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# Sewage Treatment in Class I Towns:

## *Recommendations and Guidelines*

# GRB EMP : Ganga River Basin Environment Management Plan

*by*

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

# Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin: Environment Management Plan (GRB EMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin: Environment Management Plan (GRB EMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin: Environment Management Plan (GRB EMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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# Contents

# 1. General

Sewage is a major point source of pollution. The target of "Nirmal Dhara" i.e. unpolluted flow can be achieved if discharge of pollutants in the river channel is completely stopped. Also, sewage can be viewed as a source of water that can be used for various beneficial uses including ground water recharge through surface storage of treated water and/or rain/flood water in an unlined reservoir. This may also help achieving "Aviral Dhara".

In order to reduce substantial expenditure on long distance conveyance of sewage as well as treated water for recycling, decentralized treatment of sewage is advisable. As a good practice, many small sewage treatment plants (STP) should be built rather than a few of very large capacity. All new developments must build in water recycling and zero liquid discharge systems. Fresh water intake should be restricted only to direct human-contact beneficial uses of water. For all other uses properly treated sewage/wastewater should be used wherever sufficient quantity of sewage is available as source water for such purposes. All new community sanitation systems must adopt recycling of treated water for flushing and completely isolate fecal matter until it is converted into safe and usable organic manure. The concept of decentralized treatment systems and water/wastewater management will be covered in detail in subsequent reports.

# 2. Selection of Appropriate Sewage Treatment Technology

Item 4.5.2 in Guidelines for the Preparation of Urban River Management Plan (URMP) for all Class I Towns in Ganga River Basin (Report No. 002_GBP_IIT_EQP_S&R_01) concerns with sewage treatment plant. One of the most challenging aspects of a sustainable sewage treatment system (either centralized or decentralized) design is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. The process is to be selected based on required quality of treated water. While treatment costs are important, other factors should also be given due consideration. For instance, effluent quality, process complexity, process reliability, environmental issues and land requirements should be evaluated and weighted against cost considerations. Important considerations for selection of sewage treatment processes are given in Table 1.

**Table 1: Sewage Treatment Process Selection Considerations**

| Consideration | Goal |
|---|---|
| Quality of Treated Sewage | Production of treated water of stipulated quality without interruption |
| Power requirement | Reduce energy consumption |
| Land required | Minimize land requirement |
| Capital Cost of Plant | Optimum utilization of capital |
| Operation & Maintenance costs | Lower recurring expenditure |
| Maintenance requirement | Simple and reliable |
| Operator attention | Easy to understand procedures |
| Reliability | Consistent delivery of treated sewage |
| Resource Recovery | Production of quality water and manure |
| Load Fluctuations | Withstand variations in organic and hydraulic loads |

# 3. Treatment Chain

All sewage treatment plants should follow a process chain depending upon the technology chosen and the treatment capacity. In general, treatment is to be done in three stages as per the flow sheet presented in Figure 1.

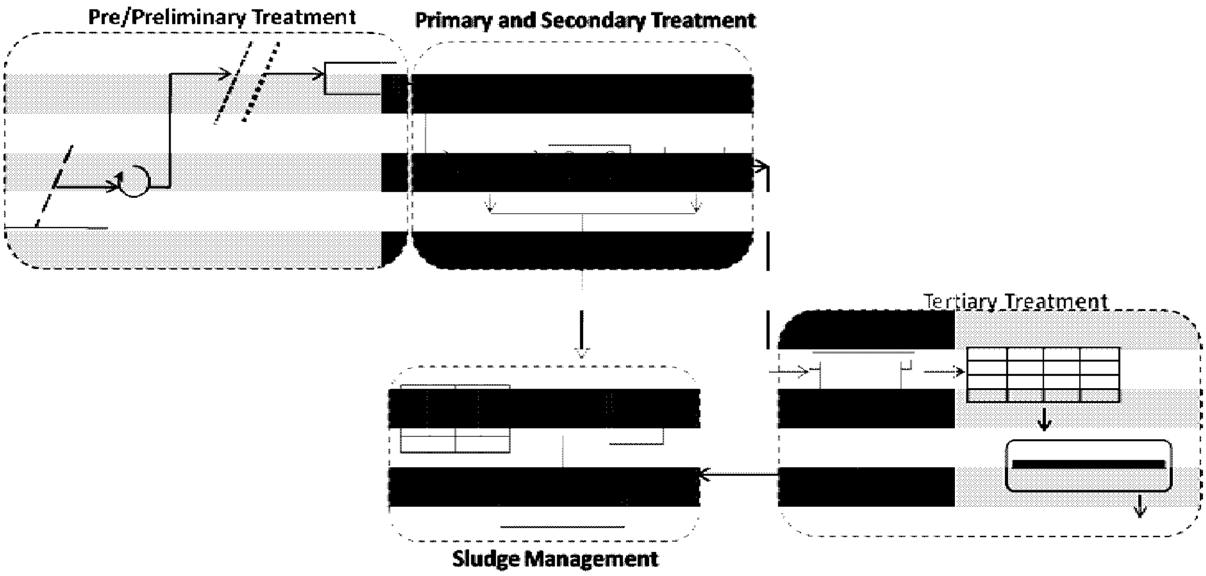


**Figure 1: Process Chain for Sewage Treatment**

Specifications and treatment objectives at each stage of treatment are as follows.

<u>Stage I</u> Preliminary Treatment:

a) Three Stage Screening: - 25 mm bar racks (before pumping)
- 12 mm bar racks
- 5 mm mesh (< 2 mm mesh for Membrane Bio Reactor, MBR)

b) Aerated Grit Chamber if following unit operation is aerobic and Normal Grit Chamber if following unit operation is anaerobic.

Expected effluent quality after preliminary treatment:

- No floating materials including polythene bags, small pouches, etc.
- Proper collection and disposal of screening and grit.

<u>Stage II</u> Primary and/or Secondary Treatment: Many options are available for second stage treatment. These options can be grouped into following three categories.

a) Pond Based Systems or
b) Activated Sludge Process (ASP) and its Modifications or equivalent systems including but not limited to SBR, UASB followed by ASP, ASP operated on Extended Aeration mode (EA-ASP), ASP with Biological Nutrient Removal (ASP+BNR), and MBBR or
c) Membrane Bio Reactor (MBR)

Expected effluent quality after primary and secondary treatment:

- BOD < 30 mg/L
- SS < 20 mg/L
- Nitrified effluent

A brief description of various technological options available for secondary treatment are presented in Appendix I. EA-ASP, ASP+BNR are considered to be variations of ASP and produce more or less same quality effluent (particularly when tertiary treatment is adopted after secondary treatment) and have approximately same treatment plant footprint. The treatment cost is also of the same order and hence are not considered to be distinctly different than ASP.

<u>Stage III</u> Tertiary Treatment: Coagulation-flocculation-settling followed by filtration and disinfection is generally recommended. Other processes could be selected on the basis of land availability, cost considerations, O&M cost, reuse option, compatibility issues in case of up-gradation of existing plants, etc. However, disinfection operation should invariably be included. Expected effluent quality after tertiary treatment:

- BOD < 10 mg/L
- SS < 5 mg/L
- Phosphate < 0.5 mg/L
- MPN of fecal coliforms < 23/ 100 mL

Where sewage flows are low and/or land can be spared without compromising on other developmental objectives or agriculture, waste stabilization ponds followed by constructed wetland can be adopted without coagulation-flocculation-settling.

# 4. Cost of Treatment and Land Requirement

Comprehensive analysis of capital cost, operation and maintenance costs, reinvestment cost, energy cost and land requirement based on data obtained from various STPs in the Ganga river basin and elsewhere in India has been done. This analysis has been summarized in Figure 2 as linkage between the treatment cost (₹/KL as in 2010) and the required footprint of the treatment plant ($m^2$/MLD) for various suggested technological options. For a particular desired effluent quality, the technological option with higher treatment cost will generally require lower treatment plant footprint, and vice versa.

# 5. Decision Matrix

The selection of a process requires analysis of all factors, not just treatment costs. In order to provide additional factors for the final considerations, key parameters need to be evaluated and weighed as shown in the Exhibit 1 to reach a final recommendation. The matrix attributes are ranked as Low, Medium, High and Very High recognizing that differences between processes are relative, and often, the result of commonly accepted observations. The column entitled "Typical Capacity Range" is added to illustrate the range in which the treatment plants based on specific processes have been built so far in the country should not be construed as showing technological limitations, nor to affirm that plants outside that range do not exist. The ranges simply indicate most frequently found sizes. A comparison of treatment costs and evaluation of various technologies for sewage treatment in India is presented in Table 2.

In general it is accepted worldwide that the technologies which are deemed to be appropriate have to be qualified through application of a rigorous framework underscoring the performance expectations as well as the choice should be concurrent with the socio-economic acceptability.

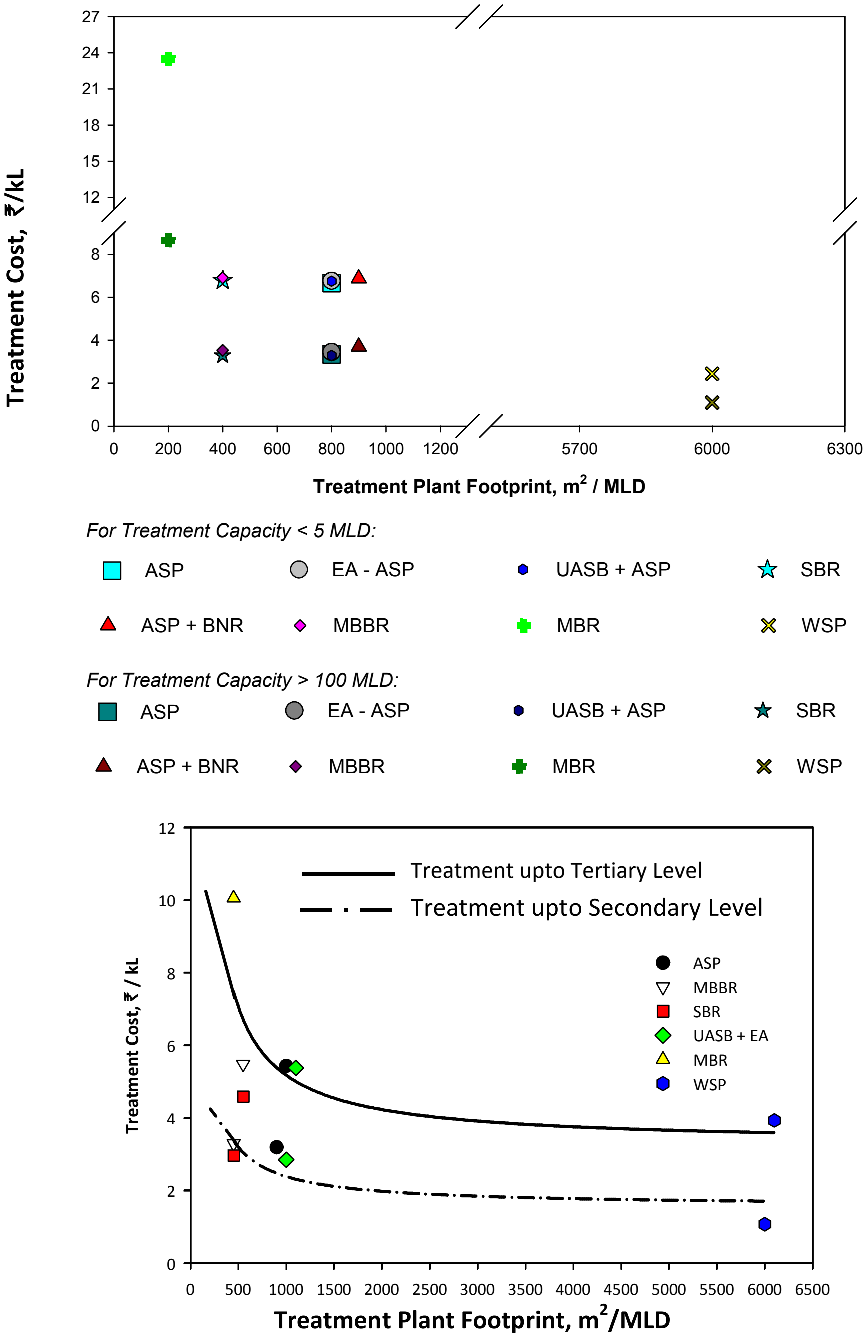


**Figure 2:** **Treatment Cost (as in 2010) and Corresponding Plant Footprint for various Secondary Treatment Options**

## Table 2: Comparison of Treatment Costs of Various Technologies for Sewage Treatment in India

| S. No. | Assessment Parameter/Technology | ASP[*,a] | MBBR[*,c] | SBR[*,a] | UASB+EA[*,b] | MBR[*,a] | WSP[**,b] |
|---|---|---|---|---|---|---|---|
| **1.0** | **Performance after Secondary Treatment** | | | | | | |
| 1.1 | **Effluent BOD**, *mg/L* | <20 | <30 | <10 | <20 | <5 | <40 |
| 1.2 | **Effluent SS**, *mg/L* | <30 | <30 | <10 | <30 | <5 | <100 |
| 1.3 | **Faecal coliform removal**, *log unit* | upto 2<3 | upto 2<3 | upto 3<4 | upto 2<3 | upto 5<6 | upto 2<3 |
| 1.4 | **T-N Removal Efficiency**, *%* | 10-20 | 10-20 | 70-80 | 10-20 | 70-80 | 10-20 |
| **2.0** | **Performance After Tertiary Treatment** | | | | | | |
| 2.1 | **Effluent BOD**, *mg/L* | <10 | <10 | <10 | <10 | <10 | <10 |
| 2.2 | **Effluent SS**, *mg/L* | <5 | <5 | <5 | <5 | <5 | <5 |
| 2.3 | **Effluent $NH_3N$**, *mg/L* | <1 | <1 | <1 | <1 | <1 | <1 |
| 2.4 | **Effluent TP**, *mg/L* | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| 2.5 | **Effluent Total Coliforms**, *MPN/100 mL* | 10 | 10 | 10 | 10 | 10 | 10 |
| **3.0** | **Capital cost** | | | | | | |
| 3.1 | **Average Capital Cost (Secondary Treatment)**, *₹. Lacs/MLD* | 68.00 | 68.00 | 75.00 | 68.00 | 300.00 | 23.00 |
| 3.2 | **Average Capital Cost (Tertiary Treatment)**, *₹. Lacs/MLD* | 40.00 | 40.00 | 40.00 | 40.00 | | 40.00 |
| 3.3 | **Total Capital Cost (Secondary + Tertiary)** *₹. Lacs/MLD* | **108.00** | **108.00** | **115.00** | **108.00** | **300.00** | **63.00** |
| 3.4 | **Civil Works**, *% of total capital costs* | 60.00 | 40.00 | 30.00 | 65.00 | 20.00 | 90.00 |
| 3.5 | **E & M Works**, *% of total capital costs* | 40.00 | 60.00 | 70.00 | 35.00 | 80.00 | 10.00 |
| **4.0** | **Area Requirements** | | | | | | |
| 4.1 | **Average Area**, *$m^2$ per MLD*<br>*Secondary Treatment + Secondary Sludge Handling* | 900.00 | 450.00 | 450.00 | 1000.00 | 450.00 | 6000.00 |
| 4.2 | **Average Area**, *$m^2$ per MLD*<br>*Tertiary Treatment + Tertiary Sludge Handling* | 100.00 | 100.00 | 100.00 | 100.00 | 0.00 | 100.00 |
| 4.3 | **Total Area, *$m^2$ per MLD***<br>*Secondary + Tertiary Treatment* | **1000.00** | **550.00** | **550.00** | **1100.00** | **450.00** | **6100.00** |

**Sludge Treatment:** *** Thickener + Centrifuge; ** Drying**

**Process Type :** **[a] Aerobic; [b] Anaerobic-Aerobic; [c] Anoxic/Anaerobic-Aerobic**

| S. No. | Assessment Parameter/Technology | ASP[*,a] | MBBR[*,c] | SBR[*,a] | UASB+ASP[*,b] | MBR[*,a] | WSP[**,b] |
|---|---|---|---|---|---|---|---|
| **5.0** | **Operation & Maintenance Costs** | | | | | | |
| **5.1** | **Energy Costs (Per MLD)** | | | | | | |
| 5.1.1 | **Avg. Technology Power Requirement**, *kWh/d/MLD* *Secondary Treatment + Secondary Sludge Handling* | 180.00 | 220.00 | 150.00 | 120.00 | 300.00 | 2.00 |
| 5.1.2 | **Avg. Technology Power Requirement**, *kWh/d/MLD* *Tertiary Treatment + Tertiary Sludge Handling* | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 5.1.3 | **Avg. Non-Technology Power Req.**, *kWh/d/MLD* *Secondary Treatment* | 4.50 | 2.50 | 2.50 | 4.50 | 2.50 | 2.50 |
| 5.1.4 | **Avg. Non-Technology Power Req.**, *kWh/d /MLD* *Tertiary Treatment* | 0.20 | 0.20 | 0.20 | 0.20 | | 0.20 |
| 5.1.5 | **Total Daily Power Requirement (avg.)**, *kWh/d /MLD* | 185.70 | 223.70 | 153.70 | 125.70 | 302.50 | 5.70 |
| 5.1.6 | **Daily Power Cost (@₹ 6.0 per KWh)**, *₹. /MLD/h* *(Including Standby power cost)* | 46.43 | 55.93 | 38.43 | 31.43 | 75.93 | 1.43 |
| 5.1.7 | **Yearly Power Cost**, *₹. lacs pa/MLD* | **4.07** | **4.90** | **3.37** | **2.75** | **6.65** | **0.49** |
| **5.2** | **Repairs cost (Per MLD)** | | | | | | |
| 5.2.1 | **Civil Works per Annum**, *as % of Civil Works Cost* | 3.00 | 3.00 | 3.00 | 3.00 | | 3.00 |
| 5.2.2 | **E&M Works**, *as % of E&M Works Cost* | 1.00 | 1.00 | 1.00 | 1.00 | | 1.00 |
| 5.2.3 | **Civil Works Maintenance**, *₹. Lacs pa /MLD* | 1.94 | 1.30 | 1.04 | 2.11 | | 1.70 |
| 5.2.4 | **E & M Works Maintenance**, ₹. *Lacs pa*/MLD | 0.43 | 0.65 | 0.81 | 0.38 | | 0.06 |
| 5.2.5 | **Annual repairs costs**, *₹. Lacs pa/MLD* | **2.38** | **1.94** | **1.84** | **2.48** | | **1.76** |
| **5.3** | **Chemical Cost (Per MLD)** | | | | | | |
| 5.3.1 | **Recurring Chemical/Polymer Costs**, *₹. Lacs pa/MLD* *Secondary Treatment* | 0.40 | 0.40 | 0.40 | 0.40 | | 0.00 |
| 5.3.2 | **Recurring Chemical**, *₹. Lacs pa/MLD* *(Alum, Chlorine, Polymer) Costs, Tertiary Treatment* | 4.00 | 4.00 | 2.00 | 5.00 | | 6.00 |
| 5.3.3 | **Other Chemical Cost**, *₹. Lacs pa/MLD* | 0.90 | 0.90 | 0.90 | 0.90 | | 1.20 |
| 5.3.4 | **Total Chemical Cost**, *₹. Lacs pa/MLD* | **5.30** | **5.30** | **3.30** | **6.30** | | **7.20** |
| **5.4** | **Manpower Cost (Assuming 50 MLD Plant)** | | | | | | |
| 5.4.1 | **Manager**, ₹. pa (1 No.) | 3.60 | 3.60 | 3.60 | 3.60 | | 3.60 |
| 5.4.2 | **Chemist/Engineer**, *₹. pa (1 No.)* | 3.60 | 3.60 | 3.60 | 3.60 | | 3.60 |
| 5.4.3 | **Operators**, *₹. Pa (@₹. 12000 pm)* | 8.64 | 5.76 | 4.32 | 8.64 | | 4.32 |
| 5.4.4 | **Skilled technicians**, *₹. pa (@₹. 10000 pm)* | 7.20 | 4.80 | 3.60 | 7.20 | | 1.20 |
| 5.4.5 | **Unskilled personnel**, *₹. pa (@₹. 7000 pm)* | 5.04 | 2.88 | 2.16 | 5.04 | | 8.64 |
| 5.4.6 | **Total Salary Costs**, *₹. Lacs pa* | 28.08 | 20.64 | 17.28 | 28.08 | | 21.36 |
| 5.4.7 | **Benefits (50% of total salary)**, *₹. Lacs pa* | 14.04 | 10.32 | 8.64 | 14.04 | | 10.68 |
| 5.4.8 | **Salary + Benefits**, *₹. Lacs pa* | **42.12** | **30.96** | **25.92** | **42.12** | | **32.04** |
| 5.4.9 | **Total annual O&M costs**, *₹. Lacs pa* | **629.26** | **638.11** | **451.22** | **618.96** | **832.55** | **504.86** |

| S. No. | Assessment Parameter/Technology | ASP[*,a] | MBBR[*,c] | SBR[*,a] | UASB+EA[*,b] | MBR[*,a] | WSP[**,b] |
|---|---|---|---|---|---|---|---|
| **6.0** | **NPV (2010) of Capital + O&M Cost for 15 years, *₹. Lacs*** | **14838.92** | **14971.67** | **12518.32** | **14684.42** | **27488.27** | **10722.96** |
| | **Present (2010) Treatment Cost, paisa/L** | **0.54** | **0.55** | **0.46** | **0.54** | **1.00** | **0.39** |
| **7.0** | **Average Capital Cost, ₹. Lacs/MLD** *upto Secondary Treatment* | **68.00** | **68.00** | **75.00** | **68.00** | | **23.00** |
| 7.1 | **Yearly Power Cost,** *₹. lacs pa/MLD* *upto Secondary Treatment* | 4.04 | 4.87 | 3.34 | 2.73 | | 0.10 |
| 7.2 | **Annual Repairs Cost**, *₹. Lacs pa/MLD* *upto Secondary Treatment* | 1.50 | 1.22 | 1.16 | 1.56 | | 1.11 |
| 7.3 | **Annual Chemical Cost**, *₹ Lacs pa/MLD* *upto Secondary Treatment* | 0.85 | 0.85 | 0.85 | 0.85 | | 0.60 |
| 7.4 | **Manpower Cost**, *₹. Lacs pa* *for 50 mld plant upto secondary treatment* | 33.70 | 24.77 | 20.74 | 33.70 | | 25.63 |
| 7.5 | **Total Annual O&M Costs,** *₹. Lacs pa* *upto Secondary Treatment* | **353.02** | **372.11** | **288.15** | **290.72** | | **116.09** |
| 7.6 | **NPV (2010) of Capital + O&M Cost for 15 years**, *₹. Lacs* *upto Secondary Treatment* | **8695.35** | **8981.58** | **8072.24** | **7760.85** | | **2891.39** |
| 7.7 | Present (2010) Treatment Cost, *paisa / L* *upto Secondary Treatment* | **0.32** | **0.33** | **0.29** | **0.28** | | **0.11** |

**Sludge Treatment:** *** Thickener + Centrifuge; ** Drying**

**Process Type :** [a] **Aerobic;** [b] **Anaerobic-Aerobic;** [c] **Anoxic/Anaerobic-Aerobic**

1. No Sludge Drying Beds. However can be provided to cater 25 % of sludge dewatering under emergency conditions
2. No FPU after UASB, only Extended Aeration (EA Process)
3. UASB not Recommended for influent $SO_4$> 25 mg/L
4. No Biological Phosphorus Removal, Coagulants are necessary
5. No Energy Recovery system recommended only if BOD <250 mg/L
6. Less than 5h HRT MBBR is not acceptable
7. Less than 14 h HRT SBR is not acceptable for plants with peak factor 2.5
8. Repair + Chemical + Manpower Cost of MBR is ₹. 500 Lac per 50 MLD
9. O&M of MBR includes all chemical (Cleaning, Polymer etc.,) cost
10. Capital cost of MBR includes membrane replacement cost for 15 years
11. All WSP,s should have mechanical pretreatment works (All types of screens & Grit chambers)
12. SBR data is based on data collected from working Indian SBR with bio selector, OUR control, RAS, Nitrogen removal
13. Manpower cost is assumed to be 20 percent less for treatment only upto secondary stage

**ASP** **: Activated Sludge Process**
**MBBR** **: Moving Bed Biological Reactor**
**SBR** **: Sequential Batch Reactor**
**UASB** **: Upflow Anaerobic Sludge Blanket**
**EA** **: Extended Aeration**
**MBR** **: Membrane Bio Reactor**
**WSP** **: Waste Stabilization Pond**

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

| Criteria | ASP | UASB+ASP | SBR | MBBR | MBR | WSP |
|---|---|---|---|---|---|---|
| **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 | Very High | Medium |
| Potential of Total / Faecal Coliform Removal | High | High | Very High | Very High | Very High | Low |
| Potential of DO in Effluent | High | High | High | High | High | High |
| Potential for Low Initial/Immediate Oxygen Demand | Very High | Very High | Very High | Very High | Very High | Very High |
| Potential for Nitrogen Removal (Nitrification-Denitrification) | Low | Low | Very High | Medium | Medium | Low |
| Potential for Phosphorous Removal | Low | Low | Very High | Medium | Medium | Low |
| **Performance Reliability** | Very High | Medium | Medium | High | Very High | Medium |
| **Impact of Effluent Discharge** | | | | | | |
| Potential of No Adverse Impact on Land | Medium | Medium | High | High | Very High | High |
| Potential of No Adverse Impact on Surface Waters | High | High | High | High | Very High | High |
| Potential of No Adverse Impact on Ground Waters | High | High | High | High | Very High | Medium |
| **Potential for Economically Viable Resource Generation** | | | | | | |
| Manure / Soil Conditioner | Medium | Medium | Medium | Medium | Low | Low |
| Fuel | High | Medium | Low | Low | Low | Low |
| Economically Viable Electricity Generation/Energy Recovery | Very High | High | Low | Low | Low | Low |
| Food | Medium | Low | Low | Low | Low | Low |
| **Impact of STP** | | | | | | |
| Potential of No Adverse Impacts on Health of STP Staff/Locals | Medium | Low | High | High | High | Medium |
| Potential of No Adverse Impacts on Surrounding Building/Properties | High | Medium | High | High | High | Very High |
| **Potential of Low Energy Requirement** | Medium | Medium | Medium | Medium | Low | Very High |
| **Potential of Low Land Requirement** | High | Medium | High | High | Very High | Low |
| **Potential of Low Capital Cost** | Medium | Medium | Medium | Medium | Low | Very High |
| **Potential of Low Recurring Cost** | Medium | Medium | Medium | Medium | Low | High |
| **Potential of Low Reinvestment Cost** | Medium | Medium | Medium | Medium | Low | High |
| **Potential of Low Level of Skill in Operation** | High | Medium | High | Low | Low | Very High |
| **Potential of Low Level of Skill in Maintenance** | High | Very High | High | Medium | Low | Very High |
| **Track Record** | Very High | High | High | Low | Low | Medium |
| **Typical Capacity Range, MLD** | All Flows | All Flows | All Flows | Smaller | Smaller | All Flows |

Low | Medium | High | Very High

ASP : Activated Sludge Process
MBBR : Moving Bed Biological Reactor
SBR : Sequential Batch Reactor
UASB : Upflow Anaerobic Sludge Blanket
EA : Extended Aeration
MBR : Membrane Bio Reactor
WSP : Waste Stabilization Pond

# 6. Sludge Management

The sludge dewatering should be done using thickener followed by filter press or centrifuge or any other equivalent mechanical device. Sludge drying beds (SDB) should be provided for emergency only. SDBs should be designed only for 25% of the sludge generated from primary and secondary processes. The compressed sludge should be converted into good quality manure using composting and/or vermi-composting processes. Energy generation through anaerobic digestion of sludges in the form of biogas and subsequent conversion to electrical energy as of now is viable only when sewage BOD > 250 mg/L. Single fuel engines should be used for conversion of biogas to electrical energy. Hazardous sludge, if any should be disposed of as per the prevailing regulations.

# 7. Flow Measurement

Flow measuring devices should be installed after the Stage I Treatment as well as at the outlet of the sewage treatment plant. These flow devices should be of properly calibrated V notch with arrangements for automatic measurement of head. Additional electronic or other type of flow meters may also be installed. Arrangements should be made for real time display of measured (both current and monthly cumulative) flows at prominent places.

# 8. Bioassay Test

The bioassay test is gaining importance in wastewater treatment plant design and operation as the whole effluent toxicity (WET) test. This test uses a standard species of aquatic life forms (like fish, algae) as a surrogate to measure the effect of the effluent on the receiving stream. The flow-through method employing continuous sampling is recommended for on-site tests.

- Flow rate (retention time): For a flow-through system, the USEPA Manual for Acute Toxicity Test of Effluents (USEPA, 2002) specifies that the flow rate through the proportional dilutor must provide for a minimum of five 90% replacements of water volume in each test chamber every 24 h (i.e. a retention time of 4.8 h) (see Figure 3). This replacement rate should provide sufficient flow to maintain an adequate concentration of dissolved oxygen (DO). This implies a maximum HRT of 5.3 h (i.e. $0.9V/Q = 4.8$) for a flow-through system. Therefore, a flow-through pond with a maximum HRT of 5 h for 100% exposure is recommended for bioassay test of tertiary-treated effluent.
- Total flow requirement: 10% of the flow (subjected to maximum 1 MLD) is required to pass through the bioassay pond.

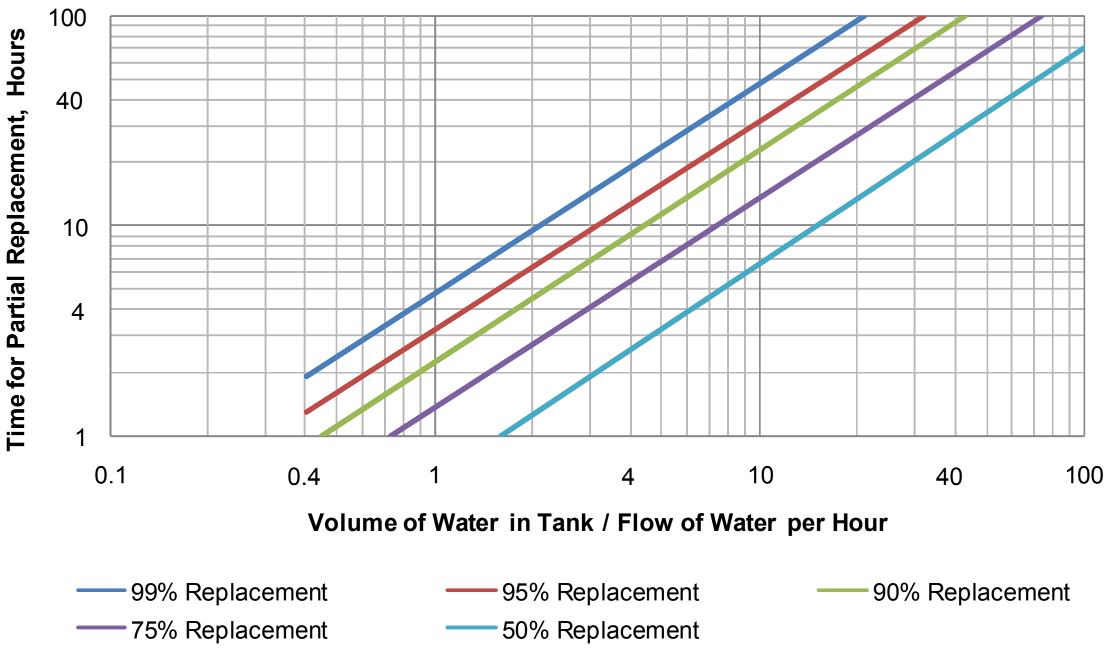


**Figure 3: Approximate times required to replace water in test chambers in flow-through tests (For Example: For a chamber containing 4 L, with a flow of 2 L/h, the above graph indicates that 90% of the water would be replaced every 4.8 h. The same time period, such as hours, must be used on both axes, and the same unit of volume, such as liters, must be used for both volume and flow (Adapted from USEPA, 2002)**

- Depth of flow-through system or pond: The depth of the flow-through bioassay pond should be within 1.5 to 2.5 m based on an equivalent system of wastewater-fed fish pond (aquaculture) (Costa-Pierce, 1998; Hoan and Edwards, 2005).
- Test organisms: In the bioassay pond, locally found fish, algae and daphnia should be inhabited in the bioassay pond. USEPA (2002) and APHA *et al*. (1995) have recommended following freshwater fish species when fish is the preferred form of aquatic life/test organism:
  1. *Oncorhynchus mykiss* (rainbow trout) and Salvelinus fontinalis (brook trout)
  2. *Pimephales promelas* (fathead minnow)
  3. *Lepomis macrochirus* (Bluegill sunfish)
  4. *Ictalurus punctatus* (Channel catfish)

  Based on above, following equivalent fish species are recommended under Indian conditions.

  1. *Puntias stigma*
  2. *Puntias sophore*
  3. *Anabas*
  4. *Chela bacalia*
  5. *Puntias ticto* and
  6. *Colisa faciatus*

Other freshwater fish species like *Gambusia affinis* (mosquito fish) can also be considered. *Daphnia pulex* and *D. magna* (daphnids), *Selenastrum sp*., *Scenedesmus aculeala*, *Scenedesmus guadacanda* are also recommended similar to the recommendations made by USEPA (2002) for bioassay test.

- <u>Stocking density and number of test organisms</u>: For flow-through tests, the live weight of test organisms in the system must not exceed 7.0 g/L (i.e. 7.0 kg/$m^3$) of volume at l5°C, or 2.5 g/L (i.e. 2.5 kg/$m^3$) at 25°C (USEPA, 2002). A minimum of 20 organisms of a given species are required for the test.
- <u>Feeding requirement</u>: Considering the bioassay of tertiary-treated sewage effluent and fish as the preferred form of aquatic life/test organism, 32% protein feed at 1% of the stocking biomass/d in two daily slots (preferably morning and evening) with a floating system need to be fed (Costa-Pierce, 1998). The feeding regime for fish mentioned in USEPA (2002) can also be adopted.
- <u>Aeration and oxygen requirements</u>: Sufficient DO (4.0 mg/L for warm water species and 6.0 mg/L for cold water species) should be maintained in the pond for proper environment for test organisms. The DO depletion is not a problem in case of a flow-through system because aeration occurs as the water pass through the system. If DO decreases to a level that would be a source of additional stress, the turnover rate of the water volume must be increased (i.e. the HRT of the system must be decreased) sufficiently to maintain acceptable DO levels (USEPA, 2002). Alternatively fountain or cascade aeration arrangements may be provided.
- <u>Requirement of Dechlorination</u>: Dechlorinated effluent only should be passed through the bioassay pond. If the effluent from the STP is chlorinated, the total residual chlorine in the effluent should be non-detectable after dechlorination.
- <u>Bioassay test acceptability criterion</u>: No mortality (100% survival) of test organisms under any condition.

**Salient Features of Recommended STPs**

- Continuous measurement of flow at the inlet and outlet
- Excellent preliminary treatment
- Treatment up to tertiary level
- Online bioassay test
- Designed and built as modular units
- Pumping and STPs to be taken together for contracting/bidding

# 9. Justification for Recommending Tertiary Treatment and Zero Liquid Discharge

The trends in water quality of river Ganga based on the past 25 years of data on more than 70 station spread over entire course of the river reveals that coliform and fecal coliform levels are of main concern (refer Report No 023_GBP_IIT_EQP_ANL_01 Ver 1_June 2012). Further, this report reveals that for control of coliforms, disinfection of treated wastewater is essential. However, no disinfection method is found to be effective in reducing coliform levels from secondarily treated wastewater. As such it is essential to have tertiary treatment for any disinfection method to be very effective (refer Report No 023_GBP_IIT_EQP_ANL_01 Ver 1_June 2012). Also, tertiary treatment of wastewater improves chances of reuse and recycle, and hence recovering the expenditure on sewage treatment. There are many examples of reuse and recycle of treated wastewater world wide as well as in India (refer Report No 012_GBP_IIT_EQP_SOA_01 Ver 1_June 2011). Considering this it is recommended that sewage be treated to tertiary level and reused instead of discharging into the river in a time bound manner to reduce abstraction of river water and exploitation of ground water.

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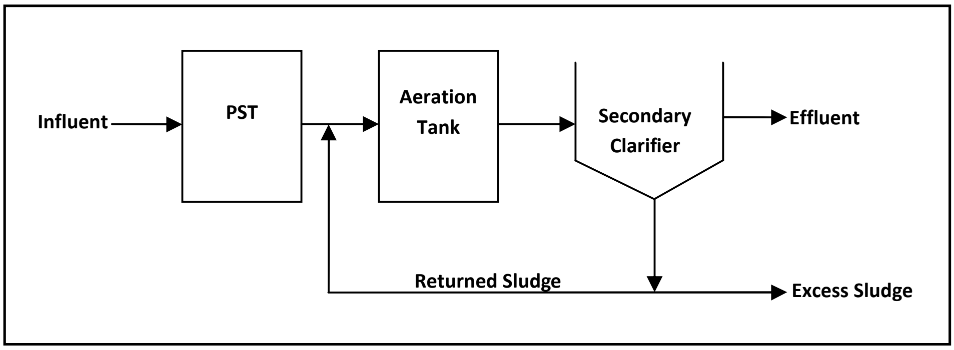
# Appendix I: Exhibits on Options for Secondary Treatment

## Exhibit 1: ASP - Conventional Activated Sludge Process




**Schematic Diagram of a Conventional Activated Sludge Process**

Activated Sludge Process (ASP) is a suspended growth aerobic process. It is provided with primary clarifier to reduce the organic load in biological reactor (aeration basin). About 40% of organic load is intercepted in primary clarifier in the form of sludge, decreasing the loading in the aeration tank. Detention period in aeration tank is maintained between 4-6 h. After aeration tank, the mixed liquor is sent to secondary clarification where sludge and liquid are separated. A major portion of the sludge is re-circulated and excess sludge is sent to a digester.

Sludge generated in primary clarifier and excess sludge from secondary clarifier are not matured, digestion of such sludge is essential before disposal. In anaerobic sludge digestion, such sludge produces biogas which can be used for power generation by gas engines. Generated power can be used for operation of plant.

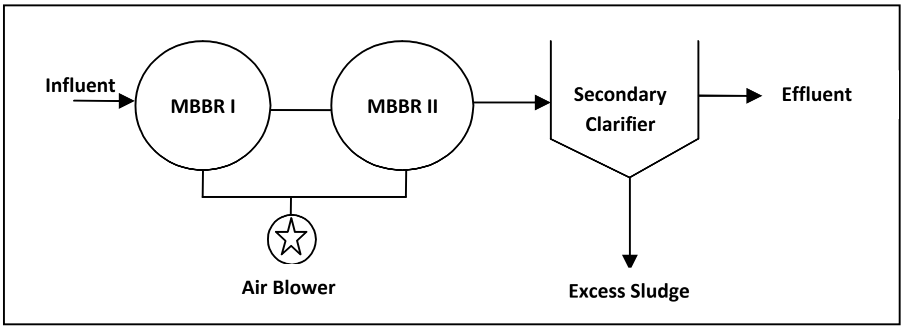
**Merits**

- Good process flexibility
- Reliable operation
- Proven track record in all plant sizes
- Less land requirements
- Low odor emission
- Energy production
- Ability to withstand nominal changes in water characteristics

**Demerits**

- High energy consumption
- Skilled operators needed
- Uninterrupted power supply is required
- Requires sludge digestion and drying
- Less nutrient removal

## Exhibit 2: MBBR - Moving Bed Biofilm Reactor




**Schematic Diagram of a Moving Bed Bio-Reactor**

Moving Bed Biofilm Reactor is an aerobic attached biological growth process. It does not require primary clarifier and sludge recirculation. Raw sewage, after screening and de-gritting, is fed to the biological reactor. In the reactor, floating plastic media is provided which remains in suspension. Biological mass is generated on the surface of the media. Attached biological mass consumes organic matter for their metabolism. Excess biological mass leaves the surface of media and it is settled in clarifier. Usually a detention time of 5 to 12 h is provided in the reactors.

MBBR were initially used for small sewage flow rates and because of less space requirement. In large plant, media quantity is very high and it requires long shut down period for plant maintenance. In fact, it may not be successful for large capacity plants. Moreover the plastic media is patented and not available in the open market, leading to single supplier conditions which limit or deny price competition. In addition, due to very less detention time and other engineering factors, functional Moving Bed Biofilm Reactor in India do not produce acceptable quality effluent.

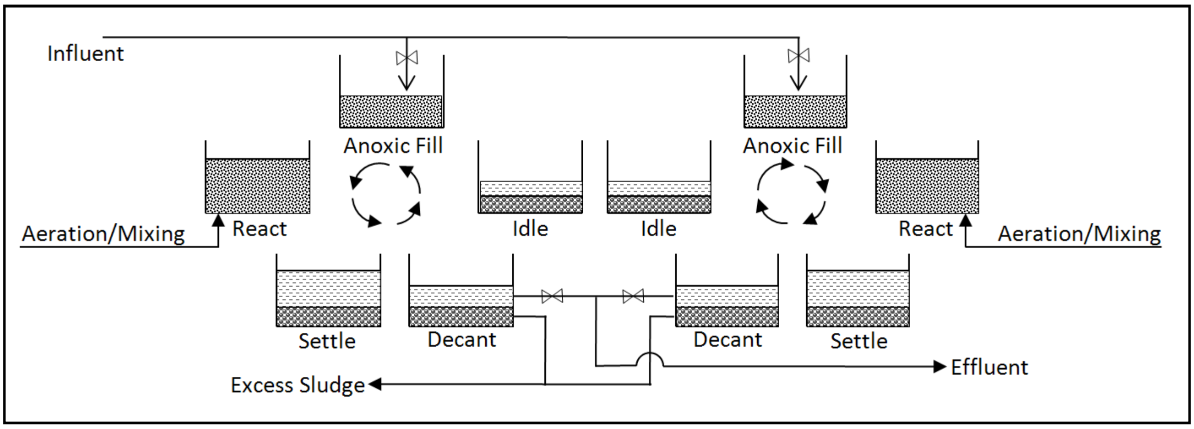
**Merits**

- Moving Bed Biofilm Reactor needs less space since there is no primary clarifier and detention period in reactor is generally 4-5 h.
- Ability to withstand shock load with equalization tank option
- High operator oversight is not required

**Demerits**

- High operating cost due to large power requirements
- Not much experience available with larger capacity plants (>1.5 MLD)
- Skilled operators needed
- No energy production
- Effluent quality not up to the mark in India
- Much less nutrient removal
- Designed criteria not well established

## Exhibit 3: SBR - Sequencing Batch Reactor




**Schematic Diagram of a Sequencing Batch Reactor (A Continuous Process "In Batch")**

It is a fill-and-draw batch aerobic suspended growth (Activated Sludge) process incorporating all the features of extended aeration plant. After screening and de-gritting, sewage is fed to the batch reactor. Reactor operation takes place in certain sequence in cyclic order and in each cycle, following operations are involved

- Anoxic Filling tank
- Aeration
- Sedimentation/clarification
- Decantation
- Sludge withdrawal

A number of large-scale plants exist around the world with several years of continuous operation. In India also, there are large scale plants operating efficiently since more than a year. Hundreds of full-scale plants operated on Sequencing Batch Reactor Technology are under successful operation in Japan. Some parts are patented and not available in the open market, leading to single supplier conditions which limit or deny price competition.

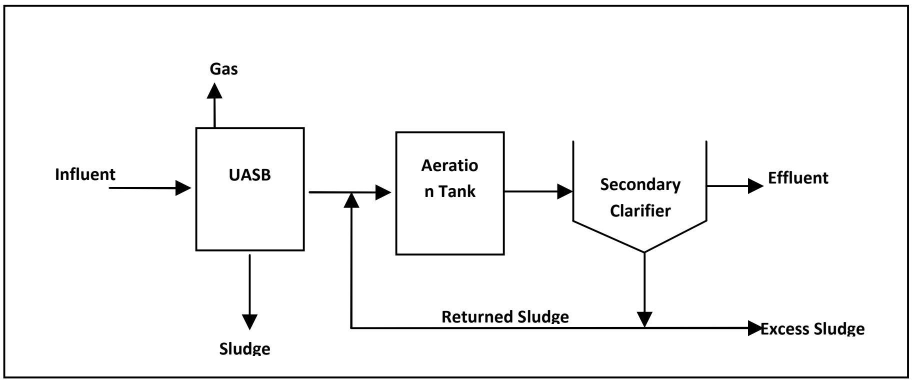
### Merits

- Excellent effluent quality
- Smaller footprint because of absence of primary, secondary clarifiers and digester
- Recent track record available in large applications in India also
- Biological nutrient (N&P) removal
- High degree of coliform removal
- Less chlorine dosing required for post disinfection
- Ability to withstand hydraulic and organic shock loads

### Demerits

- Comparatively high energy consumption
- To achieve high efficiency, complete automation is required
- Highly skilled operators needed
- No energy production
- Uninterrupted power supply required

**Exhibit 4: UASB+ASP - Upflow Anaerobic Sludge Blanket Followed by Activated Sludge Process**




**Schematic Diagram of an Upflow Anaerobic Sludge Blanket Process followed by ASP**

It is an anaerobic process in which influent wastewater is distributed at the bottom of the UASB reactor and travels in an up-flow mode through the sludge blanket. Critical components of UASB design are the influent distribution system, the gas-liquid-solid separator (GLSS) and effluent withdrawal design. Compared to other anaerobic processes, UASB allows the use of high hydraulic loading.

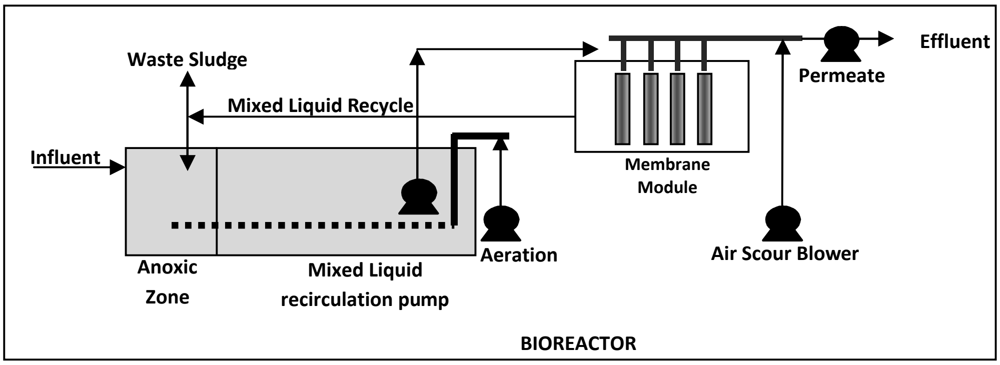
**Merits**

- Relatively simple operation and maintenance
- No external energy requirement and hence less vulnerable to power cuts
- No primary treatment required
- Energy production possible but generally not achieved
- Low sludge production
- No special care or seeding required after interrupted operations
- Can absorb hydraulic and organic shock loading

**Demerits**

- Post treatment required to meet the effluent standard
- Anoxic effluent exerts high oxygen demand
- Large Land requirement
- More man-power require for O&M
- Effluent quality is not up to the mark and poor fecal and total coliform removal
- Foul smell and corrosion problems around STP area
- High chlorine dosing required for disinfection.
- Less nutrient removal

## Exhibit 5: MBR - Membrane Bioreactor




**Schematic Diagram of a Membrane Bioreactor**

It is a biological reactor with a suspended biomass. The solid-liquid separation in membrane bioreactor is achieved by a microfiltration membrane with pore sizes ranging from 0.1 to 0. 4 µm. No secondary clarifier is used and has the ability to operate at high MLSS concentrations. Membranes are patented and not available in the open market, leading to single supplier conditions which limit or deny price competition.

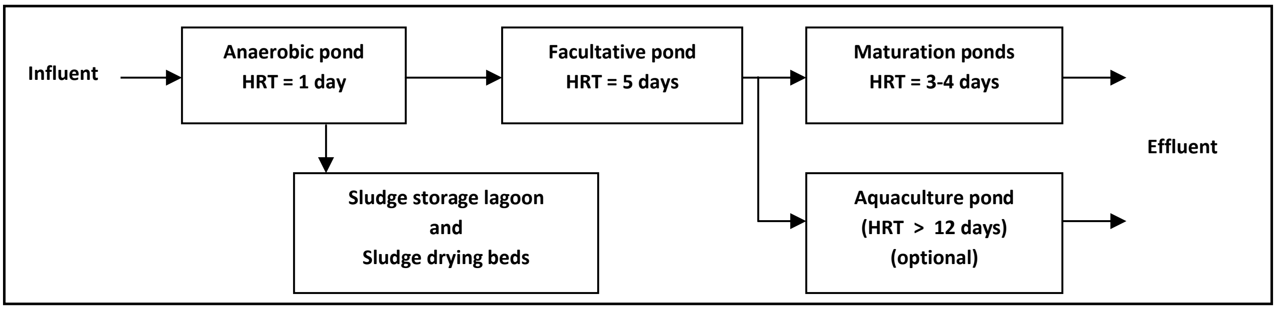
**Merits**

- Low hydraulic retention time and hence low foot print (area) requirement
- Less sludge production
- High quality effluent in terms of low turbidity, TSS, BOD and bacteria
- Stabilized sludge
- Ability to absorb shock loads

**Demerits**

- High construction cost
- Very high operation cost
- Periodic cleaning and replacement of membranes
- High membrane cost
- High automation
- Fouling of membrane
- No energy production

## Exhibit 6: WSP - Waste Stabilization Pond (Combination of Anaerobic and Aerobic Pond)




**Schematic Diagram of a Waste Stabilization Pond**

Sewage is treated in a series of earthen ponds. Initially after screening and de-gritting it is fed to an anaerobic pond for initial pretreatment; depth of anaerobic pond is usually 3 to 3.5 m; as a result the lower section of pond does not get oxygen and an anaerobic condition is developed. BOD reduction takes place by anaerobic metabolism and gases like ammonia and hydrogen sulphide are produced creating odor problems. After reduction of BOD by 40% it enters the facultative/aerobic pond, which is normally 1 - 1.5 m in depth. Lesser depth allows continuous oxygen diffusion from atmosphere; in addition algae in the pond also produces oxygen.

Though BOD at the outlet remains within the range, sometimes the effluent has green color due to presence of algae. The algae growth can contribute to the deterioration of effluent quality (higher total suspended solids) from time to time. Moreover, coliforms removal is also in 1-2 log order. The operating cost of a waste stabilization pond is minimum, mostly related to the cost of cleaning the pond once in two to three years. A waste stabilization pond requires a very large land area and it is normally used for small capacity plant, especially where barren land is available.

### Merits

- Simple to construct and operate and maintain
- Low operating and maintenance cost
- Self sufficiency, ecological balance, and economic viability is greater
- Possible recovery of the complete resources
- Good ability to withstand hydraulic and organic load fluctuations

### Demerits

- Requires extremely large areas
- Large evaporation loss of water
- If liner is breached, groundwater is impacted
- Effluent quality may vary with seasons
- No energy production
- Comparatively inferior quality of effluent
- Less nutrient removal
- High chlorine dosing for disinfection
- Odor and vector nuisance
- Loss of valuable greenhouse gases to the atmosphere

## Exhibit 7: CW - Constructed Wetlands

Wetlands are natural processes similar to stabilization ponds. Wetlands are shallow ponds comprising of submerged plants and floating islands of marshy species. Natural forces including chemical, physical, biological and solar is involved in the process to achieve wastewater treatment. Thick mats of vegetation trap suspend solids and biological process takes place at the roots of the plants. It produces the desired quality of treated sewage but land requirement is very high, though it is less compared to waste stabilization pond. Running cost is comparatively low.

Wetland process have not yet established compared to other processes. There are two types of systems; surface and subsurface distribution of sewage. The type of vegetation grown varies, in some cases there is regular tree cutting and plantation as a part of maintenance work. Plants like Typha, Phragamites, Kattail can be used in India. Another type of wetlands use a plant called duckweed for treatment. This weed has a very fast metabolic rate and absorbs pollutants very quickly.

**Merits**

- Simple to construct and operate and maintain
- Low operating and maintenance cost
- Self sufficiency, ecological balance, and economic viability is greater
- Possibility of complete resource recovery
- Good ability to withstand hydraulic and organic load fluctuations

**Demerits**

- Requires large area
- Large evaporation loss of water
- Not easy to recover from massive upset
- If liner is breached, groundwater is impacted
- Effluent quality may vary with seasons
- No energy production
- No nutrient removal
- Odor and vector nuisance
- Loss of valuable greenhouse gases to the atmosphere