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COMPENDIUM OF SEWAGE TREATMENT TECHNOLOGIES

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MINISTRY OF ENVIRONMENT & FORESTS
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Foreword

Municipal sewage is the main source of pollution of rivers. The magnitude of this problem has increased in recent years due to rapid industrialisation and urbanisation. Due attention has, however, not been given to tackling the sewage so generated. This has contributed to degradation of water quality in a number of stretches of several rivers in the country.

Ganga Action Plan (GAP), the first systematic attempt at river conservation, was launched in the year 1985 to improve the water quality of river Ganga by preventing the domestic pollution load from reaching the river. Over time, this evolved into the National River Conservation Plan and pollution abatement works were initiated on several major rivers of the country. Treatment plants based on various technologies have been set up over the last two decades. Vast experience is thus available in the country on the working of these Sewage Treatment Plants. IIT Kanpur was entrusted with preparation of a compendium to provide an overview of different technological options available for treatment of sewage and assessment of their performance.

I hope the compendium will act as a store house of information on available technologies for sewage treatment and will cater to the needs of the Government agencies, policy makers, academicians and all others concerned with river conservation.

(JAIRAM RAMESH)

विजय शर्मा
Vijai Sharma

सत्यमेव जयते

सचिव
भारत सरकार
पर्यावरण एवं वन मंत्रालय
Secretary
Government of India
Ministry of Environment and Forests

Preface

The compendium of Sewage Treatment Technologies has been prepared for the National Ganga River Basin Authority by IIT Kanpur.

This document is based on the experience gained from the working of several sewage treatment technologies under the National River Conservation Plan (NRCP), particularly the Ganga Action Plan (GAP) and the Yamuna Action Plan (YAP), during the last two decades.

The compendium is a collation of information about the performance of sewage treatment plants gathered from Central and State Government agencies, various organizations and experts. The efforts of IIT Kanpur in this regard are gratefully acknowledged.

I hope that the compendium will prove useful in the selection of appropriate treatment technologies by the implementing agencies and urban local bodies.

Vijai Sharma
(VIJAI SHARMA)

जहाँ है हरियाली।
वहाँ है खुशहाली।।

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Acknowledgement

This compendium is a collation of information gathered from various individuals, central and state government agencies, other organizations and institutions and through extensive site visits.

The information pertains to sewage treatment plants (STPs) constructed in India (Ganga River Basin in particular) over the last two decades. Specifically, some of the information is derived from one of our earlier studies on the subject in collaboration with Foundation for Greentech Environmental Systems, New Delhi. Substantial inputs and feedback were also received from the National River Conservation Directorate, NRCD, MoEF, GOI, New Delhi. Suggestions and feedback from various NRCD officers, particularly, Shri Rajiv Gauba, Joint Secretary, Shri Lalit Kapur, Director and Shri Lalit Bokolia, Joint Director during preparation of this compendium are gratefully acknowledged.

- Vinod Tare and Purnendu Bose

Contents

Executive Summary

This compendium of sewage treatment technologies has been prepared, based on primary and secondary data gathered from operation of sewage treatment plants (STPs) in the country over the last two decades. The data gathered was assimilated and analyzed for determination of treatment efficiency, treatment cost and land requirements of various technological options available for sewage treatment. Finally, various available treatment options have been categorized and specific recommendations made regarding various technological options for sewage treatment in the various regions. Though the study is based primarily on the sewage treatment technologies adopted in the Ganga basin, the experience of other parts of the country has also been incorporated to develop the guidelines.

The salient aspects of the existing STPs in the Ganga river basin are as follows,

- Various technologies adopted for sewage treatment in the basin include, 1) Waste Stabilization Ponds (WSPs), 2) Duckweed Pond Systems (DPS), 3) Karnal Technology, 4) Facultative Aerated Lagoons (FAL), 5) Trickling Filter (TF), 6) Activated Sludge Process and its modifications (ASP), 7) BIOFOR process, 8) ASP BIOFOR-F process, 9) Fluidized Aerated Bed (FAB) process, 10) Submerged Aerated Fixed Film (SAFF) process, 11) Rotating Biological Rope Contactor (RBRC) process, 12) Up flow Anaerobic Sludge Blanket (UASB) process, and 13) Down Hanging Sponge Bio tower (DHSB) process,
- 32 STPs (728 MLD treatment capacity) were constructed and 11 existing STPs (151 MLD treatment capacity) were renovated under the Ganga Action Plan Phase I (GAP-1). Activated sludge process (ASP) was the most preferred technology, with ASP and its minor variants accounting for almost 62% of the total capacity.
- 26 STPs (722 MLD treatment capacity) were set up under the Yamuna Action Plan, Phase-I (YAP-I). Up flow Anaerobic Sludge Blanket (UASB) process was the most preferred treatment technology, accounting for 83 percent of the total installed treatment capacity.

- Concurrently with YAP, 30 STPs having 2325 MLD of sewage treatment capacity were added in Delhi under the river conservation programme of the Government of NCT Delhi. Most of these STPs are based on ASP technology or its minor variants. A large STP (182 MLD capacity) has been constructed at Rithala using the BIOFOR-F technology.

In addition to the technological options discussed above, several other technologies have been used with success in various parts of India. These include the Sequential Batch Reactor (SBR) technology and its minor modification known as the CTECH process, which has been employed in several places in western and southern India. Another promising technological option is the Moving Biological Bed Reactor (MBBR), which is very similar to the FAB system mentioned earlier. Further in many places in western and southern India, the UASB process has been used in conjunction with FAL and a Final Polishing Unit (FPU) or in conjunction with the ASP process to provide high quality treatment.

The categorization of the treatment technologies has been done based on comprehensive analysis of performance and cost data from a large number of sewage treatment plants in the Ganga river basin and elsewhere employing all the technological options mentioned above. The treatment technologies have been divided into four categories. This classification may not be universal, but is certainly valid based on experience with wastewater treatment plants over the past two-three decades in India in general, and the Ganga basin in particular. The classification and its basis is explained as follows.

Category I:

Technologies with good performance, low energy requirement, low resource requirements and associated costs, but high land requirements fall in this category. Waste stabilization pond systems (WSPS) and slow rate trickling filters (TF) are the examples of this category of treatment systems. Such systems should be adopted wherever, 1) land availability is not a problem, and 2) winter temperatures are not very low. Effluent from well designed and well maintained systems of this type will meet the Indian standards for discharge into water bodies (i.e., $BOD_5 < 30$ mg/L, $SS < 30$ mg/L)

Category II:

Technologies with good performance, high energy requirement, high resource requirements and associated costs, and moderately low land requirements fall in this category. The 1) ASP system and its minor modifications, 2) UASB system with FAL and FPU units for downstream treatment and 3) UASB system with ASP for downstream treatment are examples of this category of treatment systems. These technologies may be adopted wherever land is a constraint. Effluent from well designed and well maintained systems of these types will meet the Indian standards for discharge into water bodies (i.e., $BOD_5 < 30$ mg/L, SS < 30 mg/L) with HIGH DEGREE OF RELIABILITY.

Technologies with very good performance, very high energy requirement, very high resource requirements and associated costs, and low land requirements also fall in this category. Various advanced aerobic processes, i.e., BIOFOR, ASP BIOFOR-F, FAB/MBBR, SAFF and SBR/CTECH are examples of this category of treatment systems. These technologies may be adopted wherever land is a major constraint. Effluent from well designed and well maintained systems of these types will easily satisfy the Indian standards for discharge into water bodies. In fact, the effluent from above systems are expected to produce effluent with $BOD_5 < 20$ mg/L, SS < 20 mg/L with HIGH DEGREE OF RELIABILITY.

Category III:

Technologies with moderate performance, moderate energy requirement, moderate resource requirements and associated costs, and moderately low land requirements fall in this category. High rate TF with both gravel and plastic media and FAL are examples of this category of treatment systems, with the overall assessment of TF systems being slightly better than that for FAL. These technologies can be adopted wherever adopting technologies of category II is not possible due to cost considerations and adoption of technologies of Category I is impractical due to land constraints. The effluent from systems of this type in combination of downstream treatment system such as Maturation Pond can meet the Indian standards (i.e., $BOD_5 < 30$ mg/L, SS < 30 mg/L) for discharge into water bodies.

Category IV:

Technologies with marginal performance, but low energy requirement, moderate resource requirements and associated costs and moderately low land requirements fall in this category. The UASB system with FPU for downstream treatment is an example of this type of treatment system. Such a system may not meet the Indian standards (i.e., $BOD_5 < 30$ mg/L, SS < 30 mg/L) for disposal into water bodies even when a final polishing unit (FPU) having 24 – 48 h retention time is provided for further treatment of UASB effluent.

Some other technologies, i.e., Karnal Technology, DPS, RBRC and DHSB have been used in the Ganga basin in various small wastewater treatment plants. No specific categorization is provided for these technologies, since enough data is not available to accurately assess the performance of these technologies. However, among the above, DPS is a proven technology and may well be categorized in Category I. The other technologies, i.e., Karnal Technology, RBRC and DHSB are not recommended for widespread adoption without further assessment.

Producing Effluent of Recyclable Quality

It should be noted that none of the technological options discussed above produce water of recyclable quality (i.e., $BOD_5 < 5$ mg/L, SS < 5 mg/L). For that purpose, tertiary treatment of the biologically treated effluent through coagulation-flocculation (C-F), sedimentation and rapid sand filtration (RSF)/dual media filtration (DMF) is required. Alternatively, the Membrane Bio-reactor (MBR) process may be applied to directly produce recyclable effluent. No STPs in the Ganga river basin produce recyclable quality effluent. However, some STPs producing recyclable quality effluent for industrial purpose employing these technologies are operating in Western and Southern India.

Cost of Treatment and Land Requirement

Comprehensive analysis of capital cost, O&M cost, reinvestment cost, energy and land requirement based on data obtained from various STPs in the Ganga river basin and elsewhere in India was performed for preparing this report. This analysis has been summarized in Figure 1 as linkage between the total annualized cost (Rs/kL as in 2008) and the land area requirement (m^2/MLD) for various available technological options. For a particular desired effluent quality, the technological option with more annualized cost will generally require less land area and vice-versa.

For example, among the treatment options that produce effluent of quality better than Indian standard for discharge into water bodies (i.e., BOD_5 < 30 mg/L, SS < 30 mg/L), unlined WSP has the lowest treatment cost (~ Rs 1/kL) but the highest land requirements (~ 20000 m^2/MLD), while an advanced aerobic process like SBR/CTECH will have high treatment cost (~ Rs 5/kL) but low land requirement (~ 600 m^2/MLD). The conventional ASP is somewhere in the middle, with moderate treatment costs (~ Rs. 3.5/kL) and moderate land requirements (~ 2000 m^2/MLD). Similarly, among treatment options that produce effluent of recyclable quality (i.e., BOD_5 < 5 mg/L, SS < 5 mg/L), the ASP + C-F + RSF/DMF process has the lowest treatment cost (~ Rs 6.50/kL) but the highest land requirements (~ 3000 m^2/MLD), while the MBR process will have highest treatment cost (~ Rs 9/kL) and the lowest land requirements (~ 600 m^2/MLD). The SBR + C-F + RSF/DMF process will have an intermediate treatment cost (~ 7.50/kL) and also an intermediate treatment area requirement (~ 1200 m^2/MLD).

Improvement of River Water Quality

It should be noted that none of the treatment technologies discussed above can completely remove nutrients (especially nitrate) from the sewage. In addition, there is a severe lack of dilution water in the dry season in most rivers. Considering the above factors, substantial growth of algae or other aquatic plants such as water hyacinth in receiving water bodies cannot be ruled out even if all influent sewage is intercepted and treated using the most efficient technologies before discharge into rivers. Thus, the original objectives of the RAPs, i.e., restoration of bathing quality water in the rivers may not be fulfilled unless the supply of dilution water in these rivers is increased substantially. It is advisable that sewage is treated to recyclable water quality and used for various purposes including recharging local water bodies such as lakes, ponds, etc.

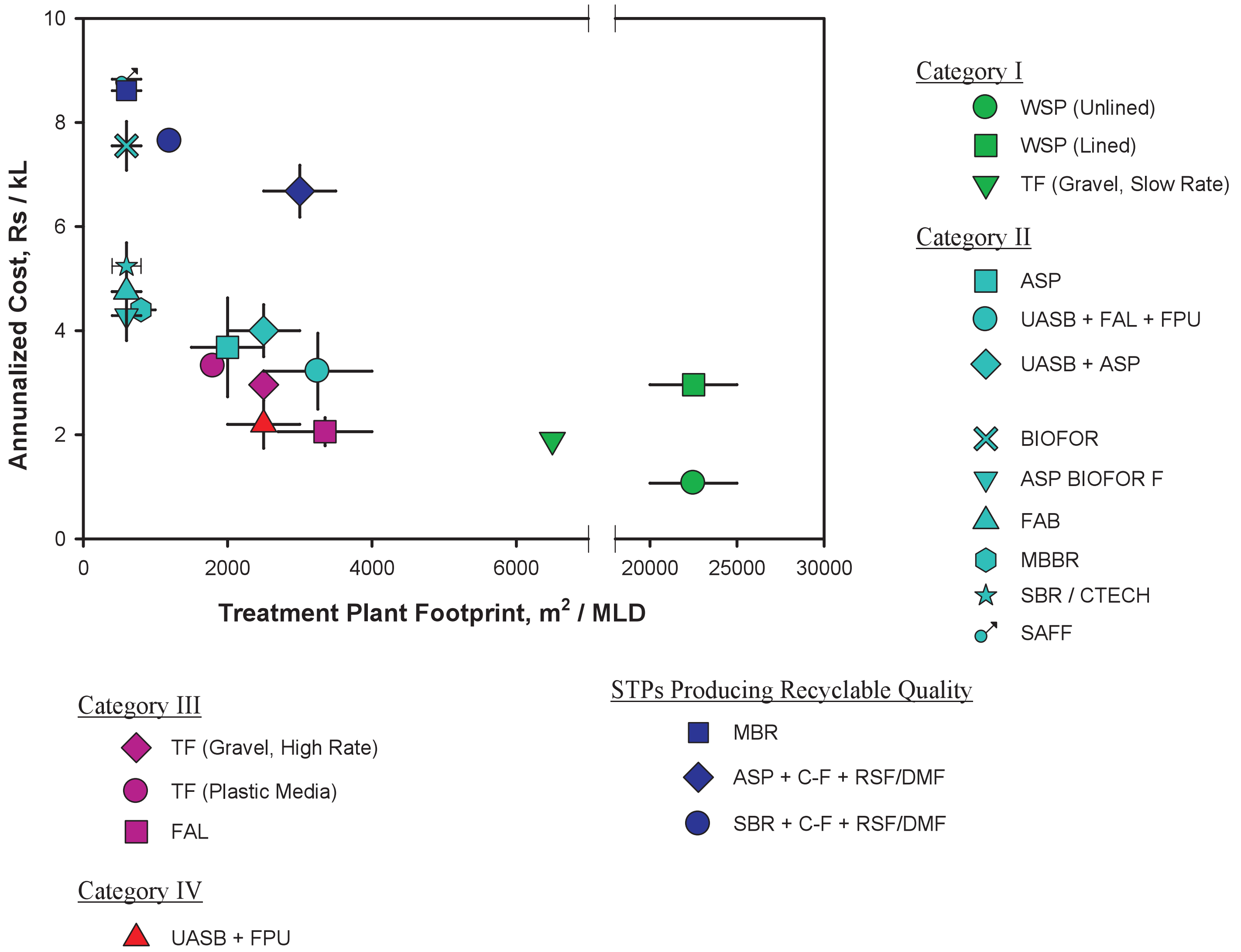

Figure 1: **Annualized Cost (as in 2008) of Treatment and Corresponding Land Requirement for Various Treatment Technologies**

1. Introduction

To prevent the pollution of river Ganga and to improve its water quality, an Action Plan known as the Ganga Action Plan was formulated in the year 1984 on the basis of a comprehensive survey of Ganga Basin carried out by the Central Pollution Control Board under Assessment and Development Study of River Basin (ADSORB). The objective, at the time of launching the Ganga Action Plan in 1985, was to improve the water quality of the river Ganga to acceptable standard by preventing the pollution load from reaching the river. Various schemes of interceptions & diversion and treatment of sewage have been undertaken under the Ganga Action Plan (GAP).

Since 1985, more than 70 sewage treatment plants have been constructed under the GAP and Yamuna Action Plan (YAP). These plants are based on a range of technologies involving varying levels of mechanisation, energy inputs, land requirement, skilled manpower, etc. In the early stages, the selection of technology was based on past experience and its perceived performance efficiency. Moreover, at different stages of these Action Plans a number of technologies have been tried out on pilot scale and some of them have been scaled up for larger capacity plants. Over the last 20 years a considerable experience and expertise has been developed within the country in this sector. However, the level of performance of these plants with regard to effluent quality, energy consumption, process stability, resource recovery, capital and O&M costs, etc. has varied considerably.

This compendium of sewage treatment technologies is brought out to provide guidelines to the implementing agencies/local bodies for selection of appropriate technology. The analysis and inferences made regarding STPs rely heavily on secondary data from various sources, though some primary data has also been obtained through visits to various STPs in the Ganga river basin and elsewhere in India. The focus is mainly on centralized wastewater treatment options and does not include information on decentralized and in-stream/in-situ wastewater treatment technologies.

The document begins with an overview of the STPs constructed/renovated in the Ganga basin over the last two decades (Chapter 2). This is followed by a listing of the data sources used for preparation of the compendium (Chapter 3) and a summary of the data analysis (Chapter 4) to arrive at the main conclusions (Chapter 5). ‘Technology Fact Sheets’ for various technologies are provided in the Appendix.

2. Overview of Treatment Technologies

Sewage Treatment Infrastructure under GAP-I

A treatment capacity of 728 MLD has been created by constructing 32 new STPs and 151 MLD capacity augmented in 11 existing STPs under the GAP-I. Relevant details are presented in Table 1.

Table 1: Technology wise Distribution of STP Capacity Created under GAP-1

Technology	No. of Plants		STP Capacity, MLD			% of Total in GAP	
	Old	New	Old	New	Total	New	Total
ASP	4	10	61.0	362	423	50	48
UASB	-	3	-	55	55	8	6
WSP	3	12	13.5	126	140	17	16
TF	4	2	76.8	58	135	8	15
FAL	-	3	-	47	47	6	5
RBRC	-	1	-	0.3	0.3	0	0
RF-AS	-	1	-	80	80	11	9
Total	**11**	**32**	**151**	**728**	**880**	**100**	**100**

ASP : Activated sludge process
UASB : Up flow anaerobic sludge blanket process
WSP : Waste stabilisation pond
TF : Trickling filter
FAL : Facultative aerated lagoon
RBRC : Rotating biological rope contactor
RF-AS : Roughing filter – Activated sludge process

Activated sludge process was the most preferred technology accounting for 48% of total STP capacity created under GAP-I. If its design variants i.e., aerated lagoons and RF-AS are clubbed together, ASP accounts for almost 62% of the total capacity. Waste stabilisation pond system (WSPS) accounted for 16% of total capacity. Four existing STPs and two new STPs were based on trickling filter technology, which together accounted for 15% of the total GAP-I capacity.

UASB technology which was introduced on pilot and experimental basis accounted for 6% of total capacity. A 5 MLD STP based on UASB technology was implemented on a pilot basis in Kanpur to assess the suitability of the technology for domestic wastewater. Based on the performance of the pilot plant a full scale UASB plant of 36

MLD capacity was constructed in the same complex, primarily for treatment of tannery wastewater. The innovative aspect of the treatment scheme was mixing of sewage with the tannery wastewater in a ratio of 3:1 to make the latter more amenable to treatment. Simultaneously another full scale UASB plant of 14 MLD was constructed at Mirzapur, this time for treating only domestic wastewater. All the three plants were used in conjunction with a settling pond called ‘final polishing unit’ (FPU).

Sewage Treatment Infrastructure under Yamuna Action Plan

The experience under GAP was mixed in terms of efficiency of treatment versus energy consumption and cost of operation and maintenance. Drawing lessons from the GAP, the Yamuna Action Plan (YAP) opted for energy neutral and energy recovery technologies for sewage treatment. The experience gained from the experimental UASB plants in Kanpur and Mirzapur and from the waste stabilisation ponds was used extensively. The key factors that went against the conventional aerobic systems were their high energy requirements, unreliable power supply situation in the GAP-I states, and higher O&M costs; while those in favour of UASB and WSP were their robustness, low or no dependence on electricity, low cost of O&M and low skilled manpower requirement.

Moreover, the possibility of resource recovery from biogas and aquaculture respectively also influenced the selection process. In addition, two STPs of 10 MLD capacity each were constructed in Delhi based on BIOFOR technology, which was a new and patented system. Details regarding the treatment infrastructure built under the YAP are presented in Table 2.

Table 2: Technology wise Distribution of STP Capacity Created under YAP

Technology	No. of Plants	STP Capacity, MLD	% of Total in YAP
UASB	16	598	83
WSP	10	104	14
BIOFOR	2	20	3
Total	**28**	**722**	**100**

Pilot Plant Implementation

During the YAP a great deal of flexibility was offered for innovation and experimentation with the newer sewage treatment technologies which offered high end performance with regard to effluent quality and compactness. Two STPs of 3 MLD each based on fluidized aerated bed (FAB) technology and 2 STPs of 2 MLD each based on Submerged Aerated Fixed Film (SAFF) technology were set up. These plants are termed as ‘mini STPs’ and are located in Delhi. In addition 10 very small size treatment plant of 15 m^3/day capacity were constructed which were attached to community toilet complexes. These plants are based on ‘Johkasou’ concept of Japan which means small individual household level wastewater treatment system. They involve a combination of typical processes such as sedimentation, diffused aeration, attached biomass, disinfection, etc. and are prefabricated with fibre reinforced plastic. These are very compact plants and are appropriately called ‘micro STPs’. In addition, a pilot project was carried out at Gaziabad along side a UASB plant wherein 3 MLD of sewage after treatment in the screening and grit chamber was diverted for irrigation of a plantation of eucalyptus trees. A six hectare plot was used to assess the effectiveness and suitability of this so called ‘Karnal technology’.

Treatment Capacity Created by the Govt of NCT of Delhi

Concurrently with YAP, over 2325 MLD of sewage treatment capacity was added in Delhi under the river pollution control programme by the Government of NCT of Delhi. During the last 25 years or so, about 30 STPs have been constructed in Delhi. They are all based on either conventional activated sludge process or its variants e.g., extended aeration process or advanced multistage aeration processes. Two of the recently commissioned STPs at Okhla and Rithala in this group have been included in the current document. Former is a conventional activated sludge process plant while the latter involves two-stage treatment comprising of high rate activated sludge process followed by second stage aeration and rapid sand filtration (BIOFOR - F technology). Both the plants have sludge digesters where the biogas yield is reported to be consistently high. The later plant is equipped with a state-of-the-art biogas to electricity generation system and is claimed to be self sufficient in its energy requirement.

Decentralized Treatment

A large number of community toilet complexes (CTC) for urban communities and for floating population were constructed under both GAP and YAP. The main objective was to prevent open defecation in general and along the river banks in particular, thus improving sanitation, public health, leading to minimization of the discharge of organic waste into the river. Considering the expected large user base, water based systems were the obvious choice for CTCs. The technology adopted was 'pour flush latrines' with a water seal attached to a septic tank or directly to the sewer lines.

Novel Treatment Technologies in Other Parts of India

In addition to the treatment technologies adopted in the Ganga river basin, several novel technology options were implemented elsewhere in India over the last two decades. These include Sequential Batch Reactor (SBR) and Cyclic Activated Sludge Process (marketed as C-TECH) implemented in Navi Mumbai, Goa and southern India. Several small plants based on MBR technology have also come up in Bangalore, Mysore, Pune and Chennai for producing recyclable quality effluent. In addition several STPs are being operated by various industries (e.g., RCF Mumbai and CPCL Chennai) for producing water fit for use in industrial applications. The input to these plants is raw sewage, which is treated by biological process and tertiary filtration.

3. The Database

The performance data for most of the plants mentioned in Chapter 2 was evaluated for the preparation of this document. Specifically, the list of documents referred to for this purpose is given in Table 3.

Table 3: Key Documents Referred for the Study

Title	Agency / Author	Year
NRCP Guidelines	Ministry of Environment and Forest	April 2002
Evaluation of Ganga Action Plan	Ministry of Environment and Forest	April 1995
Yamuna action plan – Approach paper	Ministry of Environment and Forest	Undated
Performance review of Yamuna Action Plan	Alternate Hydro Energy Centre IIT Roorkee	July 2002
Pollution study for Yamuna action plan – II : Executive summary and strategic considerations	Tokyo Engineering Consultants Co., Ltd, Japan	October 2002
Status report on Dinapur sewage treatment plant and surroundings	Central Pollution Control Board, New Delhi	November 2001
Special assistance for project implementation for Yamuna action plan project – Final report.	SAPI team for JBIC	June 2000
Wastewater treatment for pollution control	Soli J. Arceivala	1998
A design manual for waste stabilisation ponds in India	Mara, D.D. et. al.	1997
A guide to the development of on-site sanitation	R. Franceys, J. Pickford and R. Reed., WHO	1992
Report on institutional strengthening – Yamuna action plan project	ACORD, New Delhi	March 2001
Inception report – JBI funded Agra municipal reform project	IPE Consultants, New Delhi	March 2003
Case study on sewage treatment plants and low cost sanitation under river action plans, Volume I: Technical	Foundation for Greentech Environmental Systems, New Delhi	February 2004
UASB technology for sewage treatment in India: Experience, Economic evaluation and its potential in other developing countries	Paper presented at the 12th international water technology conference in Alexandria, Eygpt	May 2009
Sewage treatment issues: The developer's perspective	ASSOCHM-ACME seminar on Innovations in Wastewater Treatment and Economic Reuse	September 2006
Technology Options for Urban Sanitation in India	Water and Sanitation Program, Government of India	September 2008
Evaluation of Operation and Maintenance of Sewage Treatment Plants in India-2007	CPCB, Control of urban pollution series, CUPS/68/2007	January 2008

Through field visits to the STPs and discussions with plant operators, detailed information with respect to the performance, capital and operation and maintenance cost and other operational issues was collected from some representative STPs in the country. The STPs studied alongwith relevant details are presented in Table 4.

Table 4: Treatment Plants Studied in Detail

Plan/ Places	STP Covered	Remarks
Under Ganga Action Plan		
Varanasi	RF-ASP at Dinapur	80 MLD plant having
Allahabad	ASP	60 MLD conventional ASP plant
Under Yamuna Action Plan		
Vrindavan	WSP	4 and 0.5 MLD plants
Mathura	WSP	12.5 MLD Masani nala plant
Agra	UASB	78 MLD with biogas utilisation
Faridabad	UASB	20 MLD plant with biogas utilisation
Gaziabad	Karnal technology	3 MLD
Delhi	BIOFOR	10 MLD STP at Sen Nursing Home nala
Under Govt. of Delhi's own plan		
Delhi	BIOFOR-F	182 MLD STP, the largest advanced system covered in the study
Delhi	ASP	72 MLD STP at Okhla
Delhi	DPS	1 MLD
Pilots Plants Built Under YAP-I		
Delhi	FAB	3 MLD decentralised plant in a low income community
Delhi	SAFF	--do--
Karnal	DHSB	Polishing unit downstream of a UASB.
Under Gomti Action Plan		
Lucknow	FAB	42 MLD STP
Plants in Mumbai Region		
Navi Mumbai	SBR (CTECH)	Recently commissioned 100 MLD plant in Nerul
Mumbai	ASP + Tertiary Filtration	STP for water reclamation at RCF, Chembur operating since 2000
Plants in Goa		
Goa	SBR (CTECH)	12.5 MLD STP at Panjim

Table 4 continued..........

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Plan/ Places	STP Covered	Remarks
Plants in Gujarat		
Ahmedabad	UASB + FAL + FPU	106 MLD STP
Vadodara	UASB + ASP	43 MLD STP
Plants in Karnataka		
Bangalore	MBR	1 MLD plant at Cubbon Park for reclamation of water
Bangalore	TF-BIOFOR	60 MLD plant at V-Valley for polishing treatment of secondary treated sewage
Plants in Tamil Nadu		
Chennai	MBR	1 MLD at TIDEL Park commissioned in 2006
Chennai	SBR-Tertiary Filtration	water reclamation in CPCL, Chennai
Plants in Hyderabad		
Hyderabad	ASP-Tertiary Filtration	10 MLD STP
Hyderabad	UASB – FAL - FPU	A 172 MLD STP under commissioning

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4. Data Analysis

Activated Sludge Process (ASP)

Detailed data as obtained from the three ASP plants, literature survey and NRCP guidelines are presented in Table 5. Performance data of the above STPs and corresponding literature values are presented in Table 6.

Table 5: Key Parameters for ASP Based STPs

STP Location	Capacity MLD	Land ha/MLD	Energy Consumption kWh/MLD	O&M Costs as in 2003 Rs. million/ MLD	Capital Costs as in 2003 Rs. million/ MLD
Allahabad	60	0.18	225	0.49	3.3
Varanasi	80	0.25	180	0.40	2.2
Okhla	72	0.15	211	0.44	2.6
Literature*	-	0.19-0.23	182-228	-	4.33-5.12
MOEF	-	0.2	-	0.36	4.2-4.8

** Source : Arceivala, 1998*

Table 6: Performance of ASP based STPs (Monthly Averages)

STP Location	Effluent BOD mg/L	Effluent COD mg/L	Effluent SS mg/L	Effluent FC MPN/100 mL	Effluent DO mg/L
Allahabad	29-33	280	40-44	$10^6 – 10^7$	3
Varanasi	13-77	98-168	25-121	$10^5 – 10^8$	3
Okhla	<30	40-60	30	$10^4 – 10^5$ (TC)	2
Literature*	<30 (85-92% Removal)	-	-	60 – 90 % Removal	-

** Source : Arceivala, 1998*

Trickling Filter (TF)

Six high rate TF based plants of different capacities were either renovated or newly constructed during GAP-I in West Bengal. While the cost and other relevant data of these plants could not be obtained, plant performance data is presented in Table 7.

Table 7: Performance of TF based STPs (Monthly Averages)

STP Location	Effluent BOD mg/L	Effluent TSS mg/L	BOD Removal %	TSS Removal %
Kamarhatti	32-48	40-70	61	65
Kalyoni	42-62	60-100	65	46
Chandan Nagar	35-35	20-80	63	55
Srerampore	32-68	20-90	71	64
Howrah	18-52	20-60	73	65

Waste Stabilization Ponds (WSPs)

Detailed data obtained from the six WSP based plants, literature survey & NRCD guidelines are presented in Table 8. Performance data of the above STPs and corresponding literature values are presented in Table 9.

Table 8: Key Parameters for WSPs based STPs

STP location	Capacity MLD	Land ha/ MLD	Energy Consumption kWh/MLD	O&M Costs as in 2003 Rs. million/ MLD	Capital Costs as in 2003 Rs. million/ MLD
Vrindavan	0.5	1.00	Negligible	0.65	6.6
Vrindavan	4	1.50	Negligible	0.10	4.5
Karnal	8	2.31	Negligible	0.10	1.4
Palwal*	9	2.08	Negligible	0.09	2.1
Mathura	12.5	1.12	Negligible	0.06	3.5
Howrah	30	0.78	Negligible	0.08	2.4
Literature[+]	-	0.9-2.6	Negligible	-	1.1 -1.44

*+ Source : Arceivala, 1998; * Source : MOEF, 1998*

Table 9: Performance of WSP based STPs (Monthly Averages)

STP location	Effluent BOD mg/L	Effluent SS mg/L	Effluent FC MPN/100 mL
Vrindavan	40-79	54-139	10^6 - 10^8
Vrindavan	30-60	-	-
Karnal	70-100	44-70	10^5 - 10^8
Mathura	20-30	-	104
Howrah	13	39	-
Literature[+]	75-85% Removal	-	60 – 99.9% Removal

+ Source : Arceivala, 1998

Up-Flow Anaerobic Sludge Blanket (UASB) Process

Detailed data obtained from the 8 UASB plants and literature survey are presented in Table 10. Performance data of the above STPs and corresponding literature values are presented in Table 11.

Table 10: Key Parameters for UASB based STPs

STP Location	Capacity MLD	Land ha/ MLD	Energy Consumption kWh/ MLD	O&M Costs as in 2003 Rs. million/ MLD	Capital Costs as in 2003 Rs. million/ MLD
Panipat	10	0.30	15	0.17	3.4
Faridabad	20	0.29	17	0.13	3.6
Yamunanagar	25	0.28	15	0.11	3.3
Gurgaon	30	0.32	14	0.10	3.1
Panipat	35	0.29	14	0.09	3.2
Karnal	40	0.20	14	0.09	3.2
Gaziabad	56	0.23	14	0.08	2.4
Agra	78	0.26	11	0.07	2.4
Literature[1]	-	0.14-0.19*	Nil	-	2.9-3.7*
MOEF[2]	-	0.2	-	0.2	2.8-3.4*

*1. Source : Arceivala, 1998; 2. Source : MOEF, 1998; * Excluding post treatment requirements*

Table 11: Performance of UASB based STPs

STP Location	Effluent BOD mg/L	Effluent COD mg/L	Effluent SS mg/L	Effluent FC MPN/100 mL	Effluent DO mg/L
Panipat	-	288-352	-	10^6-10^7	Nil
Faridabad	27-30	99-170	25-45	10^5	Nil
Yamunanagar	-	240-320	-	10^6-10^7	Nil
Gurgaon	-	112	-	10^6-10^7	Nil
Panipat	-	-	-	10^6-10^7	Nil
Karnal	-	112-128	-	10^6-10^7	Nil
Gaziabad	28-33	280	-	10^6-10^7	Nil
Agra	50-55	-	89-111	10^6-10^7	Nil
Literature[1]	75-85% Removal	74-78% Removal	-	-	-

1. Source : Arceivala, 1998

In addition to the UASB + FPU systems mentioned above, two UASB + FAL + FPU systems located in Ahmedabad and Hyderabad and a UASB + ASP system in Vadodara was also studied. The treatment efficiency of these three plants was much superior to the UASB + FPU plants in Haryana and UP constructed under the YAP and was comparable to that of various ASP based plants examined during the study. It was thus concluded that UASB + FAL + FPU or UASB + ASP plants can be considered to be at par with conventional ASP plants in terms of treatment efficiency. However, the land area requirement of a UASB + FAL + FPU plant is considerably larger than a comparable ASP plant, though the treatment costs are marginally lower. The land area requirement of a UASB + ASP plant is comparable to a conventional plant, but the treatment costs are considerably higher.

Facultative Aerated Lagoons (FAL)

Three STPs based on this technology were installed under GAP in Bihar. However, under YAP no such plants were installed. Literature survey indicate that land requirements of a FAL system, at 0.3 to 0.4 ha/MLD is comparable to ASP systems. However, capital and O&M costs are much lower. A well functioning facultative lagoon will achieve 70-90% BOD removal, 70-80% SS removal and 60-99% FC removal.

Duckweed Pond System (DPS)

Although no STP based on this technology was set-up under GAP/YAP, a pilot project was implemented jointly by the Municipal Corporation of Delhi, the Central Pollution Control Board and Sulabh International in Delhi. The 1 MLD pilot plant was commissioned in 1994-95. Typically sewage after primary treatment is treated in a DPS. Performance characteristics of typical DPS based STPs are presented in Table 12.

Table 12: Performance of STPs based on DPS

Parameter	Stage of Treatment		
	Raw Sewage	After Primary Settling	After Duckweed Pond
BOD, mg/L	120-237	80-110	16-27
SS, mg/L	195-918	40-480	10-90
COD, mg/L	370-650	160-245	55-80
Total N, mg/L	16.5-79	11.7-46	10-25
Total P, mg/L	1.1-3.9	0.2-3.6	0.1-2.5
Faecal Coliform, MPN/100 mL	$7.2\text{-}88 \times 10^5$	$9\text{-}11 \times 10^5$	$2\text{-}8 \times 10^3$

(Source: CPCB, 2001)

Notes:

1. Coliform removal is around 3 log scale.
2. Data based on two case studies of Delhi and Bhubaneshwar

Advanced Aerobic Processes (AAP)

The wastewater treatment plants mentioned below have been clubbed together as advanced aerobic processes.

- BIOFOR technology based STP at Dr. Sen Nursing Home (SNH) Nalla, Delhi
- Two stage ASP BIOFOR-F technology based STP at Rithala, Delhi
- Fluidized Aerated Bed (FAB) technology based STP at Molarband, Delhi
- FAB technology based STP at Lucknow
- Submerged Aerated Fixed Film (SAFF) technology based STP at Holambi, Delhi

Detailed data obtained from these plants are summarized in Table 13 and their performance is presented in Table 14. The data show that the performance of this group of STPs is clearly superior to those in other categories mentioned earlier. In addition to the above plants, two plants based on SBR technology in Navi Mumbai and Goa were also studied. Their performance is comparable to other AAPs.

Table 13: Key Parameters for Advanced Aerobic Process based STPs

STP Location	Capacity MLD	Land ha/ MLD	Energy Consumption kWh/ML	O&M Costs as in 2003 Rs. million/ MLD	Capital Costs as in 2003 Rs. million/ MLD
BIOFOR, SNH Nalla, Delhi	10	0.04	220	0.8	6.5
ASP BIOFOR-F, Rithala	182	0.08	180	0.18	5.2
FAB, Molarband	3	0.06	133	0.66	4.6
FAB, Lucknow	42	0.03	99	0.59	3
SAFF, Holambi	2	0.05	390	1.1	7

Table 14: Performance of Advanced Aerobic Process Based STPs

STP Location	Effluent BOD mg/L	Effluent COD Mg/L	Effluent SS mg/L	Effluent FC MPN/100 mL	Effluent DO mg/L
BIOFOR, SNH Nalla, Delhi	<10	-	<15	10^6	2-3
ASP BIOFOR-F, Rithala	<15	-	12-22	10^5	>1.5
FAB, Molarband	<10	88	20	10^5	1-2
FAB, Lucknow	<20	<100	27	-	1-2
SAFF, Holambi	<5	16	15	750	-

Plants Producing Recyclable Quality Effluent

Five plants producing recyclable quality effluent suitable for industrial and certain domestic uses were also studied. These include two MBR plants in Bangalore and Chennai, two ASP + tertiary filtration plants in Mumbai and Hyderabad and one SBR + tertiary filtration plant in Chennai. BOD_5 and SS in the effluent from these plants were < 5 mg/L, while effluent COD was <20 mg/L. The DO concentration in the effluent was > 3 mg/L. FC removal is reported to be 6-7 logs for MBR plants whereas for the plants employing tertiary filtration FC removal is 5-6 logs.

5. Assessment of Technologies

As part of evaluation methodology for various technological options for sewage treatment, a number of parameters have been identified. These include performance, stability, resource requirement and associated costs, impact of effluent discharge on environment and possibility of resource recovery. The rationale for assessment of the technology options based on the identified evaluation parameters is presented in the following sections.

Each technology option has been graded on a scale for each of the identified evaluation parameters. As per the appraisal scale, a technological option is rated as 'very high', 'high', 'medium' or 'low' depending upon its assessment vis-à-vis a particular parameter based on the understanding of the problems associated with it. The consolidated assessment of all technological options in the above manner is presented as an 'Exhibit' at the end of this chapter.

Performance in Terms of Quality of Treated Sewage

Conventionally, the major concern in terms of discharge of treated or untreated wastewaters in water bodies has been the presence of organic matter and pathogens. These are responsible for (i) spoiling aesthetics of water bodies, (ii) depletion of dissolved oxygen resulting in adverse impact on aquatic life, and (iii) spread of water born diseases. Effluent discharge standards for TSS, BOD and FC adopted in RAPs typically address these issues. Any treatment technology must ensure that these discharge standards are met. Potential of technologies producing recyclable quality effluent (MBR, ASP + C-F + RSF/DMF and SBR + C-F + RSF/DMF) to meet discharge standards are obviously 'very high'. Also, the potential of advanced aerobic treatment technologies (BIOFOR, ASP BIOFOR F, FAB, MBBR, SBR, CTECH and SAFF) examined in this study in terms of meeting the discharge standards are 'very high'. Potential of some other technologies, i.e., ASP and UASB + ASP examined in this study are also 'very high', while that of UASB + FAL + FPU is 'high' to meet the discharge standards. Potential for other technologies such as WSP and low rate TF to meet discharge standards are also ‘high’. Potential for technologies such as FAL and high rate TF to meet discharge standards are ‘medium’, while that of ‘UASB + FPU’ system is ‘low’. However potential for FAL System in combination with maturation pond to meet the discharge standard is ‘high’.

To safeguard against the spread of water borne diseases due to the discharge of sewage to the water bodies, CPCB had undertaken a study to come-up with desired and maximum levels of coliform in the treated wastewater. High level of coliforms in the treated effluents and in rivers is a significant issue to be addressed properly. The potential for coliform removal in all aerobic processes namely, ASP, TF, FAL, UASB + FAL + FPU, UASB + ASP and various advanced aerobic processes has been observed to be 3-4 logs and hence rated as ‘medium’. Potential coliform removal in WSP or low rate TF is also ‘medium’. However, the potential coliform removal in UASB + FPU process is generally lower than aerobic processes. Potential coliform removal is ‘high’ in recycling technologies involving tertiary filtration, and is ‘very high’ for the MBR process.

The potential of DO in the effluent is ‘high’ for nearly all aerobic systems. However, the effluent from the UASB + FPU process has ‘low’ potential for effluent DO, while the FAL, UASB + FAL + FPU, and the high rate TF based processes have ‘medium’ potential for DO in the effluent.

Effluent from aerobic processes has ‘very high’ or ‘high’ potential for not exerting initial or immediate oxygen demand (IOD). Effluent from the FAL process has ‘medium’ potential for not exerting IOD, while the effluent from the UASB + FPU process has ‘low’ potential for not exerting IOD.

As of now, effluent discharge standards for major nutrients such as nitrogen and phosphorous are not imposed in RAP. However, these are important and will need to be considered in future. The ability to remove nutrients such as nitrogen and phosphorous must be given due consideration in selection technology. WSP systems, because of high biological growth rates, assimilate more nutrients and hence the potential for nutrient removal in such systems is ‘high’. In general, in biological processes, nutrient removal is related to biomass growth. The biomass growth is typically more in aerobic processes compared to anaerobic processes. Also treatment technology based on aerobic processes can be easily expanded to include nutrient (particularly nitrogen) removal compared to plants based on anaerobic processes.

Performance Stability

Potential for performance stability is generally ‘very high’ for processes producing recyclable quality effluent, while it is ‘high’ for most of the other process including WSP, notwithstanding marginal variations occasionally due to unsatisfactory sludge settling or excessive leakage of algae in the WSP effluents. Exceptions are the UASB + FAL + FPU, FAL and high rate TF processes, for which the performance stability is ‘medium’. The FAL and TF based plants frequently give marginal variations in the effluent quality due to limited control on operational parameters for biological growth control. UASB + FPU performance by and large varies significantly due to overflow of bio-solids in effluent as a result of the rise in sludge blanket and inability of operators to monitor sludge bed.

Resource Requirements and Associated Costs

All treatment technologies were judged against the following parameters, 1) Potential for low capital cost, 2) potential for low energy requirements, 3) potential for low recurring cost, 4) potential for low reinvestment cost, 5) Potential for low level of operator skills and 6) potential for low land requirements. Unlined WSP systems were rated ‘very high’ in terms of parameters 1, 2 and 5, and ‘low’ in terms of parameter 6. Lined WSPs were rated similarly except against parameter 1, where it was rated as ‘medium’. Other aerobic processes are rated mostly ‘medium’ for the above parameters, with the potential for low land requirements being ‘high’ for advanced aerobic processes. The UASB + FPU system is comparable to ASP in terms of capital cost, recurring cost, level of skill required for O&M and land requirement, while being rated ‘high’ in terms of potential for low energy requirements. All the processes producing recyclable quality effluent are rated ‘low’ for the parameters 1-5 and ‘very high’ for parameter 6.

Impact of Effluent Discharge

All treatment technologies were judged against the following parameters, 1) Potential for no adverse impact on land 2) potential for no adverse impact on surface water, 3) potential for no adverse impact on groundwater. In addition to having low BOD and SS, WSP effluents contain less nutrients to support aquatic growth. Hence the WSP systems are rated ‘high’ with respect to parameters 1 and 2. Effluents from advance aerobic processes typically have high DO and may not have adverse impact on land and water and hence can also be rated ‘high’ vis-a-vis parameters 1-3. ASP, TF and FAL yield effluents that may become anoxic due to subsequent biological action, and may have slight adverse impact if used for land application. As such they are rated as ‘medium’ with respect to parameter 1. Effluents from UASB + FAL + FPU and UASB + ASP systems may have some adverse impacts on land, surface water and groundwater and hence rated ‘medium’ against parameters 1-3. Anaerobic effluents (from UASB + FPU systems) typically have low oxidation-reduction potential (ORP) and lead to reducing conditions. This leads to adverse impact on both land and water bodies and hence UASB + FPU effluents were rated ‘low’ against parameters 1 and 2.

Potential of Resource Generation

Typically three types of end products, which can be treated as resources, are produced from sewage treatment – treated effluent, excess biomass or sludge, which can be used as manure or soil conditioner; biogas, which can be used as a fuel for power generation or other uses.

In the water scarcity regions, the potential for recycling of the treated effluent for industrial, irrigation and other purpose is very high.

Substantial quantity of sludge is produced from ASP, UASB and advance aerobic processes that can have potential for application to land as manure or soil conditioner. However, the information available on fate of sludge generated from such plants reveals that it contributes marginally in terms of resource generation. As such on this basis, potential for manure/soil conditioner production from these treatment options can be rated as ‘medium’. Potential for manure/soil conditioner production from WSP is ‘low’.

Biogas is produced from sludge in ASP process and from the UASB reactor. This could be used as fuel or for generating electricity. However, at most of the plants, actual electricity generation is not sufficient to make the plant self sustainable completely. Even if sufficient biogas is produced to run the plant on sustained basis, as of now it is not economically viable to generate electricity from biogas.

The potential for fish production in the treated effluent of WSP systems is ‘medium’. Potential for fish or any other food production is ‘low’ in all other treatment options.

Impact of STP

Different technology have varying degree of local impacts because of foul odours, release of corrosive and harmful gases such as H_2S, ammonia, methane and flies nuisance, etc. Parameters used for judging these impacts were, 1) Potential for no adverse impacts on the health of STP staff/locals, and 2) potential for no adverse impact on surrounding buildings/properties. Advanced aerobic processes are judged to be the best from the point of view of parameters 1 and 2, and hence are given ‘high’ rating. On the other hand while the WSP or TF systems may not have major emissions, there could be concerns on odour and mosquito breeding. Hence such systems are given a ‘medium’ rating with respect to parameter 1.

Overall Assessment

Based on the assessment of all technologies with respect to various parameters discussed above (also as shown in Exhibit), the technologies have been divided into four categories.

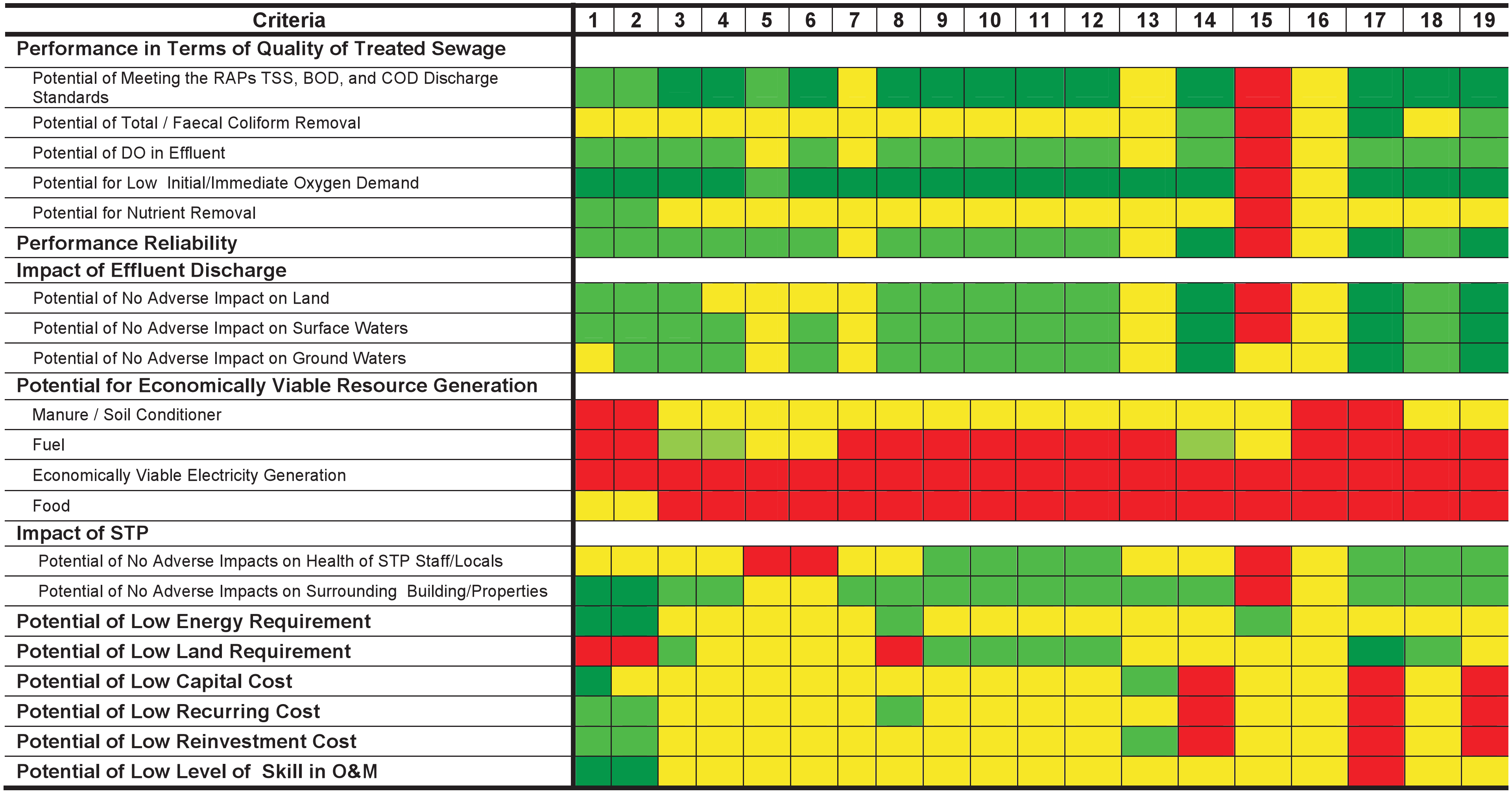
Category I : WSP, slow rate TF

Category II : ASP, UASB + FAL + FPU, UASB + ASP, and all advanced aerobic processes

Category III : FAL and high rate TF (both gravel and plastic media)

Category IV : UASB + FPU

Exhibit 1: Assessment of Technology Options for Sewage Treatment in the Ganga River Basin



Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Performance in Terms of Quality of Treated Sewage																			
Potential of Meeting the RAPs TSS, BOD, and COD Discharge Standards	High	High	Very High	Very High	High	Very High	Medium	Very High	Very High	Very High	Very High	Very High	Medium	Very High	Low	Medium	Very High	Very High	Very High
Potential of Total / Faecal Coliform Removal	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	Low	Medium	Very High	Medium	High
Potential of DO in Effluent	High	High	High	High	Medium	High	Medium	High	High	High	High	High	Medium	High	Low	Medium	High	High	High
Potential for Low Initial/Immediate Oxygen Demand	Very High	Very High	Very High	Very High	High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Low	Medium	Very High	Very High	Very High
Potential for Nutrient Removal	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Medium	Medium	Medium	Medium
Performance Reliability	High	High	High	High	High	High	Medium	High	High	High	High	High	Medium	Very High	Low	Medium	Very High	High	Very High
Impact of Effluent Discharge																			
Potential of No Adverse Impact on Land	High	High	High	Medium	Medium	Medium	Medium	High	High	High	High	High	Medium	Very High	Low	Medium	Very High	High	Very High
Potential of No Adverse Impact on Surface Waters	High	High	High	High	Medium	High	Medium	High	High	High	High	High	Medium	Very High	Low	Medium	Very High	High	Very High
Potential of No Adverse Impact on Ground Waters	Medium	High	High	High	Medium	High	Medium	High	High	High	High	High	Medium	Very High	Medium	Medium	Very High	High	Very High
Potential for Economically Viable Resource Generation																			
Manure / Soil Conditioner	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium	Medium
Fuel	Low	Low	High	High	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	High	Medium	Low	Low	Low	Low
Economically Viable Electricity Generation	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Food	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Impact of STP																			
Potential of No Adverse Impacts on Health of STP Staff/Locals	Medium	Medium	Medium	Medium	Low	Low	Medium	Medium	High	High	High	High	Medium	Medium	Low	Medium	High	High	High
Potential of No Adverse Impacts on Surrounding Building/Properties	Very High	Very High	High	High	Medium	Medium	High	High	High	High	High	High	High	High	Low	Medium	High	High	High
Potential of Low Energy Requirement	Very High	Very High	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium
Potential of Low Land Requirement	Low	Low	High	Medium	Medium	Medium	Medium	Low	High	High	High	High	Medium	Medium	Medium	Medium	Very High	High	Medium
Potential of Low Capital Cost	Very High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	Low	Medium	Medium	Low	Medium	Low
Potential of Low Recurring Cost	High	High	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Low	Medium	Medium	Low	Medium	Low
Potential of Low Reinvestment Cost	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	Low	Medium	Medium	Low	Medium	Low
Potential of Low Level of Skill in O&M	Very High	Very High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Medium	Medium

1: WSP (Unlined)	2: WSP (Lined)	3: ASP BIOFOR F	4: ASP	5: UASB + FAL + FPU	6: UASB + ASP
7: TF (Plastic, high rate)	8: TF (Gravel, slow rate)	9: FAB	10: MBBR	11: SBR / CTECH	12: SAFF
13: TF (Gravel, high rate)	14: ASP + C-F + RSF / DMF	15: UASB + FPU	16: FAL	17: MBR	18: BIOFOR
19: SBR + C-F + RSF / DMF					

🟥 Low 🟨 Medium 🟩 High ■ Very High

Appendix

Technology Fact Sheets for Various Treatment Options

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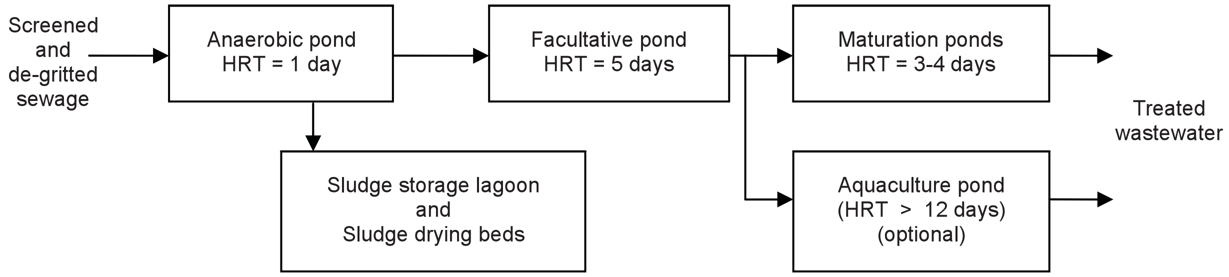
Exhibit A-1: Waste Stabilisation Pond Systems (WSPS)

Schematic



Key features of the technology

- Simple to construct, operate and maintain
- Does not involve installation of expensive electro-mechanical equipment
- Operates on a combination of solar energy and natural forces and thereby has very low O&M costs
- Extremely robust and can withstand hydraulic and organic shock loads
- Effluents from maturation pond are safe for reuse in agriculture and aquaculture

Performance

- Can reliably produce high quality effluent with low BOD, SS, Fecal Coliform and high DO levels
- BOD reduction of the order of 90 % and more
- Suspended solids reduction is somewhat less due to possible overflow of algae
- Coliform reduction could be up to 6 log units.
- Total nitrogen removal between 70-90%
- Total phosphorus removal between 30-45%

Specific requirements

- In case of unlined ponds, soil and geo-hydrological survey during planning stage to assess risk of groundwater contamination
- Sulphate concentration in raw wastewater under 300 mg SO4/L to avoid odour nuisance

Land requirement

- 0.80 – 2.3 hectares/MLD. 3 – 4 times the land requirement for ASP.

Energy requirement

- Energy requirements essentially for the operation of screen and grit chamber. Negligible compared to ASP.

Capital costs

- Rs. 1.5 – 4.5 million per MLD capacity. The higher values are for lined ponds.

O&M Costs

- Rs. 0.06-0.1 million/year/MLD installed capacity. Much lower than ASP or TF.

Advantages

- The inherent simplicity of construction offers low cost technology option
- High quality effluent at least operating costs
- Low skill requirement for operation of the plant
- Fish yield from aquaculture ponds around 4-7 tonnes/ha/year

Disadvantages

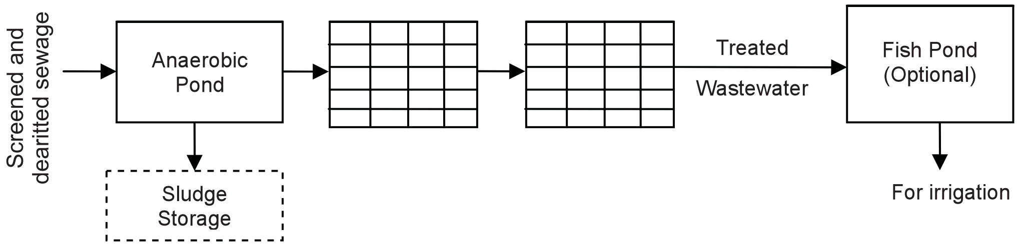
- Large land requirement
- High cost of lining
- Likelihood of odour nuisance and mosquito breeding in poorly maintained WSPs
- If unlined, likelihood of groundwater contamination in porous and fractured strata

Applicability

- Suitable under warm Indian climatic conditions
- For areas with easy availability of land
- In areas with social preference for aquaculture
- In areas with low, unreliable or expensive power supply

Exhibit A-2: Duckweed Pond System (DPS)

Schematic



Key features of the technology

- Natural and simple wastewater system involving sheltered pond like culture plots
- A large pond subdivided into smaller cells through floating bamboo or other material to break the wave and wind action
- Extremely rapidly growing floating duckweed vegetation serving as a dynamic sink for organic carbon, dissolved nutrients and minerals
- Thick mat of duckweed out-competing and inhibiting growth of other aquatic plants
- Pond functioning as a facultative lagoon with deeper layers under anaerobic environment
- Retention period in the system 7 – 21 days
- Shallow water depths from 1.25 m up to 2 m
- Continuous process requiring intensive management for optimum production
- Yield of large quantities of proteinaceous matter as fish feed or as a supplement for animal feed

Performance

Can meet Indian discharge standards for BOD and SS. Removal of N and P is also substantial.

- For settled wastewater, BOD and SS below 30 mg/L are attainable at 12 d detention
- High nutrient and mineral removal due to uptake by duckweeds

Specific requirements

- Primary treatment including screening, grease trap, grit removal and sedimentation
- Preferably the influent BOD, SS and ammonia to be under 80 ppm, 100 pm and 50 ppm respectively
- A series of smaller cells of around 10 m x 10 m to 10 m x 30 m to break the continuum in the pond (cell size as a function of wind speed, pond size and wave action)
- Cell borders made with floating bamboo mats or PVC profiles to shelter from wind and wave action
- Impermeable lining of clay or artificial liners in case of pervious and fractured strata
- Outlet structure with variable weir height
- Nitrogen loading of around 9 kg/ha/day
- Small size culture ponds for duckweed seedlings and as fish nursery ponds
- Duckweed drying and processing unit in case of large harvest and for sale as animal feed
- In case of downstream aquaculture ponds – introduce suitable species of fishes e.g., Grass Carp, Common Carp, Silver Carp, Rohu, Mrigal, Cattla, and freshwater prawns

Land requirement

- 2 to 6 ha/MLD for 7 to 20 days of detention period. Comparable to WSPS.

Options

- Pre-treatment comprising anaerobic pond or primary sedimentation
- In combination with aquaculture pond on downstream to utilise duckweed as fish feed
- Supplementary aeration in aquaculture ponds to augment oxygen supply in summer season

Dos and don'ts

- Inclusion of downstream aquaculture ponds for resource recovery and financial sustainability
- Feeding only settled sewage into duckweed ponds
- Protection of the ponds against flooding
- Avoid construction on porous soils, fractured strata and on alkaline soils
- Avoid duckweed ponds in cold climatic conditions

Capital costs

- Of the same order as WSP with additional cost of floating cell material

Operation and maintenance

- Daily harvesting to ensure productivity and health of duckweed colonies
- Avoid breakage of the thick mat of duckweed
- Prevent piling up or accumulation of weed culture on one side of the pond
- Prevent toxins and extremes of pH and temperature
- Prevent crowding due to overgrowth
- Prevent growth of other vegetation
- Vector control measures
- De-sludging of duck pond once in two years

O&M costs

- Rs. 0.18 million/MLD/year. More than WSPS and UASB. Less than ASP.

Includes:

- manpower costs for maintaining the primary treatment section, harvesting duckweed and management of fish ponds
- Costs of post processing of duckweed for value addition as a fish feed or as animal feed supplement

Advantages

- Less sensitive to low temperatures, high nutrient levels, pH fluctuations, pests and diseases compared to other aquatic plants
- Reduced suspended solids in effluent due to elimination of algae
- Simultaneous significant nutrient removal
- Easy to harvest compared to water hyacinth
- Complete cover prevents breeding of mosquitoes and odour nuisance
- Yield of highly protein containing vegetative material (35-45%) as animal feed
- Duckweed as an excellent feed for aquaculture
- Realisation of tangible economic returns from sale of raw or processed weed or fish
- Least cost of O&M
- Creation of a micro-enterprise with sustainable income generation potential

Disadvantages

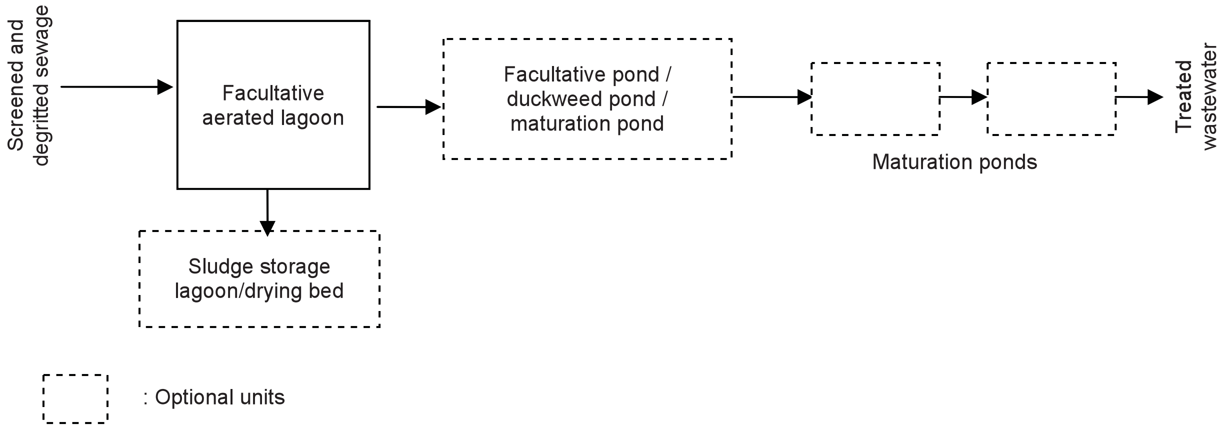
- Low pathogen removal due to reduced light penetration
- Duckweed die off in cold weather conditions

Applicability

- Low strength domestic wastewater or after primary sedimentation with influent BOD < 80 mg/L
- In combination with existing WSP
- Rural and semi urban settlements with easy land availability
- As a polishing pond for an existing activated sludge plant or other technology based STPs

Exhibit A-3: Facultative Aerated Lagoon (FAL)

Schematic



Key features of the technology

- Simple flow scheme without primary or secondary settling and sludge recirculation
- Deep lagoon with anaerobic bottom layer and aerobic top layer
- Simultaneous degradation of sludge in the bottom and dissolved organics in the top layer
- Lower energy input corresponding to requirement for maintaining only desired DO levels in the top layer and not for creating completely mixed conditions

Performance

As per the information in literature based on Indian experience the following performance is expected from a well functioning facultative aerobic lagoon :

BOD removal	70-90 %
Suspended solids removal	70-80 %
Coliform removal	60-99 %

Specific requirements

- Typical hydraulic detention time of 3 days or more
- Depth between 2-5 m depending on local soil and groundwater conditions
- Effective outlet structure with baffles and stilling basin to prevent solids overflow

Land requirement

- Between 0.27 to 0.4 ha/MLD (higher than ASP)

Power requirement

- 18 KWh / ML treated. Much lower than ASP. Comparable to UASB

Options

- Grit chamber as a preliminary treatment unit
- Multiple cells of lagoons in series for higher pathogen reduction
- Long narrow layout of lagoon for low dispersion coefficient
- Downstream ponds for polishing (facultative or duckweed and maturation)
- Arrangement for sludge withdrawal without the need for emptying of lagoon
- Provision of sludge storage lagoon

Dos and don'ts

- Avoid construction on porous soils and fractured strata or provide impervious lining
- Attain a balance between depth of lagoon and number of small capacity aerators to create two distinct zones of aerobic and anaerobic conditions in the top and bottom layers

Capital costs

- Rs. 2.2 to 2.9 million/MLD (Comparable to ASP/TF/UASB)

Operation and maintenance

- Desludging of lagoon once a year or according to the situation

O&M costs

- Between 0.15 to 0.2 million/MLD/yr. Lower than ASP but higher than UASB.

Advantages

- Simple operation of the plant requiring lower skilled manpower
- Minimum civil, electrical and mechanical installation
- Scheme devoid of primary and secondary settling tanks as well as sludge digestors
- Lower energy costs compared to other aerobic processes
- Lower O&M cost

Disadvantages

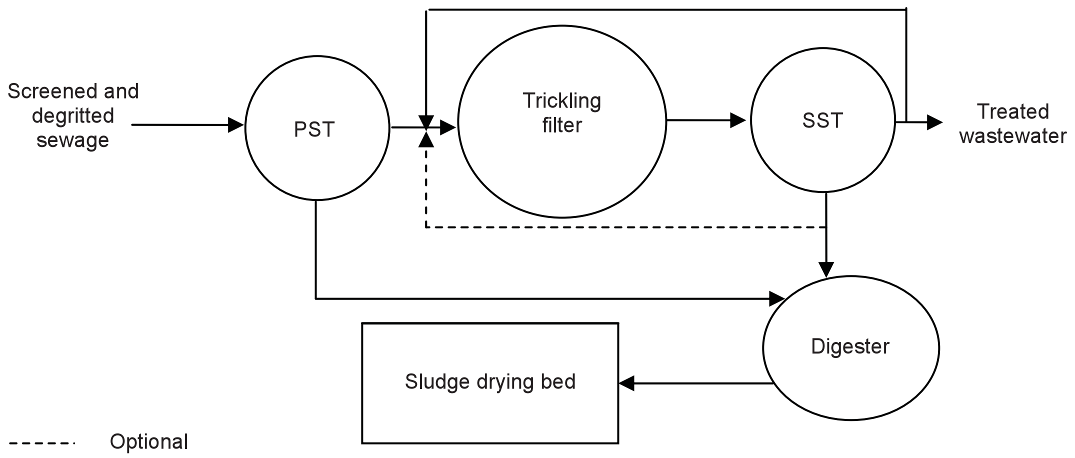
- Possibility of groundwater contamination in porous and fractured strata
- High cost of lining

Applicability

- Stand alone system for sewage treatment
- As a pre-treatment unit for WSP
- As an up-gradation option for overloaded WSPs

Exhibit A-4: Trickling Filter (TF)

Schematic



Key features of the technology

- A proven 100 year old technology
- Rugged system with simple and silent operation
- Lower process monitoring requirement as compared to ASP
- Consistent effluent quality

Performance

- Performance of a slow rate trickling filter is comparable to ASP

Land requirement

- Between 0.25 to 0.65 hectares/MLD (approximately double that of ASP)

Power requirement

- 180 KWh/ML treated. Marginally lower than ASP.

Dos and don’ts

- Provide effective and efficient mechanical screens to prevent problems of clogging
- Provide for recirculation of effluent to avoid low flow conditions and reduce odour and flies

Capital costs and O&M Costs

- Not available, but expected to be slightly lower than ASP.

Operation and maintenance

- Efficient operation of screens to prevent clogging
- Provide consistent hydraulic loading to prevent damage to the bio-film
- Maintenance of the turntable
- Cleaning of filter media once in 5-7 years or more

Advantages

- Simple operation of the plant requiring lower skilled manpower
- Rugged system, less prone to hydraulic and organic over loading
- Reduced requirement for process monitoring
- Sludge with better settling characteristics

Disadvantages

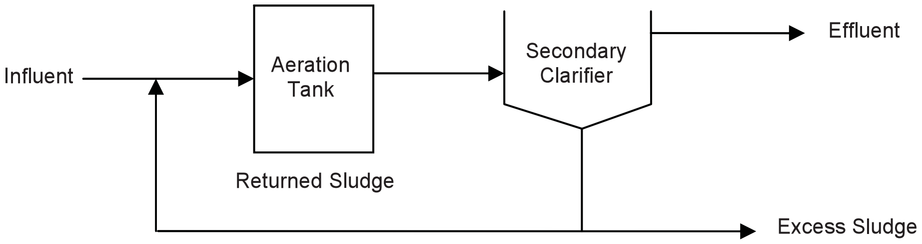
- Blockage of ports in distribution arm
- Blockage of bio-filter due to excess biomass growth or floating matter
- Frequent mechanical breakdown of the turntable
- Odour and filter flies may be unavoidable

Applicability

- Stand alone treatment for sewage if operated at slow rates
- As a high rate roughing filter for high BOD wastewater
- In combination with ASP for good and consistent performance

Exhibit A-5: Activated Sludge Process (ASP)

Schematics



Key features

- Proven and tested for more than 7-8 decades all over world
- Several modifications/advances possible to meet specific requirements

Performance

Very good performance in terms of BOD and SS. Treated effluent can most often satisfy the current Indian effluent discharge standards. Performance is critically dependent on sludge settling characteristics and design of secondary clarifier. Sludge settling characteristics are typically influenced by bio-flocculation which in turn depends on growth rate of micro-organisms. Growth rate is generally controlled by controlling biological solids retention time/food to micro-organism ratio.

Specific requirements

- Un-interrupted power supply for aeration and sludge recirculation
- Maintenance of biomass concentration in the aeration tank and proper settling in the secondary clarifier

Dos and Don'ts

- Carefully monitor the reactor sludge levels and sludge withdrawal
- Regular painting/coating of corrosion susceptible materials/exposed surfaces

Capital cost

- The capital cost is in the range of Rs. 2-4 million per MLD capacity. Approximately 55 % cost is of civil works and remaining 45 % is for electrical and mechanical works

Operation and Maintenance

- Careful monitoring and control of sludge quantity in the aeration tank
- Regular maintenance of aeration and recycle system

O & M Costs

- The O & M costs based on the data collected from various Indian plants varies in the range of Rs. 0.3 – 0.5 million/year/MLD installed capacity

Land Requirement

- 0.15 – 0.25 hectares/MLD installed capacity

Energy Requirement

- 180 – 225 KWh/ML treated

Advantages

- Performance is not significantly affected due to normal variations in wastewater characteristics and seasonal changes
- Less land requirements

Disadvantages

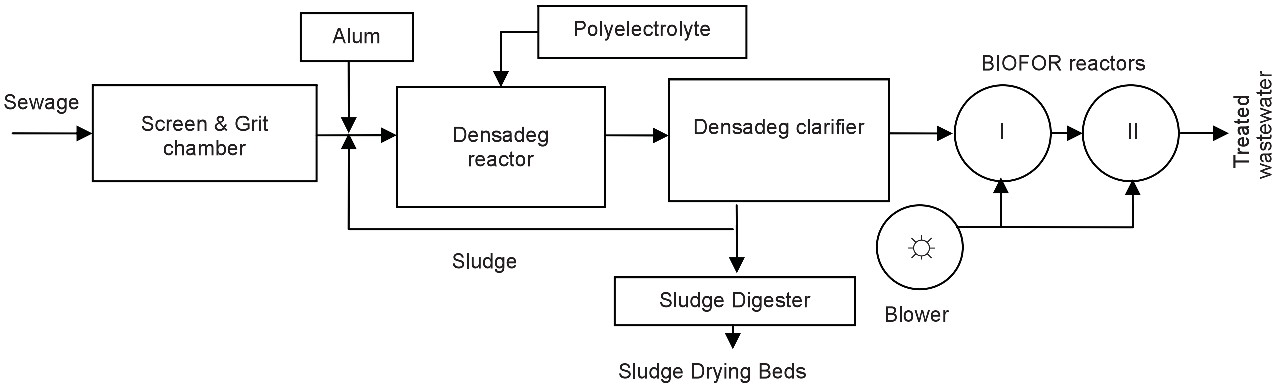
- High recurring cost
- High energy consumption
- Performance is adversely affected due to interruption in power supply even for a short period
- Foaming, particularly in winter season, may adversely affect the oxygen transfer, and hence performance
- Requires elaborate sludge digestion/drying/disposal arrangement

Applicability

- The most widely used option for treatment of domestic wastewater for medium to large towns where land is scarce

Exhibit A-6: BIOFOR Technology
(Biological Filtration and Oxygenated Reactor)

Schematic



Key features of the technology

- Enhanced primary treatment with addition of coagulants and flocculants
- High rate primary tube settlers and integrated thickening offering space economy
- Two stage high rate filtration through a biologically active media and with enhanced external aeration
- Co-current up flow movement of wastewater and air enable higher retention and contact
- Treatment scheme excluding secondary sedimentation but recycling of primary sludge
- Deep reactors enabling low land requirements
- A compact and robust system

Performance

- Suspended solids and BOD removal of 90% and 70% respectively in the primary clarifier
- High quality effluent with BOD under 10 mg/L and total system efficiency of 94-99.9%
- Low turbidity with suspended solids under 15 mg/L and total system efficiency of 98%
- Pathogen removal of 2 on the log scale

Specific requirements

- Addition of alum as coagulant (~ @ 60 ppm)
- Polyelectrolyte for high rate sedimentation (~ @ 0.2-0.3 ppm) in tube settlers
- Special and patented granular filter media 'Bioloite' made of clay
- Backwash of BIOFOR bed and recycle of the wastewater
- Treatment (digestion) and disposal of sludge from clarifier (not provided at the STPs due to space limitations)

Energy Requirement

- 220 - 335 kWh/ML treated. Approximately double of ASP

Land requirement

- 0.04 hectares per MLD installed capacity (excluding land requirement for sludge drying beds). Much lower than ASP.

Sludge production

- Thickened sludge @ 1000 kg/MLD wastewater treated (about 14.5 m^3/MLD)

Capital costs

- Rs. 6.5 – 8.1 million per MLD capacity. More than double that of ASP.

O&M costs

- Rs. 0.86 million/year/MLD installed capacity (does not include the full cost of sludge disposal). Much higher than ASP.

Advantages

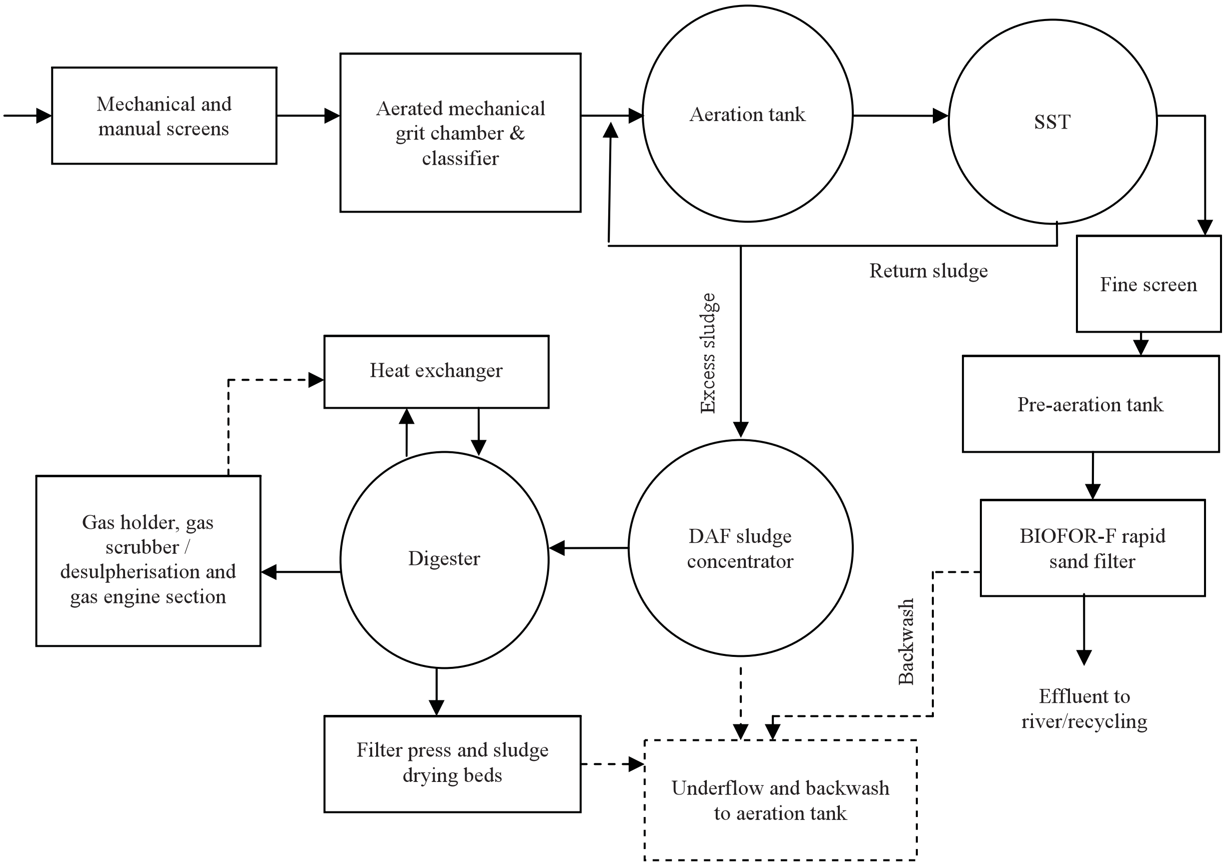
- Compact layout as a result of high rate processes
- Higher aeration efficiency through co-current diffused aeration system
- Space saving as secondary sedimentation is dispensed
- Able to withstand fluctuations in flow rate and organic loads
- Compliance with stricter discharge standards
- Effluent suitable for industrial applications e.g., cooling water or ground water recharging
- Effluent suitable for UV disinfection without filtration
- Absence of aerosol and odour nuisance in the working area
- Absence of corrosive gases in the area
- Lower operation supervision enables lesser manpower requirement

Disadvantages

- Continuous and high chemical dosing in primary clarification
- Undigested sludge from primary clarification requiring post treatment

Exhibit A-7: High Rate Activated Sludge Biofor–F Technology

Schematics



Notes :

1. DAF : Dissolved air floatation system for sludge concentration
2. BIOFOR-F : Multimedia down flow rapid sand filter

Key features

- In general, high level of mechanisation and sophistication
- The flow scheme excludes primary sedimentation tank
- Superior aerated grit chamber and classifier
- Circular aeration tank with tapered air diffusion system
- Second stage aeration and rapid sand filtration through a biologically active filter media
- Dissolved air floatation for sludge thickening
- Digester heating and temperature controlled anaerobic sludge digestion
- Mixing of digester contents through biogas
- Dynamic cogeneration of electrical and thermal energy through gas engines

Land requirement

- 0.08 hectare/MLD installed capacity (including land for sludge treatment and handling). Much lower than ASP.

Energy requirement

- Unit power requirements : 180 kWh/ML treated
- 85% requirement being met through captive generation from biogas cogeneration system

Sludge production

- 8.1 m^3 / ML sewage treated

Capital costs

- Rs. 5.2 million per MLD capacity. More than double that of ASP.

O&M costs

- Rs. 0.18 million/year/MLD installed capacity (including cost of sludge disposal). Comparable to ASP.

Advantages

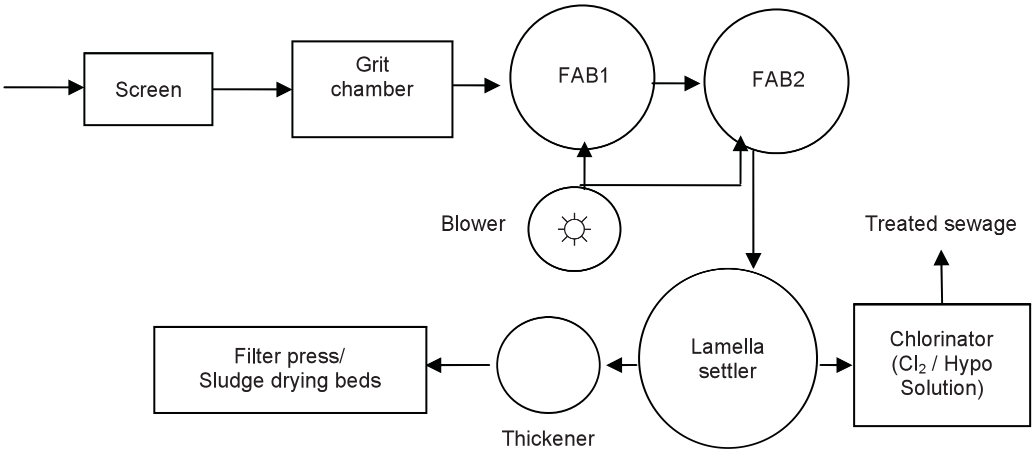
- Compact layout as a result of high rate processes
- Higher aeration efficiency through diffused and tapered aeration system
- Space saving as primary sedimentation is dispensed
- Compliance with stricter discharge standards
- Effluent suitable for high end industrial applications
- Stable digester performance and consistent gas production
- Almost self sufficient in energy requirement due to gas engine based cogeneration system
- Absence of aerosol and odour nuisance in the working area

Disadvantages

- None, except high cost

Exhibit A-8: Fluidized Aerated Bed (FAB)

Schematic



Key features of the technology

- A compact and robust system involving extended aeration process with submerged aeration
- Biomass growth on fluidized bed of plastic media enabling retention of biomass and long solid retention time in the reactor leading to low ‘food to micro-organism ratio’ and higher organic removal
- Two stage biological oxidation
- Flexibility in handling organic load by adjusting quantity of fluidized media
- Treatment scheme excluding primary sedimentation and sludge digestion
- Reactors up to 5 m deep enabling low land requirements
- Tube settlers again offer space economy
- Ability to withstand limited organic overload

Specific requirements

- Special grade plastic proprietary media custom made for offering high specific surface area
- Diffused aeration system
- Submerged stainless steel screens at the outlet of FAB reactors to prevent media overflow
- Tube settlers for compact clarifier

Options

- Addition of coagulant and polyelectrolyte for compact plants
- Tertiary treatment of chlorination
- Sludge treatment through thickener and bag filter press or drying beds

Land requirement

- 0.06 hectare per MLD installed capacity. Much lower than ASP.

Energy requirement

- Between 99 to 170 kWh/ML sewage treated. Slightly lower than ASP.

Performance

- High BOD removal with effluent concentration under 10 mg/L
- High suspended solids removal with effluent concentration under 20 mg/L
- Faecal coliforms removal of the order of 2-3 on log scale at FAB-2 stage

Dos and don’ts

- Effective multistage self cleaning screens required to prevent choking of FAB reactor outlets
- Adequate sludge storage facility or sludge drying beds to be provided

Capital costs

- Rs. 3-5 million per MLD installed capacity. Higher than ASP. The plastic media constitutes about 30% of the plant cost.

O&M costs

- Between Rs. 0.6-0.75 million per year per MLD installed capacity. About 50% higher than ASP.

Other aspects

- Requires effective multi stage screens to prevent chocking of submerged screen at FAB outlet and tripping of system due to plastic bags and pouches
- Calibration of treatment capacity by adding or removing plastic media within 10-50% range
- Possibility of chocking at FAB outlet due to fluidized media. Requires effective air flushing valve to prevent tripping of the system
- Blockage of media in case of excess biomass growth or low hydraulic loads
- Longer shutdowns may lead to septic conditions
- Restarting after a long shutdown may take long to stabilise
- Uncertainty regarding durability of media under varying climatic conditions
- Lack of availability of additional quantity of media which is a proprietary item may cause operational difficulties

Advantages

- Exclusion of primary treatment step of sedimentation
- Deep reactors enabling small space requirements
- Ability to effectively treat dilute domestic wastewaters
- Elimination of the need for sludge recirculation and monitoring of MLSS in the reactor
- Capacity to handle shock loads
- Low head loss in the fluidized filter bed
- Low and stabilised sludge production eliminating the need for sludge digestion
- Simple and reliable operation
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

- Reliance on patented filter media
- Reliance on flocculants, polyelectrolyte and chemical disinfectant (optional)
- Requires skilled manpower
- Choking of reactor due to floating plastic matter

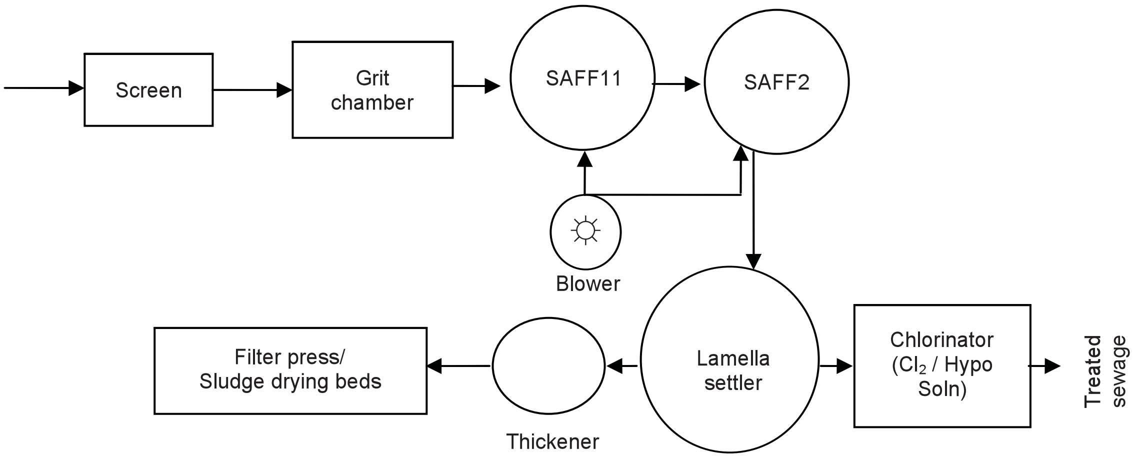
Applicability

The FAB technology based system is particularly applicable for:

- small to medium flows in congested locations
- sensitive locations
- decentralised approach
- Reliving existing overloaded STPs

Exhibit A-9: Submerged Aeration Fixed Film (SAFF) Technology

Schematic



Key features of the technology

- Essentially a trickling filter with enhanced oxygen supply through submerged aeration
- Unconventional plastic media offering high void ratio and specific area compared to stone and aggregates
- Large biomass and long solid retention time in the reactor leading to low 'food to micro-organism ratio' and higher organic removal
- Two stage biological oxidation
- Treatment scheme excluding primary sedimentation and sludge digestion
- Reactors up to 6 m deep enabling low land requirements
- Tube settlers again offer space economy

Specific requirements

- Special grade plastic proprietary media offering high specific surface area
- Diffused aeration system
- Tube settlers for compact clarifier

Land requirement

- 0.05 hectares per MLD installed capacity. Much lower than ASP

Energy requirement

- 390 kWh/ML treated. Much larger than ASP

Performance

- High BOD removal of 98% with effluent concentration under 10 mg/L
- High suspended solids removal with effluent concentration under 20 mg/L
- Faecal coliforms removal of the order of 2-3 on log scale at SAFF-2 stage

Dos and don’ts

- Effective multistage self cleaning screens required to prevent clogging of the media
- Primary sedimentation would be desirable to prevent clogging
- Adequate sludge storage facility or sludge drying beds to be provided

Capital costs

- Rs. 7 million per MLD installed capacity. Much larger than ASP. The proprietary plastic media constitutes high percentage of the plant cost

O&M costs

- Rs. 1.14 million per year per MLD capacity. Much higher than ASP

Other aspects

- Requires effective multi stage screens to prevent blockage of submerged media
- Blockage of media in case of excess biomass growth
- Uncertainty regarding durability of media under varying climatic conditions

Advantages

- Deep reactors enabling small space requirements
- Ability to effectively treat dilute domestic wastewaters
- Low and stabilised sludge production eliminating the need for sludge digestion
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

- Clogging of reactor due to absence of primary sedimentation
- Reliance on proprietary filter media
- High reliance on external energy input
- Requires skilled manpower

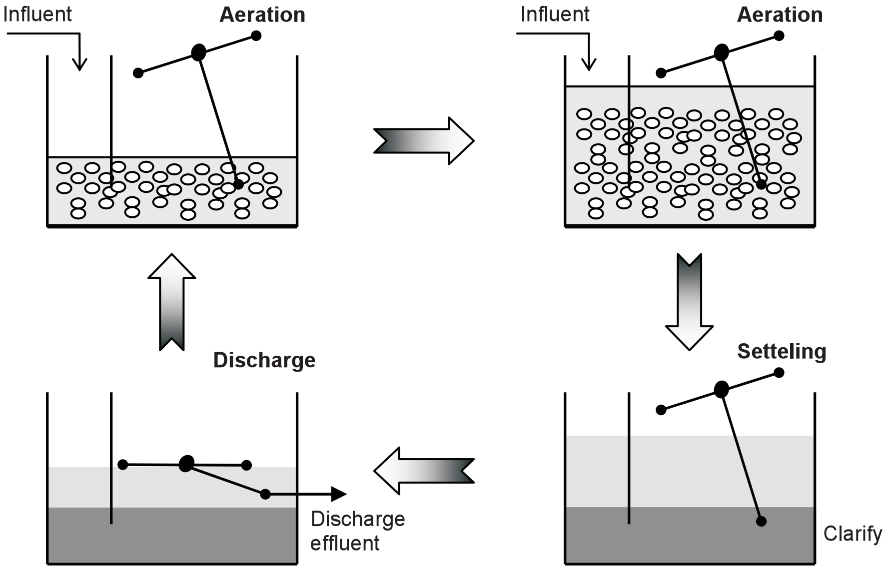
Applicability

The SAFF technology based system is particularly applicable for:

- Small to medium flows in congested locations
- Sensitive locations
- Decentralised approach
- Reliving existing overloaded trickling filters

Exhibit A-10: Cyclic Activated Sludge Process (CASP)

Schematic



Key features of the technology

- Essentially activated sludge process operated in batches through auto control
- Aeration and settling in one tank leading to lower plant foot print
- Savings in air/oxygen supply and hence energy
- Two levels of treatment possible depending on the requirement
- Treatment scheme excluding primary sedimentation and sludge digestion

Specific requirements

- Complete reliance on auto control; uninterrupted power supply is a must
- Diffused aeration system
- Several moving parts

Land requirement

- 0.1 – 0.15 hectares per MLD installed capacity. Lower than ASP

Energy requirement

- 150 – 200 kWh/ML treated. Slightly lower than ASP

Performance

- High BOD removal of 98% with effluent concentration under 10 mg/L
- High suspended solids removal with effluent concentration under 20 mg/L
- Faecal coliforms removal of the order of 2-3 on log scale

Dos and don’ts

- Influent equalization/storage may be required
- Primary sedimentation would be desirable to prevent clogging
- Adequate sludge storage facility to be provided

Capital costs

- Not available being a patented technology

O&M costs

- Expected to be higher than ASP

Other aspects

- Not much experience under Indian conditions
- Excess sludge to be handled separately
- Failure in auto control may lead to plant failure

Advantages

- Can be designed to remove N and P along with carbon removal
- Absence of odour and improved aesthetics
- Absence of emission of corrosive gases

Disadvantages

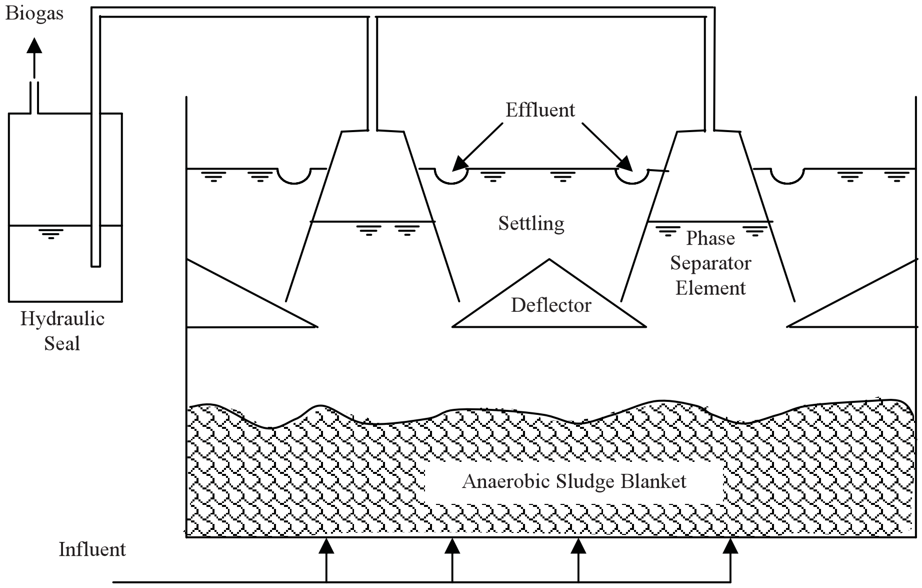
- No provision for sludge management
- No provision of primary treatment
- High reliance on external energy input
- Requires skilled manpower

Applicability

The Cyclic Activated Sludge Process (CASP) may be applicable for:
- small to medium flows in congested locations
- sensitive locations
- decentralised approach
- reliving existing overloaded trickling filters

Exhibit A-11: Upflow Anaerobic Sludge Blanket (UASB) Process

Schematics



Key features

- No mechanical components or external energy requirements in the reactor, therefore process not vulnerable to power cuts
- No primary treatment; suspended solids in the wastewater serve as carrier material for microbial attachment
- Recovery of gas with high calorific value
- Low sludge production
- Relatively simple routine operation and maintenance
- Biological activity can be restarted without any external seeding or special care after interrupted operations

Performance

An UASB reactor can bring down the BOD of the domestic wastewater to 70-100 mg/L and suspended solids (TSS) to 50-100 mg/L. However, sludge washout from the reactor is possible and effluent BOD and TSS is very high during such episodes. The effluent is strongly anoxic with high immediate oxygen demand (IOD). Should not be directly discharged into water bodies or used for aquaculture or irrigation without re-aeration.

Specific requirements

- Use of anticorrosive materials/paints on exposed surfaces
- Frequent cleaning/de-sludging of distribution/division boxes and influent pipes
- Skilled supervision during start-up and for control of biomass levels within the reactor
- Post treatment of the UASB effluent is invariably required
- Control of toxic materials and sulfates in the wastewater is required for efficient operation

Land requirement

- 0.2-0.3 hectares per MLD installed capacity. Comparable to that of ASP.

Energy requirement

- 10 – 15 KWh/ML treated. Much less than ASP or TF, but more than WSPS.

Dos and don'ts

- Prevent mixing of industrial effluents with toxic elements and sulfates/sulfides
- Carefully monitor the reactor sludge levels and sludge withdrawal
- Regular painting/coating of corrosion susceptible materials/exposed surfaces

Capital cost

- Rs. 2.5 – 3.6 million per MLD capacity. Almost same as that of ASP.

O & M costs

- Rs. 0.08-0.17 million/year/MLD installed capacity. Much lower than ASP or TF, but higher than WSPS.

Advantages

- Sludge handling is minimized
- Power supply interruptions have minimal effect on plant performance
- Can absorb hydraulic and organic shock loading

Disadvantages

- In general can not meet the desired effluent discharge standard unless proper post treatment is adopted, which in turn may make the treatment scheme energy intensive or may require large land area
- Effluent is anoxic and invariably exerts substantial initial/instantaneous oxygen demand which may have adverse impact on receiving inland water bodies or when used for irrigation
- Stability in performance is questionable unless sludge wash out is prevented
- Fecal and Total coliform removal is poor
- Aesthetically the effluent has poor acceptability due to its black color
- Exploitation of biogas generated is unsustainable during domestic sewage treatment

Applicability

- The suitability of this technology may be doubtful as a stand-alone secondary treatment option

Notes