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ANALYSIS

Economic and environmental impacts of pollution control regulation on small industries: a case study

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Abstract

Adoption of technology for abatement of pollution and improved production process is almost mandatory now in the industrial sector for protecting the global environment. Various environmental regulations are being implemented in the industries in the third world. However, the small-scale industry components of the industrial sectors, which contribute significantly to total pollution, are yet to adopt such abatement technology on a wide scale. High initial investment cost for abatement technology has been a crucial reason in this regard. Under that circumstances, the early adopters of abatement technology gained an advantage in the competitive market by increasing their net return per unit of production for being able to calculate correctly the actual benefits of such investment. The non-adopters who lacked such knowledge lost out in the competition. The present paper tries to investigate the impact of air pollution control regulation on secondary lead smelting industry in the unorganized sector in two urban wards within the city of Kolkata in India. The results showed that the units after adopting the abatement technology were able to receive positive net return from the additional investment on control device and also benefited the society and the environment at large. The total economic value consisting of all these benefits has been found to be highly significant. Thus, the result is instructive for the non-adopters and may encourage them to adopt the abatement technology for themselves as well.

Keywords: Environmental regulation; Small-scale industry; Abatement technology and Secondary lead smelting units

1. Introduction

During the last few years, the awareness of people for the protection of environment in society has been gradually increasing. Various types of pressure groups are acting in defense of the environment. The governments are also promoting more and more regulations to protect the environment and the community in general.

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To control the emission from production processes, air quality regulations lay down stringent equipment specifications that are required to be implemented by the polluting industries. The adoption of production and abatement technology is mandatory now with respect to global environmental problems. However, while relevant technology and control equipment may be developed and available for use, the important question is whether they may be adopted or by-passed by the firm. Obviously, the decision to adopt is largely determined by a proper assessment or comparison of costs and benefits of such devices. From the regulatory authority's point of view the installation of pollution control devices would be beneficial to the environment in and around the production premises and to overall society welfare. On the other hand, the two alternative courses of action before the firm, namely, the decision to produce by regulating emissions and to opt for closure of operations are influenced by an assessment of the comparative costs and benefits of these alternative options. One thus realises that the objective function of the regulator and regulated, so far as air pollution abatement is concerned, may not necessarily converge. While social planners are more concerned with the overall social welfare, the private firms' investment decisions with respect to the adoption of the abatement technology are guided by their own profit maximization motives.

Under the present liberalized regime and the transition of the industrial sector towards greater market orientation, the future growth prospects of the small-scale industrial sector (SSI) appear to be bright (Hussain, 1997; Planning Commission, 1996). With subcontracting emerging to be an important strategy of large multinationals under the economic reforms (Janardhan, 1997; Ramaswamy, 1999), productive activities are expected to gravitate towards the small and the unorganized sector in the third world.

However, in the literature on development and environment, one finds emphasis on two controversial characteristics of small-scale enterprises. On the one hand, from the point of view of sustainable development, small industries are valued in developing countries (Schumacher, 1989). On the other hand, from the environment point of view, since they add to the pollution problem, they are considered to be relatively hazardous (Dasgupta et al., 1998). One thus faces a dilemma in this respect. It is here that the search of the policy makers is towards the development of appropriate pollution control technology specific to the type of industry, such that the conflicting situation may not persist. The development and availability of such technology are now a growing reality. While a number of units in the small unorganized sector have been able to adopt such abatement devices, many others have failed to install them. Operating with unskilled labour, under highly competitive unregulated market, the willingness and ability to control the level of pollution effectively have generally been found to be missing here. It is possible that the actual knowledge about the economic feasibility, social and environmental effects of such abatement technology may be difficult to acquire or calculate on their part. Lastly, the mobilization of necessary finances for setting up of control devices is not easy for these units. It is but natural that they tend to overlook the prospective opportunities that emerge from such technologies and regulations.

This paper deals with an exercise on the Cost–Benefit approach (Dasgupta and Pearce, 1972; Little and Mirless, 1968; Mishan, 1972; UNIDO, 1972) for calculating the total economic value, consisting of private, social and environmental net benefits, of the impact of environmental regulation applying to the Secondary Lead Smelting units of the unorganized small-scale enterprise. In developed countries concerted efforts in implementing stringent environmental regulations along with high labour cost have led to the closure of many smelting activities. On the other hand the secondary lead smelting units in the unorganized sector, called backyard smelters, in the developing countries are playing a significant role in the total supply of lead. While Secondary Lead smelting units play significant role in recycling of hazardous wastes generated in battery industry, at the same time, on account of their emission of flue gas and dust, they are a source of air pollution of hazardous nature and recognized as 'red category' or 'most hazardous' industry. The unregulated activities in these units not only expose the workers to lead, being located close to residential areas, but also pose an exceptional health hazard to children and adults living nearby. In recent years, a number of secondary lead smelting units, being located within or in close proximity to residential areas, have been subjected to much community pressure for improved environmental programmes (Pargal and Wheeler, 1996). Such pressures are in addition to the stringent regulations for adopting pollution control device that has been introduced by the regulatory authority, the Pollution Control Board.[1] This study also helps to identify the relevant factors that may be crucial in explaining the flexibility and viability of technology adoption. On the basis of a case study of the few firms, which have been able to install the abatement device, it will be instructive to understand the constraints that may operate with respect to the other firms which are yet to install the technology for air pollution abatement.

The paper has been organized as follows. The next section is devoted to a detailed discussion about the data set and methodology that has been used in the study. The analysis of the data is reported in Section 3. Conclusions have been presented in the final section.

2. Data and methodology

The purpose of the control device is to clean and de-dust the flue gas containing chemical components and hazardous lead dust particles that are generated in the process of the smelting operation, before it is released to the atmosphere. A diagram of the production process and controlling systems has been shown inAppendix A. A production device is a furnace, locally known as 'vatti', where the lead wastes are melted and flue gas and dust are generated. These flue gas and dust are trapped in the control device with the help of an ID fan (induced draught fan) and pass through (i) a cyclone/impact separator,[2] (ii) bag filter and (iii) a scrubber. While cyclone/impact separators are designed for the collection of bigger sized particles, bag filters in the bag house arrest almost all the remaining particles from the dust and allow only almost cleaned gas with finer particles to pass through. At the final stage a scrubber collects the finer particles and cleans the other gaseous components and allows cleaned air to be emitted in the atmosphere through chimney. The dust collected from the control devices being charged with leaden matter is recycled for further use.

The use of this device has two sides, it creates values and it imposes costs. To a producer in a smelting unit the investment for the installation of any abatement technology along with its operation and maintenance cost is an additional one over and above the cost of production, which is already being incurred. On the other hand, benefit may be obtained from the use of device in two ways: by reducing the necessary energy for the use of improved furnace for operating the device, it saves the consumption of fuel; and by reusing the dust collected with the help of control device, it reduces the waste generated in the process of production. A profit maximizing producer or private investor takes the investment decision regarding control technology by taking into account the net profit at the margin. From his point of view, it is the cost involved and the profit generated that are crucial variables in determining the choice of control technology.

On the other hand, a social planner or policy maker is interested more in the social cost and benefits of any action i.e. the cost a society bears and the benefits accruing from the relevant activity. The ultimate objective should be to maximize the social welfare associated with any action. As it is related to the social welfare problem, the adoption of any abatement technology may not be successful unless it is acceptable to the polluters and sufferers. The use of a controlling device, instead, may help society by offering a clean environment. As a result, the productivity of human beings may increase through a reduction in loss of mandays due to the health hazards that unclean technology creates. The benefit of this increased productivity of human beings would be enjoyed also by the producers. In addition, the production of the controlling device and its related accessories may generate more employment.

The evaluation of costs incurred by and benefits obtained from the adoption of a controlling measure with respect to engineering and technological specifi-

[1] At present the stack emissions from lead smelting units would not exceed 10 mg/NM^3 for lead and $50 mg/Nm^3$ for suspended particulate matters (Rajagopalan, 2001).

[2] Though in the total controlling system both of them serve the same purpose, their design and construction materials are different. A cyclone separator, which is a traditional system, is made out of metal. But an impact separator is a concrete structure and has a longer life, so relatively cheaper, compared to a cyclone separator. But it was a newly developed system and only one unit introduced it at the time of survey.

cations is simple because the goods are marketed goods. But the evaluation of social and environmental costs and benefit cannot be done easily due to the fact that most of them are non-marketed goods. Various indirect methods are used for estimation of such benefits.

The cost–benefit analysis of decision making to evaluate the efficiency of the adopted technology attempted by us was based on both primary and secondary information. The selected study area covered two municipal wards in the city of Kolkata in India. The controlling authority here, the West Bengal Pollution Control Board(WBPCB), has played a proactive role by providing domestically developed technology, which was simpler, relatively cheaper and more suitable to such small units, to implement the air pollution control regulation. The data were collected from many sources namely from the owners themselves, the workers of such units, WBPCB and the producer of the device. In the pre-regulation period about 50 secondary lead smelting units had been operating within the study area. The area was sparsely populated at that time. Smelting operations could be done without any control device causing pollution by emission of smoke containing huge amounts of lead particles. With the influx of population the area was gradually converted into residential-cum-factory area. At the beginning, pressurized by local residents, they started their operation at night. But that could not be accepted by WBPCB as a solution to the pollution problem. The stringent regulation imposed by the regulatory authority, combined with objections by local people, all units were forced to shut down operations for not having pollution abatement devices. Ultimately after the provision of control technology by WBPCB only 12 units were able to install the pollution control devices successfully. The remaining units either closed down or shifted to areas on the fringes of the city which were not within easy reach of the regulatory authority. The primary data were collected by conducting a survey on those 12 units.

As has been mentioned earlier, due to the very small size of the secondary lead smelting units of unorganized sector, a well maintained and compiled data set was difficult to come by. Records regarding the production system, output produced, inputs used, the cost and price figures from all the producers were not available to the extent desirable.[3]

The required information regarding production levels, inputs used, emission levels etc., for the respective units, however, was obtained from the reports submitted to the WBPCB. In order to enrich the data set, since no single source of data was considered sufficient for the analysis, further information was collected from technologists, scientists, engineers, local people, doctors as also from other records, reports and books and were supplemented for the study.

3. Measurement of costs and benefits

3.1. Financial aspects

The availability of production permits per unit from the regulatory authority is subject to the adoption of air pollution control equipment for ensuring the maintenance of prescribed regulatory standard of emitted air. The units cannot also operate violating the restriction as neighbouring population force them to shut down by activating the regulatory authority. Therefore, the options open to them are either adoption of air pollution control technology or closing of the units. Even then some illegal operations are done at night in the fringe areas of the city where there are less community pressures. The owners are compelled to bear the sunk costs due to the decisions of closing down of units. On the other hand, positive net returns may be achieved, even though marginally, by operating a unit illegally for one shift without control device or for two or three shifts with device. Therefore, the decision to invest in abatement technology would be determined by comparing the net returns from these two alternatives. But in estimating the net returns in both the cases the limitation of the study is the non-availability of information about the level of expenditure, revenue earned and other such data from the non-adopter units or earlier data from

[3] Though the questionnaire was prepared to enquire about all such information, ultimately that questionnaire could not be followed strictly. Instead, based on that questionnaire the information has been collected through discussion with entrepreneurs.

adopter units. Thus, it is the additional revenue derived as a result of additional expenditure incurred on account of the installation of a control device in the adopter units, that has been sought to be compared, instead of comparing the net returns obtained 'before' and 'after' the installation of abatement device. Any positive value of this net return in the post-device situation may be considered as an advantage for the adoption of control device.

As a complete series of information is not available, both expenditure and revenue for the adoption of control device have been sought to be estimated by taking a number of alternative values. Table 1 depicts the range of values for each of the variables that have been collected from different sources. The following assumptions have been made on the basis of primary and secondary sources of information.

(i) As the oldest device has been operating for the past 6 years since 1994, without any major shortcoming, then except for some unnatural causes, it may be expected to run another few years in its present condition. The expected life of the device may be assumed to be at least 10 years.

(ii) The costs of electricity, bags, etc. are directly related to the volume of production and the total hours of operation. Though the consumption of electricity increases with the hours of operation, the cost of replacement per bag decreases with the increase in number of shifts operated. For the estimation of total cost, it is assumed that if the unit runs only one shift, only one time replacement of bags is necessary in a year. However, if the unit runs either two or three shifts, the bags are required to be replaced twice a year.[4]

(iii) Being small sized firms they have to borrow money from the imperfect private capital markets and pay high rate of interest relative to the bank or government rate of interest.

(iv) As no additional labour is required for operating the device, additional expenditures on labour use is assumed to be zero here.

(v) The quantity of dust collected also varies due to the difference in the quality of inputs. The average quantities taken here are 23 kg and 40 kg for two kinds of inputs, respectively.

(vi) According to one experiment, the gas that comes out from the furnace at the entry point of the device contains suspended particulate matters (SPM) on an average 19,000 mg/NM^3 where the amount of lead is 7000 mg/NM^3 i.e., the proportion of lead in dust is about 37%.[5] In another study by the WBPCB in 1996, it was shown that at the entry point of the device the air contained SPM of about 12,000 mg/NM^3 SPM in which lead was 6240.02 mg/NM^3, indicating that the proportion of lead comprised about 50% of the total dust. This can now be collected through the device—a major part of which comes out at the end of the bag house and the remaining part becomes deposited in the

Table 1
Financial and other information of the secondary lead smelting units

Item of information	Values[a]		
	Maximum	Minimum	Average
(1)	(2)	(3)	(4)
Cost of air pollution control device (Rs. Lakh[b])	2.5	2.0	2.25
Cost of civil construction works (Rs. Lakh)	–	–	0.60
Cost of maintenance (yearly) (Rs. Lakh)	0.15	0.25	0.20
Number of filter bags used	36	24	–
Price of raw materials (Rs./kg.)			
(i) Battery scrap	20	14	17
(ii) Slag containing 25–30% lead	8	–	8
Price of coal (Rs./kg)	6	4	5
Price of Bag (Rs./bag)	225	175	200
Price of lead ingot (Rs./kg)	36	30	33
Collection of dust from bag house (kg./kg of raw material)			
(i) Output/input ratio—25%	0.045	0.035	0.040
(ii) Output/input ratio—30%	0.027	0.019	0.023

Source: Reports from WBPCB, Survey data.

[a] Number of units surveyed is 12 in total which are located within Calcutta city area and have adopted air pollution control device. All prices are at 1999 price level.

[b] 10 lakhs=1 million.

[4] The per unit price of electricity for industrial units is considered as Rupees.3 (an Indian currency), which is charged by the supplying authority. The number of bags is taken as 28, which is the standard number in such a unit.

[5] The level of SPM, released in the air in post-device period, is between 3–13 μg/NM^3 in which amount of lead is maximum 0.02–1.2 μg/NM^3. These are far below the permissible ranges.

Table 2

Estimated revenue–cost ratio (R/C ratio), internal rate of return (IRR) and pay back period (at 1999 price level) for a given level of investment and rate of recovery of dust in a unit operating one shift

Investment (Rs. Lakh)	Recovery rate of dust/kg of input (kg)	Rate of interest (%)	Maintenance cost/year (Rs. Lakh)	Price of charcoal					
				Rs. 4.5 per kg			Rs. 5.0 per kg		
				R/C ratio	IRR	Pay back period (years)	R/C ratio	IRR	Pay back period (years)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rate of discount=10%									
A. Level of investment—Rs.4.0 lakhs and rate of recovery of dust—0.023 kg per kg of raw materials									
4.0	0.023	12	0.15	0.82			0.87		
			0.20	0.79			0.84		
			0.25	0.77			0.81		
B. Level of investment—Rs. 4.0 lakh and rate of recovery of dust—0.040 kg per kg of raw materials									
4.0	0.040	12	0.15	1.09	0.16	6	1.14	0.19	6
			0.20	1.05	0.14	6	1.10	0.17	6
			0.25	1.02	0.11	7	1.07	0.14	6
C. Level of investment—Rs.4.5 lakh and rate of recovery—0.023 kg per kg of raw materials									
4.5	0.023	12	0.15	0.75			0.80		
			0.20	0.73			0.77		
			0.25	0.71			0.75		
D. Level of investment—Rs. 4.5 lakh and rate of recovery—0.040 kg per kg of raw materials									
4.5	0.040	12	0.15	1.00	0.09	7	1.04	0.13	7
			0.20	0.97	0.07	8	1.02	0.11	7
			0.25	0.94	0.05	8	0.98	0.09	8

Source: Estimation.

sedimentation tank used for the cleaning of gas, from where it may again be re-used as input. This study has used 30% lead recovery rate in general as shown in Chatterjee et al., 1998.

(vii) The fuel used in this production is charcoal obtained by burning wood. As regards charcoal it was found that its price, as reported in the primary data collected from the different units under consideration, varies from Rupees(Rs.)[6] 4/kg to Rs. 6/kg depending on its quality. In order to be able to estimate the value of the charcoal saved, on account of the introduction of the device, two alternative average values of charcoal, Rs. 4.5/kg and Rs. 5.0/kg, were assumed.

(viii) If the input, the lead waste, contains 60–70% of lead, the price per kg of input may vary from Rs. 16 to Rs. 20. But in case of the 25–30% recovery rate, the price comes down to Rs. 8/kg. The price of dust which is not a marketed product, may be considered at Rs 8/kg when it contains lead around 30% of the total dust, which may be reused in the production process.

The estimation of additional cost and revenue realised by a firm of a given size has been done for different alternative values of fixed costs, maintenance cost, number of shifts operated, rate of interest and rate of recovery of dust. All the costs and revenues have been estimated at the 1999 price level.

It was mentioned earlier that previously the secondary lead smelting units were operated at night. But the installation of the device now enables them to operate during 24 h a day. However, the results show that after the introduction of the devices the

[6] Rupees is an Indian currency. The exchange value of $1 is about Rs.47.0.

running of the units in only one shift, i.e., for 6 to 7 h per day using only 1 MT of lead waste for 300 days per year does not appear to be economically viable if a sufficient amount of dust is not being recovered (see Table 2). On the other hand, the increase in the amount of dust makes, though marginally, the net return positive. But it is evident that the operation of the units only for two shifts per day (around 6–7 h with 1 MT of lead waste per shift) and on an average of a total of 300 days per year generates quite a significant amount of additional revenue over the additional expenditure for the device as a result of collection of more dust. The internal rate of return is also significantly high. The pay back period could be achieved within a few years just after the installation of the machine (see Table 3). Hence, the amount of dust collected through the control device, which would save the purchase of raw material, is a crucial factor in achieving the positive net return from this additional investment. Operation of three shifts per day, thus, will be more profitable to the unit. It has been mentioned earlier that the dust collected from the bag house is not the total amount that is collected by the controlling system. A part is deposited in the sedimentation tank. Therefore, the use of the total amount of dust collected from the bag house and sedimentation tank may earn a positive return even by running one shift per day.

In general the recycling industry is constrained by the lack of guaranteed demand and lack of assured supply of waste. But there is a demand for lead for its various uses and more than about 50% of total lead supplied in the market come from the secondary lead smelting units. Operation of two shifts under such a situation should be possible. However, belonging to the unorganized sector and being small in size they do not have control over the input market. Under such circumstances the expected return may not be realised fully. Provided there exists an assured supply of

Table 3
Estimated revenue–cost ratio (R/C ratio), internal rate of return (IRR) and pay back period (at 1999 price level) for a given level of investment and rate of recovery of dust in a unit operating two shifts

Investment (Rs. Lakh)	Recovery rate of dust/kg of input (kg)	Rate of interest (%)	Maintenance cost/year (Rs. Lakh)	Price of charcoal					
				Rs. 4.5 per kg			Rs. 5.0 per kg		
				R/C ratio	IRR	Pay back period (years)	R/C ratio	IRR	Pay back period (years)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rate of discount=10%									
A. Level of investment—Rs.4.0 lakhs and rate of recovery of dust—0.023 kg per kg of raw materials									
4.0	0.023	12	0.15	1.38	0.44	4	1.46	0.52	3
			0.20	1.34	0.41	4	1.42	0.49	3
			0.25	1.30	0.38	4	1.38	0.46	4
B. Level of investment—Rs.4.0 and rate of recovery of dust—0.040 kg per kg of raw materials									
4.0	0.40	12	0.15	1.83	1.05	2	1.92	1.22	2
			0.20	1.74	1.00	2	1.86	1.15	2
			0.25	1.74	0.94	3	1.82	1.10	2
C. Level of investment—Rs.4.5 and rate of recovery of dust—0.023 kg per kg of raw materials									
4.5	0.023	12	0.15	1.28	0.33	4	1.36	0.40	4
			0.20	1.25	0.31	4	1.29	0.38	4
			0.25	1.22	0.28	5	1.29	0.35	4
D. Level of investment—Rs.4.5 and rate of recovery of dust—0.040 kg per kg of raw materials									
4.5	0.040	12	0.15	1.71	0.79	3	1.78	0.90	3
			0.20	1.66	0.75	3	1.74	0.86	3
			0.25	1.62	0.72	3	1.69	0.82	3

Source: Estimation.

Table 4
Estimated break-even point achieved by the firm operating two shifts

Investment (Rs. Lakh)	Rate of increase of (%)		Price of charcoal											
			Rs.4.5 per kg						Rs.5.0 per kg					
			Rate of interest per year						Rate of interest per year					
	O&M cost	Return obtained	12%		13%		15%		12%		13%		15%	
			Discount rate (%)		Discount rate (%)		Discount rate (%)		Discount rate (%)		Discount rate (%)		Discount rate (%)	
			10	12	10	12	10	12	10	12	10	12	10	12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
A. Rate of recovery of dust—0.023 kg per kg of raw materials														
4.0	0	0	3.67	3.77	3.82	3.93	4.16	4.30	3.20	3.27	3.31	3.39	3.56	3.66
	0	5	3.25	3.32	3.35	3.43	3.57	3.65	2.91	2.96	2.99	3.05	3.16	3.23
	0	10	2.99	3.04	3.06	3.12	3.22	3.28	2.71	2.75	2.77	2.82	2.91	2.95
	5	0	3.87	3.99	4.05	4.18	4.46	4.64	3.32	3.40	3.45	3.54	3.74	3.85
	5	5	3.36	3.44	3.47	3.55	3.71	3.80	2.98	3.04	3.07	3.13	3.26	3.33
	5	10	3.06	3.11	3.14	3.19	3.31	3.37	2.76	2.80	2.83	2.87	2.97	3.02
	10	0	4.15	4.31	4.38	4.57	4.99	5.27	3.47	3.57	3.62	3.73	3.98	4.12
	10	5	3.49	3.58	3.61	3.71	3.89	4.00	3.07	3.13	3.16	3.23	3.37	3.45
	10	10	3.14	3.20	3.22	3.29	3.41	3.48	2.82	2.86	2.89	2.94	3.04	3.10
4.5	0	0	4.51	4.68	4.73	4.93	5.26	5.52	3.88	4.00	4.05	4.18	4.43	4.59
	0	5	3.83	3.93	3.96	4.07	4.25	4.38	3.41	3.39	3.52	3.61	3.76	3.85
	0	10	3.44	3.51	3.53	3.61	3.73	3.82	3.12	3.18	3.20	3.26	3.37	3.44
	5	0	4.87	5.09	5.17	5.43	5.92	6.31	4.09	4.23	4.29	4.45	4.77	4.98
	5	5	3.99	4.11	4.14	4.27	4.48	4.63	3.52	3.16	3.64	3.74	3.90	4.01
	5	10	3.53	3.61	3.64	3.72	3.86	3.95	3.19	3.25	3.28	3.34	3.46	3.53
	10	0	5.52	5.90	6.06	6.59	8.33	–	4.39	4.58	4.66	4.88	5.36	5.70
	10	5	4.20	4.34	4.38	4.53	4.79	4.98	3.66	3.76	3.79	3.90	4.10	4.23
	10	10	3.65	3.74	3.76	3.86	4.01	4.11	3.27	3.34	3.86	3.44	3.56	3.65
B. Rate of recovery of dust—0.040 kg per kg of raw materials														
4.0	0	0	2.04	2.06	2.09	2.11	2.18	2.21	1.89	1.90	1.93	1.94	2.01	2.03
	0	5	1.96	1.98	2.00	2.02	2.08	2.10	1.83	1.84	1.86	1.88	1.93	1.95
	0	10	1.90	1.91	1.93	1.95	2.00	2.02	1.78	1.79	1.81	1.82	1.87	1.88
	5	0	2.06	2.08	2.11	2.13	2.21	2.24	1.90	1.92	1.94	1.96	2.03	2.05
	5	5	1.98	2.00	2.02	2.04	2.10	2.12	1.84	1.85	1.87	1.89	1.95	1.96
	5	10	1.91	1.93	1.95	1.96	2.02	2.04	1.79	1.80	1.82	1.83	1.88	1.90
	10	0	2.09	2.11	2.13	2.16	2.24	2.27	1.92	1.94	1.96	1.98	2.05	2.07
	10	5	2.00	2.02	2.04	2.06	2.12	2.15	1.85	1.87	1.89	1.90	1.96	1.98
	10	10	1.93	1.94	1.96	1.98	2.04	2.06	1.80	1.81	1.83	1.84	1.89	1.91
4.5	0	0	2.40	2.44	2.47	2.50	2.60	2.64	2.22	2.24	2.27	2.30	2.38	2.41
	0	5	2.28	2.30	2.33	2.36	2.44	2.47	2.12	2.14	2.16	2.18	2.25	2.28
	0	10	2.18	2.20	2.22	2.25	2.31	2.34	2.04	2.06	2.08	2.10	2.16	2.18
	5	0	2.44	2.48	2.51	2.54	2.65	2.69	2.24	2.27	2.30	2.33	2.42	2.45
	5	5	2.30	2.33	2.36	2.39	2.47	2.50	2.14	2.16	2.18	2.21	2.28	2.31
	5	10	2.20	2.22	2.24	2.27	2.34	2.37	2.05	2.07	2.09	2.11	2.18	2.20
	10	0	2.48	2.52	2.55	2.59	2.70	2.75	2.27	2.30	2.33	2.36	2.45	2.49
	10	5	2.33	2.36	2.39	2.42	2.51	2.54	2.16	2.18	2.21	2.23	2.31	2.33
	10	10	2.22	2.25	2.27	2.29	2.36	2.39	2.07	2.09	2.11	2.13	2.20	2.22

Source: Estimation.

secondary lead waste, the results then show that the introduction of the device, which involves excess expenditures, is financially gainful from the producer's point of view.

Table 4 depicts the values of the break-even point, on which the firm's investment decision depends, for alternative values of investment costs, price of charcoal, rate of interest, rate of recovery of dust and different levels of operation and maintenance costs and return obtained (for different levels of input prices) for operating two shifts per day. It is observed from the table that two factors, (i) rate of investment cost and (ii) rate of dust collection, appear to be crucial for reaching the break-even point earlier. In a given situation the break-even period would be reduced further for operation of three shifts per day. Therefore, from the private owner's point of view operation of his unit for one shift without control device is less profitable than the operation of only two shifts with device due to a positive net return from the additional investment.

3.2. Environmental aspects

The air pollution due to the emission from these units which contains considerable amounts of lead in SPM and some gaseous components has serious negative impacts on human health and various economic goods and services both in and outside the production place. The external effects lead to the reduction of productivity of human resources and also of natural resources and impose important economic and social costs on the society.

Hence, along with a comparison of financial benefits and costs achieved due to the introduction of such pollution control measures, the evaluation of health impacts is also essential for setting priority of action in this respect. The estimation of net environmental benefits quantitatively (if not possible, then qualitatively) helps the society to make more rational decisions for allocating scarce financial resources.

Lead is a very toxic element causing a variety of effects even at a low dose level. The environmental lead exposures have both short and long-term effects on human health. Most important short-term effects of lead on human health is abdominal pain, along with loss of appetite and metallic taste in the mouth, which the local residents complained of earlier. The long-term effects are renal problems affecting kidney function, hypertension, effects on bone, fatigue, joint pain, anemia, reducing mental functioning, etc.

In mid-nineteenth century occupational lead poisoning was a common disorder in the United Kingdom and 1888 following the deaths of several employees in the lead industry, a parliamentary enquiry was initiated into working conditions in lead factory (Tong et al., 2000). In most highly industrialized countries, strict control and improvement in industrial methods have helped to ensure that occupational lead poisoning is less prevalent than formerly. In developing countries, however, it remains a problem of potentially huge dimension. But the absorption capacity varies among different persons, different age groups and different communities. The deposition of lead on the root, leaf, surface of the plant and water bodies in and around the production premises is responsible for toxic lead effect that causes a problem in photosynthesis, plant growth and other parameters (WHO, 1989).

The focus here may be made on the estimation of the short run impacts of lead exposure in the lead smelting industry on human health in and outside the factory premises. The study on the long-term impacts is well documented in the studies conducted in developed countries particularly in USA. It is seen from a study that the phasing out of lead in gasoline reduced significantly the number of persons affected by IQ loss, hypertension, cerebrovasculer accident, brain infraction, etc. in USA. Hungarian study also showed about 70% decline in blood lead level due to nearly 80% reduction of lead in gasoline (The Regional Environmental Centre (REC), 1998). But the study on long-term impact could not be attempted in the present study for lack of information because of their migratory nature of employment in the units. The lead dust is absorbed into the human body by inhalation and ingestion through food. It was further supported by the information recorded from the survey by interviewing an older worker in one of the 12 units who has been found to be working since the 'no-device' period and could escape from such long-run diseases, that the abdominal pain, loss of appetite, metallic tastes in the mouth–all the immediate effects of lead absorption–which were the regular health features experienced by them previously, have been reported to be totally absent in the post-device period.

One possible method of estimation of the damage to health in monetary terms of this lead-related health hazards would be to estimate the total expenditure made by the affected persons towards curing such diseases. However, due to the very nature of the employment pattern observed in these small-scale industries such estimation could not be attempted. These types of studies with respect to developing countries are also the least documented in the literature. The labourers employed in such units were mostly temporary workers, who migrated from neighbouring places. There was no practice of keeping records of illness of those workers. It has been reported that they used to work for short spans in these jobs in the pre-device period. The labourers had a practice of leaving for home periodically in a year mostly for reasons of ill health and left the job forever after maximum of 6 to 7 years. Approximately 4 months of working period in a year were lost by them. However, in the post-device period the turnover rate, the frequency of leaving jobs, had declined significantly. Due to the better work environments in the present context the labourers are willing to continue with their jobs in these units. Alternatively, an attempt has been made to estimate the value of loss of labour hours due to absenteeism in the job as a result of ill health in no-device situation, as a proxy of health impact. It is assumed that in the pre-device period a labourer lost a minimum of 2 years from his total service period of 32 years.[7] The loss of earning then, at 1999 price level, is estimated as about Rs. 937 per year at the rate of Rs. 50 per day for 300 days in a year for a labour within the tenure of his working age. Therefore, for the introduction of device in a unit employing three labourers per shift and operating two shifts per day, it is possible for the labourers to earn at least Rs. 5622.0 more per year by saving the loss of working days as a result of an improved working environment. The net present value of this flow of environmental benefit at 10% rate of discount is about Rs. 28000.0 during the life years of the device. In the post-device period it would also be considered as the additional benefit generated to the society and should be added to the social benefit obtained from the introduction of the device.

The benefits from the change in the air quality can also be realised in terms of (i) increasing productivity of labour on account of improvement in the quality of health and (ii) increased efficiency on account of being able to remain in the same occupation and unit for a greater length of his working life. These enhance the opportunities in labour market.

It was also recorded from the survey that the trees, ponds and water bodies in the neighbouring places were covered with lead inhibiting the growth of fruits and flowers in the pre-device era. The growth of fruits and flowers, the absence of any trace of lead dust on the leaves of trees, in the pond or water bodies in and outside the factory premises can be taken as an indicator of cleaner environment experienced in the post-device period. The estimation of monetary value of these improvements could not be attempted for lack of data.

The measurement of impact of controlling air pollution on the neighbouring locality would also be possible through a survey similar to the present study. But it was beyond the scope of the present study. The results of the surveys conducted on children in different developing countries including India conclude that blood lead level of significant number of children exposed to lead due to conventional and cottage lead smelters, lead mining, battery factories, lead in petrol is higher than the level prescribed by the Environmental Protection Agency (EPA). The mean blood lead level concentration among 93 randomly selected rickshaw pullers in India was 53 μg/dl compared to the normal level of ≤25 μg/dl (Tong et al., 2000). Observation from a secondary source, conducted within the study area, is instructive in this respect (WBPCB, 1996). The operations of the smelting units generated noxious fumes and dust spreading over the locality. Clothing on the roofs for drying was dirtied, dusts settled on bed and sometimes even on the foodstuff. Residents also complained of

[7] The working age of a hard working labour is assumed as 18 to 50 years.

disorder of stomach and lungs from various fumes. It is pointed out in the study that all the short-term effects of lead poisoning, commonly experienced in the pre-installation period, are found to have been removed and the positive changes and growth have been observed in the natural environment now in the post-device period. The value of the benefits enjoyed by the previously sufferers on account of the improvement in the environment can similarly be estimated in terms of the expenditure estimated for curing the related diseases and the value of production obtained from natural environment. Thus, the value of environmental gain, if estimated, in and outside the production unit together, by cleaning the adjoining environment, would be significantly high and have to be adjusted with the cost of production.

3.3. Social aspects

In estimating the benefits gained by society with respect to pollution abatement activity, the returns from investment of capital should be assigned some premium by taking into account the gains from alternative uses of this fund (Singh, 1994). Instead of adopting a control device a firm may invest on other equipment but at the cost of the existing smelting unit. The sunk cost due to the closure of the unit may obviously be higher compared to the gain from alternative use of fund. On the other hand, the net financial return from investment on control device has been found to be positive. This may be the prime consideration to a smelting firm while taking the decision to invest on a control device. But in addition society gains a cleaner environment from this investment, which increases the productivity of human beings as well as the natural world.

The social benefits obtained from this project in particular, are manifold. As discussed above, the clean environment due to the reduction of dust, which was initially released in the air, has increased the productivity of human beings by reducing the loss of mandays for improved health as well as of nature by growing fruits and flowers.

Another significant benefit of the introduction of pollution control measure obtained by the society is the creation of new activity in the form of the domestically produced pollution control devices. This new activity is obvious in providing job opportunities to society, not only in these producing units, but also in the production of components such as bags and other spare parts and as also in maintenance related activities by locally trained people. In a developing country with high levels of unemployment, the opportunity cost of labour may be taken to be zero. Then, the income earned through employment, in such new activities, is obviously an addition to the national income. From a single unit operating two shifts per day, society can earn Rs.31200.0 per year or discounted total income about Rs. 2.0 lakhs[8] over 10 years period in the first round only by rendering maintenance services and producing bags.[9]

3.4. Total economic value

Total economic value of the impact of lead pollution control regulations is then the sum of the net return obtained at the firm level for investing money on abatement technologies, net environmental benefits achieved as a result of pollution free air and net social benefits for generating employment opportunities for the manufacture and maintenance of pollution control equipment. The results show that a private investor may save money by reducing the consumption of energy and purchase of inputs over and above the net profit from output sale. The present value of this saved money at 10% rate of discount by operating two shifts in a day for 300 days in a year by a single producer over the life of the machine (10 years in this case) varies from Rs. 3.0 lakhs to Rs.9.0 lakhs depending on the cost of investment, rate of interest paid on the fund borrowed, price of charcoal and rate of recovery of dust. In addition present value of the benefits obtained by society is the sum of Rs. 0.28 lakhs for the reduction in loss of mandays due to improved health in the said production unit and Rs.2.00 lakhs for creating new job opportunities in

[8] 1 lakh is equivalent to 0.1 million.

[9] It has been assumed here that the yearly earnings are Rs. 20,000.0 and Rs.11,200.0 from providing maintenance services and from selling of bags, respectively.

the field of production of control equipment and bags and maintenance services over that 10 years period. Hence, the total economic value would at lest be Rs. 5.28 lakhs. It should be noted that the benefits gained by the workers from the improvement in working environment and the benefits from the improvement in natural environment could not be quantified and added to this. The adoption of control devices by neighbouring firms would help the society in generating more benefits from cleaner environment.

4. Summary and conclusion

At the beginning of this decade the sole regulatory measure that was adopted by the pollution control authority of West Bengal (WBPCB) was to stop the production of lead by the secondary lead smelting units as this production entailed the disposal of 'hazardous substance' which were polluting the environment. However, the policy makers realised that the recycling of hazardous wastes which these Secondary Lead Smelting units could undertake and the consequent recovery of lead on their part, which was an important intermediate input for various productive activities, should not be ignored. Hence, the WBPCB, with the help of the scientists developed an air pollution control device, which might be installed by these units. Hence, as against 'closure option', there was now before the firms, another alternative, namely, the adoption of such control device.

However, what was puzzling was that, despite this available alternative, there appeared to be few takers. In other words, while many firms chose the closure option, only a few opted for the control device that had been developed. Why were there such a few takers? The plausible explanations might be many. One of the reasons was that they were compelled to adopt the control device due to stringent regulation and pressure from localities and were forced to close their units for higher initial cost of the device. Another possible explanation was that the market for lead smelting, used by those smelting units, had not been expanding fast enough. As demand was near stagnant levels the adopters of control devices have been able to use the opportunities to extend the scale of their operations by increasing the number of shifts and thus they achieved higher rates of returns. The non-adopters on the other hand, not being able to estimate the benefits of controlling device, failed to compete with the adopters by operating only one shift illegally (if possible) and were edged out. In this study an attempt has been made in estimating the net benefits achieved by the units and society at large, from the adoption of control device, even though it involves additional installation costs.

The necessary information to carryout such a study has been collected from different secondary sources, primary source which was done through survey of the existing units existing in two urban wards within Kolkata city that adopted the technology.

A cost–benefit method was applied to the data collected for the comparison of costs incurred for and the benefits obtained from the installation of the control device from economic, social and environmental points of view to study the appropriateness of the investment in this regard.

It has been observed from the analysis of the results that as against confining the production only to the night shift, which was the practice earlier, the use of the device has enabled the secondary lead smelting units to operate these factories throughout the day or to utilize their full productive capacity to meet the existing demand for their products. The lack of assured supply of inputs would be the only constraint in this respect. The results show that to a private investor the amount of dust collected is a crucial factor to determine the level of net return obtained from the installation of the device. It is further observed that if dust is collected properly, then for all combination of costs and prices, each of the units may be operated profitably even if it runs one shift only. However, it will be highly profitable if the units run two shifts per day using 1 MT of raw materials per shift for 300 days per year. These findings may be crucial from the point of view of other units in introducing similar investment decisions regarding the adoption of the developed technology.

Apart from the financial profitability considerations of the private investors the system involves also considerable social and environmental significance for the workers and the immediate neighbourhood surrounding these units. Therefore, efforts to increase the awareness of the owners of the respective units regarding the financial viability of technology and the judiciousness of their investment decisions relating to it are of crucial importance. For the benefit of industry from the socio-economic and environmental points of view financial assistance could also be considered.

The detailed analysis of the productivity of the device indicates that it is not only beneficial from the point of view of the private producers, but it also benefits the environment and the society at large. As against the closure option, from the society's point of view, it is beneficial to continue the productive activity, which is possible by adopting this technology. Since the initial investment costs which the firms are required to bear are quite significant, it may be useful to provide some financial assistance by way of soft loans for installation of device to these small units. As it is remunerative, there is no necessity of subsidising the cost of control device. Lastly, it is also to be mentioned that a proper maintenance of the device through regular checking of the pollution level by the regulatory authority is an important component to ensure the expected air pollution abatement results.

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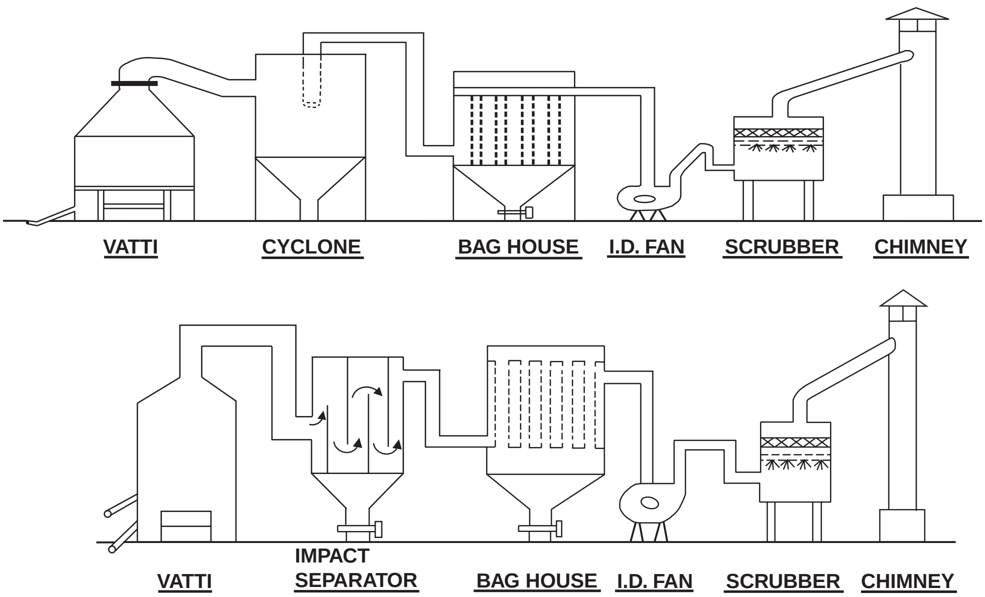
Appendix A

Diagram of the production process and control device (West Bengal Pollution Control Board, 1997).



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