Optimization of Sewage Treatment Technologies on the basis of Life Cycle Cost Analysis (LCCA)

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ABSTRACT

There are many Sewage Treatment technologies available for the treatment and reuse of sewage in India and to select a technology that is appropriate for the desired treatment in the specific region such as rural, urban or metropolitan area depends on the volume of daily flow, sewage characteristics, degree of treatment needed, disposal of the effluent, area of land required for the plant, capital cost of installation, power required for the treatment, annual operation and maintenance cost.

It is found that the Waste Stabilization Pond is the most economical and cost effective technology to treat municipal sewage where the cost of land is low i.e. approx. in the range upto Rs. 50 Lacs per ha (i.e., Rs. 50 per sqft or Rs. 500.00/sqm). Where the cost of land is medium, i.e. beyond Rs. 50 Lacs per ha, the Upflow Anaerobic Sludge Blanket (UASB) with final polishing pond is economical upto Rs.100Lacs per ha. For high land cost above Rs.100 Lacs per ha or scarcity of land, Fluidized Aerobic Bed (FAB) Reactor, Sequencing Batch Reactor (SBR) & Activated Sludge Process (ASP) are found to be economical.

INTRODUCTION

Wastewater treatment systems are generally capital-intensive and require expensive, specialized/skilled operators. Therefore, before selecting and investing in wastewater treatment technology, it is always preferable to investigate whether pollution can be minimized or prevented. For any pollution control initiative an analysis of cost effectiveness needs to be made and compared with all conceivable alternatives. The technology that is more appropriate in terms of technical acceptability, economic affordability and social attractiveness has to be considered.

The latest innovative and technological developments are the changes in process design, which incorporate energy conservation, resource recovery such as nutrient, energy and water for reuse. Even though there are many sewage treatment technologies available, it is difficult to select a technology that is appropriate for the desired treatment. This paper highlights the application of the Life cycle cost analysis as a tool for the selection of appropriate technology of sewage treatment and aims to provide guidance/

methodology in the appropriate STP technology selection for mega, metro, urban and semi-urban areas.

Wastewater Treatment Technologies Selected for Life Cycle Cost Analysis

1) Activated Sludge Process (ASP).
2) UASB Technology with post treatment Final Polishing Pond (UASB+FPP).
3) Fluidized Aerobic Bed (FAB) Reactor.
4) Sequencing Batch Reactor (SBR).
5) Waste Stabilization Pond (WSP).

Components of Life Cycle Cost

Capital Cost of Construction of STPs

Initial investment costs are costs that will be incurred prior to the commissioning of the system. All initial costs are to be added to the LCCA total at their full value. A 10 MLD capacity plant of aforesaid technologies were designed and the capital costs of construction for WSP, UASB and ASP has been estimated as per the Schedule of Rates of West Bengal, and accordingly per MLD cost were arrived at, presented in Table 1 to Table 3 respectively, used in this study. The cost of construction per MLD for the FAB and SBR has been personally enquired from M/s Thermax, Pune and M/s C-Tech, Mumbai respectively and verified from other sources , are presented in Table 4.

Table 1: Abstract of cost estimate for ASP of 10 MLD

Sl. No.	Description	Amount in Rs.
1	Construction Cost of primary units	2,158,709.00
2	Primary sedimentation with sludge pump	12,317,485.00
3	Final clarifier with aeration basin	4,684,549.00
4	Sludge treatment unit	14,138,402.00
5	Miscellaneous units	7,211,140.00
6	Office, Laboratory setup, Staff Quarters and Compound Wall	2,635,000.00
7	Electrification works	2,750,000.00
8	Site development and landscaping work	1,699,000.00
	Total	47,684,284.00
	Cost Per MLD	4,768,428.00
	Say,	4,800,000.00

Table 2: Abstract of cost estimate for UASB of 10 MLD

Sl. No.	Description	Amount in Rs.
1	Construction Cost of primary units	2,158,709.00
2	Cost of UASB Reactors 2 nos. with all connections	18,991,140.00
4	Polishing pond and necessary connections	7,316,000.00
3	Miscellaneous structure	8,946,747.00
5	Office, Laboratory setup, Staff Quarters and Compound Wall	2,635,000.00
6	Electrification works	1,750,000.00
7	Site development and landscaping work	1,699,000.00
	Total	43,996,596.00
	Cost Per MLD	4,399,660.00
	Say,	4,400,000.00

Table 3: Abstract of cost estimate for WSP 10 MLD

Sl. No.	Description	Amount in Rs.
1	Construction of Anaerobic pond of size 100 x 51 x 3.5 m	1,061,078
2	Construction of facultative pond of size 285 x 140 x 2 m	4,221,708
3	Construction of maturation ponds 2 nos. of size 310 x 145 x 1.5 m each	8,572,186
4	Miscellaneous structure	2,158,709
5	Provision for Office, Laboratory, internal Roads	2,500,000
6	Provision for Water supply compound wall/ fencing	1,500,000
7	Provision for Tree planting as buffer zone	480,000
	Total	20,493,681
	Cost Per MLD	2,049,368
	Say,	2,050,000

Table 4: Capital Cost per MLD of various Technologies

Sl. No.	Type of Technologies / Process	Capital Cost in Rs. lacs.
A	Referred from M. Tech. Dissertation work	
1	Activated Sludge Process (ASP)	48.00
2	Upflow Anaerobic Sludge Blanket with Final Polishing Pond (UASB + FPP)	44.00
3	Waste Stabilization Pond (WSP)	20.50
B	Cost from various sources	
1	Sequencing Batch Reactor (SBR)	55.00
2	Fluidized Aerobic Bed (FAB)	50.00

Required Land Area of STPs Per MLD

Land area required per MLD of different STPs are calculated from process design data, as shown in Table 5.

Table 5: Required land area per MLD of various technologies

Area / Technology	WSP	UASB+FPU	ASP	FAB	SBR
Area in m^2 for 10 MLD	91666.7	22620	10352.25	1935	3150.35
Area in m^2 for 1 MLD	9166.67	2262	1035.2	193.5	315.035
Area in ha per MLD	0.917	0.226	0.104	0.019	0.032

Note : For FAB and SBR centrifuge assumed instead of Sludge drying beds.

Annual Operation And Maintenance Cost of Different STPs

The annual operation and maintenance charges were calculated based on the energy required, personnel, chemicals required and other repair etc. Careful / accurate attention is needed in the calculation of AM cost as it is highly sensitive in technology selection in the life cycle cost analysis.

The annual operation and maintenance cost of various STPs per MLD have been calculated based on different expenditure components required for a 10MLD plant, as shown in Table 6 & Table 7. Annual O&M cost with full potential of revenue generation and without revenue generation has been produced in Table 8.

Table 6: Requirement of personnel in various STPs of 10MLD

Sl. No.	Description	Annual salary in Rs.	WSP	UASB	ASP	FAB	SBR
1	AE	338,280	1	1	1	1	1
2	JE	258,360	1	2	2	2	2
3	Fitter I class	73,800		1	1	1	1
4	Electrician I class	73,800		1	1	1	1
5	Fitter II class	61,560	1				
6	Electrician II class	61,560	1	1	1		1
7	Gardener	49,200	1	1	1	1	1
8	Jr. Acct.	123,000	1	1	1	1	1
9	UDC Sr. Asst	110,760	1	1	1	1	1
10	LDC Typist/Jr. Asst	98,400	1	1	1	1	1
11	Peon	73,800		1	1	1	1
12	Lab Asst.	73,800	1	1	1	1	1
13	Lab Attendant	61,560	1	1	1	1	1
14	Sweeper	36,960	1	1	1	1	1
15	Operators	73,800		10	12	5	5
16	Labors / Beldars	36,960	10	20	20	10	10

Table 7: Annual O&M cost in various STPs in Rs. Lacs

Sl. No.	Cost Component	WSP	UASB	ASP	FAB	SBR
1	Establishment cost	16.43	31.69	33.16	23.69	24.30
2	Electric energy charges	10.63	15.11	43.61	43.15	24.30
3	Minor repairs, spares, grease, etc	0.85	6.10	7.20	8.75	10.45
4	Consumables, Chemicals, Chlorine	18.43	1.43	7.48	8.64	8.64
5	Miscellaneous	0.20	0.32	0.20	0.47	0.54
6	Others desilting of ponds in WSP	4.20	0.00	0.00	0.00	0.00
	Total cost.	50.74	54.65	91.65	84.69	68.24
	Annual O&M cost per MLD	5.07	5.46	9.17	8.47	6.82

Table 8: Annual O&M cost (per MLD) of 10MLD STPs

Sl. No.	Description of Items	ASP	UASB+FPP	FAB	SBR	WSP
1	Capital cost in lacs per MLD	48.00	44.00	50.00	55.00	20.50
2	Annual O&M cost in lacs per MLD	9.17	7.16	8.47	8.70	5.07
3	Revenue generation potential per MLD	1.69	1.69	1.07	1.07	1.19
4	Net O&M cost in lacs per MLD	7.48	5.47	7.40	7.63	3.88

Life Cycle Cost Analysis for STPs

Life Cycle Cost Analysis is an essential design tool for controlling the initial and the future cost of building ownership. Life Cycle Cost (LCC) is defined as "the total discounted cost of owning, operating, maintaining, and disposing of a building or a building system" over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over period of time. The sum of initial and future costs associated with the construction and operation of a building over a period of time (20 years) is called the life cycle cost of a facility, taking into consideration the future maintenance and replacement costs in their selections.

Life cycle cost for 20 years = Capital Cost including land cost + Present Worth of AM cost for 20 years.(assuming interest rate of 10%)

Present worth of AM cost for 20 years = AM cost*[{1-1/(1+i)^n}/i]
Where i = interest rate (10% assumed)
n = Total life or period (20 years assumed).

Life cycle cost has been prepared based on data derived from a 10MLD plant i.e.

1) Land requirement per MLD of sewage, shown in Table 5.
2) Unit cost of annual O&M per MLD of STP, referred from Table 8.
3) Rate of land is considered as Rs. 1.00 lacs per hectare.
4) Unit cost of construction of STP per MLD, as shown in Table 4.

The life cycle cost for each technology has been calculated in Table 9 and plotted in graph. The graph showing the comparison of LCC among technologies is furnished in Figure 1. The life cycle cost for each technology for various capacities of STPs with land cost as Rs.1.00lacs/ha has been prepared in Table 9 and plotted in graph (Figure 2). The graph showing the variation of life cycle cost Vs land cost for the technologies for 1MLD plant is furnished in Figure 3 and its corresponding values in Table 11.

Table 9: LCC Analysis of different technologies

Sl. No	Description	Unit	WSP	UASB+ FPP	FAB	ASP	SBR
1	Design Flow	MLD	1.00	1.00	1.00	1.00	1.00
2	Unit area of STP required	ha	0.917	0.226	0.019	0.104	0.032
3	Area required for design flow	ha	0.92	0.23	0.02	0.10	0.03
4	Rate of land	Rs. in Lacs / ha	1.00	1.00	1.00	1.00	1.00
5	Unit cost of construction of STP	Rs. in Lacs / MLD	20.50	44.00	50.00	48.00	55.00
6	Unit cost of annual O&M of STP	Rs. in Lacs / MLD	3.88	5.47	7.40	7.48	7.63
7	Cost of land	Rs. in Lacs	0.92	0.23	0.02	0.10	0.03
8	Cost of construction of STP	Rs. in Lacs	21.42	44.23	50.02	48.10	55.03
9	Total cost of annual O&M of STP	Rs. in Lacs	3.88	5.47	7.40	7.48	7.63
10	Capitalised cost of O&M for 20 years @ 10% int.	Rs. in Lacs	33.03	46.57	63.00	63.68	64.96
11	Life cycle cost of STP for 20 years	Rs. in Lakhs	54.45	90.80	113.02	111.79	119.99

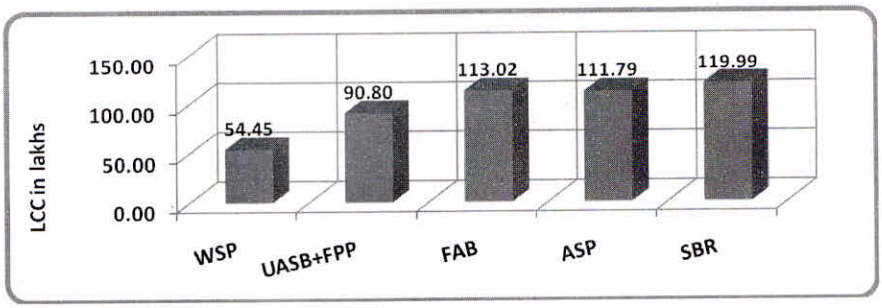

Fig. 1: Comparison of Life cycle cost per MLD of technologies

Table 10: Life cycle cost of varying capacity for land cost of Rs.1.00lacs/ha

CAPACITY in MLD	WSP	UASB+FPP	FAB	ASP	SBR
	Rs. In crores				
1	0.54	0.91	1.13	1.12	1.20
10	5.44	9.08	11.30	11.18	12.00
20	10.89	18.16	22.60	22.36	24.00
30	16.33	27.24	33.91	33.54	36.00
40	21.78	36.32	45.21	44.71	48.00
50	27.22	45.40	56.51	55.89	60.00
60	32.67	54.48	67.81	67.07	71.99
70	38.11	63.56	79.11	78.25	83.99
80	43.56	72.64	90.42	89.43	95.99
90	49.00	81.72	101.72	100.61	107.99
100	54.45	90.80	113.02	111.79	119.99

Table 11: Life cycle cost for different technologies of varying land cost

Land cost Rs in Lakhs	WSP	UASB+FPP	FAB	ASP	SBR
	Rs. In crores				
0	0.54	0.91	1.13	1.12	1.20
50	0.99	1.02	1.14	1.17	1.22
100	1.45	1.13	1.15	1.22	1.23
150	1.91	1.24	1.16	1.27	1.25
200	2.37	1.36	1.17	1.32	1.26
250	2.83	1.47	1.18	1.38	1.28
300	3.29	1.58	1.19	1.43	1.30

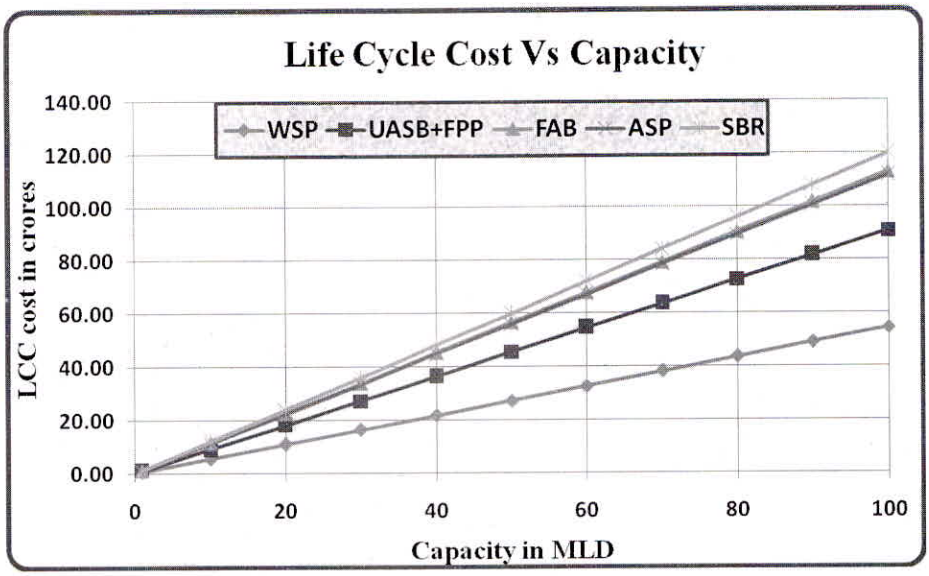

Fig. 2: Life cycle cost vs capacity, considering land cost Rs.1.00 lacs/ha

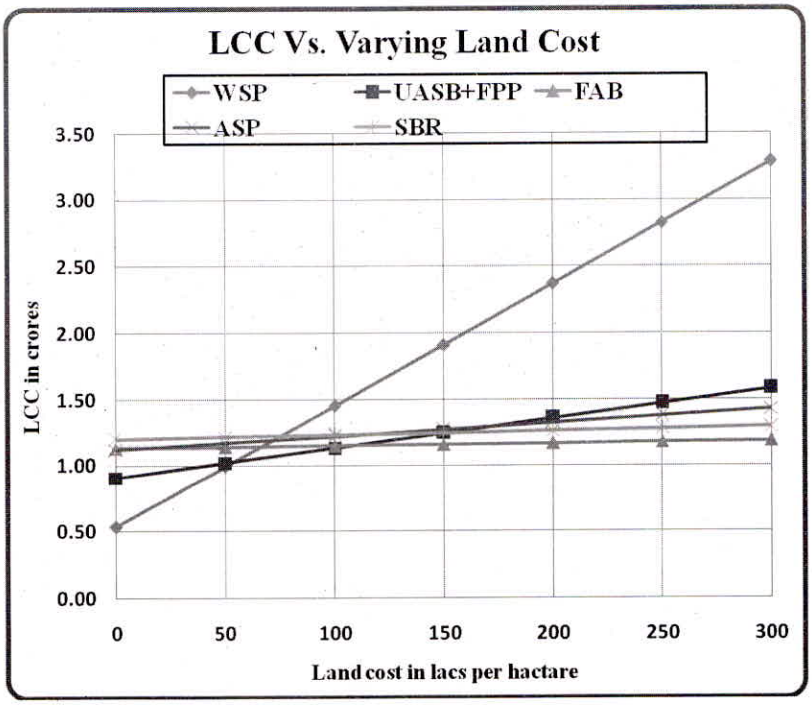

Fig. 3 : Life cycle cost vs land cost for 1.00 MLD plant

RESULTS AND DISCUSSION

Based on the study, evaluation based on different parameters has been summarized to make a choice for selection for appropriate technology, as shown in Table 12.

Table 12: Evaluation of Wastewater Treatment Technology

Sl. No.	Evaluation Parameter	WSP	UASB + FPP	ASP	FAB	SBR
		Rank (1 = Best)				
1.	Capital cost of Construction	1	2	3	4	5
2.	Revenue generation potential	3	1	2	5	4
3.	Land area requirement	5	4	3	1	2
4.	Operation & Maintenance cost	1	2	4	3	5
5.	Operability	1	2	3	4	5
6.	Reliability	1	2	5	4	3
7.	Power use	1	2	5	4	3
8.	Effluent quality	5	4	3	2	1
9.	Life Cycle Cost Analysis (for fixed land cost)	1	2	5	3	4

RECOMMENDATIONS

From the above study, it has been observed that,

1. WSP is the most economical and cost effective technology for low cost of land (approx. Rs.50.00lacs / ha) & a suitable option for Urban and Semi- urban areas where land is inexpensive, climate favourable and a simple method of treatment is desired not requiring equipment and operating skills
2. The UASB with FPP comes to the next option for medium cost of land (upto Rs.100lacs / ha) & is a suitable technology for all medium and small size cities / towns where required land can be made available, and treated effluent can be used for irrigation purpose along with aquaculture in Final Polishing Pond.
3. For high cost of land or land scarcity areas where huge area is not available, FAB, SBR and ASP are found to be economical in order, a suitable option in Mega & Metropolitan areas.

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