AN ECONOMIC APPROACH TO MANAGE INDUSTRIAL WATER POLLUTION IN RIVER BASINS: CASE OF KELANI RIVER BASIN, SRI LANKA.

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ABSTRACT

Water pollution is the major environmental problem in industrial sector in Sri Lanka. Past experience reveals that existing regulatory mechanism based on Command-and-Control (CAC) alone has provides little incentive for industrial firms to invest in technical improvements to comply with pollution discharge standards. The need for pollution prevention through a mix of regulatory and economic policies has been identified by relevant policy formulating bodies in Sri Lanka. These policies can be implement effectively by taking a river basin as an administrative unit. The main objective of this study was to examine the applicability of economic approach in conjunction with the regulatory approach to manage industrial water pollution in Sri Lanka.

Plant level data were obtained from firms located in Kelani River basin for this analysis. Primary data on abatement costs and emission concentrations of influent and effluent for parameters of BOD, COD and TSS were collected from four industry sectors namely textile, food processing, chemical and rubber industries. Standard software was used to estimate pollution abatement cost function. Marginal Abatement Cost (MAC) function was derived from the econometric results. A pair- wise comparison was done to find out the cost effective abatement policies.

The estimated Marginal Abatement Cost was 20.00 Rs./ Kg of COD where the pollution level reaches the National Environmental Standards (NES) or pollution level abated up to 250mg of COD. This value can be used to set base values to introduce incentive based policies. A charge can be levied for each additional unit of pollution, which exceeds the NES. Otherwise, a per unit pollution tax of 28.00 Rs. can be imposed for each additional lunit of pollution that exceeds the NES. Firms with abatement costs higher than the tax *may pay the tax. The revenue generated from the charge can be directed to a pollution Control and Abatement fund, which can be utilized by firms to adopt clean technologies. The result of pair-wise comparison revealed that the cost-effective abatement cost is 51 Rs. / Kg of COD. This can also be used to set cost-effective incentive based policies. Even if this value is greater than the above-mentioned value (28.00 Rs.) it is still cost effective for firms. However, it is wise to introduce such policies to countries, which are at the initial stages of introducing such policies. This would provide reasonable time for firms to get adjusted to new policies and subsequently the charge level or tax can be raised up to cost-effective abatement level. An efficient level of abatement can be achieved by introducing such polices to manage water pollution in a river basin effectively.*

1. INTRODUCTION

During the past decades surface and ground water has deteriorated significantly in Sri Lanka, due to rapid industrial development. The chemical industry, textile, tannery, pulp and paper, food-processing plants mainly contribute to the serious water pollution problem in the cities. The Kelani river is the main supply source of drinking water for the Colombo Metropolitan region. The downstream Kelani river basin from the river mouth up to Glencorse has been identified as an environmentally sensitive area, considering the importance of maintaining the quality of water within acceptable limits (Munasinghe et. al., 2000). At certain locations in urbanized and industrialized areas, the quality of water in the Kelani river basin falls short of acceptable limits due to pollution caused by point and non-point sources. Most of the manufacturing industries are heavily concentrated in the western Province, which covers a considerable fraction of the Kelani river basin.

Most of the private sector industries are located in the Western Province, especially in areas on either side of the Kelani river, due to the availability of relatively better infrastructure facilities and proximity to the Colombo port. Most of the largest export processing zones and industrial estates in Sri Lanka, namely, Katunayake and Biyagama export processing zones and Seethawake industrial estate are also located in this river basin. Much of the effluent from industries, reach the Kelani river through city drainage systems and through natural streams.

2. RESEARCH PROBLEM

Until now, managing of the problem of water pollution is purely rely on Command and Control approach (C&C) by the government of Sri Lanka. Therefore the pollution control authority (Central Environmental Authority –CEA) has taken various proactive measures to manage industrial pollution using the existing regulatory mechanism. However past experience revealed that there are many shortcomings in the existing regulatory mechanism. At present, general standards and some industrial specific standards are used to control industrial water pollution. These standards are specified on concentration of pollutants in the effluents and are not on the pollution load. It provides a perverse incentive to dilute pollution in water so as to comply with the concentration-based standards. Therefore the total amount of industrial pollution released to the environment cannot be reduced by merely setting concentration standards. It would damage the environment when the cumulative effect of pollution exceeds the natural assimilation capacity of the environment. It also leads to excessive use of water (which is free or under-priced) to achieve these standards. Enforcing and monitoring of standards is also very difficult due to the high transaction cost involved. Moreover the government has limited funds to cover this transaction cost. Further, the EPL charge alone does not generate sufficient public finances to provide attractive incentives to industrialists to encourage adoption of clean technologies.

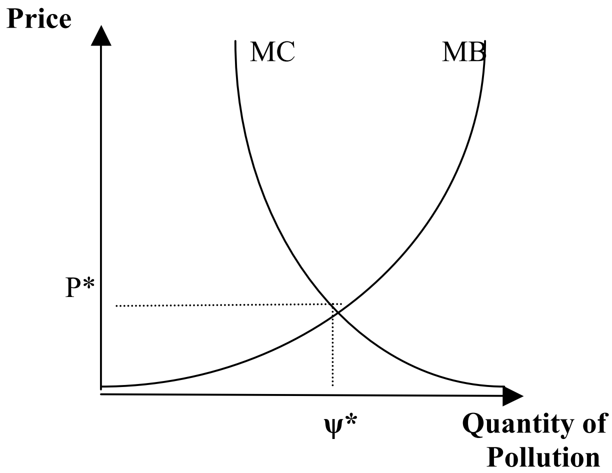
Considering above factors environmental policy making as well as industrial promotion bodies in Sri Lanka are looking for alternative efficient and cost effective policy approaches to bring solutions to the problem of water pollution. To introduce such policies, policy formulators need immense information which is still lacking in Sri Lanka. Therefore the objectives of this study as follows.

Main Objective: The main objective of the study is to introduce an economic approach that can be used in conjunction with the existing regulatory measures to manage industrial water pollution in Sri Lanka.

Specific Objectives: to estimate marginal pollution abatement cost function for industries located in the Kelani river basin; to estimate a pollution charge that could be levied on industries to achieve water quality standards specified by the government;to present other potential policy options based on economic instruments that could be used in conjunction with regulatory measures through review of literature.

3. RESEARCH METHODOLOGY

Conceptual framework



MC – Marginal Cost of Pollution Reduction
MB – Marginal Benefit of Pollution Reduction
P* - Optimal pollution charge
Ψ* - Optimal Standard

Figure 3.1Optimal level of pollution

According to the pollution abatement theory, the socially optimal level of pollution is reached where Marginal Benefit (MB) of pollution reduction equates Marginal Costs (MC) of pollution reduction at the point where Ψ* as depicted in figure 3.1 .It is the point at which the benefit of one extra unit of pollution reduction equates the costs of that extra unit of pollution reduction. In terms of environment policy, there are two ways of reaching the point Ψ* (Pearce and Turner, 1990). The level of the charge, which equates the marginal abatement cost, and the marginal damage function is referred to as the Pigovian charge. Under ideal conditions, the regulator would be able to identify precisely the marginal damage functions characterizing each and every polluter, and would impose a Pigovian charge corresponding to the optimal level of pollution or socially optimal level of pollution for each and every polluter. In Figure 3.1 optimal level of charge is at P*. the most common way is to simply set a standard that stipulates that the amount of pollution reduction is Ψ* .

Although the potential benefits of industrial pollution control are clear in theory, it is difficult to estimate in practice. However, plant -level database provide some useful information to estimate abatement costs (Dasguptha et.al, 1996). Therefore policy makers continue to consider costs. Hence, information about abatement costs would be extremely useful for the design of cost-effective regulation.

Estimation of MAC function

The estimations are based on cost estimates of end-of –pipe pollution reduction method since the study utilized direct abatement cost function.

Joint- Treatment Assumption

It is assumed that marginal abatement cost (MAC) of end-of-pipe (EOP) treatment that will be derived would apply to joint pollutant BOD and Total Suspended Solids (TSS). Different EOP technologies are capable of treating BOD and TSS jointly. For example, BOD and TSS can be reduced by approximately 75% using trickling filters. In practice, joint treatment is what is really taking place. Hence it is safe to assume that a single MAC applies for both pollutants.

To measure MAC, the study would utilize the cost function developed by Dasguptha et. al. (1996). They included the following variables in the formulation of the cost function.

[1]TAC j = f (Wj, Ej/Ij, Ms, Xj)
Where:
TACj: Total annual cost of abatement for the plant
Wj: Total annual wastewater volume

Ej/Ij: Vector of effluent/influent ratios, which can be interpreted either as concentration ratios (since waste water volume is constant across influent and effluent for each plant, it cancels out the concentration ratio).

The marginal abatement cost function is given as follows:

$$\frac{\partial C\,j}{\partial E} = \frac{\partial f\ (\ Wj,\ Ej/Ij,\ Ms,\ Xj\ )}{\partial E}$$

Dasguptha et al. have derived (1996)the following equation for direct abatement cost function, using a simple constant- elasticity (log-log) specification.

Direct Abatement Cost Function

$C = e^{\alpha 0}\ W^{\beta 1}\ [\ E/I\ ]^{\beta 2}$
Where C is the annual operating and Maintenance cost
$\alpha 0$, $\beta 1$, $\beta 2$ are parameters to be estimated.
e is the base of natural logarithm.

Marginal Abatement Coat Function

[1] Ms or vector of input prices at all location of the plant (s) was not included in the model because the study deals only with cross sectional data for firms in a small region. Xj or vector of relevant plant characteristics was also not included in the model for the same reason and for some practical difficulties in obtaining firm level data.

$$\frac{\partial C}{\partial E} = \beta_2 e^{\alpha 0} W^{\beta 1} [E/I]^{\beta 2}$$

The end-of – pipe cost data was fitted into the above cost function to derive the total cost and MAC of industries.

The point where MACs are equal across polluting sources and least-cost option can be achieved according to the equi-marginal principle of optimality.

Study area

The Kelani river is the third largest river in Sri Lanka. The "Kelani River Basin" has been declared as an environmentally sensitive area by cabinet paper No. 93/340/166 that contains Kelaniya, Kolonnawa, Biyagama, Homagama, Hanwella, Ruwanwella and Dehiovita Divisional Secretariat. The Kelani river was selected for this analysis based on the following reasons. The first is the location of the Ambathale water intake along this segment, which is the major source of supply of drinking water to the Greater Colombo area which has the highest population density in Sri Lanka. Secondly, the Kalani river basin has been declared an environmentally sensitive area by a Cabinet Paper no.93/340/166. Thirdly, most of the industries that contributed significantly to the problem of water pollution are located in this area.

Data / variables

The study utilizes the direct abatement cost function which was presented by Dasguptha et al. (1998).

Abatement cost variables;

- Effluent Abatement Expenditure (C)

Equipment Cost		
Operational Cost-	Chemicals	Rs./yr
	Energy	Rs./yr
	[2]Labor	Rs./yr
	Sludge dumping	Rs./yr

[2] Labor cost implies both skilled and unskilled labor for treatment plant operations.

- Maintenance cost
- Annual volume of waste water (F)
- Influent [3]Concentration(I_1) of BOD (mg/l) , (I_2)COD (mg/l) and (I3) TSS (T_3) (mg/l)
- Effluent Concentration of (E1) BOD (mg/l), (E2) COD (mg/l) and (E3) TSS mg/l

Annualizing of Capital Cost

The following methodology was adopted to obtain annualized capital cost. The annualized capital cost methodology assumes that the value (capital plus interest) of the facility or the end-of-pipe technology is consumed over life time in equal increments (Ebarvia,1994). The following formula was used.

$$\text{Annualized capital cost} = \frac{1}{PVA} * K = \frac{1}{\sum_{t=1}^{n} 1/(1+r)^t} * K$$

Data were collected from the following high water polluting industrial sectors which posses effluent treatment facilities such as; textile industry, rubber based industry, food processing industry, chemical industries

5. RESULTS AND DISCUSSION

5.1 The Abatement Cost Function

The results are shown below with estimates and coefficients of the Cobb-Douglas form. In this log-linear model, all the key parameters have the expected signs as well asand high level of a statistical significance. The coefficients of two independent variables had positive sign as expected. The degree of fit to the data for a sample size of 24 firms is also high (Adjusted R2 = 0.58). The results suggest the economies of scale on pollution abatement, since the cost elasticity of treatment volume is approximately 0.7 and the standard error of the estimate is very small (t=0.12). The capital cost for each firm is very high compared to operational and maintenance costs. Therefore the economies of scale may be mainly due to economies in capital cost. The elasticity of total cost with respect to quantity of wastewater treated is 0.7322. The elasticity with respect to extent of abatement is 0.6713.

The estimated direct abatement cost function can be illustrated as follows.

$$C = e^{-3..916} F^{0.732} E^{0.33} I^{-0.67}$$

[3] the concentration figures are given as load based in the tested model.

As indicated in the regression analysis, I and E in principle represented whole vectors of different parameters e.i. BOD, COD and TSS. But the parameter of TSS was not significant in any regression model, fitted in this analysis.

Several regression models were estimated using Time Series Statistical Package taking effluent/influent ratios of vector of parameters mentioned above. Among those models the above mentioned model was chosen based on several criteria. First, this model had the highest R-square value (R2 = 0.58). The common parameter for both BOD and COD, namely the adjusted COD was included in this model to get a realistic abatement cost function. According to previous studies it has been suggested COD is a good proxy to measure the pollution load and some literature suggest BOD also as a good proxy (ADB, 1997).

5.2 The Marginal Cost of Abatement

The marginal cost function was derived from the direct abatement cost function. The corresponding functional form can be illustrated as follows.

$$MAC = 0.33\, e^{-3..916}\, F^{0.732}\, E^{0..33}\, I^{-0.67}$$

This function can be used to estimate the cost of reduction on effluent for a given level of flow and influent concentration. It can be observed that marginal costs are inversely related to volume of waste water since the unitary values of the coefficients of flow (F) in the cost function indicates the economies of scale. The graph corresponding to the marginal abatement cost function is depicted in figure 5.1

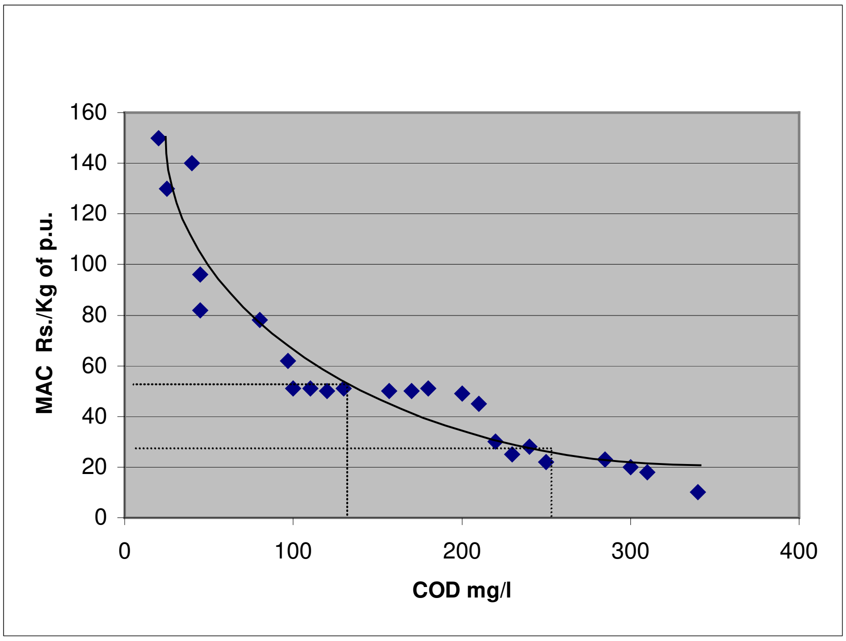


Figure 5.1 Marginal Cost Curve

It can be observed that marginal costs are inversely related to pollution load or to the volume of wastewater. It means, with the increase of abatement or, lesser the pollution remained in the effluent higher the marginal cost for achieving that amount of abatement. It is also observed that marginal cost of pollution reduction is comparatively low up to 100 kg of COD level of pollution reduction and begins to increase exponentially there on. According to this analysis, it is clear that unit cost to achieve National Environmental Standard is approximately 28.00 Rs. /Kg COD.

5.3 Cost- effective Pollution Abatement

A pair- wise comparison of MACs of each firm was done using a spreadsheet analysis to find out the point to set a policy option on the least feasible cost of abatement. It should be noted that, difficulties aroused when trying to find an exact point of equating MAC in each firm. Sample size o 24 industries would be not enough to generate such an exact figure and also it would need further information on abatement calculations such as firm characteristics etc. However, given data set permitted to find an approximate figure as an alternative to that. According to that analysis it was observed that, at a point where marginal cost of abatement equalize across several firms or nearly 36 % of total number of industries as the marginal cost of pollution reduction was 51.00 Rs. /Kg of COD. Therefore this value can be taken as the least feasible cost level, which was laid at 51 Rs./ kg of COD as mentioned in the above paragraph.

The pollution reduction target to achieve NES (ei; 250 mg of COD/l) can be taken to set any of the above-mentioned incentive based policies in conjunction with the standards where at the initial stage of introducing incentive based policies. This would allow firms to get adjusted to the new policy change within a reasonable time period. After analyzing its performance, there is chance to raise this abatement level up to the cost –effective abatement cost level since it is still cost –effective for firms. Therefore per unit of charge of pollution or per unit tax of pollution or per unit price of pollution permit can be raised to achieve cost-effective level of abatement.

6. CONCLUSION AND RECOMMENDATIONS

Market based instruments, which are several, fundamentally provides information/incentives in the form of pollution fees, pollution tax or pollution permits etc. to motivate self-regulation of pollution generation. To introduce such policies the pollution control authorities need immense information to take correct decisions at time. For any market based instrument adopted for abating pollution, the cost of abatement will play a central role in the calibration of the relevant economic instrument, be it charges, taxes, subsidies or regulated prices.

For countries that are at the initial stage of introducing incentive based policy instruments, the least-feasible cost of pollution abatement policy can be taken as a base to set various incentive based policy options depending on the effectiveness of such policies (Perman et. al. 1996). This is purely to avoid an unreasonable burden on firms that need to undergo a transitional period until it adjusts to newly introduced schemes even along with existing regulatory mechanism. The following recommendations can be made based on the findings of this study. The following policy options can be recommended based on the finding s of this study.

One option would be the introduction of a pollution charge to comply with standards. A charge can be set at 28 Rs./kg of COD for this particular river basin at the initial stage of introducing such a scheme, to achieve National Environmental Standards. Then it can be raised to 51 Rs./kg of COD, which is still cost effective to firms to abate up to that level as a cost- effective charge. Such a feasible charge would encourage most firms with treatment plants to abate up to cost-effective level of abatement. The revenue generated from these charge can be used to form a pollution control and abatement fund which can be utilized by firms to adopt clean technologies.

Another policy option would be an introduction of a tradable permit scheme to industries located in that river basin. Then the total amount of emission that can be released into the river basin can be quantified; accordingly pollution permits can be distributed among firms. The permit holder has a maximum emission level it must abide by. The innovative feature of the marketable permit is that these rights are tradable. The point where MAC equate across firms, is the equilibrium price of permits and it would be the cost effective level of abatement. Therefore the cost-effective level of abatement 51.00 Rs./Kg of COD, which is an outcome of this study, can be taken as the base for setting permit price, once a pollution target is established. However, the government has to play an important role in the allocation of initial permits, creation of secondary markets for the permits, and monitoring of compliance by firms.

Introduction of a tax subsidy scheme would be another policy option. Under this a Pigouvian tax unit of pollution starting at the cost-effective level of abatement ie. 51.00Rs/ Kg of COD would be levied on all firms, which are located in the river basin at the initial stage of introducing tax subsidy scheme. This scheme provides an opportunity to firms with low abatement costs to achieve higher environmental standards.

In conclusion a pollution tax, marketable pollution permits, and effluent charges are cost effective if these policy options are set by considering the cost-effective level of abatement. It should be noted that this study is purely for illustrative purposes on potential options to control pollution.

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