	Rs. 231.75 millions

(iii) with best available technologies: Rs. 177.43 millions

Abatement costs to achieve the annual target of SPM abatement by Tisco alone:

(i) with existing abatement measures: not possible

(ii) with alternate abatement measures: Rs. 223.34 millions

(iii) with best available technologies: Rs. 176.42 millions

Therefore, it is clear that Tisco alone can make the needed SPM abatement and even at less cost. It shows that Tisco has the capability to abate more SPM with cost effective measures. The results show that Tisco alone can make the required amount of abatement needed for the keeping the bubble limit same with much less cost and earn the emission reduction certificates for its addition abatement. These certificates can be sold in the open market to those companies for them abatement is not possible or more cost intensive.

7.2.2 Emission offsets:

Offsets are designed when further pollutions are not allowed. The present limit of bubble cannot be extended and new/extension activities are to be undertaken.

Offsets of 5 and 8 MT can be created by making annual SPM abatement of 218.22, and 221.22 respectively. Tisco is the only company in the sample that can make additional abatements of required quantities. Therefore, Tisco was considered to make required abatements for the offsets. The associated additional costs are calculated for required offsets and summarized as follows:

Offset (MT)	Total Additional Abatement Cost with Alternate Technologies (Rs. Millions)	Total Additional Abatement Cost with BATs (Rs. Millions)
5	6.34	7.30
8	10.15	16.34

If there is any extension activity in the region then these additional abatements (offsets) can be purchased from Tisco after making payments.

8. DEVELOPMENT OF ABATEMENT COST CURVES AND MARKET BASED INSTRUMENTS (EXCLUDING CAPITAL COST OF THE DEVICES)

8.1 Construction of Abatement and Marginal Cost Curves:

The capital cost of the devices was included in the development of abatement and marginal cost curves in last section.

The capital cost can be considered as sunk cost for such devices. In that case only annual operating cost will take part in developing cost curves and market-based instruments. Therefore, in this section market-based instruments are developed on the basis of operating costs only. The abatement technologies are ranked as per their unit abatement costs. Highest rank is given to the technology having least per unit abatement cost. Then the abatement and marginal cost curves are drawn in a similar manner as in section 7.

8.1.1 For existing abatement technologies:

The abatement and marginal cost curves are given in Figures 8.1 and 8.2 for existing abatement measures in all the companies. Similar curves are drawn for TISCO alone and given in Figures 8.3.and 8.4.

8.1.2 For alternate abatement technologies:

The abatement and marginal cost curves of alternate abatement technologies in all the selected companies are drawn and given in Figures 8.5 and 8.6 respectively. The same curves for alternate measures in TISCO alone are plotted and mentioned in Figures 8.7 and 8.8.

8.1.3 For best available technologies (BATs):

The abatement and marginal cost curves of best available technologies in all the selected companies are given in Figures 8.9 and 8.10 respectively. The similar curves for BATs in TISCO alone are mentioned in Figures 8.11 and 8.12.

8.1.4 Comparison of cost curves:

The abatement cost curves and marginal cost curves for all three sets of the abatement measures in selected companies are given in Figures 8.13 and 8.14 respectively. Separate abatement cost curves and marginal cost curves of all the three sets of the technologies in TISCO are also drawn and given in Figures 8.15 and 8.16.

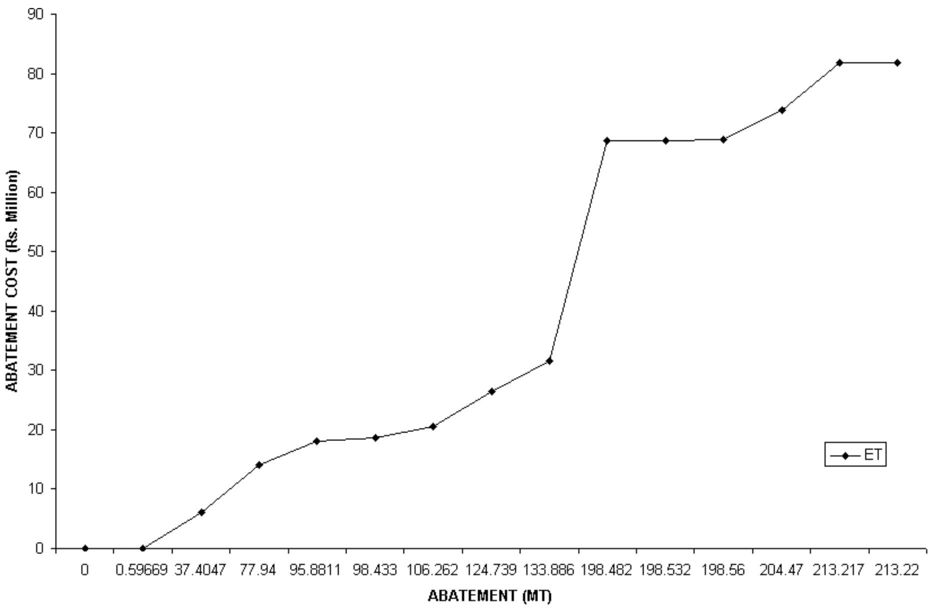

FIGURE 8.1: ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

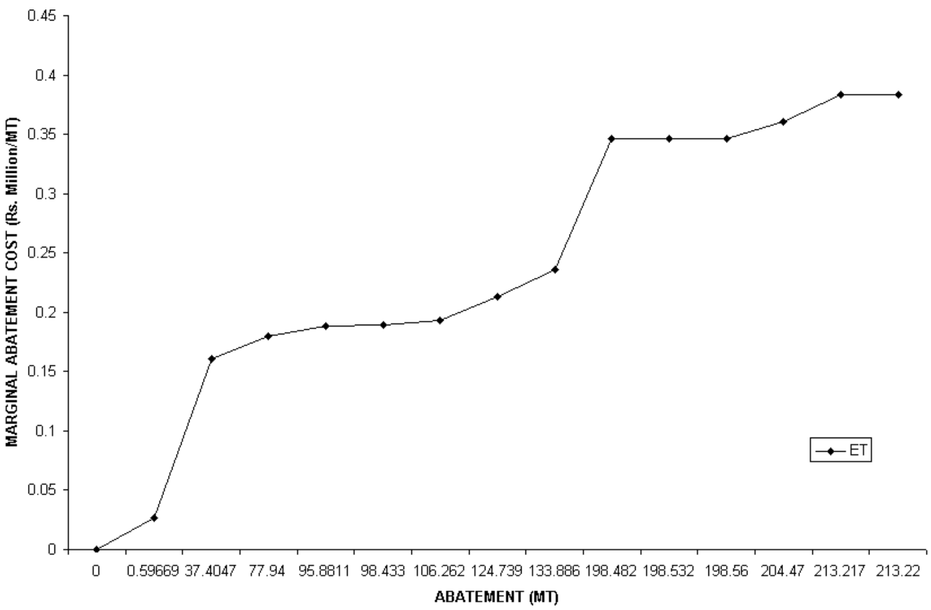

FIGURE 8.2: MARGINAL ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

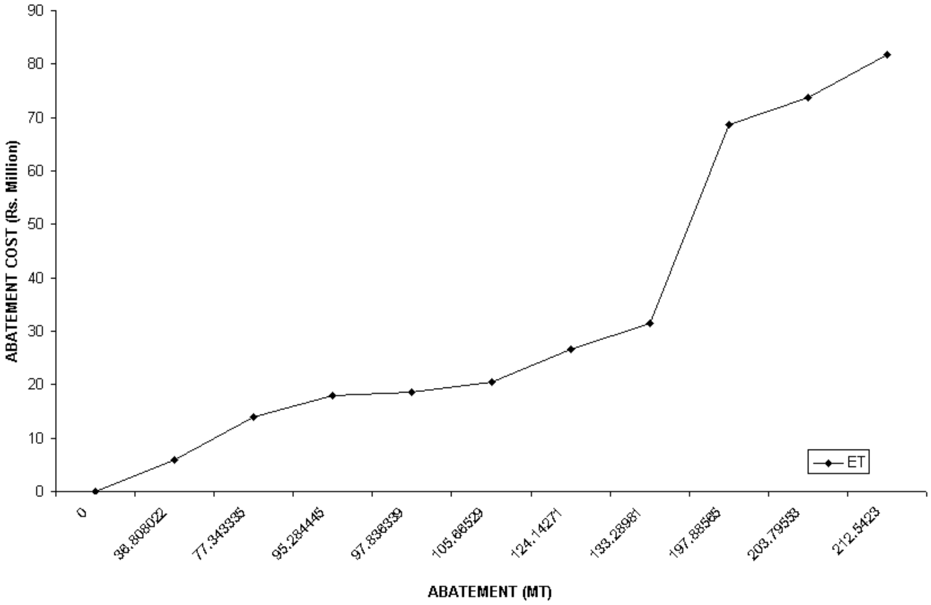

FIGURE 8.3: ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COST

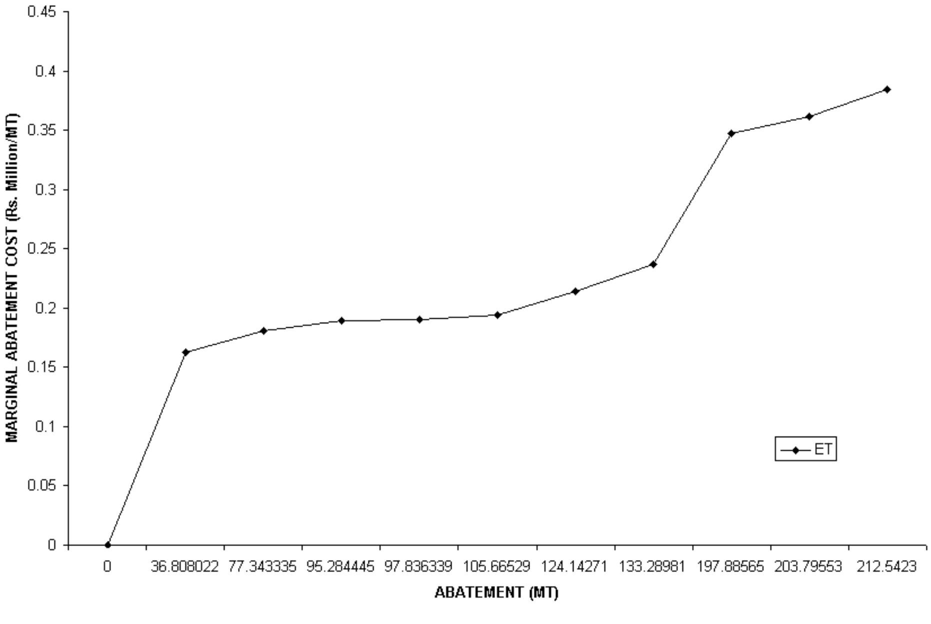

FIGURE 8.4: MARGINAL ABATEMENT COST CURVE OF EXISTING TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COST

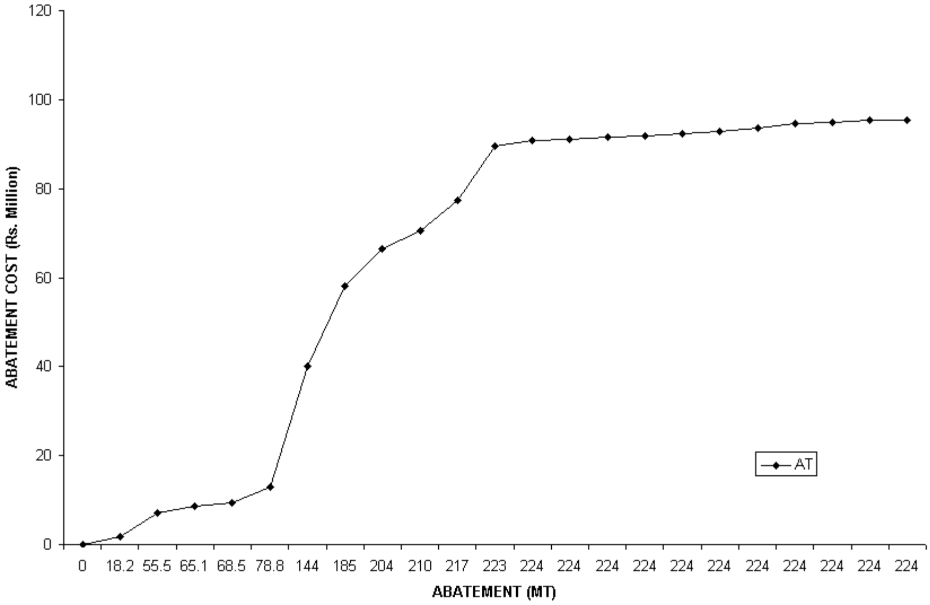

FIGURE 8.5: ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

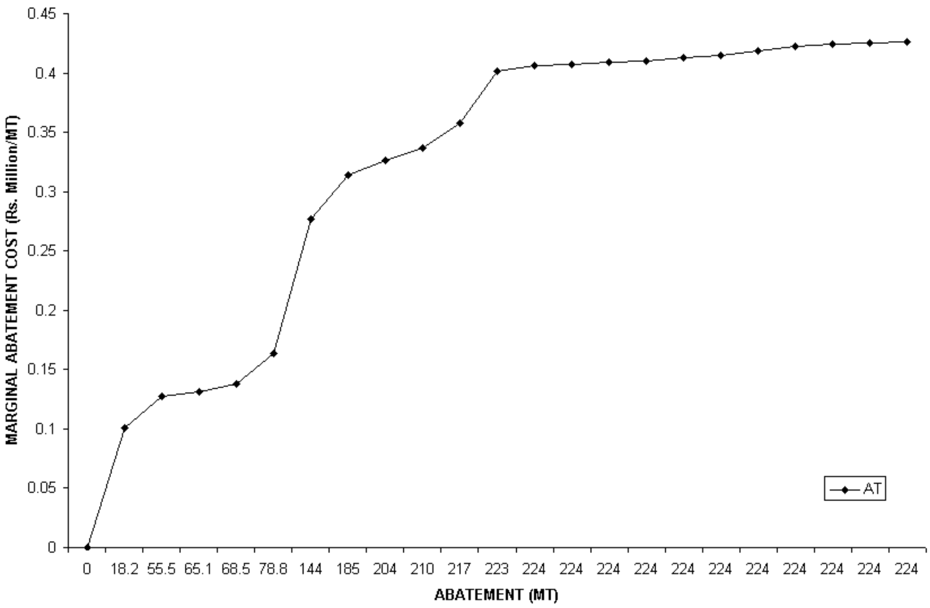

FIGURE 8.6: MARGINAL ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

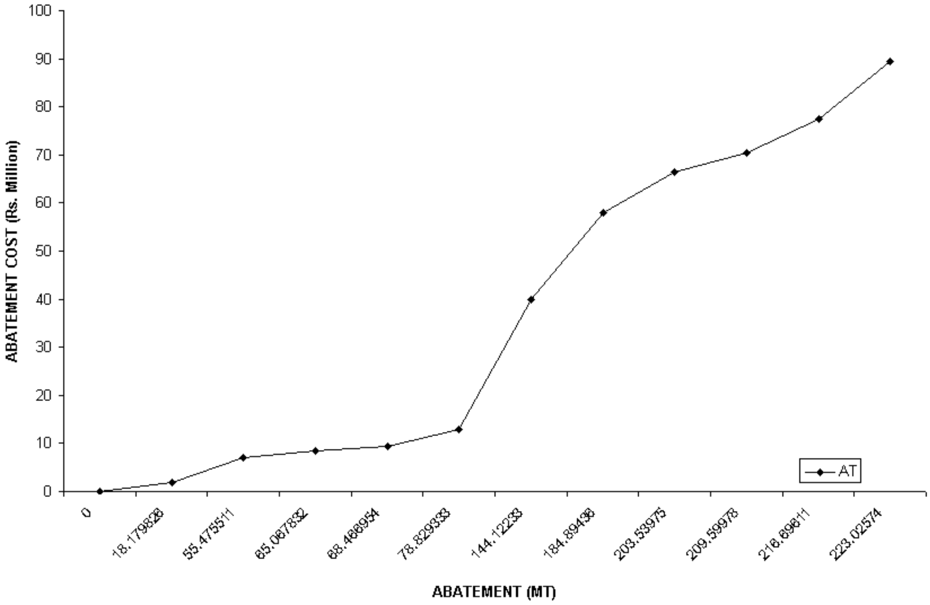

FIGURE 8.7: ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COST

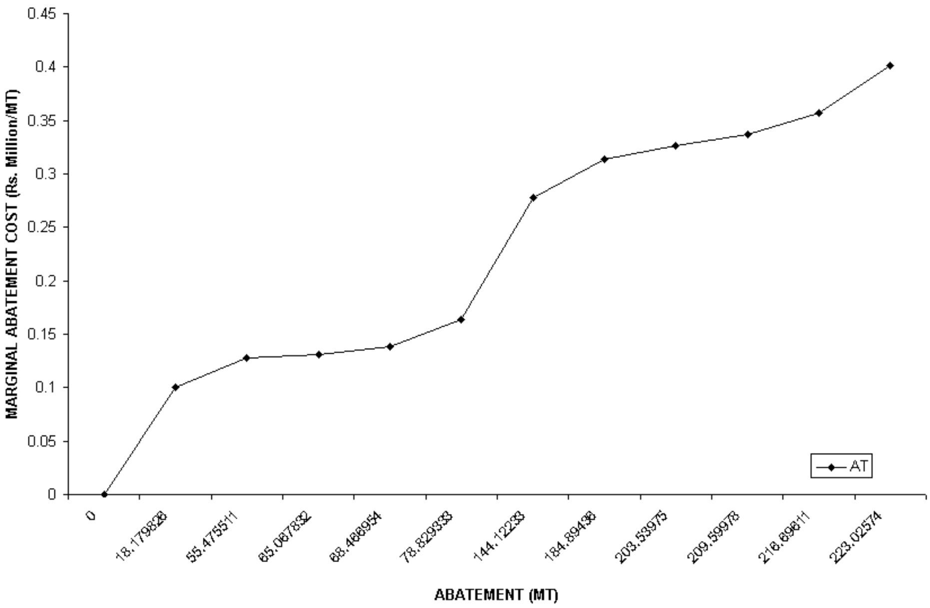

FIGURE 8.8: MARGINAL ABATEMENT COST CURVE OF ALTERNATE TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COST

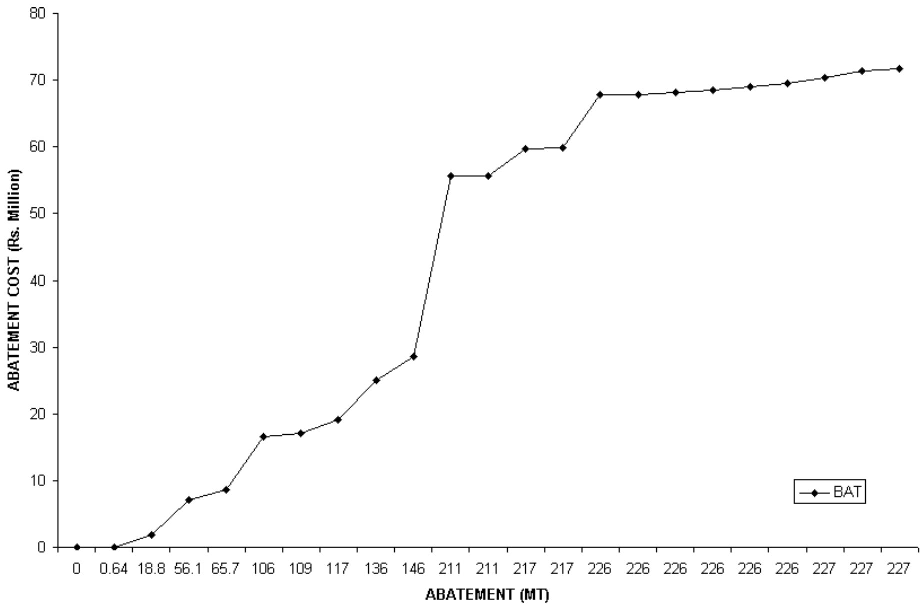

FIGURE 8.9: ABATEMENT COST CURVE OF BATs IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

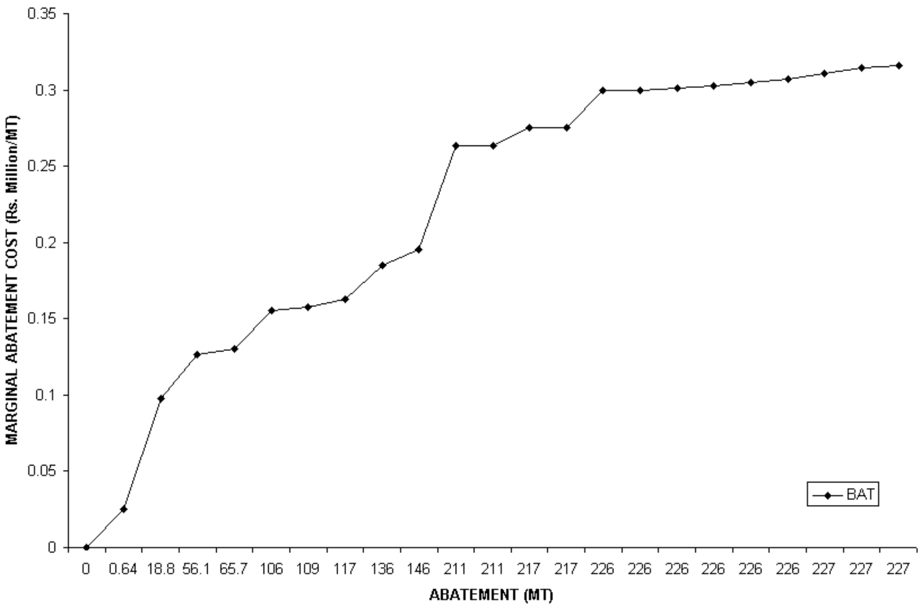

FIGURE 8.10: MARGINAL ABATEMENT COST CURVE OF BATs IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COST

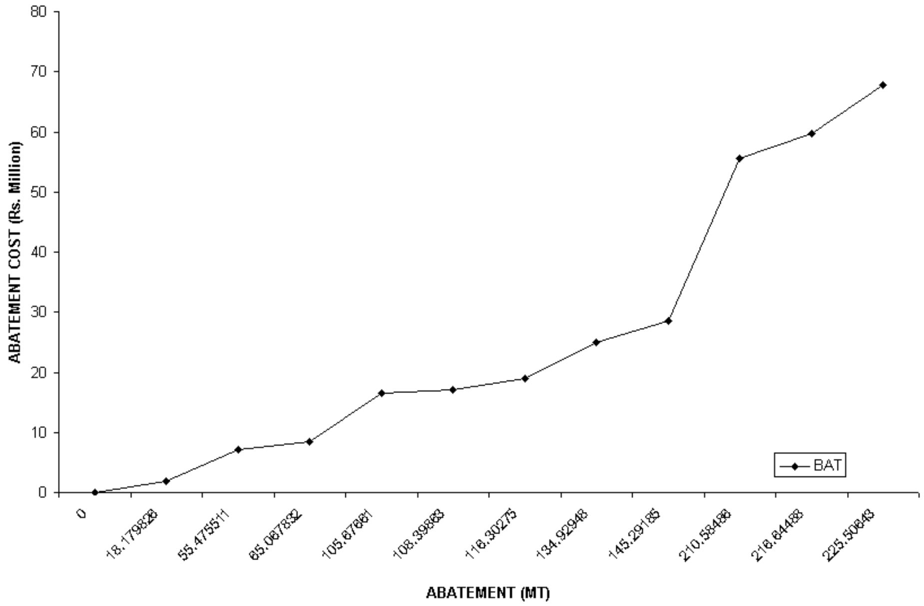

FIGURE 8.11: ABATEMENT COST CURVE OF BATs IN TISCO WITHOUT CONSIDERING CAPITAL COST

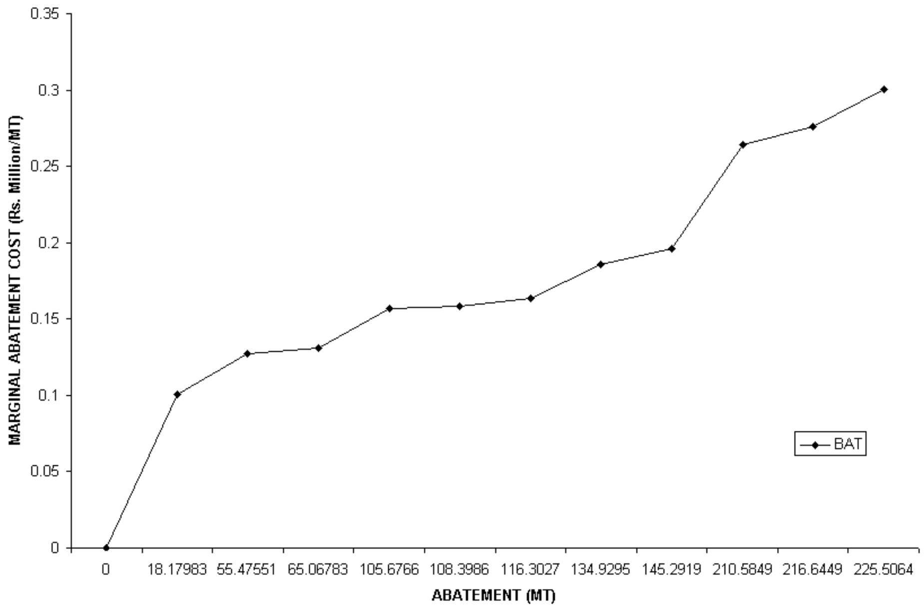

FIGURE 8.12: MARGINAL ABATEMENT COST CURVE OF BATs IN TISCO WITHOUT CONSIDERING CAPITAL COST

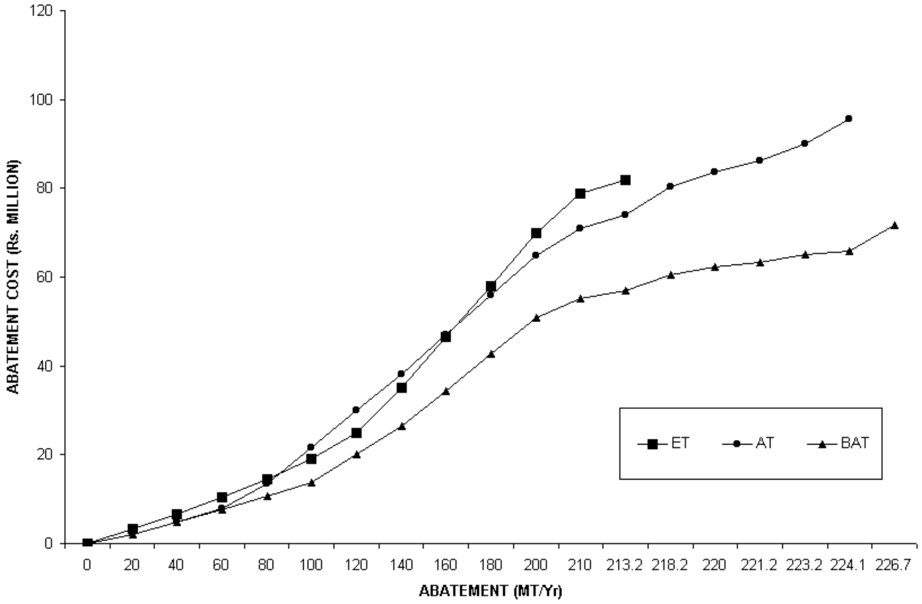

FIGURE 8.13: COMPARISON OF ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COSTS

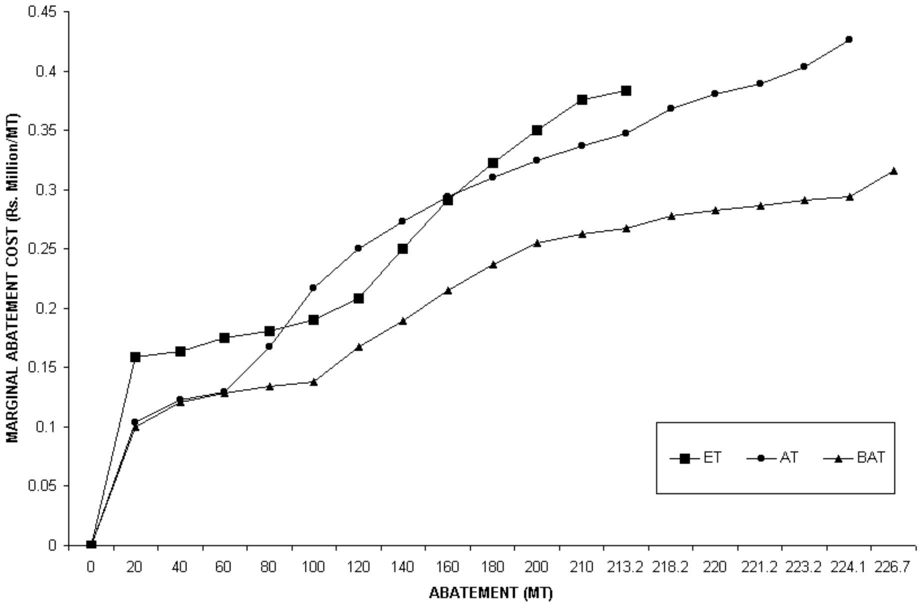

FIGURE 8.14: COMPARISON OF MARGINAL ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN ALL COMPANIES WITHOUT CONSIDERING CAPITAL COSTS

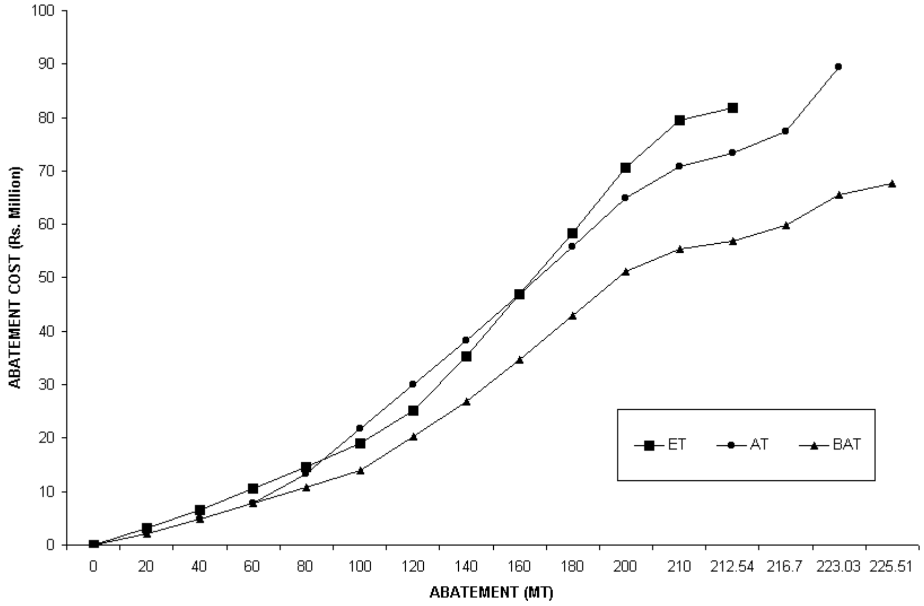

FIGURE 8.15: COMPARISON OF ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COSTS

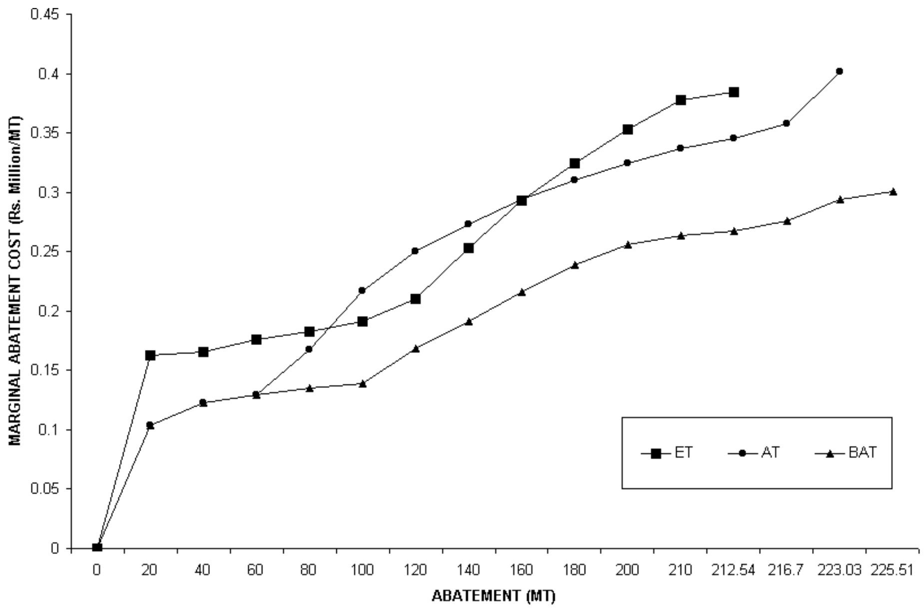

FIGURE 8.16: COMPARISON OF MARGINAL ABATEMENT COSTS OF ALL SETS OF TECHNOLOGIES IN TISCO WITHOUT CONSIDERING CAPITAL COSTS

8.2 Development of Market Based Instruments:

The current situation in all selected companies is as follows:

Emission of SPM before Treatment	: 230.46 MT p.a.
Abatement	: 213.22 MT p.a.
Net Emissions after Treatment	: 17.24 MT p.a.
Abatement cost	: Rs. 346.26 millions

The abatement cost curves or marginal cost curves developed in section 8.1 are used to calculate abatement cost for desired level of abatements with alternate / best available technologies at different sources without taking into consideration the capital costs of the devices.

Two market-based instruments, bubble and offset, are evaluated as follows:

8.2.1 Environmental bubble:

The present net annual emission of SPM 17.24 MT is considered as limit of the bubble. To achieve this amount of net annual emission the companies are to abate 213.22 MT SPM. The associated operating cost with existing technologies in all companies comes out Rs. 81.80 millions (Figure 8.1). The associate operating cost for this abatement with alternate technologies is calculated as Rs. 74.07 millions from Figure 8.5. The same level of abatement with best available technologies can be achieved with an operating cost of Rs. 56.95 millions only (Figure 8.9). Therefore, it is clear that the operating cost of Rs. 7.73 millions and Rs. 24.85 millions can be saved in making same amount of abatement using alternate and best available technologies respectively. The results can be summarized as follows:

Bubble's limit of SPM emissions: 17.24 MT

To keep the bubble's limit same the target annual SPM abatement = 213.22 MT

Abatement costs (operating) to achieve the annual target of SPM abatement by all companies:

(i) with existing abatement measures:	Rs. 81.80 millions (under CAC)
(ii) with alternate abatement measures:	Rs. 74.07 millions
(iii) with best available technologies:	Rs. 56.95 millions

Abatement costs (operating) to achieve the annual target of SPM abatement by Tisco alone:

(i) with existing abatement measures: not possible

(ii) with alternate abatement measures: Rs. 74.07 millions

(iii) with best available technologies: Rs. 57.38 millions

The operating costs to make the required SPM abatements with alternate technologies in all the companies (including Tisco) and Tisco alone are same. It is because the alternate technologies for Tisco are considered in both cases due to their less operating cost (Figures 8.5 and 8.7). The operating cost for per unit abatement with alternate technologies is less in Tisco than the other companies. All other companies can abate 1.068 MT SPM at the operating cost of Rs. 5.97 millions. It is much more than the Tisco. Therefore, it is better for other companies to buy required emissions from Tisco.

The operating cost for making an abatement of 213.22 MT with best available technologies is slightly higher in case of Tisco than all companies. It is due to the fact that Tata Pigments is using Bag Filters with least operating cost but its capacity is 643 tpa only (Figure 8.9). While operating cost of TCIL is also less than some units of Tisco but again its capacity is only 50 tpa (Figure 8.9). These two companies are not in position to abate more, hence they will not be able to earn ERCs. Therefore, in case of best available technologies these two companies should be allowed to make their own abatements while other companies can purchase ERCs from Tisco.

In both the cases Tisco is the only company in the selected group that can earn ERCs.

8.2.2 Emission offsets:

Offsets of 5 and 8 MT can be designed by making annual SPM abatement of 218.22, and 221.22 respectively. Tisco is the only company in the sample that can make additional abatements of required quantities. Therefore, Tisco was considered to make required abatements for the offsets. The associated additional operating costs are calculated for required offsets and summarized as follows:

Offset (MT)	Additional Operating Cost with Alternate Technologies (Rs. Millions)	Additional Operating Cost with BATs (Rs. Millions)
5	6.30	3.61
8	12.01	6.32

For any expansion or new activity in the region Tisco can be consulted for ERCs / offsets.

9. DEVELOPMENT OF MARKET BASED INSTRUMENTS USING LINEAR PROGRAMMING MODEL

The companies do abatements of SPM as per their requirement of emissions allowed by the pollution control board. The current situation in all selected companies is as follows:

Emission of SPM before Treatment	: 230.46 MT p.a.
Abatement	: 213.22 MT p.a.
Abatement cost	: Rs. 346.26 Millions
Net Emissions after Treatment	: 17.24 MT p.a.

Optimum abatement schedule can be calculated using following linear programming model described in section 5:

$$\text{Minimize } Z = \sum_j C_{ij}\, r_{ij} \quad \text{....(9.1)}$$

Subject to:

$$r_{ij} \le \frac{E_{ij}}{100} * e_{bij} \quad \text{....(9.2)}$$

$$\sum_j (e_{bij} - r_{ij}) = \sum_j e_{ij} \quad \text{....(9.3)}$$

$$r_{ij} \ge 0$$

No MBIs were developed for NOx because non-availability of required data. Two market based instruments-bubble and offset-were evaluated as follows:

9.1 Development of Environmental Bubble:

In the current situation all selected companies make 17.24 MT annual SPM emissions. An environmental bubble with its limit equal to current emissions 17.24 MT can be developed. Required SPM abatement can be evaluated for bubble's emissions limit. The proposed model 9.1 can be used to evaluate optimum abatements at different locations for desired level of abatement. Unit abatement costs (Cij), where i=SPM, can be calculated from total cost / operating cost and abatement data for alternate and best available technologies at different locations.

9.1.1 With alternate abatement technologies:

SPM emissions before treatment are calculated from Table 6.3 and per unit abatement costs (with capital cost and without capital cost) are evaluated from Table 6.4. Cost and efficiency of selected alternate abatement technologies are given in Table 9.1.

Table 9.1: Cost and Efficiency of Alternate Abatement Technologies

Comp-any	Location (j)	Abatement Device	Efficiency (%) E_{ij}	SPM Emissions (TPA) Before Treat-ment e_{bij}	Per Unit Abatement Cost (Rs. ,000/T) C_{ij}	
					With Capital Cost	Without Capital Cost
TISCO	1.Boiler House	ESP (T)	99.9	18198.02	0.281183	0.100386
TISCO	2.LD#2 Secondary Emission	ESP (B)	99.9	37333.02	0.493446	0.140928
TISCO	3.Sintering Plant 2 Waste Gas	ESP (B)	99.9	9601.924	0.494859	0.152205
TISCO	4.Sintering Plant 1 Waste Gas	ESP (B)	99.9	3402.524	0.732597	0.268452
TISCO	5.Coke Oven Waste Gas Stack	Scrubber (B)	80	12952.97	0.969005	0.334624
TISCO	6.Power House#3	ESP (B)	99.9	65358.36	-	0.414233
TISCO	7.Power House#4	ESP (B)	99.9	40812.84	-	0.442239
TISCO	6.Power House#3	ESP (T)	99.9	65358.36	1.26833	-
TISCO	7.Power House#4	ESP (T)	99.9	40812.84	1.354083	-
TISCO	8.Sintering Plant 2 Dedusting Unit	Bag Filter (B)	99.9	18664.06	0.556015	0.450245
TISCO	9.Sintering Plant 1 Dedusting Unit	Bag Filter (T)	99.9	6066.09	0.868029	0.683619
TISCO	10.Blast Furnace Stove Chiminey	Scrubber (B)	80	8870.42	3.015238	0.977265
TISCO	11.Refractory Material	Scrubber B)	80	7912.032	3.149229	1.902956
Tata Pigments	12.Calciner and Roasting Furnace	Scrubber (T)	80	643.3344	4.703118	2.659484
TCIL	13.Boiler	Bag Filter (T)	99.9	62.5464	4.346556	3.504905
Telco	14.Wartshilla DG-3	Scrubber (B)	80	75.37937	8.232922	6.052717
Telco	15.Wartshilla DG-1	Scrubber (B)	80	70.93647	8.05354	6.431811
Telco	16.Forge Stack # 5	Bag Filter (B)	99.9	81.13512	8.376812	6.754757
Telco	17.Forge Stack # 11	Bag Filter (B)	99.9	63.04029	8.625007	6.954893
Telco	18.TP-15 Themopac Boiler	Scrubber (T)	80	114.6676	18.54648	9.94723
Telco	19.Forge Stack # 9	Scrubber (T)	80	103.9328	23.62454	10.97464
Telco	20.Wartshilla DG-2	Scrubber (B)	80	35.7846	15.96468	12.7499
Telco	21.Nilgata DG	Scrubber (B)	80	29.17776	21.26936	15.63691
Tata Rayerson	22.Hot Water Generator	Scrubber (T)	80	4.080408	-	33.54444
Tata Rayerson	22.Hot Water Generator	Scrubber (B)	80	4.080408	87.46638	-

The alternate technology for each emission source was selected from all possible measures on the basis of its per unit abatement cost (Table 6.4). The selections are made on the basis on per unit total abatement cost that includes capital cost and on the basis of operating cost only. There are three sources, power house # 3, power house # 4 (both at Tisco) and hot water generator (Tata Rayerson), where different abatement measure are selected on the basis of selection criterion.

The proposed model uses the information given in Table 9.1 to find out optimum abatement at different emitting sources using capital cost and not using capital cost. The TORA package was used to run the model. The results obtained for the bubble are given in Table 9.2.

Table 9.2: Optimum Abatements for the Bubble with Alternate Technologies at Different Locations

Company	Location (j)	Optimum Abatement (tpa) r_{ij}	
		With Total Cost	**With Operating Cost**
Abatement Cost (Rs. Million)		**205.34**	**74.07**
TISCO	1.Boiler House	18179.80	18179.80
TISCO	2.LD#2 Secondary Emission	37295.70	37295.70
TISCO	3.Sintering Plant 2 Waste Gas	9592.32	9592.32
TISCO	4.Sintering Plant 1 Waste Gas	3399.12	3399.12
TISCO	5.Coke Oven Waste Gas Stack	10362.40	10362.40
TISCO	6.Power House#3	65293	65293
TISCO	7.Power House#4	40772	40772
TISCO	8.Sintering Plant 2 Dedusting Unit	18645.4	18645.4
TISCO	9.Sintering Plant 1 Dedusting Unit	6060.02	6060.02
TISCO	10.Blast Furnace Stove Chiminey	3616.24	3616.24
TISCO	11.Refractory Material	0.00	0.00
TCIL	12.Calciner and Roasting Furnace	0.00	0.00
Tata Pigments	13.Boiler	0.00	0.00
Telco	14.Wartshilla DG-3	0.00	0.00
Telco	15.Wartshilla DG-1	0.00	0.00
Telco	16.Forge Stack # 5	0.00	0.00
Telco	17.Forge Stack # 11	0.00	0.00
Telco	18.TP-15 Themopac Boiler	0.00	0.00
Telco	19.Forge Stack # 9	0.00	0.00
Telco	20.Wartshilla DG-2	0.00	0.00
Telco	21.Nilgata DG	0.00	0.00
Tata Rayerson	22.Hot Water Generator	0.00	0.00
Total Abatement		**213216**	**213216**

Table 9.2 indicates that optimum abatements are same at all the emitting sources in both the cases. All optimum abatements are at Tisco only. As per current situation Tisco abates 212.54 MT SPM under CAC with cost of Rs. 345.92 millions (including capital cost) or Rs. 81.72 millions (operating cost). For the Bubble Tisco abates 213.22 MT of SPM with abatement cost of Rs. 205.34 millions (with capital cost) or Rs. 74.07 millions (without capital cost). There is lot of cost saving also. The additional abatement made by Tisco can be rewarded as ERCs to Tisco and which can be sold in the market to other companies.

9.1.2 Abatement with Best Available Technologies:

The model 9.1 can calculate optimum abatements to meet required abatement of 213.22 MT for the bubble's limit. The cost and efficiency data of the BATs have been calculated and listed in Table 9.3.

Table 9.3: Cost and Efficiency of Best Available Technologies (BATs)

Company	Location (j)	Abatement Device	Efficiency (%) E_{ij}	SPM Emissions (TPA) Before Treat-ment e_{bij}	Per Unit Abatement Cost (Rs. ,000/T) C_{ij}	
					With Capital Cost	Without Capital Cost
TISCO	1. Boiler House	ESP (T)	99.9	18198.02	0.281183	0.100386
TISCO	2. LD#2 Secondary Emission	ESP (B)	99.9	37333.02	0.493446	0.140928
TISCO	3. Sintering Plant 2 Waste Gas	ESP (B)	99.9	9601.924	0.494859	0.152205
TISCO	4. Sintering Plant 2 Dedusting Unit	Bag Filter (B)	99.9	18664.06	0.556015	-
TISCO	4. Sintering Plant 2 Dedusting Unit	ET-ESP	99.8	18664.06	-	0.322118
TISCO	5. Sintering Plant 1 Waste Gas	ET-MC	80	3402.524	0.3124	0.220425
TISCO	6. Sintering Plant 1 Dedusting Unit	Bag Filter (T)	99.9	6066.09	0.868029	0.683619
TISCO	7. Coke Oven Waste Gas Stack	Scrubber (B)	80	12952.97	0.969005	0.334624
TISCO	8. Power House#3	ESP (T)	99.9	65358.36	1.26833	-
TISCO	8. Power House#3	ESP (B)	99.9	65358.36	-	0.414233
TISCO	9. Power House#4	ET-ESP	99.5	40812.84	0.846048	0.197002
TISCO	10. Blast Furnace Stove Chiminey	Scrubber (B)	80	8870.42	3.015238	-
TISCO	10. Blast Furnace Stove Chiminey	ET-ESP	99.9	8870.42	-	0.902777
TISCO	11. Refractory Material	ET-Bag Filter	99.9	7912.032	1.051322	0.242911
TCIL	12. Boiler	ET-Cyclone	80	62.5464	2.772909	0.639525
Tata Pigments	13. Calciner and Roasting Furnace	ET-BF	99.9	643.3344	0.11495	0.024895

Telco	14. Wartshilla DG-1	Scrubber (B)	80	70.93647	8.05354	6.431811
Telco	15. Wartshilla DG-3	Scrubber (B)	80	75.37937	8.232922	6.052717
Telco	16. Forge Stack # 5	Bag Filter (B)	99.9	81.13512	8.376812	6.754757
Telco	17. Forge Stack # 11	Bag Filter (B)	99.9	63.04029	8.625007	6.954893
Telco	18. Wartshilla DG-2	ET-Cyclone	80	35.7846	3.597665	0.838349
Telco	19. TP-15 Themopac Boiler	Scrubber (T)	80	114.6676	18.54648	9.94723
Telco	20. Nilgata DG	Scrubber (B)	80	29.17776	21.26936	15.63691
Telco	21. Forge Stack # 9	Scrubber (T)	80	103.9328	23.62454	10.97464
Tata Rayerson	22. Hot Water Generator	ET-Scrubber	80	4.080408	10.51553	2.450735

The model equations (9.1, 9.2 & 9.3) are developed with data given in Table 9.3. The model is solved with TORA package. The location-wise optimum abatements are listed in Table 9.4.

Table 9.4: Optimum Abatements with Best Available Technologies in all Selected Companies

Company	**Location (j)**	**Optimum Abatement (tpa) r_{ij}**	
		With Capital Cost	**Without Capital Cost**
Abatement Cost (Rs. Million)		**175.14**	**56.94**
TISCO	1. Boiler House	18179.80	18179.80
TISCO	2. LD#2 Secondary Emission	37295.70	37295.70
TISCO	3. Sintering Plant 2 Waste Gas	9592.32	9592.32
TISCO	4. Sintering Plant 2 Dedusting Unit	18645.40	18645.40
TISCO	5. Sintering Plant 1 Waste Gas	2722.02	2722.02
TISCO	6. Sintering Plant 1 Dedusting Unit	6060.02	1919.72
TISCO	7. Coke Oven Waste Gas Stack	10362.40	10362.40
TISCO	8. Power House#3	61202.73	65293
TISCO	9. Power House#4	40608.80	40608.80
TISCO	10. Blast Furnace Stove Chiminey	0.00	0.00
TISCO	11. Refractory Material	7904.12	7904.12
TCIL	12. Boiler	0.00	50.03
Tata Pigments	13. Calciner and Roasting Furnace	642.69	642.69
Telco	14. Wartshilla DG-1	0.00	0.00
Telco	15. Wartshilla DG-3	0.00	0.00
Telco	16. Forge Stack # 5	0.00	0.00
Telco	17. Forge Stack # 11	0.00	0.00
Telco	18. Wartshilla DG-2	0.00	0.00
Telco	19. TP-15 Themopac Boiler	0.00	0.00
Telco	20. Nilgata DG	0.00	0.00
Telco	21. Forge Stack # 9	0.00	0.00
Tata Rayerson	22. Hot Water Generator	0.00	0.00
Total Abatement		**213216**	**213216**

Table 9.4 reveals that the most of the optimum abatements are at Tisco only. Tata Pigments is the company that has cost effective abatement device but it cannot

reduce more therefore, it can be allowed to make their abatements. TCIL has less per unit operating cost, hence, its abatement is optimum under operating cost (without capital cost) category. But if we see total cost including capital cost then its abatement is not optimum. Anyhow, the company is not in position to abate more, therefore, it cannot be considered as candidate to ERCs. Tisco is the only company that has capability to reduce more and at less cost.

The annual abatement costs with BATs are much less than existing / alternate technologies. The cost saving is an intensive to the companies to adopt the bubble policy.

9.2 Development of Emission Offsets:

The offsets of 5 MT and 8 MT of SPM abatements have been evaluated with alternate and best available technologies. For offsets of 5MT / 8MT total annual abatements would be 218.22 MT and 221.22 respectively. It is clear from section 9.1 that further abatement is possible with Tisco only. Therefore, for the proposed offsets Tisco will make the required abatements and earn ERCs.

9.2.1 With alternate abatement technologies:

The model results show that the optimum abatements, in addition to the required for the bubble, for developing an offset of 5MT would take place at Blast Furnace and Refractory Material units of Tisco. The refractory material unit of Tisco will abate more for the offset of 8MT. The abatements are same under both the cases of cost considerations.

The offsets of 5/8 MT will cost Rs. 15.28 / 24.73 millions more respectively, with annualised capital cost of the devices.

The operating costs for offsets of 5 MT and 8 MT will increase by Rs. 6.29 millions and Rs. 12 millions respectively.

9.2.2 With best available technologies:

The model results show that the optimum additional abatements for creating 5 MT offset will take place at power house # 3 (4090.3 T) and blast furnace (8859.7 T) of Tisco and boiler of TCIL (50 T). The total additional cost for this offset would be Rs. 7.92 millions, considering capital cost of the devices. For 8 MT offset further optimum abatement of 3 MT will take place at blast furnace of Tisco with additional cost of Rs. 9.05 millions. Total abatement cost for 8 MT offset would be Rs. 16.97 millions.

If we consider only operating costs of the devices to evaluate optimum abatements for creating 5 and 8 MT offsets, then the model results indicate as follows:

Additional abatements for 5 MT offset at sintering plant (4040.3 T) and blast furnace (831 T) of Tisco and Wartsilla DG 2 of Telco (28.7 T) with total additional cost of Rs. 3.6 millions. . For 8 MT offset further optimum abatement of 3 MT will take place at blast furnace of Tisco with additional cost of Rs. 2.71 millions. Total abatement cost for 8 MT offset would be Rs. 6.31millions.

The significant cost effective SPM abatements for creating offsets will be available with Tisco only.

10. RESULTS AND DISCUSSION

It is revealed from the collected data that more than 99% emissions (before treatment) of SPM and NOx are being made by Tisco alone in a group of five selected companies. There is no NOx abatement measure present in any selected company. The cost and efficiency data for abatement of NOx collected from suppliers of the technologies are not sufficient for making cost curves. Therefore no further study has been done for abatement of NOx.

The existing situation from all selected companies is as follows:

Emission of SPM before Treatment	: 230.46 MT p.a.
Emission of SPM after Treatment	: 17.24 MT p.a.
Abatement	: 213.22 MT p.a.
Abatement cost	: Rs. 346.26 Millions

Abatement cost curves (with and without capital costs) are drawn for all existing, alternate and best available technologies.

10.1 Environmental Bubble:

A. An environmental bubble was developed with its limit of 17.24 MT (existing emissions) and total abatement costs were calculated from cost curves with alternate and best available technologies. The costs are as follows:

Total abatement costs to achieve the annual target of SPM abatement (213.22 MT) by all companies:

(i) with existing abatement measures:	Rs. 346.26 millions (under CAC)
(ii) with alternate abatement measures:	Rs. 231.75 millions
(iii) with best available technologies:	Rs. 177.43 millions

Abatement costs to achieve the annual target of SPM abatement by Tisco alone:

(i) with existing abatement measures:	not possible as per installed abatement capacity
(ii) with alternate abatement measures:	Rs. 223.34 millions
(iii) with best available technologies:	Rs. 176.42 millions

It shows that best available technologies can do much better for saving abatement cost in making same amount of abatement. The cost saving is approximately 50% which is a good intensive for trading the abatements under bubble policy. Tisco alone can make required abatements for the bubble and it will cost Rs. 176.42 millions with BATs. It shows that there is no need to make the abatements by other companies except Tisco for maintaining the bubble's limit because it can do it with less cost. Additional abatements made by the Tisco can be rewarded to Tisco as ERCs and later these ERCs can be sold / used.

B. The similar analysis was also carried out with all three sets of the technologies without considering capital costs of the devices, only operating costs have been taken into account. The operating costs for the bubble of 17.24 MT emissions are as follows:

Abatement costs (operating) to achieve the annual target of SPM abatement (213.22 MT) by all companies:

(i) with existing abatement measures:	Rs. 81.80 millions (under CAC)
(ii) with alternate abatement measures:	Rs. 74.07 millions
(iii) with best available technologies:	Rs. 56.95 millions

Abatement costs (operating) to achieve the annual target of SPM abatement by Tisco alone:

(i) with existing abatement measures:	not possible as per installed abatement capacity
(ii) with alternate abatement measures:	Rs. 74.07 millions
(iii) with best available technologies:	Rs. 57.38 millions

In both cases – with and without capital cost – the abatements costs are much lower for the same bubble’s limit with best available technologies. Tisco is the only company in the group that can abate more SPM even at less cost.

There are only two companies, Tata Pigments and TCIL, have less operating costs (not total abatement costs) for unit abatement. However these companies are not in position to make more abatement. If the environmental bubble is developed on the basis of only operating costs then these two companies and Tisco will make the required abatement for the bubble. Tata Pigments and TCIL will not be able earn any ERC. Tisco will earn ERCs for its additional abatement.

If we consider capital cost also in calculating abatement costs then Tisco is the only company that can make required abatement with least cost with BATs. In this case Tisco will earn more ERCs for its additional abatement.

In both the cases ERCs can be earned by Tisco only. These ERCs can be purchased by other companies for them abatement is cost intensive.

An environmental bubble with its limit of 17.24 MT is developed and required net abatements for the bubble are calculated. The model results are compared for the net abatements of 213.22 MT and mentioned in table 10.1.

Table 10.1: Comparative Abatement Costs for the Bubble

Abatement Technologies	Abatement Cost (Rs. Millions)			
	Including capital cost	Saving %	Excluding Capital Cost	Saving %
Existing or under CAC	346.26	-	81.80	-
Alternate	205.34	40.70	74.07	9.45
Best Available	175.14	49.42	56.94	30.39

The cost saving is much more with BATs. Therefore, it suggests that if inter-firm trading is introduced the companies will focus towards cost effective measures i.e. BATs. These measures are also capable to abate more SPM emissions and the companies would try to abate more SPM with BATs and earn ERCs. As Tisco is the only company in the selected group that can abate more with less cost. Therefore, emission reduction credits will be earned by Tisco and other companies for them SPM abatement is cost intensive can purchase those credits from Tisco.

10.2 Emission Offsets:

The offsets of 5 and 8 MT of SPM load were created and total / additional costs were calculated from cost curves and LP model. The total cost includes the bubble cost and the offset cost same abatement technologies. The results are compared in Table 10.2.

Table 10.2: Comparison of Costs for the Offsets

Offset Quantity	Total / Additional Cost With Alternate Technologies (Rs. Millions)				Total / Additional Cost With Best Available Technologies (Rs. Millions)			
	Including Capital Cost		Excluding Capital Cost		Including Capital Cost		Excluding Capital Cost	
	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model	Using Cost Curves	Using LP Model
5 MT	238.09 / 6.34	220.62 / 15.28	80.37 / 6.30	80.36 / 6.29	183.72 / 7.30	183.06 / 7.92	60.56 / 3.61	60.54 / 3.60
8 MT	241.90 / 10.15	230.07 / 24.73	86.08 / 12.01	86.07 / 12.00	192.76 / 16.34	192.11 / 16.97	63.27 / 6.32	63.25 / 6.31

The cost saving is much more with best available technologies for both offsets. The required abatements for the offsets are made by Tisco only in almost all the cases. Therefore, the Tisco can be allowed to earn the credits and other cost intensive companies can purchase these credits from Tisco.

10.3 Conclusion:

The results show that there are huge cost savings in reducing the emissions with best available technologies. The cost saving is a good incentive to attract the players to adopt emission trading scheme.

The proposed LP model gives more cost effective schedules for required abatements in all the cases. The development of the model for the bubble and offset is also simple and takes less time in comparison to the development of abatement cost curves. It shows that the LP model can effectively be used for such calculations.

The effective emission trading activity can take place only among the equivalent players. It is really not present in the selected group because Tisco is the only major player in the group / Jamshedpur. Hence Tisco may dominate and monopoly can take place in long run and that would not be good for the proposed inter-firm trading.

But for getting an experience the pilot emission reduction trading (PERT) can be introduced at Jamshedpur among the local companies.

Tisco alone has 11 emitting sources with good quantity of emissions. Each emitting source can be considered as a single player in the intra-firm trading. Even we will not have large number of players to decide the market price of the ERCs, but intra-firm emission reduction trading within Tisco can improve its abatements with less cost. Therefore, intra-firm trading within Tisco can be experienced.

11. POLICY RECOMMENDATIONS

As noted from the baseline environmental conditions, a number of locations that are densely populated have very high ambient SPM concentrations in the air. Hence it is pertinent to chart ways of reducing the total SPM emissions into the air. But this has to be achieved at a minimal cost. Two types of emission reduction trading schemes are recommended:

1. Inter-firm Emission Reduction Trading:

TISCO is responsible for more than 90% of the SPM emissions in the Jamshedpur region, and also has low cost options of reducing further the SPM emissions. Available technologies, players and their roles severely restrict an emission trading market system to operate.

We recommend, in this specific circumstance, that all the major industries in the region may be asked (by the Pollution Control Board) to reduce their emissions by 5% below the consented (in the consent to operate and establish under Air Act) SPM emission levels. They could be given two options, for complying with the additional SPM emission reductions:

1. Reduce the emissions at their own site
2. Procure Certified Emission Reduction

The industries can be allowed to bid for emission reductions based on validated proposals- baseline being the present emission permits (in the consent to operate and establish under Air Act) only. Validated emission reduction proposals can be registered and based on monitoring of emission reductions, annually, the Certified Emission Reductions can be granted. These certified emission reductions could be the basis for assessing the compliance by the industries, of the additional 5%reduction.

The institutional mechanism to implement these additional emission reductions could be led by the voluntary association of Industries or a citizens/stakeholders forum to improve the Environment in Jamshedpur. This forum could establish a registry, designating validating and monitoring entities. The operational framework could be similar to that of Emission Trading under Kyoto Protocol.

2. Intra-firm Emission Reduction Trading within Tisco:

Tisco alone has 11 emitting sources with good quantity of emissions. Total SPM emission load (before treatment) from Tisco is 229.17 MT p.a. Tisco also has separate environmental division to take care of all environment related problems. The validating and monitoring activities for emission reduction certificates will not have much extra financial burden on Tisco. A good competition can be established among the emitting sources of the company, if each emitting source is considered as an independent unit. Even we will not have large number of players to decide the market price of the ERCs, but intra-firm emission reduction trading within Tisco can improve its abatements with less cost. Therefore, intra-firm trading within Tisco is recommended for getting an experience.

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