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Economic Incentives for Pollution Prevention: A Case Study of Coal Processing Industries, Dhanbad, Bihar, India

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PREFACE

The present study was undertaken to demonstrate the feasibility and cost effectiveness of formulating market based incentives for pollution prevention. The underlying purpose of the study is to illustrate the methodology and its practical application for prevention of water pollution from coal processing industries in the Dhanbad region of Bihar, India. The study is based on actual data on water quality in the region and the impacts of major polluting units. Data on pollution abatement costs however was lacking. To overcome this problem, figures for estimated costs have been used whose accuracy has not been verified. As such, the numerical results need to be treated with caution and should not in any way be taken as accurate prescriptions. This does not however detract from the major objective of the study i.e. to illustrate the method and its advantages.

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1. INTRODUCTION[1]

The Dhanbad region of Bihar in India, with a population of approximately 20 million, has historically been the premier coal mining region in India. It is also identified as one of the most polluted industrial belts in the country. Industrial activity in the region is concentrated around the Damodar river. There are at present a number of large and medium sized heavy industries in the area, including steel plants, thermal power plants, coal mines and washeries, a cement and fertilizer plant, and an explosives factory. In addition a number of small and medium sized industries including coke oven batteries and briquetting plants also operate in the area leading to air, water and soil pollution.

Air pollution in the form of suspended particulate matter, sulphur dioxide, nitrogen oxide, hydrocarbons, carbon monoxide, is caused by the three thermal power plants in the region, open cast mining, coke oven batteries, soft coke and briquette manufacturing units, steel plants, fertilizer and chemical industries. There is also extensive (mainly unauthorized) burning of coal for domestic use which contributes to extensively to the region's air pollution problems.

Water pollution in the main river Damodar is high due to effluent discharged by industries located along its banks. Suspended solids from fly ash and bottom ash are discharged into the river by the three thermal power plants. Coal washeries which discharge large quantities of coal fines, ash, shale and dirt also add to the suspended solid content of the river water. Chemical pollution in the river, in the form of ammoniacal nitrogen, phenolic waste, chemical oxygen demand, cyanide etc., is mainly from the steel plant, chemical and fertilizer units and coke oven plants. The water pollution problems are aggravated because the river water to effluent ratio decreases critically in the dry season and even effluent conforming to the prescribed standards causes severe water usage problems.

The **institutional and legal framework** for the formulation of taxes and standards is controlled by the central government authorities and the Central Pollution Control Board operating out of New Delhi. The administration of these taxes, and the monitoring and enforcement of the standards, is however done by the State and District governments.

At present there are no environmental taxes on pollution emissions. The coal pricing structure is highly regulated and subsidised resulting in overutilisation of the resource. Industry wide and general effluent and emission standards have been established. The problem however is to monitor and enforce compliance with these standards since the existing institutional mechanism is unable to effectively detect and deal with the violators.
Clearly the industrial pollution problems of the region are extremely complex and require the adoption of an integrated approach involving policy reforms, institutional changes as well as technological solutions.

The present study limits itself to addressing the water pollution problems of coal processing industries in the region i.e coal washeries and medium sized coke oven plants operating in

[1]The authors are grateful to Marcella Pavan of Fondazione ENI, and to Carlos Young and Maryanne Grieg-Gran of IIED.

the area. It will attempt to devise an innovative market based scheme that would provide an incentive for producers to stay within the effluent standards set by the Pollution Control Board, and to adopt the remedial measures that have been suggested by (various) technical studies.

A detailed survey of the status of air and water quality in the region has been undertaken and the impact of major industrial polluting units on them has been estimated (PCRI, 1991). The same survey provides information on the raw material usage, product, water consumption, quantity of effluent discharged, and air and water quality status at the major coal washeries and coke oven plants. The survey also recommends various technical and simple housekeeping remedies to be adopted by the entrepreneurs. These however, have not been implemented, mainly due to the lack of incentives and of a proper enforcement mechanism.

The present study utilises data from this survey[2] together with estimates of abatement cost structures for 11 coal washeries and 4 coke oven plants, to calculate effluent charges and effluent standards necessary to achieve target levels of discharge in the water.

2. OBJECTIVES

The objective of the study is to devise a strategy, or a set of policy instruments that would

i. lead to a reduction in the effluent discharge of total suspended solids (TSS) from the coal washeries and coke oven plants. The discharge of total dissolved solids (TDS) was found to be within the standards set by the government and was therefore not considered a problem for the concerned industries.

ii. induce these industries to innovate and adopt cleaner production and abatement technologies for treatment of total suspended solids.

[2] Data contained in Tables 1 to 8 and Graphs (appendix 1) have been taken from PCRI (1991), Report on Pollution from Coal Washeries and other Industries in Dhanbad, Bihar.

3. METHODOLOGY

Approaches

In order to devise suitable policy recommendations for achieving the objectives mentioned above, two approaches were examined: (1) abstraction charges and, (2) effluent charges and standards based on cost minimsation principles. In the final analysis the latter approach was adopted for reasons explained below. A brief description of the abstraction charge approach is also given.

A. Abstraction charges

The price of water drawn from the river was considered as an option for influencing the firms' decision about their discharge of effluent in the river. The underlying rationale is that at a certain level of treatment of effluent water, the cost of recycling this water will be less than the cost of pumping new water from the river. Given perfect competition, each firm should then treat its effluent to the level where the marginal cost of treatment will equal the water charge set at a level yielding the desired aggregate pollution abatement. Recycled water treated to a lesser degree than the desired quality used in the industrial process could therefore be mixed with the water from the river.

A policy designed according to this approach would have the additional advantage of rationalising water usage, which would be especially desirable during the dry season.

This policy would not be a novel concept for the industries in the area: they are already charged a "cess" for the use of water, although this is paid to the central government rather than to the State or District Government.

The approach was not adopted in the present study due to lack of information on the quality of water required by the industrial processes concerned and on the quantity of water abstracted.

B. Effluent charges and standards

Given our present state of knowledge about the economic costs of environmental damage, it is difficult to calculate an "optimal level" of pollution where marginal abatement costs (MAC) equal marginal benefits (MB).

A practical environmental management system is likely to revolve around effluent standards which reflect a social consensus (or technocrats' judgement) on an acceptable level of environmental quality. Even a system based on economic instruments would need to employ effluent standards to be able to gauge the effectiveness of the chosen instruments in attaining socio-economic goals.

Ideally it would be desirable to construct a marginal damage or marginal benefit curve that would determine the optimal level of abatement, in conjunction with the abatement cost curve. However since sufficient data on the health impacts of the effluents discharged was not available, the existing effluent standard for total suspended solids (TSS) has been used as a proxy for the desired level of abatement or effluent. An effluent charge for TSS was then designed that would achieve this in the most cost effective way.

This approach is not an optimality approach in the traditional sense of the term but can be used to achieve the policy objectives in a reasonably "efficient" manner. This is because under conditions of perfect competition and profit maximisation[3], the charges procedure is the <u>least cost</u> method for the achievement of specified abatement targets.

Taking aggregate abatement level to be fixed by the existing effluent standard for TSS, we then ask the question: how to achieve this in the most cost effective manner? If we were to consider only two factories with marginal abatement costs MAC1 and MAC2, then the least

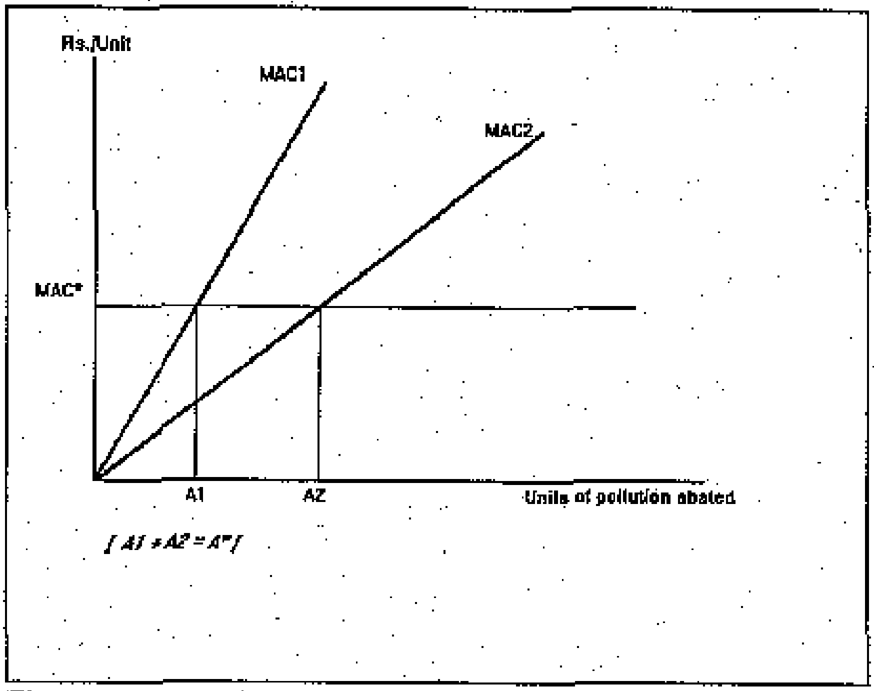

Figure 1

cost method would require allocating the aggregate abatement level between the two factories that equates their marginal abatement costs (MAC1 = MAC2). The effluent charge is then set at MAC* = MAC1 = MAC2, which equates the MAC of all firms but allows them to abate at different levels. This is represented for the two firm case in Fig.1.

The following points should be noted and considered while designing an appropriate effluent charge scheme:

i. If the charge is not set at the level MAC*, the aggregate abatement level would differ from A*. It is therefore important that the charge is set at the right level. This ofcourse depends on the assumption that the cost curves are accurately estimated. If

[3] The assumption of perfect competition is fairly realistic for coal washeries and coke oven plants in the area.

the true MAC curve is above the estimated curve then, depending on the elasticity of the marginal benefits with respect to the effluent, it may well be that a uniform standard would minimize the net loss in social surplus.

ii. The approach is useful only if the MAC across different sources are very different. In the present study it is assumed that this arises from differences in the operating and maintenance costs of treatment across firms as well as in the total quantity of waste water discharged (W_i).

Evaluation Criteria

The following criteria are used to evaluate the recommended policy mechanisms:

Does the mechanism achieve the stated goals?

Is it cost effective?

Is it administratively feasible to monitor and enforce?

Does it provide incentives for research and innovation for better pollution control and pollution prevention technologies?

- Is it publicly transparent?

The Model

The model used in the present study makes the following set of assumptions:

i. Total suspended solids is the major pollutant and is assumed to be a uniformly mixed flow pollutant.

ii. There is full information regarding the abatement technology and costs of abatement.

iii. All coal washeries and coke oven plants are making use of flocculation and sedimentation as end-of-pipe technologies for treatment of TSS and TDS. There is however considerable underutilisation of capacity evidenced by the fact that standards for TSS discharge are not being met.

iv. All firms have invested in sedimentation tanks and therefore capital costs are sunk costs and are not a decision variable for any given firm.

v. The cost function for pollution abatement is an engineering cost function which could have been derived from a well behaved production function maximised subject to input constraints for profit maximising firms. It is also assumed that the production functions for the firms differ on account of differences in the vintage of production technologies.

vi. Differences in the abatement costs of the firms are due to two factors: the quantity of waste water discharged, and, variable costs of treatment. The latter are different on account of differences in size of particles, quantity of limestone used in the flocculation process and, the volume of wet sludge.

vii. No effluent charge for TDS is considered since all firms are currently discharging well below the standard for TDS set by the Pollution Control Board (2100 mg/litre).

viii. The existing effluent standard for TSS set by the Government is 100 mg/litre.

ix. Labour costs are included in the respective components of unit abatement costs as described below.

x. The quantity of waste water discharged (W_i) by each firm i is at a level where firms cannot reduce the use of water. W_i is thus not a decision variable for the firm. Consequently the firm's decision is restricted to choosing the optimal mix between recycled water and fresh river water.

xi. The quantity of coal for the firms and industry as a whole is exogeneously determined and is taken as given.

Description of pollution abatement costs

The total abatement cost is defined as a function of various parameters that reflect inter industry differences in abatement technology for treating TDS and TSS. Table 1 provides summary data on the effluents for the 11 coal washeries and 4 coke oven plants in Dhanbad.

The abatement of TSS and TDS requires the sequential use of two main end of pipe technological processes:[4]

A. Flocculation:

If the size of the particulate matter is less than 35 microns then a flocculation treatment is applied to increase the size of the particulate. This is done to facilitate the sedimentation process in the second stage. The main operating cost of flocculation is the price and quantity of limestone (P_l and Q_l) that is added to the effluent to absorb the small particles. Capital costs for flocculation are negligible since capital equipment forms part of the sedimentation process.

Although dissolved solids do not exceed the existing standards and therefore are not a pollution problem, a by-product of the flocculation process is that it treats these as well. These "flocculated" dissolved solids (FDS) in mg/litre are defined as:

[4] The cost functions presented in this analysis are basically engineering type functions that have been worked out by the authors and would need refining and verification for further work.

$FDS_i = TDS_i * Q_i/10^3$
where $i=1.......15$ is the number of firms.

Note that no flocculation is applied if the original size of the particulate matter is greater than or equal to 35 microns.

In addition, the quantity of limestone used by a firm i is given by:

$Q_i=(35-s_i)^2$ if $s_i<35$ where s_i is the median particulate size.

$Q_i=0$ if $s_i>35$

P_l=price of limestone = Rs.5 * 10^{-6}/mg

B. Sedimentation:

Once the flocculation process is complete, waste water is subjected to a sedimentation process to reduce its load of TSS. The speed at which the suspended solids settle is directly related to the velocity of effluent flow which in turn depends on the size of the particle. Consequently the size of the pond will depend on the volume of effluent and the size of the particle.

The main cost elements in the process therefore are: a capital cost i.e. the cost of constructing the sedimentation pond, and the operating cost of sludge removal.

P_r = per unit price of sludge removal = Rs. 50/m^3

P_c = construction price per cu. meter of pond= $c(W_i)^{-1/4}$ where c=1.50

W_i = quantity of waste water discharged in '000 cu.meters per year

S_i = volume of wet sludge in cu.meters of which 5% is solids.

We define

$S_i = [FDS_i + TSS_a + Q_i]/10^6 * 100/5$

TSS_a = abated suspended solids (grams/cu.m)

In addition,

V_i = Volume of pond required to treat 1 cu.meter of effluent

We define

$V_i = 10^5 * e^{TSSa/TSSo}/x_i^3$

where TSS_o = pre-treatment suspended solids (grams/cu.m)

And,

$x_i = s_i(1 + Q_i/100)$ where x_i = median post flocculation size of particulate matter.

Note that if $Q_i = 0$, $s_i = x_i$

TSSa/TSSo is similar to an efficiency factor of abating TSS.

Based on the description of the above treatment costs, the *total abatement cost function* in present value[5] for firm i may be defined as:

$$\mathbf{C_i = W_i \{(P_lQ_i + P_rS_i)/r + P_{ci}V_i\}}$$

where r = discount rate = 10%

Note that $P_lQ_i + P_rS_i$ are the operating costs whereas $P_{ci}V_i$ is the fixed or capital cost component.

Marginal Costs

Having defined the Total Abatement Cost function as above, we then derive the marginal cost functions for all firms. This is done by taking the derivative of the cost function with respect to TSS_a.

We get the marginal cost function for firm i as follows:

$$C_i = W_i \{(P_lQ_i + P_rS_i)/r + P_{ci}V_i)\}$$

$$dC_i/dTSS_a = W_iP_r/r*10^6 + W_iP_{ci}/x_i^3 * 10^5e^{TSSa/TSSo}$$

$$= \quad Y \quad + \quad Z * e^{TSSa/TSSo}$$

where as expected, Y and Z are positive constant terms for any given firm i.

Therefore

$$MC_i = Y + Z * e^{TSSa/TSSo}$$

and marginal cost per '000 cubic meter of waste water is:

$$MC_i/W_i = (Y + Z * e^{TSSa/TSSo})/W_i$$

The marginal cost per cubic meter would be the additional cost of reducing the concentration of TSS by 1 mg/litre. The marginal cost function may be considered as a reaction function of firm i to different policy instruments. (These functions are depicted graphically for all 15

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[5] The operating life of the facility is assumed to be infinity.

firms in Appendix 1).

As mentioned above the ratio TSS_z/TSS_0 represents the efficiency of abatement and derives from variations in marginal abatement costs between firms.

The following section analyses the impacts of different policy instruments on total units of effluent abated and the associated costs.

4. POLICY IMPLICATIONS

i. Existing Policy (Effluent standard set at 100mg/litre of TSS)

The Pollution Control Board has set an effluent standard at 100mg/litre of TSS. It has been observed that this standard is not being met by the majority of firms. Enforcement is weak and violators are not penalised.

The analysis indicates that costs to the firms of keeping within the standard is high. As indicated in Table 2, the total cost of abatement (TAC) varies among the firms from Rs.37 million to Rs. 0.008 million, and the MAC varies from Rs. 1.03 to Rs. 5.02. This variation in costs is due to differences in the initial pollution load, the volume of effluent discharged, and the size of particles.

If this policy were to be effectively implemented, the total abatement would ideally have been 23 tonnes per year at a present value cost of Rs. 80 million.

<u>Evaluation in terms of the set criteria</u>

- The policy does not achieve the target of reducing the pollution load to 23 tonnes per year since the firms do not comply with the standard due to the high costs involved.
- The policy is clearly not cost effective due to the high cost of abatement for firms.
- The costs of monitoring and enforcement are high[6].
- The policy does have potential for inducing innovation of pollution control technologies if implemented effectively. But since the costs of compliance are high this has not occurred.
- The advantage of the standard is that it makes the stated goal of pollution reduction clear to the general public and the industry. However because of the high costs of abatement for the firms the policy has discouraged compliance.

ii. Effluent Charge

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[6] Precise estimates of these costs were not available.

Implicit in the standard of 100mg/litre is a total abatement level of approximately 23 tonnes of TSS per year which the Indian Government has adopted as a desirable level of total abatement. In the following analysis this level of abatement has been retained as the reference point.

Taking the MAC function as specified in Section 3 above, a series of iterations were conducted to arrive at an effluent charge level for which total abatement would be equivalent to that corresponding to the existing standard (23 tonnes per year). These results are shown in Tables 3 and 5.

According to the analysis, effluent charges set at Rs.2 per mg/'000cu.m. would induce firms to abate TSS upto levels at which the cost of the last unit abated is equal to Rs.2 for all firms. If they were to abate an extra unit each, their costs would exceed the levied charge.

The cost minimising behavior of firms and the efficient allocation of costs amongst firms, results in a lower total abatement cost of Rs.32.50 million as compared to Rs.80 million with the existing standard of 100mg/litre.

In addition, an amount of Rs.2 million per year would be collected as tax revenue, making the total cost to industry Rs.34.50 million.

Note that, as indicated in Table 5, with a charge of Rs.2, Kathara and Giddi coal washeries and Loyabad and Bararee coke oven plants do not abate at all. This is because they have very low levels of TSS to start with. They also have comparatively higher marginal costs of abatement (see Table 6). The low MAC firms i.e Jamadoba, Patherdih, Chasnala, Sudamdih, Kargali, Swang, Barora coal washeries and Bhowra coke oven plant, treat fully whereas the rest undertake partial treatment. In practical terms this would be impossible. The result could however be interpreted as an indication of extremely high levels of treatment.

Firms that do not abate or that abate only partially are taxed and therefore provide the revenue. These are the high control cost firms. This conforms to the economic rationale for setting effluent charges as opposed to setting standards.

Evaluation in terms of the set criteria

- This policy has greater probability of achieving the target of pollution reduction of 23 tonnes than the standards approach. The reason for this is that although it requires the same amount of monitoring and enforcement, it could be self-financing to the extent that the revenue from the tax could be ploughed back into strengthening the monitoring and enforcement capabilities of the local district authorities and the Bihar State Pollution Control Board.

- The policy is cost effective since the targeted level of abatement is achieved by all firms operating at least cost. The overall abatement level is achieved at a total cost to the industry of Rs.34.5 million as compared to Rs.80 million with the standard.

- The effluent charge provides the firms with adequate incentives for adopting innovative pollution control and prevention technologies.

- The policy is not as visible as the standard but if the Government were to advertise the policy prior to its implementation, it would increase public awareness and therefore give it a certain amount of public sanction.

iii. Charge cum Standard

The most effective environmental management system is likely to be one which judiciously combines regulations with economic instruments. In the present study the imposition of a "pure" effluent charge emerges as a cost effective mechanism vis-a-vis a "pure"standard. However the charges approach has an element of bias in that it collects a large part of the revenue from firms which are already abating at satisfactory levels. It is therefore suggested that a charge plus standard policy be adopted that would impose a tax on those firms whose pollution levels exceed the standard. This is achieved at a marginally lower level of total abatement as well as a lower total cost of abatement for the industry as a whole.

A series of iterations was conducted and various alternative combinations of standards and effluent charge levels were examined for their impact on total abatement, total abatement cost and total revenue (see Table 8). According to the calculations, it appears that if a ***charge of Rs.1.7 per mg/litre per '000 cu.m is levied on all firms discharging more than 150 mg/litre,*** the total abatement would be 22.3 tonnes at a total abatement cost of Rs.30.9 million and a total revenue of Rs.1.02 million. Firms polluting less than the standard of 150mg/litre can then be charged a nominal rate of Rs.0.5 or less per mg/litre. This would further increase total abatement and would also add to the tax revenues.

This combination of standards and effluent charges therefore achieves the targeted level of abatement without the bias inherent in the policy with a uniform effluent charge of Rs.2.0 per mg/litre. Furthermore the revenue collected is still sufficient to support the upgradation of the monitoring and enforcement capabilities of the State Pollution Control Board.

Evaluation in terms of the set criteria

- The policy would approximately achieve the targeted level of total abatement. The higher polluting firms will reduce the total amount abated by 22.3 tonnes per year. This is marginally less (by 0.7 tonnes) than the abatement under the pure charges scheme.

- The policy is cost effective since the reduction in abatement is achieved in the least costly manner for a sub-group of firms. It is a least cost solution which can also be feasibly implemented.

- The high costs of monitoring and enforcement can be offset by reinvesting the tax revenue towards improving the institutional capacities for monitoring and enforcement.

- The policy will provide appropriate incentives to industries to innovate and adopt pollution control and clean production technologies.

- It is publicly transparent.

This policy is more attractive to industry than the pure charge of Rs.2.0 per mg/litre per '000 cu.m., since it imposes a less stringent standard as well as levies a lower charge.

5. CONCLUSIONS

i. The major policy recommendation is to amend the existing policy of a simple effluent standard by levying a charge of Rs.1.7 on all firms exceeding pollution discharges of 150 mg/litre, and a nominal charge of Rs.0.5 on firms with discharges of less than 150mg/litre.

The effluent charge is an attractive feature for environment agencies on the following grounds:

a) it generates revenue that could be used as an "environment fund" for improving the institutional capacities of the local administration and the Pollution Control Board for monitoring and enforcing the pollution charges and standards.

b) it creates incentives for pollution control innovation and also for cleaner production methods, thereby inducing factories to increase abatement.

c) The setting of charges reveals information on the abatement cost structure of firms and therefore makes it easier to adjust the tax (as compared to adjusting the standard) in the face of changes in the economy (e.g. technological improvements, growth etc.).

ii. The coal processing industries are not independent of the production chain involving industries using or producing coal. An analysis of the impact of different policy choices cannot be considered complete without a full assessment of the forward and backward implications of these policies. It may however be safely stated that the smaller the costs borne by the coal processing industries for pollution abatement, the lesser these effects will be. The external impact of the charges are therefore more likely to be selfcontained within the industry when compared to that of the standard.

iii. It is recommended that the policy be enforced through unannounced spot checks by inspectors from the Pollution Control Board. These inspectors should be well trained and should be equipped with suitable monitoring equipment to facilitate their tasks. Moreover in order to avoid the probability of partiality in enforcement and checking, it is recommended that the inspectors be periodically transferred. This in turn would require considerable upgradation and enhancement of state and local authorities' human resources. For this reason it is recommended that the tax revenue be used to strengthen their institutional capabilities.

iv. The present excercise has not taken into consideration inter industry impacts on other polluting facilities in the region. Therefore it is imperative that any policy recommendation for the group of industries considered in this study be integrated within a more comprehensive study on environmental quality in the Dhanbad region.

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TABLE 1 - BASIC FIRM DATA

	CAPACITY	WATER				
	Coal (Mt/day)	Consumption ('000 cu.m./yr)	Effluent ('000 cu.m./yr)	TDS (mg/l)	TSS0 (mg/l)	Particle size
Coal washeries						
Jamadoba	5000	2800	800	1994	10498	18
Lodna	300	1080	300	348	175	15
Patherdih	2137	536	120	1994	10498	10
Sudamdih	4000	1872	100	820	3950	12
Chasnala	12	55	40	423	500	10
Dugda	548	900	675	477	920	5
Kargali	466	2270	2132	507	4918	5
Kathara	4384	10000	3333	287	130	20
Swang	2667	1250	950	478	1050	20
Giddi	5167	2020	635	457	95	75
Barora	670	260	200	636	4092	45
Coke ovens						
Loyabad	350	900	671	876	92	60
Bararee	150	333	360	1151	154	65
Lodna	250	187	50	1327	165	85
Bhowra	150	200	90	1043	7018	60

TABLE 2 - IMPLICATIONS OF EXISTING STANDARD Of TSS =100 MG/L

	QI (mg/l)	TSSa	E	Xi (um)	V (cu.m.)	FDS (mg/l)	S (cu.m)	Pc (Rs)	TAC (Rs)	Y	Z	Mc (Rs/mg)	Mc ('000cu.m.)	TSSa (mg/l)	TotAbat (g)
Coal washeries															
Jamadoba	289	10,398	0.99	70.02	0.78	576	0.23	300	2,783,536	800	18	848	1.06	10,398	8,318,400
Lodna	400	75	0.43	75.00	0.36	139	0.01	113	141,291	300	254	689	2.30	75	22,500
Patherdih	625	10,398	0.99	72.50	0.71	1,246	0.25	45	185,422	120	1	124	1.03	10,398	1,247,760
Sudamdih	529	3,850	0.97	75.48	0.62	434	0.10	38	71,266	100	3	107	1.07	3,850	385,000
Chasnala	625	400	0.80	72.50	0.58	264	0.03	15	8,674	40	8	58	1.44	400	16,000
Dugda	900	820	0.89	50.00	1.95	429	0.04	253	3,478,244	675	449	1,769	2.62	820	553,500
Kargali	900	4,818	0.98	50.00	2.13	458	0.12	800	37,638,456	2,132	353	3,074	1.44	4,818	10,271,976
Kathara	225	30	0.23	65.00	0.46	65	0.01	1,250	19,217,331	3,333	10,642	16,737	5.02	30	100,000
Swang	225	950	0.90	65.00	0.90	108	0.03	358	3,167,540	950	274	1,628	1.71	950	902,500
Giddi	0	0	0.00	75.00	0.24	0	0.00	238	358,422	635	1,193	1,828	2.88	0	0
Berora	0	3,992	0.98	45.00	2.91	0	0.08	75	516,491	200	30	280	1.40	3,992	798,400
Coke ovens												35,731			
Loyabad	0	0	0.00	60.00	2.78	0	0.00	503	9,380,021	671	2,578	3,249	4.84	0	0
Bararee	0	54	0.35	65.00	3.36	0	0.00	270	3,268,760	360	556	1,150	3.19	54	19,440
Lodna	0	65	0.39	85.00	2.05	0	0.00	38	38,606	50	20	79	1.58	65	3,250
Bhowra	0	6,918	0.99	60.00	7.44	0	0.14	68	514,482	90	3	97	1.08	6,918	622,620
									80,768,743					42,768	23,261,346

Parameters		
C=	2	Rs/cu.m
Pl=	0	Rs/mg
Pr=	50	Rs/cu.m
r=	0	
TSS Standa	100	mg/liter

TABLE 3 - TOTAL ABATEMENT AND COSTS: STANDARDS

STANDARD *(mg/l)*	TA *(Tonnes)*	TAC *(Rs mn)*
25	24.037	109.46
50	23.776	97.46
75	23.514	87.794
100	23.261	80.769
150	22.87	75.142
200	22.605	74.356
250	22.35	73.666
300	22.099	72.993
400	21.584	71.7
600	20.567	69.302
1000	18.594	65.244
1500	16.825	61.931
2000	15.104	58.977

Note: all figures are annual figures

TABLE 4 - TOTAL ABATEMENT, COSTS AND REVENUES: CHARGES

Charge	TA (tonnes)	TAC Rs mn)	TR Rs mn)	TCI (Rs mn)
1.1	10.69	11.969	14.975	26.944
1.2	12.88	17.412	13.702	31.114
1.3	17.51	23.575	8.826	32.401
1.4	21.05	28.355	4.453	32.808
1.5	22.56	30.501	2.613	33.114
1.6	22.74	30.787	2.492	33.279
1.7	22.93	31.8	2.329	34.129
1.8	23.13	32.146	2.109	34.255
1.9	23.20	32.375	2.079	34.454
2	23.28	32.515	2.045	34.56
2.2	23.40	32.774	1.978	34.752
2.4	23.50	33.012	1.909	34.921
2.6	23.60	33.327	1.829	35.156
2.8	23.68	33.559	1.73	35.289
3	23.70	33.724	1.8	35.524

Note: all figures are annual figures

TABLE 6 - EFFLUENT CHARGE POLICY (which complies with existing standard=100mg/l)

Charge=	Rs 2.0 per mg per '000 cu.m.

	Y	Z	W ('000cu.m. per yr)	TSSo (mg/l)	TSSa* (mg/l)	TSSa (mg/l)	Totab (grams)	TAC (Rs. mn)	TSSt (*) (mg/l)	Revenue (Rs)
Coal washeries										
Jamadoba	800	17.70846246	800	10498	10498	10498	8398400	9364764.612	0	0
Lodna	300	253.6710979	300	175	29.35518894	29.35518894	8806.556682	103073.7567	145.6448111	87386.88664
Patherdih	120	1.489160115	120	10498	10498	10498	1259760	1451810.522	0	0
Sudamdih	100	2.792534125	100	3950	3950	3950	395000	468365.2083	0	0
Chasnala	40	7.919216647	40	500	500	500	20000	41339.83135	0	0
Dugda	675	448.7692951	675	920	375.5474542	375.5474542	253494.5316	1164308.462	544.4525458	735010.9369
Kargali	2132	353.469666	2132	4918	4918	4918	10485176	16183752.87	0	0
Kathara	3333.333333	10641.58378	3333.333333	130	-150.9035476	0	0	0	130	866666.6667
Swang	950	274.3572219	950	1050	1050	1050	997500	1882754.568	0	0
Giddi	635	1193.029054	635	95	-59.90944878	0	0	0	95	120650
Barora	200	30.25558728	200	4092	4092	4092	818400	1154940.428	0	0
Coke ovens										
Loyabad	671	2577.821436	671	92	-123.8256317	0	0	0	92	123464
Bararee	360	556.1713256	360	154	-66.98574264	0	0	0	154	110880
Lodna	50	19.68171973	50	165	153.8349009	153.8349009	7691.745047	15949.24505	11.16509906	1116.509906
Bhowra	90	2.743009305	90	7018	7018	7018	631620	683951.4943	0	0
							23275848.83	32515011.04		2045175

(*) TSSt= after treatment TSS

TABLE 6 - MARGINAL COSTS OF ABATEMENT AT DIFFERENT ABATEMENT LEVELS

MCI (R per mg/l 000cu.m.)	Abatement levels (tonnes per year)																		
	0	50	100	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000	7500	10000
Coal washeries																			
Jamadoba	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011
Lodna	0.016	0.021	0.025	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023	3.023
Sudamdih	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011	1.001	1.001	1.001	1.001
Dugda	0.017	0.017	0.017	0.018	0.019	0.020	0.021	0.023	0.024	0.028	0.028	6.768	6.768	6.768	6.768	6.768	6.768	6.768	6.768
Kargali	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.013	0.014	21.325	21.325	21.325
Kathara	0.042	0.057	0.079	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420	33.420
Swang	0.013	0.013	0.013	0.013	0.014	0.014	0.015	0.015	0.016	0.016	0.017	0.017	9.508	9.508	9.508	9.508	9.508	9.508	9.508
Giddi	0.029	0.042	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401	6.401
Barora	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.013	0.014	2.004	2.004	2.004
Coke ovens																			
Loyabad	0.048	0.076	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814	6.814
Bararee	0.025	0.031	0.040	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642	3.642
Lodna	0.014	0.015	0.017	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511	0.511
Bhowra	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.011	0.901	0.901

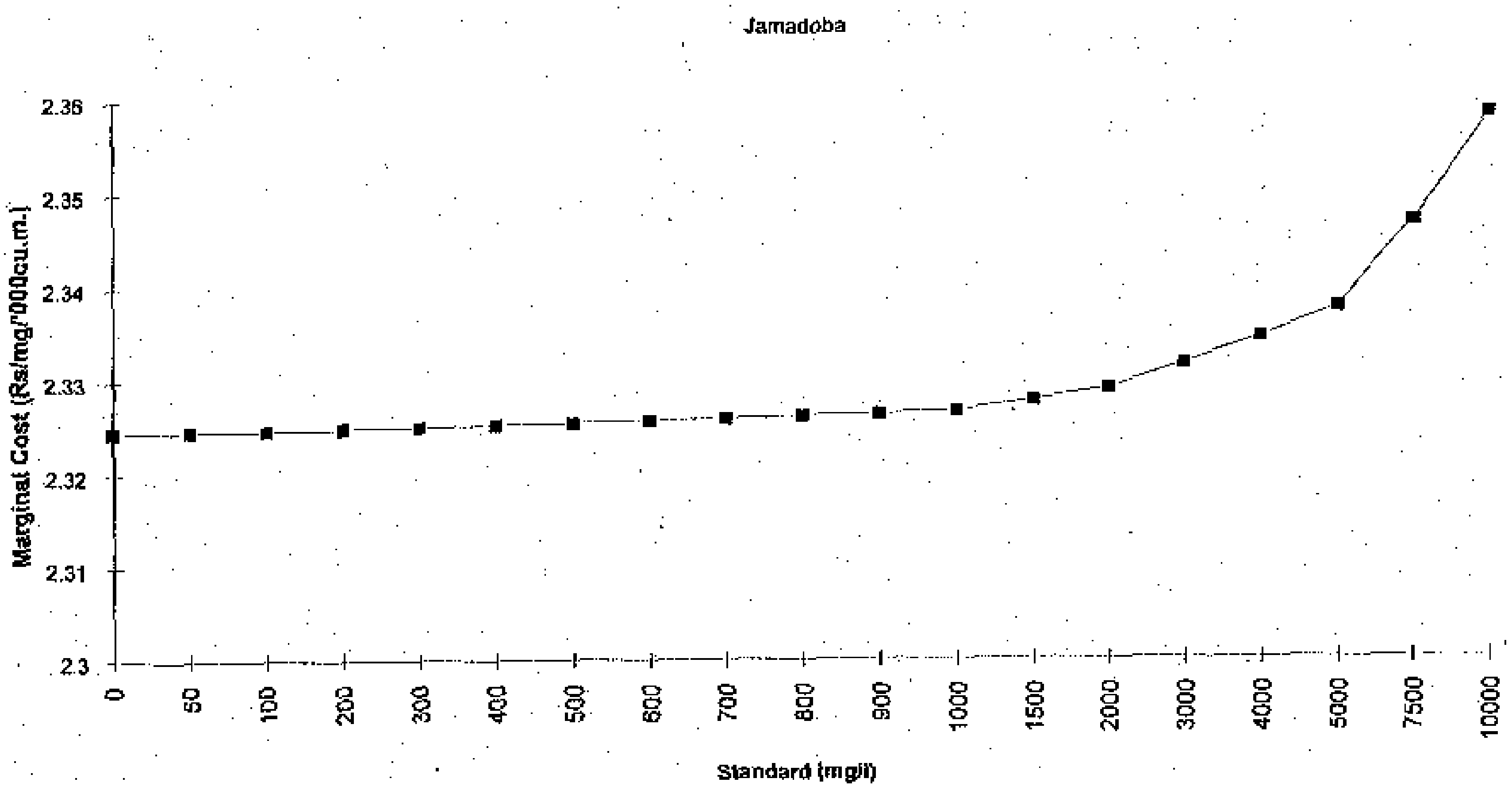
TABLE 7 - MARGINAL COSTS OF ABATEMENT IN COMPLIANCE WITH VARYING LEVELS OF EFFLUENT STANDARD

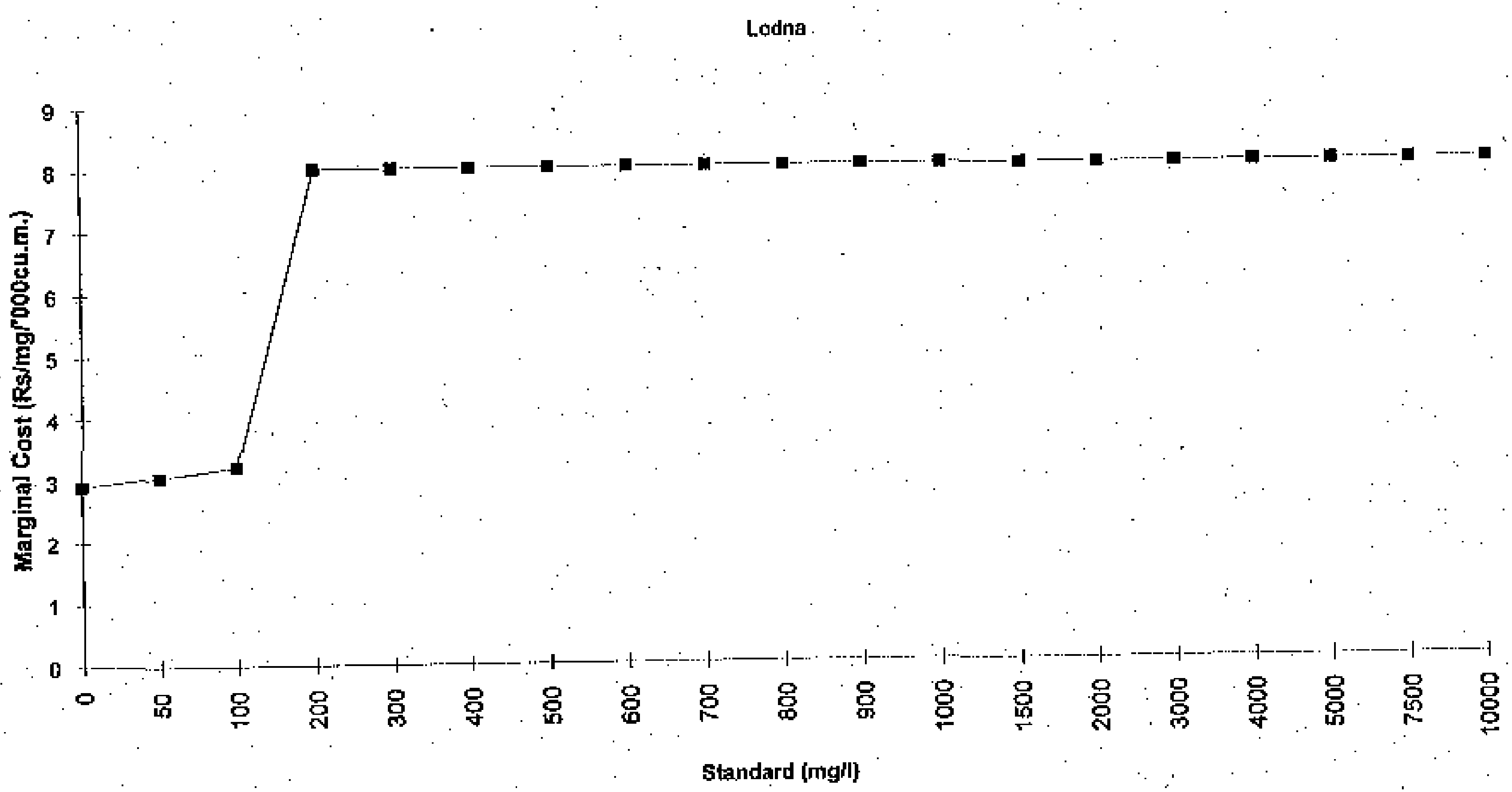
MCi ('000cu.m.)	Standard (mg/l)												
	25	*50*	*75*	*100*	*150*	*200*	*250*	*300*	*400*	*600*	*1000*	*1500*	*2000*
Coal Washeries													
Jamadoba	1.06	1.06	1.06	1.06	1.06	1.08	1.06	1.06	1.06	1.08	1.05	1.05	1.05
Lodna	2.99	2.73	2.50	2.30	1.98	1.85	1.85	1.85	1.86	1.85	1.85	1.85	1.85
Patherdih	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Sudamdih	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.06	1.05	1.05
Chasnala	1.51	1.49	1.46	1.44	1.40	1.36	1.33	1.30	1.24	1.20	1.20	1.20	1.20
Dugda	2.76	2.71	2.67	2.62	2.54	2.45	2.38	2.30	2.17	1.94	1.66	1.66	1.66
Kargali	1.45	1.45	1.44	1.44	1.44	1.43	1.43	1.42	1.42	1.40	1.37	1.33	1.30
Kathara	8.16	6.91	5.87	5.02	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19	4.19
Swang	1.77	1.75	1.73	1.71	1.68	1.65	1.62	1.59	1.54	1.44	1.30	1.29	1.29
Giddi	4.93	4.02	3.32	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
Barora	1.41	1.41	1.40	1.40	1.40	1.39	1.39	1.38	1.37	1.36	1.32	1.29	1.25
Coke ovens													
Loyabad	8.98	7.06	5.62	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84	4.84
Bararee	4.57	4.04	3.58	3.19	2.59	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54
Lodna	1.92	1.79	1.68	1.58	1.43	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39
Bhowra	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.07	1.07	1.08

TABLE 8 - STANDARDS CUM CHARGES

CHARGE (Rs)	STANDARD (Mg/L)											
	0			100			150			200		
	TA (tonnes/yr)	TAC (Rs mn)	TR (Rs mn)	TA (tonnes/yr)	TAC (Rs mn)	TR (Rs mn)	TA (tonnes/yr)	TAC (Rs mn)	TR (Rs mn)	TA (tonnes/yr)	TAC (Rs mn)	TR (Rs mn)
1.5	22,556	30,501	2,613	22,155	29,982	1,659	21,954	29,694	1,374	21,754	29,424	1,277
1.6	22,741	30,787	2,491	22,321	30,214	1,504	22,111	29,930	1,214	21,902	24,645	1,125
1.7	22,928	31,799	2,329	22,490	31,188	1,312	22,270	30,886	1,020	22,051	30,583	0,941
1.8	23,127	32,146	2,109	22,687	31,491	1,069	22,438	31,168	0,779	22,209	30,845	0,712
1.9	23,204	32,375	2,080	22,734	31,700	1,001	22,500	31,366	0,705	22,267	30,948	0,644
2	23,276	32,515	2,045	22,715	31,816	0,932	22,555	31,471	0,630	22,318	31,045	0,575
2.1	23,340	32,648	2,011	22,850	31,926	0,863	22,605	31,570	0,556	22,364	31,135	0,506
2.2	23,399	32,774	1,978	22,901	32,030	0,793	22,651	31,665	0,482	22,406	31,220	0,438
2.3	23,453	32,895	1,944	22,947	32,130	0,724	22,693	31,754	0,408	22,445	31,301	0,368
2.4	23,503	33,012	1,909	22,989	32,225	0,653	22,732	31,840	0,331	22,481	31,379	0,218
2.5	23,549	33,126	1,872	23,029	32,317	0,580	22,769	31,923	0,253	22,515	31,454	0,226

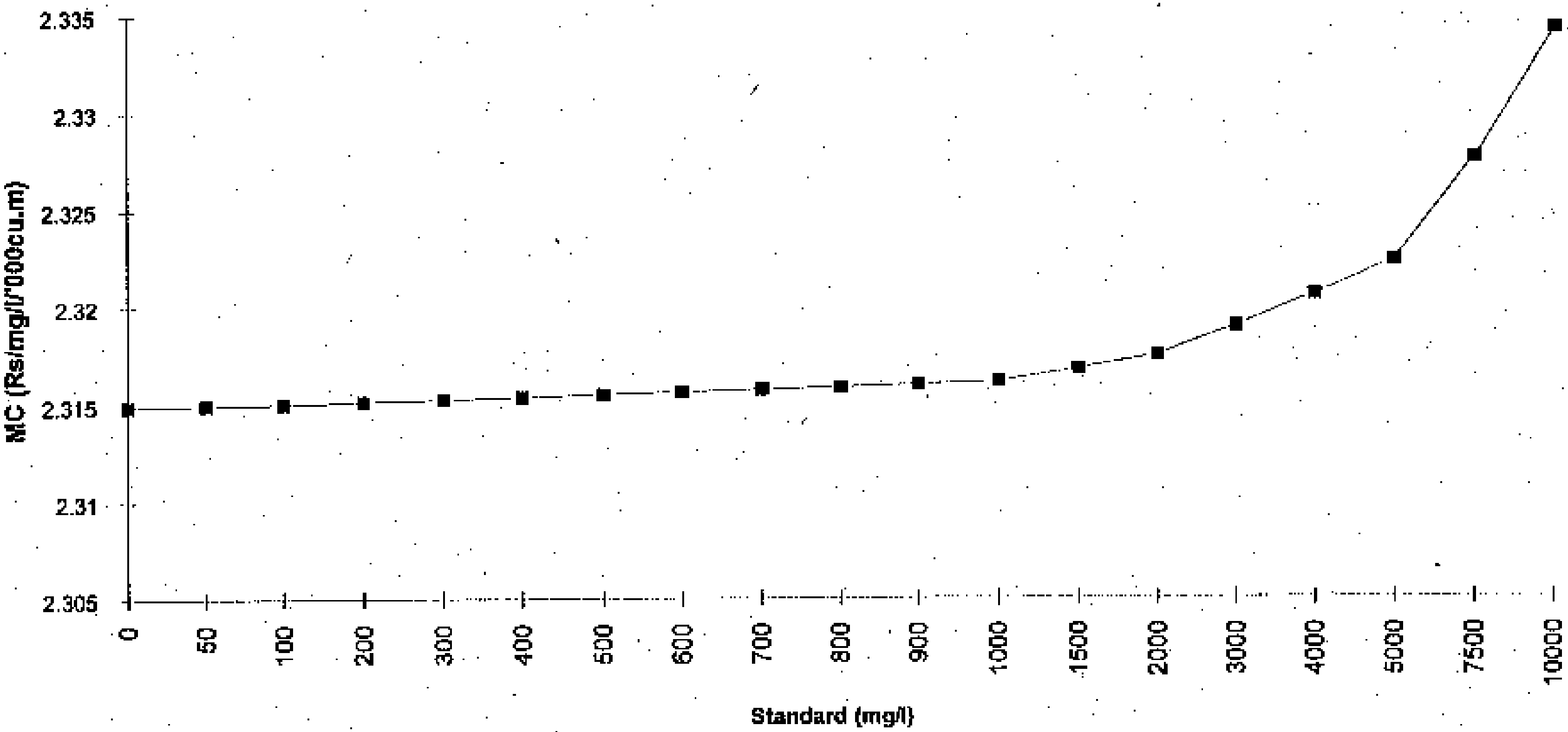
APPENDIX I


Jamadoba
Marginal Cost (Rs/mg/'000cu.m.)
2.36
2.35
2.34
2.33
2.32
2.31
2.3
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

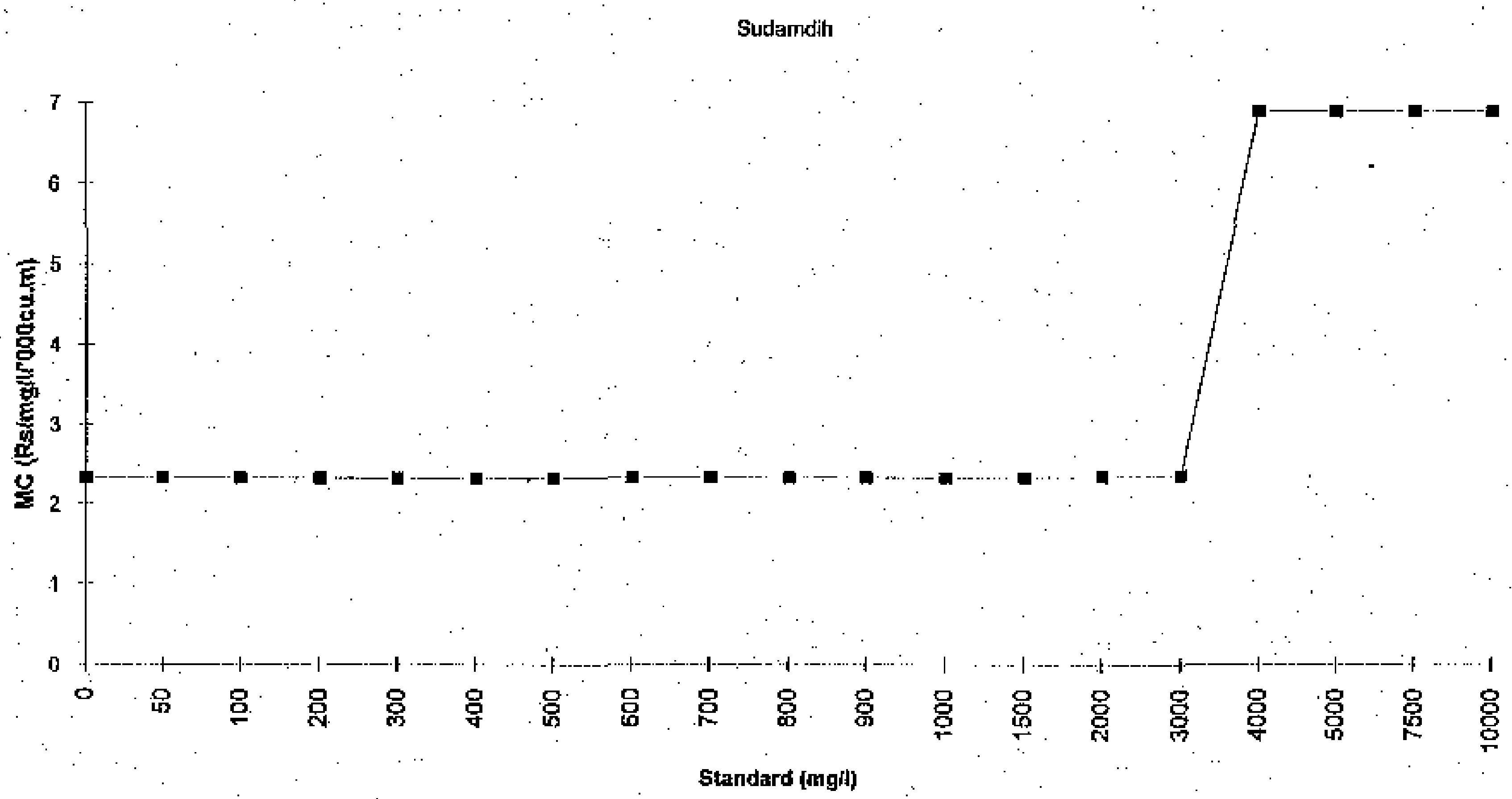


Lodna
Marginal Cost (Rs/mg/'000cu.m.)
9
8
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

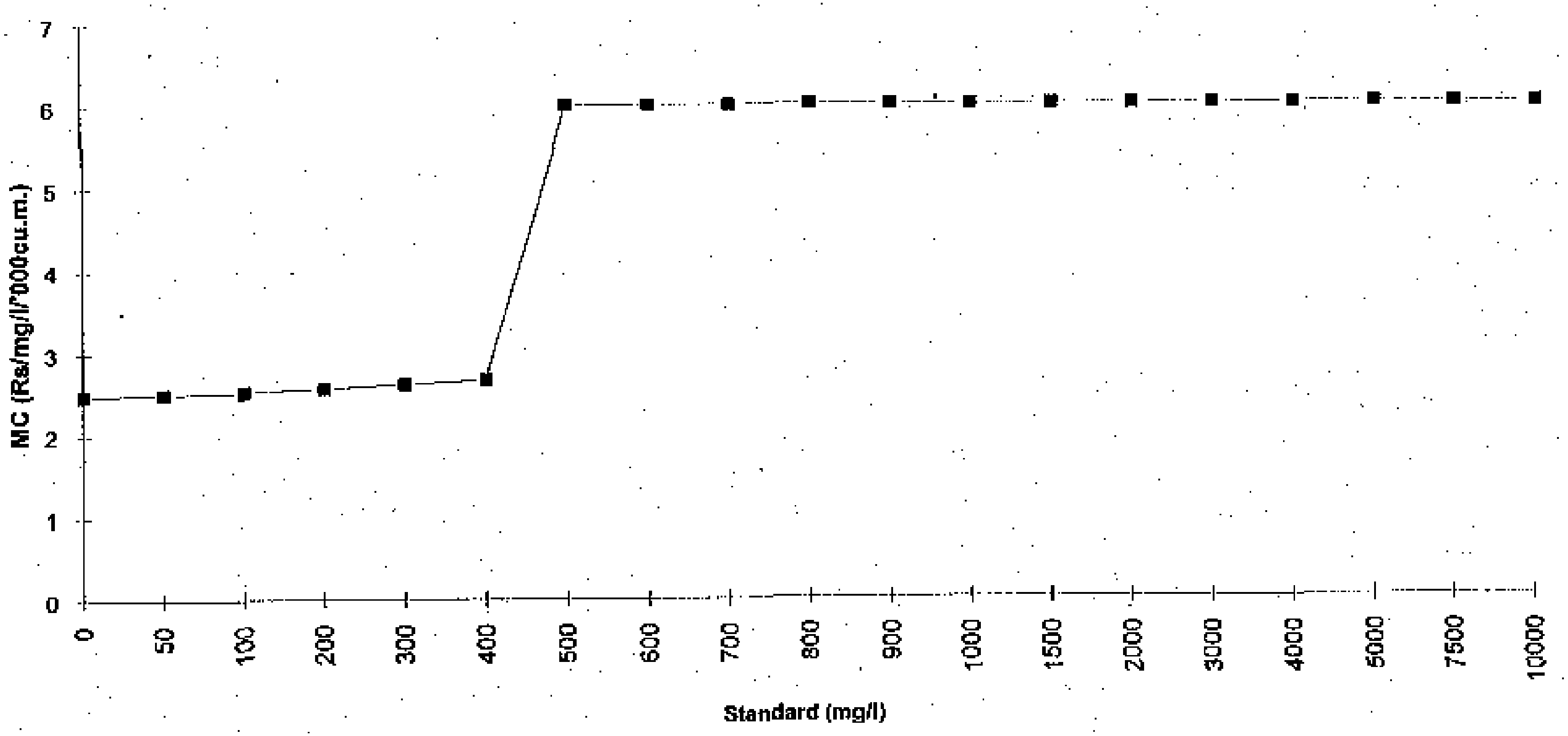
Patherdih



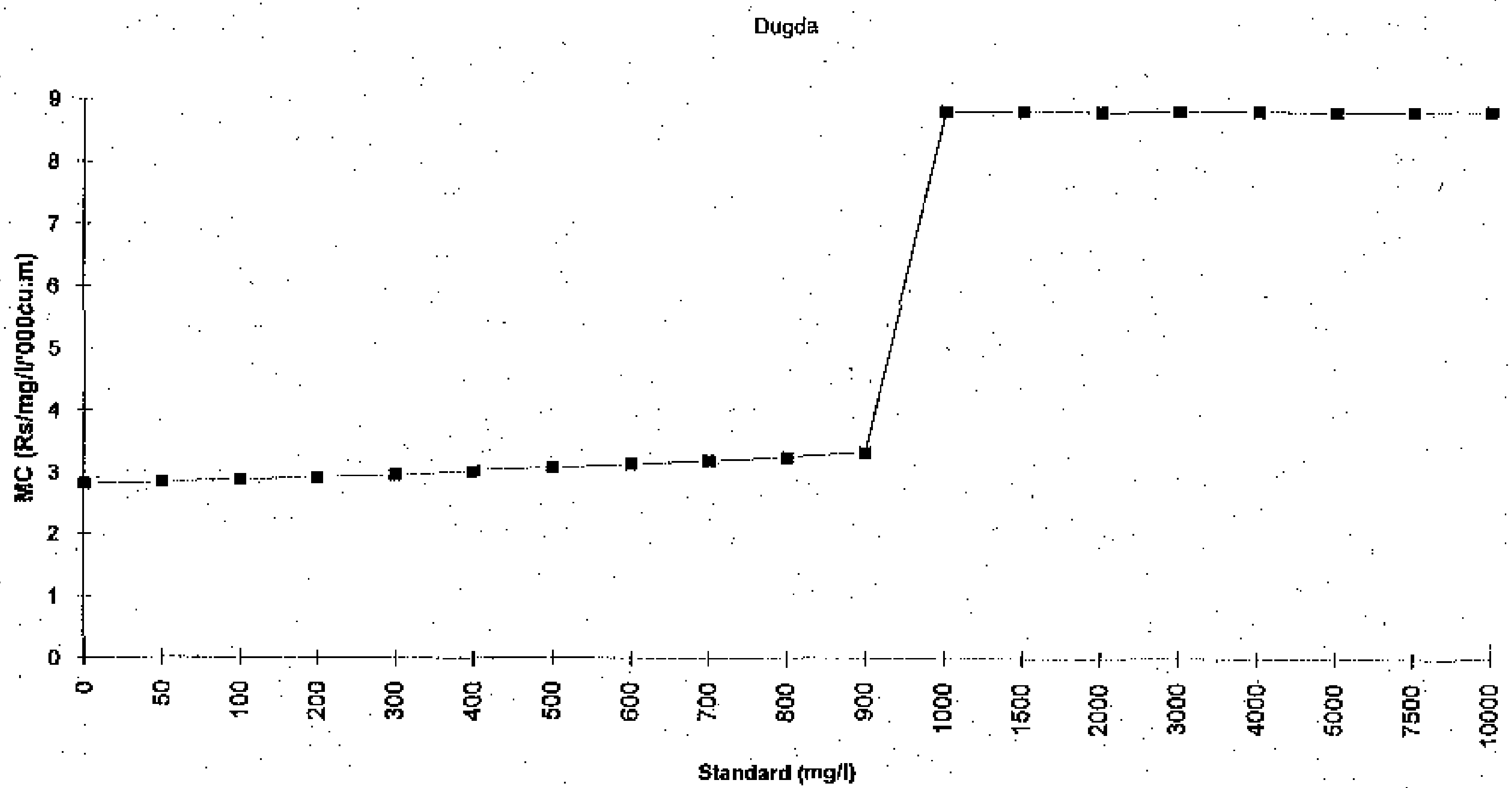
MC (Rs/mg/l/'000cu.m)
2.335
2.33
2.325
2.32
2.315
2.31
2.305
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

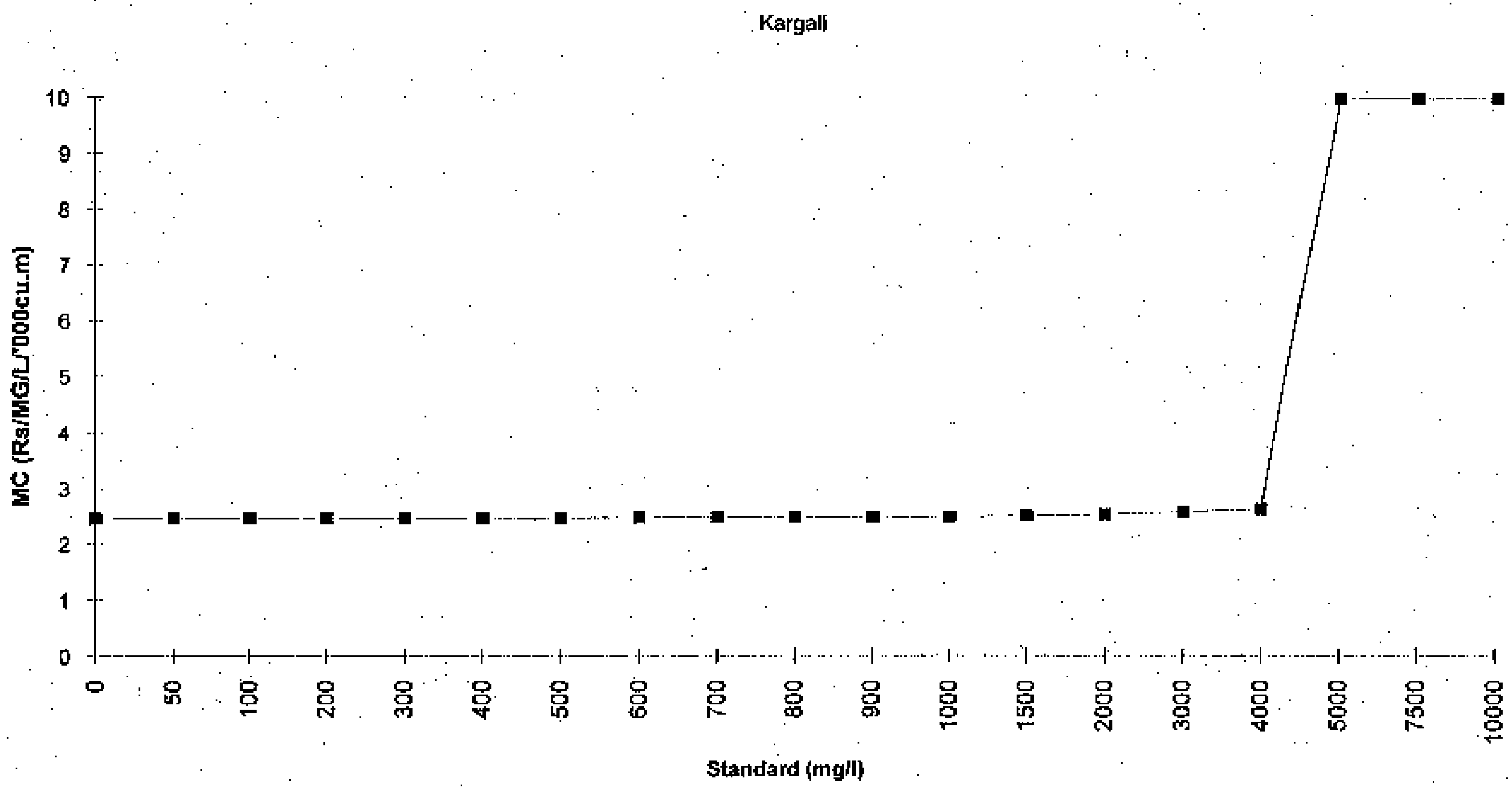

Sudamdih
MC (Rs/mg/l/'000cu.m)
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

Chasnala

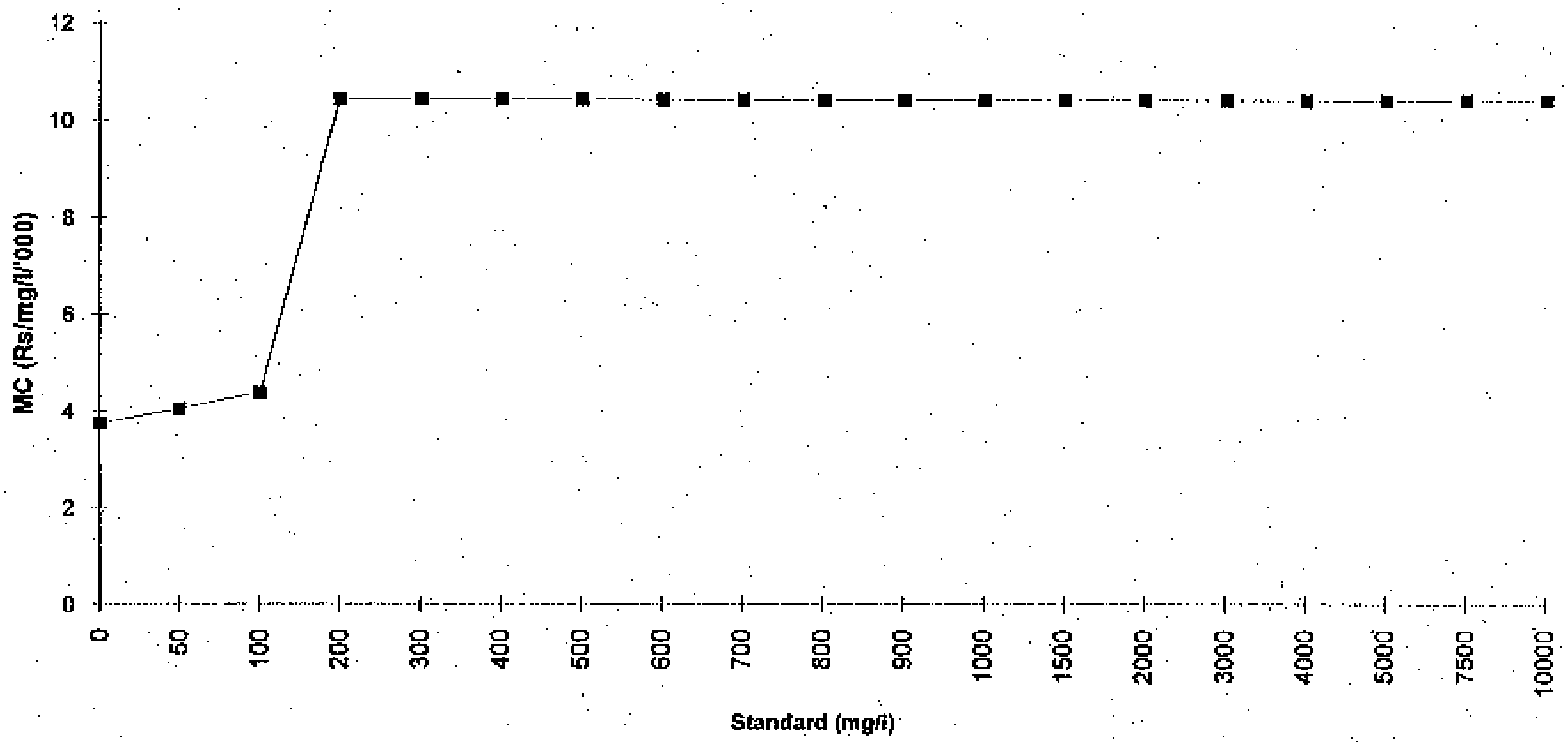


MC (Rs/mg/l/'000cu.m.)
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

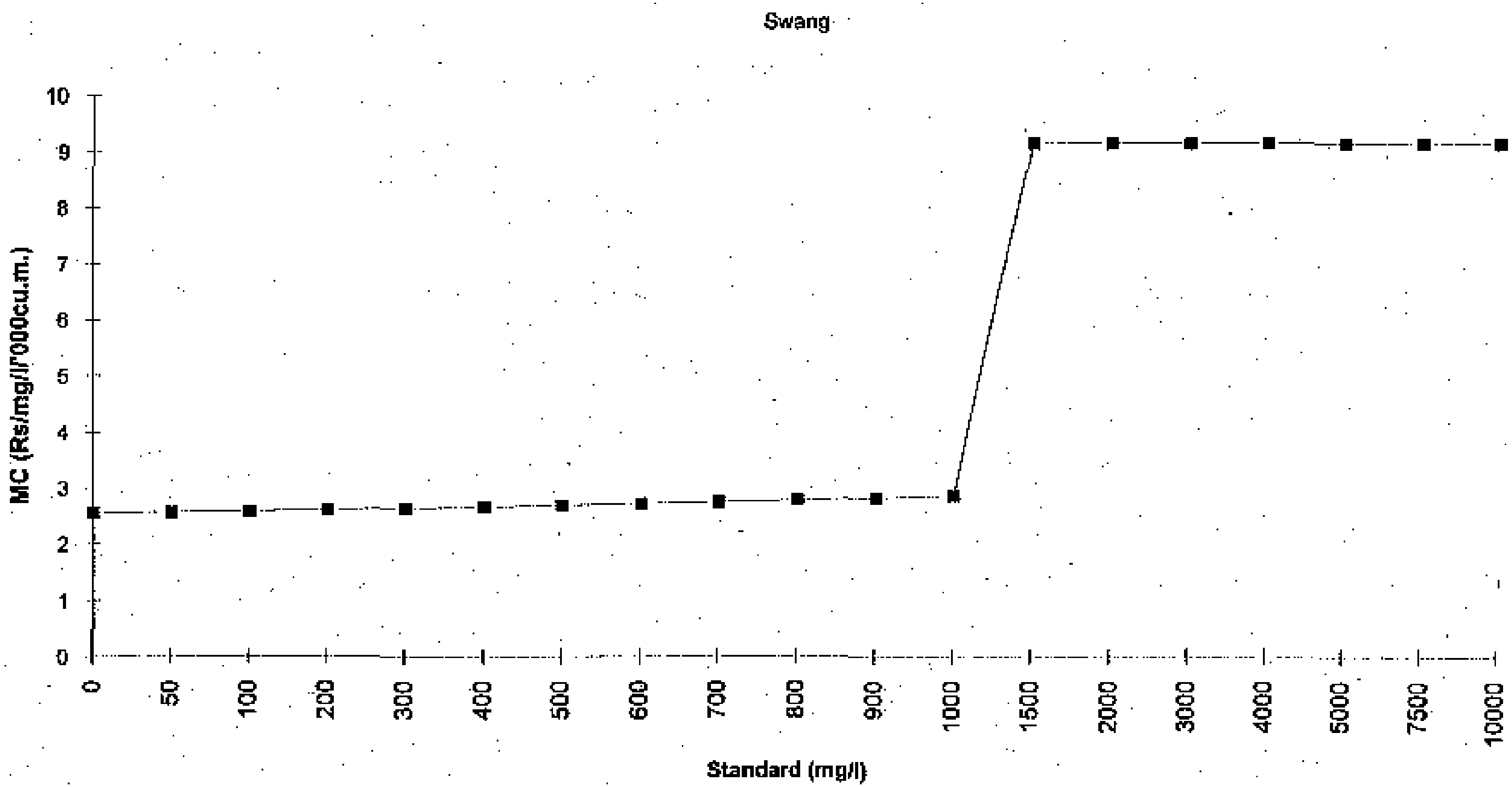

Dugda
MC (Rs/mg/l/'000cu.m)
0
1
2
3
4
5
6
7
8
9
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

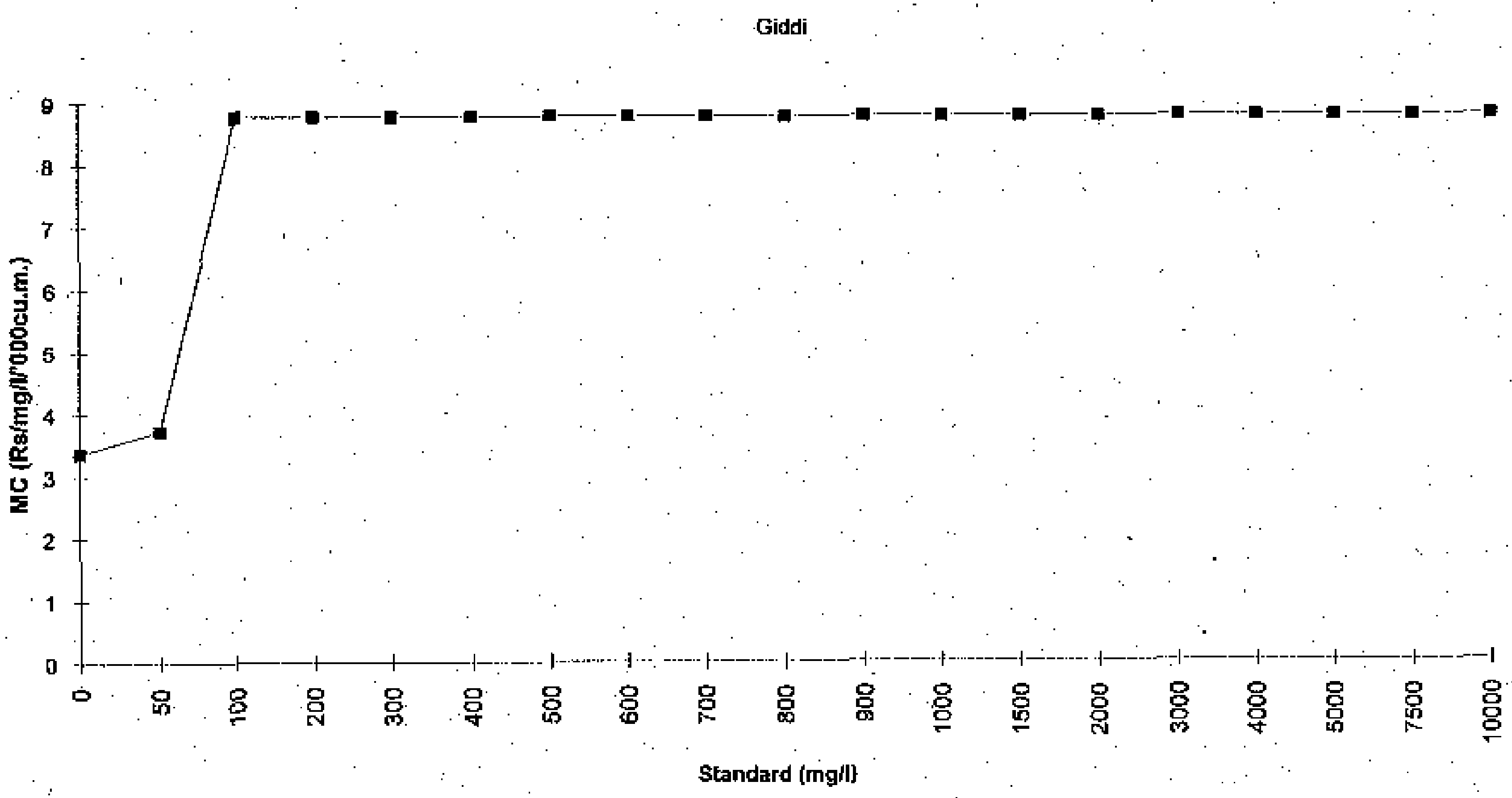

Kargali
MC (Rs/MG/L/'000cu.m)
10
9
8
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

Kathara

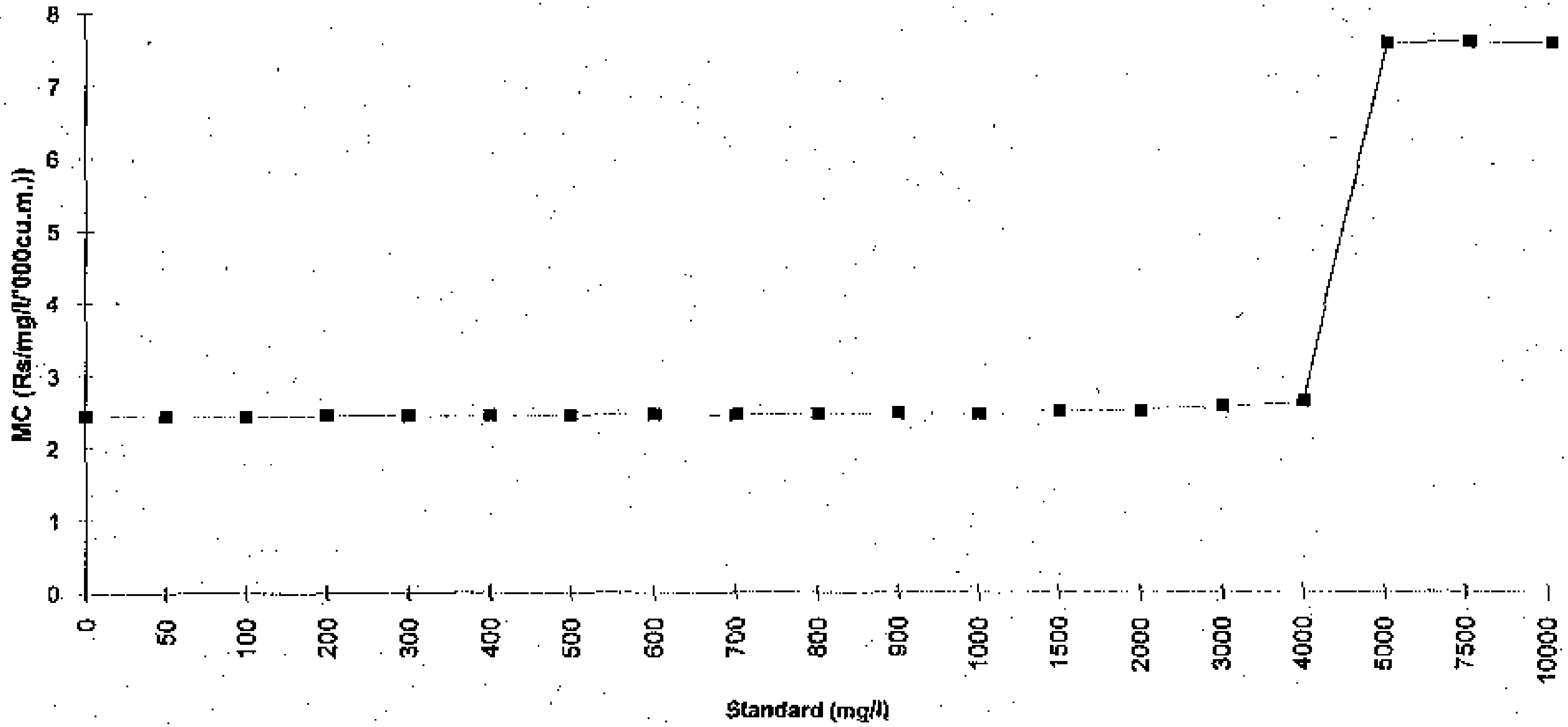


MC (Rs/mg/l/'000)
12
10
8
6
4
2
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

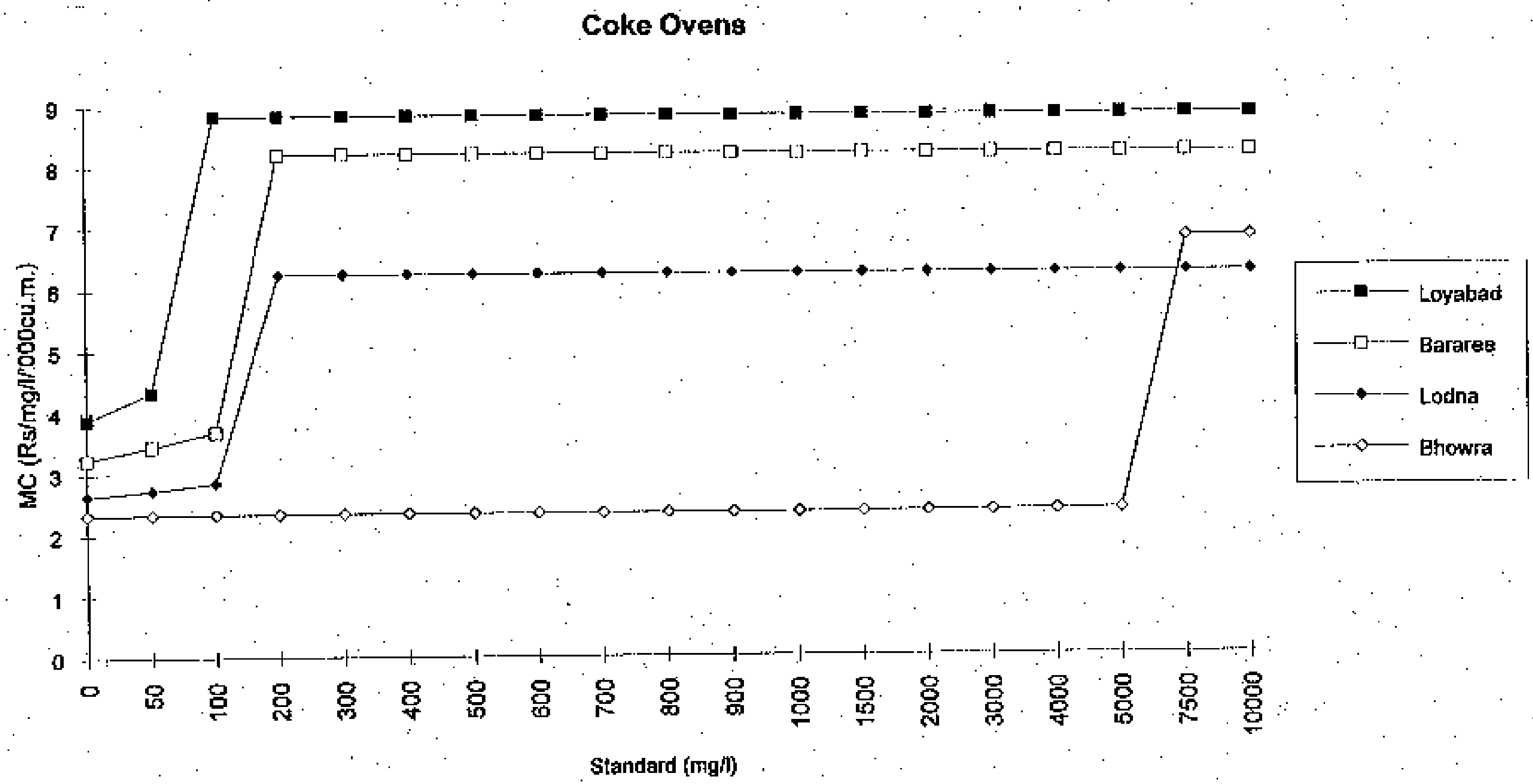

Swang
10
9
8
7
6
5
4
3
2
1
0
MC (Rs/mg/l/'000cu.m.)
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)


Giddi
MC (Rs/mg/l/'000cu.m.)
9
8
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)

Barora



MC (Rs/mg/l/'000cu.m.))
8
7
6
5
4
3
2
1
0
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)


Coke Ovens
9
8
7
6
5
4
3
2
1
0
MC (Rs/mg/l/'000cu.m.)
0
50
100
200
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
Standard (mg/l)
Loyabad
Bararee
Lodna
Bhowra

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BOOKS

Edward B. Barbier
Economics, Natural-Resource Scarcity and Development: Conventional and Alternative Views, Earthscan, London, 1989 (paperback £17.50)

The history of environmental and resource economics is reviewed; then using insights from environmentalism, ecology and thermodynamics, Barbier begins the construction of a new economic approach to the use of natural resources, particularly to the problem of environmental degradation. With examples from the global greenhouse effect, Amazonian deforestation and upland degradation on Java, Barbier develops a major theoretical advance and shows how it can be applied. This book breaks new ground in the search for an economics of sustainable development.

David W. Pearce, Anil Markandya and Edward B. Barbier
Blueprint for a Green Economy, Earthscan, London, 1989 (paperback £8.95)

This book was initially prepared as a report to the Department of Environment, as part of the response by the government of the United Kingdom to the Brundtland Report, *Our Common Future*. The government stated that: '...the UK fully intends to continue building on this approach (environmental improvement) and further to develop policies consistent with the concept of sustainable development.' The book attempts to assist that process.

Edward B. Barbier, Joanne C. Burgess, Timothy M. Swanson and David W. Pearce
Elephants, Economics and Ivory, Earthscan, London, 1990 (paperback £10.95)

The dramatic decline in elephant numbers in most of Africa has been largely attributed to the illegal harvesting of ivory. The recent decision to ban all trade in ivory is intended to save the elephant. This book examines the ivory trade, its regulation and its implications for elephant management from an economic perspective. The authors' preferred option is for a very limited trade in ivory, designed to maintain the incentive for sustainable management in the southern African countries and to encourage other countries to follow suit.

Gordon R. Conway and Edward B. Barbier
After the Green Revolution: Sustainable Agriculture for Development, Earthscan Pub. Ltd., London, 1990 (paperback £10.95)

The Green Revolution has successfully improved agricultural productivity in many parts of the developing world. But these successes may be limited to specific favourable agro-ecological and economic conditions. This book discusses how more sustainable and equitable forms of agricultural development need to be promoted. The key is developing appropriate techniques and participatory approaches at the local level, advocating complementary policy reforms at the national level and working within the constraints imposed by the international economic system.

David W. Pearce, Edward B. Barbier and Anil Markandya
Sustainable Development: Economics and Environment in the Third World, London and Earthscan Pub. Ltd., London, 1990 (paperback £11.95)

The authors elaborate on the concept of sustainable development and illustrate how environmental economics can be applied to the developing world. Beginning with an overview of the concept of sustainable development, the authors indicate its implications for discounting and economic appraisal. Case studies on natural resource economics and management issues are drawn from Indonesia, Sudan, Botswana, Nepal and the Amazon.

David W. Pearce, Edward B. Barbier, Anil Markandya, Scott Barrett, R. Kerry Turner and Timothy M. Swanson
Blueprint 2: Greening the World Economy, Earthscan Pub. Ltd., London, 1991 (paperback £8.95)

Following the success of *Blueprint for a Green Economy*, LEEC has turned its attention to global environmental threats. The book reviews the role of economics in analyzing global resources such as climate, ozone and biodiversity, and considers economic policy options to address such problems as global climate change, ozone depletion and tropical deforestation.

E.B. Barbier and T.M Swanson (eds.)
Economics for the Wilds: Wildlife Wildlands, Diversity and Development, Earthscan Pub. Ltd., London, 1992 (paperback £12.95).

This collection of essays addresses the key issues of the economic role of natural habitat and wildlife utilization in development. The book argues that this role is significant, and composes such benefits as wildlife and wildland products, ecotourism, community-based wildlife development, environmental services and the conservation of biodiversity.

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