

# Selection of Technology to Treat Waste Water Generated from Dye Intermediate Manufacturing Industry: A Case Study

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**Abstract** In this paper, we address the problem of treating waste water generated from manufacturing unit producing Dyes and Dyes Intermediates. We have considered three alternative technologies ie. Multiple Effect Evaporator (MEE), Incinerator, Electrochemical Treatment (ECT). MEE is found to be more economical compared to the other two technologies. Selection of MEE reduces the quantum of solid waste disposed and also improves the quality of effluent. The efficacy of the results presented are demonstrated by taking a case study of manufacturing unit producing Dyes and Dyes Intermediates located in GIDC Ahmadabad, India.

**Keywords:** Waste water generated, Multiple Effect Evaporator, Electrochemical Treatment, Incinerator.

## I. INTRODUCTION

Rapid industrialization and urbanization has increased quantity of polluted water discharged into natural environment. Numerous harmful and toxic materials are detected in waste water which is considered to be a danger for the environment and human safety. As a result most of our surface water bodies are rendered unfit for either industrial or domestic use causing water scarcity [1]. The objective of wastewater treatment is to remove pollutants to minimize the risk to human health and natural environment. Conventional waste water treatment techniques consisting of primary, secondary and tertiary treatment methods have been used for decades.

Primary treatment involves operations like screening and sedimentation to suspended particles and organic materials partially from the wastewater. Pre-aeration, addition of flocculating agents along with necessary mechanical agitation are used to improve efficiency of primary treatment. The secondary treatment transforms the organic material into various cell tissues and gases with the help of micro-organism specifically bacteria. Secondary treatment is usually done by attached growth processes like trickling filtration, rotating biological contactors or suspended growth process like activated sludge process. The primary and secondary treatments together bring down the level of BOD and COD significantly. Tertiary treatment is used improve the treated water quality to comply with the regulatory norms. Tertiary treatment removes substantial quantities of heavy metals, biodegradable substances, nitrogen, phosphorus, bacteria, viruses etc. Reverse osmosis and Ion exchange are also commonly used for removal of specific ions or reduction of dissolved solids [2]. Some of these treatment techniques are expensive and consume a huge quantity of chemicals and costly land area. The treatment cost of water is expected to increase further, due to stringent discharge norms prescribed by regulatory authorities. This has motivated the industries to identify suitable technologies to minimize water consumption and waste water generation. This has also helped in development of innovative, effective and economical methodologies for the treatment of wastewater and optimum use of these resources [3]. Hence, it is necessary to propose a simple optimization strategy to select suitable technology from the available alternatives.

We consider three different technologies namely, Incinerator, Electro chemical technology & Multiple effect Evaporator to demonstrate the efficacy of the proposed method. Electro chemical treatment of wastewater produces electrically active coagulants and tiny bubbles of hydrogen and oxygen in water by the use of sacrificial metal anode and cathode. The ECT has numerous advantages over the conventional technologies. [4]. Mainly, it destabilizes tiny

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colloidal matter very efficiently. Also, it helps in simultaneous flotation and coagulation with minimal quantity of sludge. In addition, the ECT equipment is very compact rendering thereby easy installation where space is a great constraint [5]. Whenever the amount of waste and its potential toxicity are increasing an incinerator is being seen as a viable solution to the waste problem. This technology is capable of reducing the waste to less than 5% at a significant high temperature and longer time. It can also oxidize any hydrocarbon vapour to carbon dioxide and water. Incinerator is fairly simple equipment which can achieve substantial removal efficiencies. It is quite effective in lowering contamination and hence reduces the pollutant because of burning of most of the gases. The design of the system is so impressive that one can hardly notice any smoke or odour [6]. Multiple effect evaporators is essentially a heat exchanger where liquid is boiled to give a vapour, it may be possible to make use of this, to treat an evaporator as a low pressure boiler and heat can be used over and over again. This makes the evaporation in the second and subsequent effects for nothing in terms of energy costs. The waste which is generated here as a concentrated bottom product have been used as a byproduct with almost negligible pollutant hence it is to be considered a highly economical.

### II CASE STUDY

A manufacturing unit producing Dyes and Dyes Intermediates located in GIDC Ahmedabad is considered in this paper. The detailed information about various products produced by the company is presented in Table (1). From Table (1) it can be observed that the main product is vinyl sulphone. Concentrated streams generated from the Manufacturing of vinyl sulphone have COD content ranging from 1 to 1.5 lakh ppm. The present study involves selection of suitable technology for treatment of highly polluted waste water. In the present study three possible technologies namely Incinerator, Electro chemical and Multiple Effect Evaporator are considered.

Table (1): Overall production capacity of the process plant under consideration

Sr. No	Product	Quantity MT/Month
1.	Vinyl Sulphone	101.0 MT/Month
2.	Dyes (acid black-210, reactive yellow MERL Red ME <sub>4</sub> BL, Black GL / GR, Black-B, Orange ME <sub>2</sub> RL)	30.72 MT/month
3.	ASC and pyrazolones	42.0 MT/month
4.	6 Nitro ad EBASA	8.2 MT/month
5.	Acetanilide	29.0 MT/month
6.	MUA	9.35 MT/month
Total		220.27 MT/month

Table (2): Detailed break up of water consumption

Sr. No.	Description	Water Consumption L/Day
(A)	Domestic + Floor washing	10000
(B)	Industrial	
1	Processing + Washing	244450
2	Cooling Water	30000
3	Vacuum Pump	32000
4	Boiler	44000
Total (A+B)		360450

Table (3): Detailed break up wastewater generation based on installed capacity

Sr. No.	Description	Waste Water generation L/Day
1	Process, Filtration and washing	92350 75816
2	Utilities	0
(a)	Cooling Tower	1500

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(b)	Boiler	2200
3	Domestic including floor washing	10000
Total		130050

The manufacturing unit uses Incinerator technology so we have taken last six month data presented in Table 4 and also daily basis data for single month which is presented in Table5 for the basis of calculation for this paper.

Table (4). Mother liquor generated and energy consumed for a period of six months.

Sr. No.	Month	ML generated In Liters	ML incinerated In Liters	CNG consumption SM <sup>3</sup>	Power Consumption KWH
1	12-Jan	552110	551000	41447	5169
2	12-Feb	382230	382400	28694	3578
3	12-Mar	488405	488500	36664	4572
4	12-Apr	509640	509400	38258	4771
5	12-May	467200	467500	35070	4373
6	12-Jun	424800	424700	31882	3976
Total		2824385	2823500	212015	26439
Monthly Average		470731	470583	35336	4407

Table (5). Details of mother liquor generated and energy consumption on daily basis during the month of June 2012.

DATE	CONDENSE MOTHER LIQUOR			CNG CONSUMED CM3	POWER CONSUMED UNIT	Operating Hrs
	INCINERATOR METER		INCEN. LTS.			
	OPEN.READ.	CLOSING READING				
1	28434200	28452200	18000	1350	168	12
2	28452200	28471200	19000	1426	178	13
3	28471200	28490000	18800	1410	176	12
4	28490000	28490000	0	0	0	0
5	28490000	28508600	18600	1396	174	12
6	28508600	28527000	18400	1380	172	12
7	28527000	28545200	18200	1366	170	12
8	28545200	28545200	0	0	0	0
9	28545200	28563400	18200	1366	170	12
10	28563400	28580400	17000	1276	160	11
11	28580400	28596400	16000	1200	150	10
12	28596400	28612600	16200	1216	152	10
13	28612600	28628600	16000	1200	150	10
14	28628600	28644600	16000	1200	150	10
15	28644600	28660600	16000	1200	150	10
16	28660600	28676800	16200	1216	152	10
17	28676800	28692800	16000	1200	150	10
18	28692800	28707800	15000	1126	140	9

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19	28707800	28722800	15000	1126	140	9
20	28722800	28722800	0	0	0	0
21	28722800	28739800	17000	1276	160	11
22	28739800	28754600	14800	1110	138	9
23	28754600	28771400	16800	1260	158	10
24	28771400	28786400	15000	1126	140	9
25	28786400	28786400	0	0	0	0
26	28786400	28805400	19000	1426	178	13
27	28805400	28824000	18600	1396	174	12
28	28824000	28840800	16800	1280	158	10
29	28840800	28858900	18100	1354	168	11
30	28858900	28858900	0	0	0	0
Total			424700	31882	3976	269

### III. CALCULATIONS

Calculation is done based on average monthly waste generation so here cost equation is derived by considering fixed & variable cost which is presented in Table 6

Table (6). Fixed and variable cost calculation for deriving cost equation of all three technologies

Variable cost	Incinerator	Electro Chemical	Multiple effect evaporator
Average Waste Generated / Month	4, 50,000 Liters	4, 50,000 Liters	4, 50,000 Liters
Average Energy Consumption	CNG = 23240 SM <sup>3</sup> Electric Power = 3810Units	Electric power = 192214 units	Steam Required = 149,750 Kg Electric Power = 20450Units
Variable cost:	CNG = Rs.47/ SM <sup>3</sup>		Steam cost = Rs.1.5/kg
(A)	Total = Rs.10, 92,280/-		Total = Rs.224625/-
(B)	Electric Power = Rs.7.5/Unit Total = Rs.28575/-	Electric Power = Rs.7.5/Unit	Electric Power = Rs.7.5/Unit Total = Rs.153375/-
Total A+B	Rs.1120855/- Per 450000 lit.	Rs.1441605/- Per 450000 lit.	Rs. 378000/- Per 450000 lit.
Total Variable cost	Rs 2.490/lit.	Rs 3.203/lit.	Rs. 0.84/lit.
<b>Fixed Cost</b>			
Cost of Unit in	Rs. 60,00,000/-	Rs. 50,00,000/-	Rs. 1,80,00,000/-
Installation Cost (15%)	Rs. 9,00,000/-	Rs. 7,50,000/-	Rs. 27,00,000/-
Total Cost(Round off)	Rs. 70,00,000/-	Rs. 57,50,000/-	Rs. 2,07,00,000/-
Depreciation cost	Rs. 10,50,000	Rs. 8,65,000	Rs. 31,05,000/-
Interest 12% Per Annum	Rs. 8,40,000/	Rs. 6,90,000/	Rs. 24,84,000/-
Maintenance 3% Per Annum	Rs. 2,10,000/	Rs. 1,75,000/	Rs. 6,21,000/-
Net Total Cost	Rs. 21,00,000/-	Rs. 17,30,000/-	Rs. 62,21,000/-
Net Total Cost /Month	Rs. 1,75,000/-	Rs. 1,50,000/-	Rs. 5,00,000/-
<b>Operators Cost</b>			
No of Operators & their monthly salary	7×15000 = Rs.105,000/-	7×15000 = Rs.105,000/-	9×15000 = Rs.1,35,000/-
No of Helpers & their	7×7000 = Rs.49,000/-	7×7000 = Rs.49,000/-	9×7000 = Rs.63,000/-

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monthly salary			
Total Operators cost	Rs.1,50,000/- (Round off)	Rs.1,50,000/- (Round off)	Rs. 2,00,000/- (Round off)
Cost Equation: Based on operator, fixed & variable cost on monthly basis	Z1=1,50,000+ 1,75,000(0.002*X)^0.6 + 2500* X X=Waste getting generated in Kilo Liters	Z2=1,50,000+ 1,50,000(0.002*X)^0.6+ 3200* X X=Waste getting generated in Kilo Liters	Z3=2,00,000+ 5,00,000(0.002*X)^0.6+ 850* X X= Waste getting generated in Kilo Liters

### IV. RESULTS AND DISCUSSIONS

After formulating the cost equation of each technology the data has been generated for various capacities by using GAMS code and Results are presented in table7.

Here the prime objective is to get the most economical technology and the Objective function is:

$$Z = \sum_j (a_j + c_j * (0.002 * x)^{0.6} + (b_j * x) * Y_j)$$

Where: Set j [ MEE, INC, ECT ] and

Parameter a<sub>j</sub> [ INC 150000, MEE 200000, ECT 150000 ]

b<sub>j</sub> [ INC 2500, MEE 850, ECT 3200 ]

c<sub>j</sub> [ INC 175000, MEE 500000, ECT 125000 ]

Here x is capacity of waste generation of a plant and its value is considered from 100 to 1200 Kilo Liters. Where Y<sub>j</sub> is considered as binary variables and their constraint equation is

$$\sum Y_j = 1.$$

All the results of various equations and MINLP model presented in this section were obtained using different GAMS solver: GAMS Rev 233 WIN-VIS 23.3.3 x86/MS Windows. The results presented in this paper of cost comparison for all three technologies at different waste water treated are shown in Graph no 1, Cost comparison of all three technologies as a cost per liter of waste water treatment is shown in Graph 2 while Graph 3 represents the solid waste generation for all three technologies at different capacities of waste water.

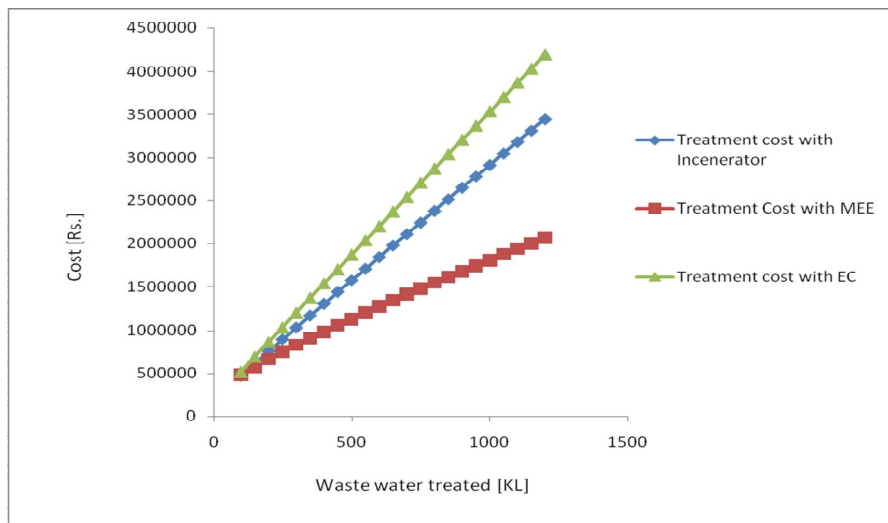


Figure 1: Effect of waste water quality on treatment cost

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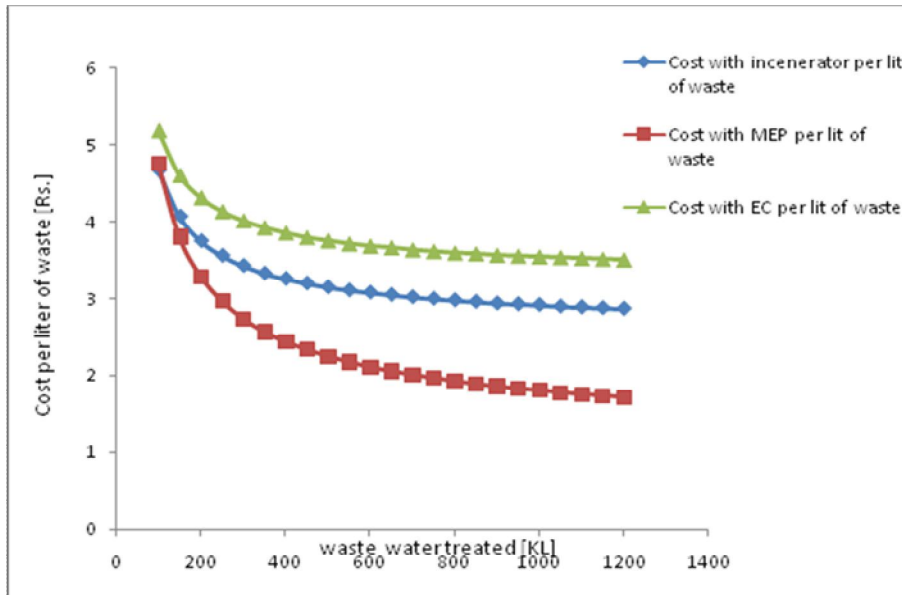


Figure 2: Waste water treatment cost per liter basis for three technologies under consideration

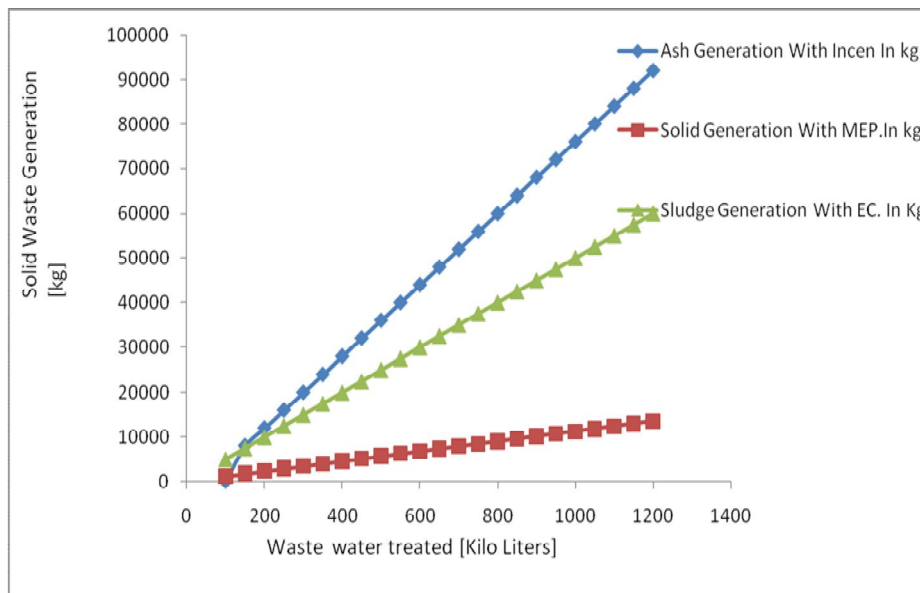


Figure 3: Solid waste generation for all three technologies at different capacity of waste.

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Table (7). Solid waste generation and their loading cost.

x = Waste in KL	Ash Generation With Incinerator In kg.	Loading Cost In Rs.	Sludge Generation With EC. In Kg	Loading Cost In Rs.	Solid Generation With MEE.In kg	Loading Cost In Rs.
100	8000	6400	5000	4000	1131	905
200	16000	12800	10000	8000	2263	1810
300	24000	19200	15000	12000	3394	2715
400	32000	25600	20000	16000	4525	3620
<b>450</b>	<b>36000</b>	<b>28800</b>	<b>22500</b>	<b>18000</b>	<b>5091</b>	<b>4073</b>
500	40000	32000	25000	20000	5657	4525
600	48000	38400	30000	24000	6788	5430
700	56000	44800	35000	28000	7919	6335
800	64000	51200	40000	32000	9050	7240
900	72000	57600	45000	36000	10182	8145
1000	80000	64000	50000	40000	11313	9050
1100	88000	70400	55000	44000	12444	9955
1200	96000	76800	60000	48000	13576	10860

Table (8). Salt is generated through Multiple effect evaporator. It is sold as by product simentenously the waste heat recovery and condensate recovered are shown in Table 9.

Table(8).Salt recovery through MEE

x = Waste in KL	Na <sub>2</sub> SO <sub>4</sub> Salt Recovered With MEE In kg	Na <sub>2</sub> SO <sub>4</sub> Salt Sold @ 8/kg
100	20000	160000
200	40000	320000
300	60000	480000
400	80000	640000
<b>450</b>	<b>90000</b>	<b>720000</b>
500	100000	800000
600	120000	960000
700	140000	1120000
800	160000	1280000
900	180000	1440000
1000	200000	1600000
1100	220000	1760000
1200	240000	1920000

Table (9).Waste heat & Condensate recovery

x = Waste in KL	Waste Heat Recovered	Condensate Recovered
100	15666	80366
200	31332	160732
300	46998	241098
400	62664	321464
<b>450</b>	<b>70497</b>	<b>361647</b>
500	78330	401830
600	93996	482196
700	101879	522429
800	101979	522529
900	102079	522629
1000	102179	522729
1100	102279	522829
1200	102379	522929

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Three different waste water treatment methods have been discussed for Vinyl Sulfone product. All three technologies are proven to bring down the COD level from 1-1.5 lakh ppm to 250 to 300 ppm. The monthly data has been considered as the base for the calculation so for the treatment of 450,000 Liters of waste Total cost with Multiple effects evaporator is Rs. 10,51,870/-(Per liter cost Rs.2.34), total cost with Incinerator = Rs.14,39,280/-(Per liter cost Rs.3.2), and with Electro chemical treatment is Rs. 17,07,343/-(Per liter cost Rs.3.79), so with MEE cost is significant low compare to other two technologies.

Electro chemical treatment has wide variety of advantages because of its simplicity and convenience in operation same way Incinerator is fairly simple equipment which can achieve substantial removal efficiencies. It is quite effective in lowering contamination and hence reduces the pollutant because of burning of most of the gases but major drawback of both of them are the waste disposal so for the treatment of 450,000 Liters of waste total waste with Multiple effect is 5,091 kg, total waste with Incinerator is 36,000 kg and total waste with Electro chemical is 22500 kg. More than that MEE allows the recovery of salt, condensate and waste heat so for the treatment of 450,000 Liters of waste total salt recover is 90,000 kg, total condensate recovery is 36,000 kg and total waste heat recovery is 22500 . Again the salt is sold as by product @ 8 Rs./Kg which lead the recovery of Rs.7,20,000/-.

### V. COST COMPARISON OF ALL THREE TECHNOLOGIES BY USING TIME VALUE OF MONEY

A perpetuity is a type of an annuity for which the regular payments continue for indefinite time. This form of annuity allows engineers, to evaluate a total equipment or any other asset cost for a conditions which allow the asset to be exchanged perpetually with a negligible effect of inflation or deflation. Capitalized costs technique is ideally suited to comparing various alternative:

$$K = C_v + C_R / [(1 + i)^n - 1]$$

K = The capitalized cost is principally considered as the original value of the equipment and the present cost of the renewable perpetuity

$C_v =$  Initial Cost  $C_R =$  Replacement Cost  $= C_v - V_s$   $V_s =$  Salvage Value

$i =$  Rate of Interest  $n =$  Service life

Table (10): Capitalized cost of all three equipments

Parameter	Incinerator	Electro chemical Technology	Multiple effect evaporator
$C_v =$	70,00000/-	57,50000/-	2,07,00000/-
$C_R =$	64,00000/-	52,50000/-	1,89,00000/-
$V_s =$	6,00000/-	5,00000/-	18,00000/-
$i =$	10%	10%	10%
$n =$	10	10	10
Capitalized cost	1,10,15700/-	90,50000/-	3,25,59000/-

### VI. PAYBACK PERIOD

In case of Multiple effect evaporator salt is sold as by product @ 8 Rs./Kg which lead the recovery of Rs.7,20,000/- Per month

Mathematically: Annuity is the sum of all the accumulated amounts from each payment:

$$S = R(1 + i)^{n-1} + R(1 + i)^{n-2} + \dots + R(1 + i) + R$$

$$S_i = R(1 + i)^n - R \quad [\text{Or}] \quad S = \{R[(1 + i)^n - 1]/i\}$$

R = Uniform Monthly Amount = 7,20,000/-

S = Total compound amount = Vs Original Amount = 2,07,00000/-

i = Rate of interest Annually = 10%

n = Payback period = 25.8 Approximate = 26 months



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## VII. CONCLUSION

Comparative study of Multiple Effect Evaporator (MEE), Incinerator, Electrochemical Treatment (ECT) for treating Dyes and Dyes Intermediates waste is conducted. MEE was found to be more economical and environmentally friendly technology. It was also found that the solids generated from MEE can be sold as by product which can lead the recovery of initial Cost of MEE in just 26 months. Moreover, incinerator ash and ECT sludge disposal problems can be avoided by using MEE infact condensate water can be recycled/ reused. The advantages of selecting MEE over Incinerator, Electrochemical Treatment (ECT) are successfully demonstrated with the help of an industrial case study of manufacturing unit producing Dyes and Dyes Intermediates located in GIDC Ahmadabad.

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### ANNEXURE I

Table (a). Cost comparison for all three technologies & The waste generation through them

x=Waste in KL	Cost with Incinerator	Cost with MEE	Cost with ECT	Ash Generation With Incen In kg.	Solid Generation With MEE.In kg	Sludge Generation With ECT. In Kg
100	466628	475365	517591	8000	1131	5000
200	750989	658540	862135	16000	2263	10000
300	1028804	823011	1202003	24000	3394	15000
400	1303071	977345	1539336	32000	4525	20000
<b>450</b>	<b>1439280</b>	<b>1051870</b>	<b>1707343</b>	<b>36000</b>	<b>5091</b>	<b>22500</b>
500	1575000	1125000	1875000	40000	5657	25000
600	1845230	1267800	2209450	48000	6788	30000
700	2114148	1406853	2542963	56000	7919	35000
800	2382012	1542891	2875723	64000	9050	40000
900	2649001	1676432	3207858	72000	10182	45000
1000	2915250	1807858	3539465	80000	11313	50000
1100	3180861	1937460	3870615	88000	12444	55000
1200	3445914	2065467	4201367	96000	13576	60000

### ANNEXURE II

Table (b). Cost comparison for all three technologies and cost per liter of waste treated

x = Waste in KL	Cost with Incinerator	Cost with MEE	Cost with ECT	Cost with incinerator per lit of waste	Cost with MEE per lit of waste	Cost with ECT per lit of waste
100	466628	475365	517591	4.67	4.75	5.18
200	750989	658540	862135	3.75	3.29	4.31
300	1028804	823011	1202003	3.43	2.74	4.01
400	1303071	977345	1539336	3.26	2.44	3.85
<b>450</b>	<b>1439280</b>	<b>1051870</b>	<b>1707343</b>	<b>3.2</b>	<b>2.34</b>	<b>3.79</b>
500	1575000	1125000	1875000	3.15	2.25	3.75
600	1845230	1267800	2209450	3.08	2.11	3.68
700	2114148	1406853	2542963	3.02	2.01	3.63
800	2382012	1542891	2875723	2.98	1.93	3.59
900	2649001	1676432	3207858	2.94	1.86	3.56
1000	2915250	1807858	3539465	2.92	1.81	3.54
1100	3180861	1937460	3870615	2.89	1.76	3.52
1200	3445914	2065467	4201367	2.87	1.72	3.50