Appendix M62:

Design Criteria for Sewerage Facilities

Contents for Appendix M62

Appendix M62.1 Design Criteria for Sewer Network

Items	Manual on Sewerage and Sewage Treatment in India *1	Japanese Standards	Adoption
1. Design flow	Peak flow (p.45) Peak factor to average flow (p.39) Contributory population Peak factor Up to 20,000 persons 3.00 20,000 - 50,000 persons 2.50 50,000 - 750,000 persons 2.25 Above 750,000 persons 2.00	Hourly maximum flow (= Peak flow) Example on middle size city Daily maximum flow : Daily average flow = 1 : 0.75 Hourly maximum flow : Daily maximum flow = 1.5 : 2 Hourly maximum flow : Daily average flow = 2 : 1	Peak flow **Peak factor to average flow** Contributory population Peak factor Up to 20,000 persons 3.00 20,000 - 50,000 persons 2.50 50,000 - 750,000 persons 2.25 Above 750,000 persons 2.00
2. Flow formula	1. Gravity flow (p.46) **Manning formula** $V=(1/n)\times(3.968\times10^{-3})\times D^{2/3}\times S^{1/2}$ $Q=(1/n)\times3.118\times D^{2/3}\times S^{1/2}$ Where Q : Flow Capacity (litter/sec) S : Slope of hydraulic gradient D : Internal diameter (mm) V : Flow velocity (m/sec) n : Manning's coefficient of roughness Cement concrete pipe (good) : 0.013 (p.47) Cement concrete pipe (fair) : 0.015 2. Pressure flow (p.48) **Hazen-Williams formula** $V=4.567\times10^{-3}\times C\times D^{0.63}\times S^{0.54}$ $Q=1.292\times10^{-5}\times C\times D^{2.63}\times S^{0.54}$ Where Q : Flow capacity (m^3/hr) D : Internal diameter (mm) V : Flow velocity (m/sec) S : Slope of hydraulic gradient C : Hazen-Williams coefficient Cast iron : 100 (p.49)	1. Gravity flow **Manning formula** $V=(1/n)\times R^{2/3}\times S^{1/2}$ $Q=A\times V$ Where Q : Flow Capacity (litter/sec) S : Slope of hydraulic gradient A : Internal area (m^2) V : Flow velocity (m/sec) R : Hydraulic radius (m) n : Manning's coefficient of roughness Cement concrete pipe: 0.013 2. Pressure flow **Hazen-Williams formula** $V=0.84935\times C\times R^{0.63}\times S^{0.54}$ $Q=A\times V$ Where Q : Flow capacity (m^3/hr) R : Hydraulic radius (m) V : Flow velocity (m/sec) S : Slope of hydraulic gradient A : Internal area (m^2) C : Hazen-Williams coefficient Cast iron : 110	1. Gravity flow **Manning formula** $V=(1/n)\times(3.968\times10^{-3})\times D^{2/3}\times S^{1/2}$ $Q=(1/n)\times3.118\times D^{2/3}\times S^{1/2}$ Where Q : Flow Capacity (litter/sec) S : Slope of hydraulic gradient D : Internal diameter (mm) V : Flow velocity (m/sec) n : Manning's coefficient of roughness Cement concrete pipe (fair) : 0.015 2. Pressure flow **Hazen-Williams formula** $V=4.567\times10^{-3}\times C\times D^{0.63}\times S^{0.54}$ $Q=1.292\times10^{-5}\times C\times D^{2.63}\times S^{0.54}$ Where Q : Flow capacity (m^3/hr) D : Internal diameter (mm) V : Flow velocity (m/sec) S : Slope of hydraulic gradient C : Hazen-Williams coefficient Cast iron : 100
3. Depth of flow	0.8 of full at ultimate peak flow (for ventilation in wastewater flow)	Full depth flow	0.8 of full at ultimate peak flow
4. Minimum velocity	V = 0.80 m/sec at design peak flow (p.52) V = 0.60 m/sec for early years (p.53)	V = 0.60 m/sec	V = 0.80 m/sec
5. Maximum velocity	V = 3.00 m/sec (p.53)	V = 3.00 m/sec (same as left)	V = 3.00 m/sec
6. Minimum diameter of sewer	D = 150 mm (p.53)	Depend of the scale of sewerage project Small scale : 150 mm Normal and large scale : 200 mm	D = 150 mm
7. Minimum depth of earth cover	H = 1.0 m (p.460)	H = 1.0 m (same as left)	H = 1.0 m (Branch sewers) H = 1.5 m (Trunk sewers, diameter 200 mm or larger)
8. Pipe materials	Concrete, Clay, Asbestos Cement, Iron and Steel, PVC, High density polyethylene (HDPE), Glass fiber reinforced Plastic (GRP) (p.87)	Concrete, Clay, Iron and Steel, PVC, High density polyethylene (HDPE) Glass fiber reinforced Plastic (GRP)	1.Gravity flow Concrete pipe (n=0.015) 2.Pressure flow Cast Iron pipe (C=100)
9. Manhole spacing	Diameter of pipe Manhole spacing (p.74) Up to 900 mm < 30 m 900 - 1,500 mm 90 - 150 m 1,500 - 2,000 mm 150 - 200 m	Diameter of pipe Manhole spacing Up to 300 mm maximum 50 m 350 - 600 mm maximum 75 m 700 - 1,000 mm maximum 100 m 1,100 - 1,500 mm maximum 150 m Above 1,650 mm maximum 200 m	Diameter of pipe Manhole spacing Up to 900 mm < 30 m 900 - 1,500 mm 90 - 150 m 1,500 - 2,000 mm 150 - 200 m
10. Manhole size (diameter)	For depths above 0.90m and up to 1.65m = 900 mm dia. (p.77) For depths above 1.65m and up to 2.30m = 1,200 mm dia. For depths above 2.30m and up to 9.00m = 1,500 mm dia. For depths above 9.00m and up to 14.00m = 1,800 mm dia. and - Width/diameter of the manhole should not be less than internal diameter of (the sewer + 150mm on both sides)	For at the starting point of sewers 900 mm dia. intermediate point (less than 600mm sewer) junction point (less than 450mm sewer) For intermediate point (less than 900mm sewer) 1,200 mm dia. junction point (less than 600mm sewer) For intermediate point (less than 1,200mm sewer) 1,500 mm dia. junction point (less than 800mm sewer) For intermediate point (less than 1,500mm sewer) 1,800 mm dia. junction point (less than 900mm sewer)	For depths above 0.90m and up to 1.65m = 900 mm dia. For depths above 1.65m and up to 2.30m = 1,200 mm dia. For depths above 2.30m and up to 9.00m = 1,500 mm dia. For depths above 9.00m and up to 14.00m = 1,800 mm dia. and - Width/diameter of the manhole should not be less than internal diameter of (the sewer + 150mm on both sides)

*1 : Published by "Central Public Health and Environmental Engineering Organization"

Appendix M62.2 Design Criteria for Pumping Station

Items	Manual on Sewerage and Sewage Treatment in India *1	Japanese Standards	Adoption
1. Design flow	Peak flow with 50% standby (p.158)	Hourly maximum flow (= Peak flow)	Peak flow with 50% standby
2. Type of pumping station	(1) Two wells type (p.154) Wet well for storing sewage + dry well for setting pumps (2) One well type Use of wet-pit pump (submersible pump)	(1) Manhole pump type Flow less than 3.0 m^3/min (2) Conventional type Flow more than 3.0 m^3/min	(1) Manhole pump type Flow less than 3.0 m^3/min (2) Conventional type (with submergible pump) Flow more than 3.0 m^3/min
3. Screen facility	(1) Bar spacing (p.201) Less than 20 mm (in case of the fine screen) (2) Quantity of screenings (p.203) 0.0015 - 0.015 m^3/ML (ML=1,000m^3)	(1) Bar spacing 15 - 25 mm (in case of the fine screen) (2) Quantity of screenings 0.001 - 0.015 m^3/1,000m^3 inflow	(1) Bar spacing Less than 20 mm (in case of the fine screen) (2) Quantity of screenings 0.0015 - 0.015 m^3/ML (ML=1,000m^3)
4. Type of pump equipment	- Centrifugal type of pump, including the submersible pump (p.158)	- Centrifugal type of pump, including the submersible pump - Diagonal flow pump	- Centrifugal type of pump, including the submersible pump
5. Composition of pump equipment		(1) Manhole type pumping station 2 units (including 1 standby pump) (2) Conventional type pumping station 3 - 6 units (including 1 standby pump) Case of 3 units 1/2Q×3units (1) Case of 4 units (1/4Q×2units) + ('2/4Q×2units(1)) Case of 5 units (1/8Q×2units) + ('2/8Q×1unit) + ('4/8Q×2(1)units) Case of 6 units (1/10Q×2units) + ('2/10Q×2units) + ('4/10Q×2(1)units)	(1) Manhole type pumping station 2 units (including 1 stand-by pump) (2) Conventional type pumping station 3 - 6 m3/min 3units 1/2Q×3units (1) 6 - 12 m3/min 4units (1/4Q×2units) + ('2/4Q×2units(1)) 12 - 24 m3/min 5units (1/8Q×2units) + ('2/8Q×1unit) + ('4/8Q×2(1)units)
6. Specification of pump equipment	Specific speed (p.158) $n_s = \frac{3.65 \times n \times (Q)^{0.5}}{H^{0.75}}$ where n_s : Specific speed n : Speed of the pump (rpm) Q : Flow-rate (m^3/sec) H : Pump head (m)	(1) Pump diameter $D = 146 \times (Q/V)^{0.5}$ Where D : Pump inlet/outlet diameter Q : Flow-rate (m^3/min) V : Velocity (=1.5 - 3.0 m/sec) (2) Motor power of pumps $P = (0.163 \times Q \times H/n) \times (1+\alpha)$ Where P : Motor power (kW) Q : Discharging flow (m^3/min) H : Pump head (m) n : Pump efficiency (60 - 85%) α : Allowance of motor power (= 0.15)	(1) Pump diameter $D = 146 \times (Q/V)^{0.5}$ Where D : Pump inlet/outlet diameter Q : Flow-rate (m^3/min) V : Velocity (=1.5 - 3.0 m/sec) (2) Motor power of pumps $P = (0.163 \times Q \times H/n) \times (1+\alpha)$ Where P : Motor power (kw) Q : Discharging flow (m^3/min) H : Pump head (m) n : Pump efficiency (60 - 85%) α : Allowance of motor power (= 0.15)
7. Minimum size of pump	100 mm (p.158)	80 mm	100 mm
8. Essential Accessories	- Flow measuring devices (p.155) - Ventilation - Hoisting equipment, etc.	- Flow measuring devices - Ventilation - Hoisting equipment, etc.	- Flow measuring devices - Ventilation - Hoisting equipment, etc.

*1 : Published by "Central Public Health and Environmental Engineering Organization"

Appendix M62.3 Selection of Sewage Treatment Methods

(1) First Stage Selection of Sewage Treatment Methods

Among the seven treatment methods shown in Volume II Table 62.7, Conventional Activated Sludge, Stabilization Ponds and Trickling Filter processes are regarded not suitable for this project due to the reasons below.

a) Conventional Activated Sludge

- This method is suitable for larger-scale treatment plant because of stable effluent quality and small footprint of the plant.
- Construction costs and O&M costs are higher than the other treatment methods.
- Many experienced operators are required for constant control of sludge concentration and dissolved oxygen levels in reactors and daily inspection of equipment
- Sludge discharge from both primary and final clarifiers is required.

b) Trickling Filter

High Rate Filter

- BOD removal rate in the high rate filter is too low that an additional treatment is necessary to meet the effluent quality standard. The following Table shows the treatment efficiency of the high rate trickling filter.

Item	Raw sewage (mg/l)	Removal rate (%)	Treated water (mg/l)	Effluent Standard (mg/l)
BOD	300	75 - 80	60 - 75	30

Low Rate Filter

BOD removal rate in the low rate filter process is 75 – 90% and its effluent will be able to meet the effluent quality standard. However, it requires ten (10) times larger land area than high rate filter. It is difficult to adopt the low rate filter process because of the limitation of available land area.

(Water Surface Loading): Low rate filter process = 1 – 4 m^3/m^2/day
High rate filter process = 10 – 40 m^3/m^2/day

c) Stabilization Ponds

- Anaerobic ponds, which are commonly included in this process, may provide bleeding ground for mosquitoes and flies, and also emit odor. They shall not share boundary with residents and tourist facilities.
- Stabilization ponds require large area, which is not available in the study area. The

required area is almost twenty (20) times larger than oxidation ditch. Required land area is calculated in Volume IV Appendix M62.4 Required Land Area of STP (SP & OD).

(2) General Description of Treatment Method for Detailed Comparison Study

Detailed comparison study is conducted on the following four treatment methods.

- **Oxidation Ditch (OD method)**
- **Aerated Lagoon (AL method)**
- **Sequencing Batch Reactor (SBR method)**
- **UASB + Aerobic Process (UASB+A)**

a) Oxidation Ditch

The oxidation ditch consists of a ring or oval shaped channel and is equipped with mechanical aeration devices. Screened wastewater enters the ditch, is aerated, and circulates at about 0.25 to 0.35 m/sec flow velocity. The BOD removal efficiency is high (75 – 95%). Oxidation ditches typically operate in an extended aeration mode with hydraulic retention time (12-36 hrs) and solids retention time. Secondary sedimentation tanks are used for most applications. The sample of the schematic flow diagram and illustration are presented in the Figures M62.3.1 and M62.3.2.

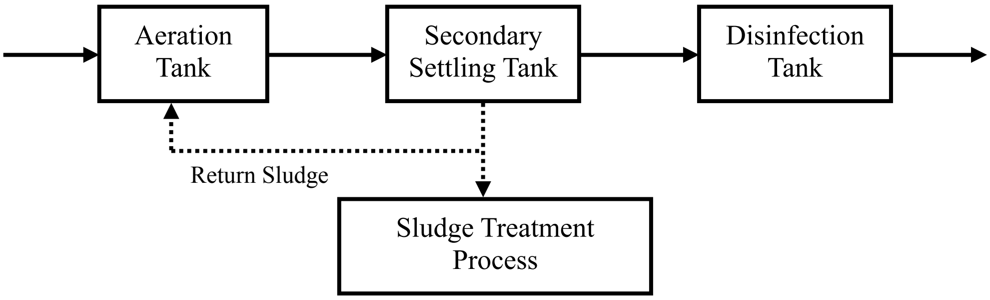


Figure M62.3,1 Schematic Flow Diagram for Oxidation Ditch Process

Figure M62.3.2 Illustration of Oxidation Ditch Process

b) Aerated Lagoons

Aerated lagoons evolved from facultative stabilization ponds when surface aerators were installed to suppress odor release from organically overloaded ponds. The aerated lagoon process is essentially the same as the activated sludge process, except that an earthen basin is used for the reactor, and this process does not depend on algae and sunlight to furnish oxygen for bacterial respiration, but instead uses diffusers or other mechanical aeration devices to transfer the major portion of oxygen and to create some degree of mixing.

Aerated lagoons are of two principal types named complete mixed lagoon and partially mixed lagoon. Complete mixed lagoon is fully aerobic from top to bottom as the aeration power input is sufficiently high to keep all the solids in suspension besides meeting the oxygenation needs of the system. On the other hand in partially mixed lagoons, some solids may leave with the effluent stream and some settle down in the lagoon since aeration power input is just enough for oxygenation and not enough for keeping all solids in suspension. The lower part of such lagoon may be anoxic or anaerobic while the upper layer is aerobic. The sample of the schematic flow diagram is presented in the Figure M62.3.3.

Figure M62.3.3 Schematic Flow Diagram for Aerated Lagoon Process

c) Sequencing Batch Reactor

A sequencing batch reactor is a fill and draw activated sludge treatment system. The unit processes in the SBR and conventional activated sludge systems are identical. Aeration and sedimentation /clarification are carried out in both systems. The BOD removal efficiency is high (75 – 95%). There is one important difference. In conventional plants, the processes are carried out simultaneously in separate tanks, whereas in SBR the processes are carried out sequentially in the same tank as shown below. The operation of step by step is presented in the Table M62.3.1.

In the SBR operation, sludge discharge usually occurs during the draw and idle steps. A unique feature of the SBR system is that there is no need for a return activated sludge system. Because both aeration and settling occur in the same chamber, no sludge is lost in these steps, and none has to be returned from the clarifier to maintain the sludge content in the aeration tank. The typical operating sequence is shown in Figure M62.3.4.

Table M62.3.1 Operational Description for SBR Process

Operation	Description
1st step: Fill	The purpose of the fill operation is to add substrate (raw sewage or primary effluent) to the reactor. The fill process typically allows the liquid level in the reactor to rise from 25% of capacity to 100%. If controlled by time, the fill process normally lasts approximately 25% of the full cycle time.
2nd step: Aeration	The purpose of aeration is to complete the reactions that were initiated during fill. Typically, aeration takes up 35% of the total cycle time.
3rd step: Settling	The purpose of settling is to allow solids separation to occur, providing a clarified supernatant to be discharged as effluent. In a SBR, this process is normally much more efficient than in a continuous flow system because in the settling mode the reactor contents are completely quiescent.
4th step: Draw and Idle	The purpose of draw is to remove clarified treated water from the reactor. Many types of decant mechanisms are in current use, with the most popular being floating of adjustable weirs. The time dedicated to draw can range from 5 to 30% of the total cycle time with 45 minutes being a typical draw period.

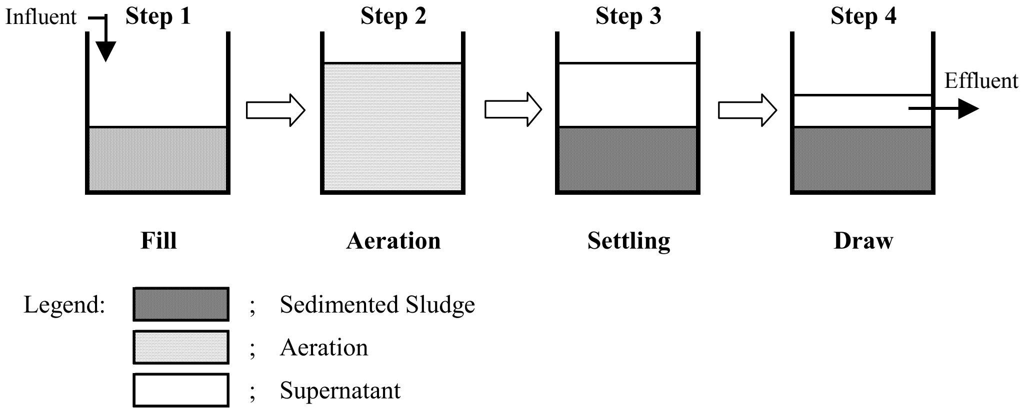


Figure M62.3.4 Typical Operating Sequence for SBR

d) UASB Process

In the upflow anaerobic sludge blanket (UASB) process, sewage to be treated is introduced in the bottom of the reactor. The sewage flow upward through a sludge blanket composed of biologically formed granules or particles. Treatment occurs as sewage comes in contact with the granules. The gases produced under anaerobic conditions (principally methane and carbon dioxide) cause internal circulation, which helps in the formation and maintenance of the biological granules. Some of the gas produced in the sludge blanket becomes attached to the biological granules. Free gas and particles with attached gas rise to the top of the reactor. The particles that rise to the surface strike the bottom of the degassing baffles, which causes the attached gas bubbles to be released. The degassed granules typically drop back to the surface of the sludge blanket. The free gas and the gas released from the granules are captured in gas collection domes located on top of the reactor. Liquid containing some residual solids and biological granules passes into a settling chamber, where the residual solids are separated from the liquid. The separated solids fall back through the baffle system to the top of the sludge blanket. To keep the sludge blanket in suspension, upflow velocity is maintained in the range of 0.6 to 0.9 m/h. Typical section of UASB is shown in Figure M62.3.5.

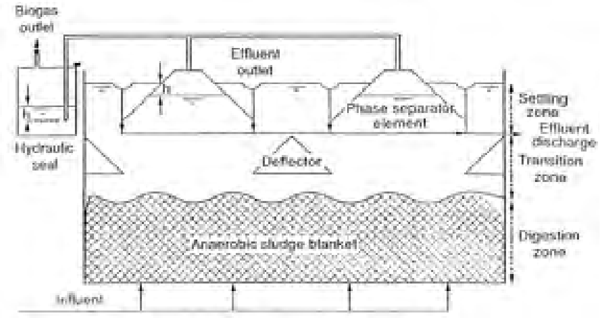


Figure M62.3.5 Upflow Anaerobic Sludge Blanket Process (UASB)

<u>Requirement for Additional Treatment Process for UASB</u>

BOD removal efficiency of typical UASB is around 60%. When it is applied to the projected sewage of BOD 300 mg/l, effluent from UASB will have 120 mg/l BOD. Additional treatment is required to achieve the effluent BOD standard of 30 mg/l. Table M62.3.2 shows the design sewage quality and efficiency of UASB method.

Table M62.3.2 Design Sewage Quality and efficiency of UASB method

Design sewage BOD quality	Typical removal rate of UASB	Expected Effluent BOD from UASB	Effluent discharge standard (BOD)
300 mg/l	60 %	120 mg/l	30 mg/l

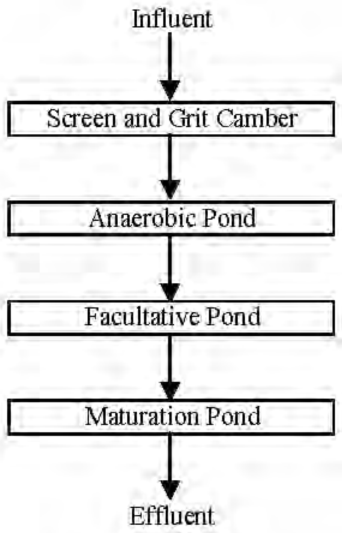
Additional treatment shall achieve BOD removal of 75%, or effluent BOD of 30 mg/l. In selecting an appropriate treatment method, the following factors are considered.

- It is preferable to use aerobic treatment method in order to minimize impact on mainly aerobic aquatic life in the receiving public waters.
- In the study area, it is difficult to secure large area required for aerated lagoons and oxidation ponds. It is ideal to use suspended or fixed media activated sludge systems in this application.

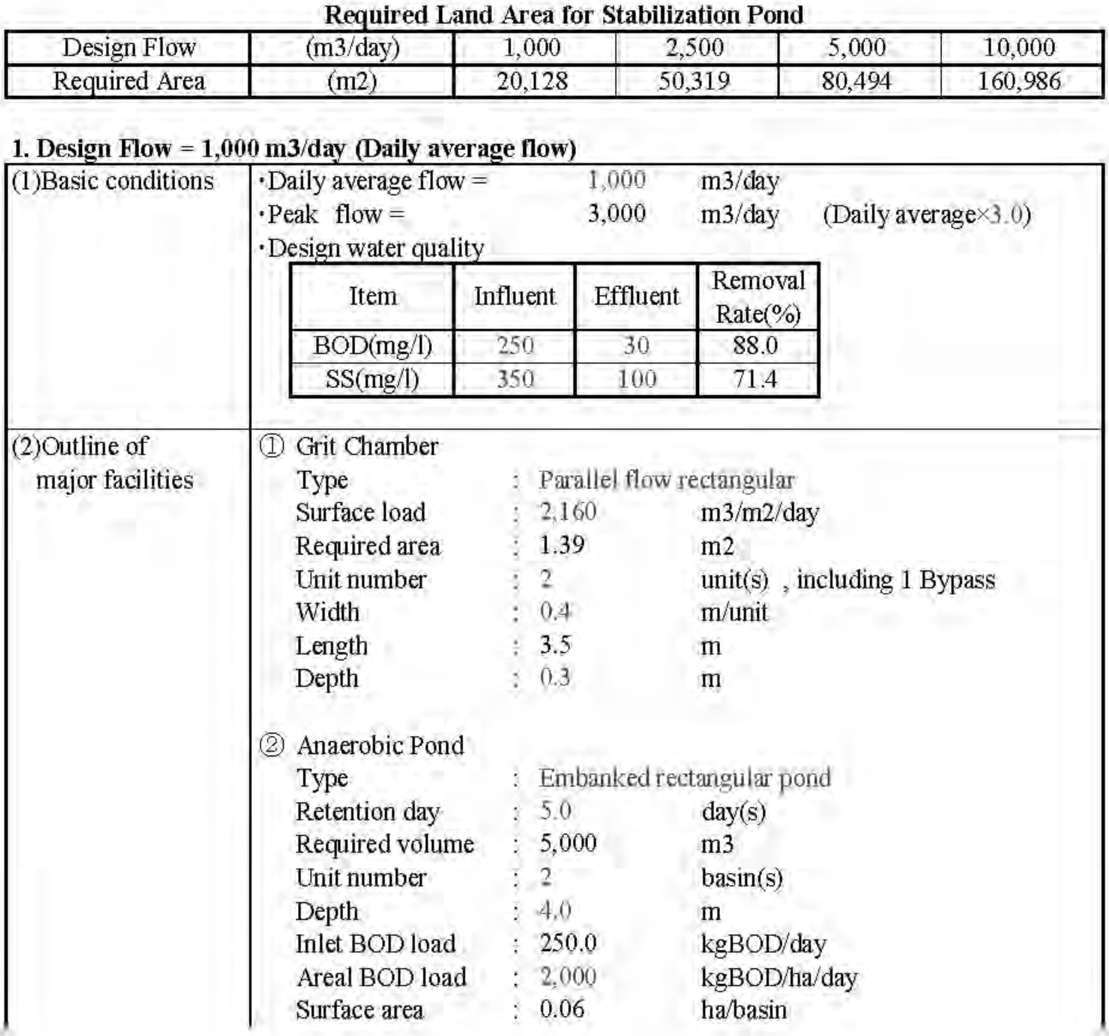
Relatively low requirement of treatment efficiency for the additional treatment to UASB enable us to choose **trickling filter method** rather than higher efficiency and energy intensive treatment, such as OD and SBR.

Appendix M62.4 Required Land Area of STP (SP & OD)

(1) Stabilization Pond



Flow Chart of Stabilization Pond



Required Land Area for Stabilization Pond

Design Flow	(m3/day)	1,000	2,500	5,000	10,000
Required Area	(m2)	20,128	50,319	80,494	160,986

1. Design Flow = 1,000 m3/day (Daily average flow)

(1)Basic conditions

·Daily average flow = 1,000 m3/day

·Peak flow = 3,000 m3/day (Daily average×3.0)

·Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber

Type	:	Parallel flow rectangular	
Surface load	:	2,160	m3/m2/day
Required area	:	1.39	m2
Unit number	:	2	unit(s) , including 1 Bypass
Width	:	0.4	m/unit
Length	:	3.5	m
Depth	:	0.3	m

② Anaerobic Pond

Type	:	Embanked rectangular pond	
Retention day	:	5.0	day(s)
Required volume	:	5,000	m3
Unit number	:	2	basin(s)
Depth	:	4.0	m
Inlet BOD load	:	250.0	kgBOD/day
Areal BOD load	:	2,000	kgBOD/ha/day
Surface area	:	0.06	ha/basin

③ Facultative Pond
Type : Embanked rectangular pond
BOD remaval ratio
at anaerobic pond : 60.0 %
Inlet BOD load : 100.0 kgBOD/day
Minimum temp. : 25.0 ℃
Areal BOD load : 20 × T-120
380.0 kgBOD/ha/day
Required area : 0.26 ha
Unit number : 2 basin(s)
Depth : 1.5 m
Surface area : 0.13 ha/basin
Retention day : 3.9 day(s)

④ Maturation Pond
Type : Embanked rectangular pond
Retention day : 5.0 days
Required volume : 5,000 m3
Depth : 1.2 m
Unit number : 2 basin(s)
Surface area : 0.21 ha/basin

(3)Required surface area

① Grit Chamber : 2.8 m2
② Anaerobic Pond : 1,250.0 m2
③ Facultative Pond : 2,631.6 m2
④ Maturation Pond : 4,166.7 m2
8,051.0 m2

(4)Required area

Required area = Required surface area × 2.5 (for maintenance space)

Approximately : 20,128 m2

2. Design Flow = 2,500 m3/day (Daily average flow)

(1)Basic conditions

- Daily average flow = 2,500 m3/d
- Peak flow = 7,500 m3/d (Daily average×3.0)
- Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 3.47 m2
Unit number : 2 unit(s) , including 1 Bypass
Width : 0.4 m/unit

	Length : 8.7 m Depth : 0.3 m ② Anaerobic Pond Type : Embanked rectangular pond Retention day : 5.0 day(s) Required volume : 12,500 m3 Unit number : 2 basin(s) Depth : 4.0 m Inlet BOD load : 625.0 kgBOD/day Areal BOD load : 2,000 kgBOD/ha/day Surface area : 0.16 ha/basin ③ Facultative Pond Type : Embanked rectangular pond BOD remaval ratio at anaerobic pond : 60.0 % Inlet BOD load : 250.0 kgBOD/day Minimum temp. : 25.0 ℃ Areal BOD load : 20 × T-120 380.0 kgBOD/ha/day Required area : 0.66 ha Unit number : 2 basin(s) Depth : 1.5 m Surface area : 0.33 ha/basin Retention day : 3.9 day(s) ④ Maturation Pond Type : Embanked rectangular pond Retention day : 5.0 days Required volume : 12,500 m3 Depth : 1.2 m Unit number : 2 basin(s) Surface area : 0.52 ha/basin
(3)Required surface area	① Grit Chamber : 6.9 m2 ② Anaerobic Pond : 3,125.0 m2 ③ Facultative Pond : 6,578.9 m2 ④ Maturation Pond : 10,416.7 m2 20,127.6 m2
(4)Required area	Required area = Required surface area × 2.5 (for maintenance space) Approximately : 50,319 m2

3. Design Flow = 5,000 m3/day (Daily average flow)

(1)Basic conditions	·Daily average flow = 5,000 m3/d ·Peak flow = 12,500 m3/d (Daily average×2.5)

・Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 5.79 m2
Unit number : 2 unit(s)
Width : 0.4 m/unit
Length : 7.2 m
Depth : 0.3 m

② Anaerobic Pond
Type : Embanked rectangular pond
Retention day : 5.0 day(s)
Required volume : 25,000 m3
Unit number : 2 basin(s)
Depth : 4.0 m
Inlet BOD load : 1,250.0 kgBOD/day
Areal BOD load : 2,000 kgBOD/ha/day
Surface area : 0.31 ha/basin

③ Facultative Pond
Type : Embanked rectangular pond
BOD remaval ratio
at anaerobic pond : 60.0 %
Inlet BOD load : 500.0 kgBOD/day
Minimum temp. : 25.0 ℃
Areal BOD load : 20 × T-120
380.0 kgBOD/ha/day
Required area : 1.32 ha
Unit number : 2 basin(s)
Depth : 1.5 m
Surface area : 0.66 ha/basin
Retention day : 3.9 day(s)

④ Maturation Pond
Type : Embanked rectangular pond
Retention day : 5.0 days
Required volume : 25,000 m3
Depth : 1.2 m
Unit number : 2 basin(s)
Surface area : 1.04 ha/basin

(3)Required surface area

① Grit Chamber : 5.8 m2
② Anaerobic Pond : 6,250.0 m2
③ Facultative Pond : 13,157.9 m2

④ Maturation Pond	:	20,833.3	m2
		40,247.0	m2

(4)Required area

Required area = Required surface area × 2.0 (for maintenance space)

Approximately : 80,494 m2

4. Design Flow = 10,000 m3/day (Daily average flow)

(1)Basic conditions

- Daily average flow = 10,000 m3/d
- Peak flow = 22,500 m3/d (Daily average×2.25)
- Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber

Type	:	Parallel flow rectangular	
Surface load	:	2,160	m3/m2/day
Required area	:	10.42	m2
Unit number	:	2	unit(s)
Width	:	0.4	m/unit
Length	:	13.0	m
Depth	:	0.3	m

② Anaerobic Pond

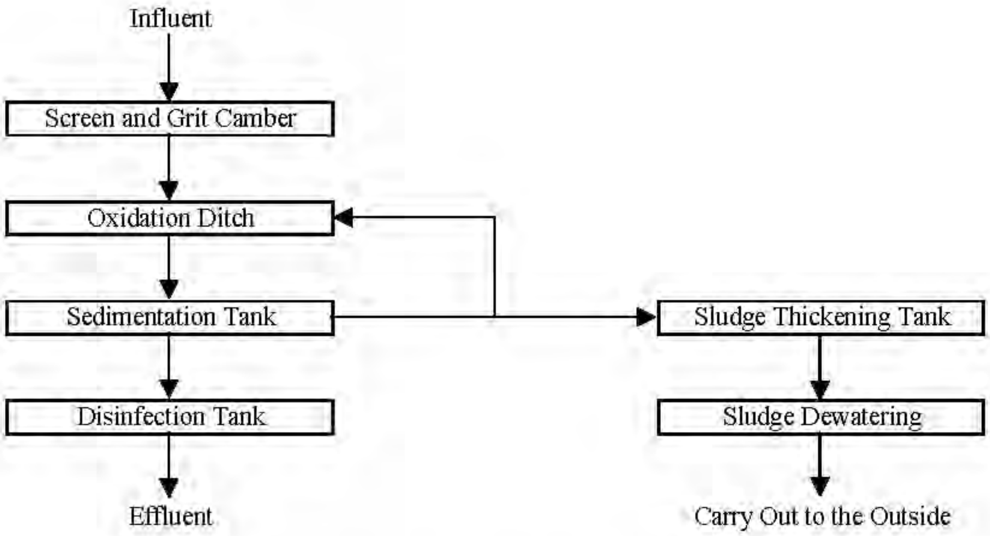
Type	:	Embanked rectangular pond	
Retention day	:	5.0	day(s)
Required volume	:	50,000	m3
Unit number	:	4	basin(s)
Depth	:	4.0	m
Inlet BOD load	:	2,500.0	kgBOD/day
Areal BOD load	:	2,000	kgBOD/ha/day
Surface area	:	0.31	ha/basin

③ Facultative Pond

Type	:	Embanked rectangular pond	
BOD remaval ratio at anaerobic pond	:	60.0	%
Inlet BOD load	:	1000.0	kgBOD/day
Minimum temp.	:	25.0	℃
Areal BOD load	:	20 × T-120	
		380.0	kgBOD/ha/day
Required area	:	2.63	ha
Unit number	:	4	basin(s)
Depth	:	1.5	m
Surface area	:	0.66	ha/basin
Retention day	:	3.9	day(s)

	④ Maturation Pond Type : Embanked rectangular pond Retention day : 5.0 days Required volume : 50,000 m3 Depth : 1.2 m Unit number : 4 basin(s) Surface area : 1.04 ha/basin
(3)Required surface area	① Grit Chamber : 10.4 m2 ② Anaerobic Pond : 12,500.0 m2 ③ Facultative Pond : 26,315.8 m2 ④ Maturation Pond : 41,666.7 m2 80,492.9 m2
(4)Required area	Required area = Required surface area × 2.0 (for maintenance space) Approximately : 160,986 m2

(2) Oxidation Ditch



Flow Chart of Oxidation Ditch

Required Land Area for Oxidation Ditch

Design Flow	(m3/day)	1,000	2,500	5,000	10,000
Required Area	(m2)	1,140	2,399	4,448	8,592

1. Design Flow = 1,000 m3/day (Daily average flow)

(1)Basic conditions

·Daily average flow = 1,000 m3/day
·Peak flow = 3,000 m3/day (Daily average×3.0)
·Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 1.39 m2
Unit number : 2 unit(s) , including 1 Bypass
Width : 0.4 m/unit
Length : 3.5 m
Depth : 0.3 m

② Oxidation Ditch
Type : Endless ditch flow type
Hydraulic retention time : 15.0 hours
Required volume : 625 m3/day
Depth : 3.0 m
Unit number : 2 basin(s)
Width : 4.0 m
Length : 26.0 m

	③ Sedimentation Basin Type : Circular tank with sludge collector Sueface load : 20.0 m3/m2/day Unit number : 2 basin(s) Required area : 25.0 m2/basin Depth : 4.0 m Diameter : 5.6 m/basin ④ Disinfection Tank Type : Chlorination type Retention time : 15.0 min Required volume : 10.4 m3 Width : 1.0 m Depth : 1.0 m Length : 10.4 m ⑤ Sludge Thickening Tank Type : Circular tank with sludge collector Dry solid load : 30.0 kgDS/m2/day Unit number : 2 basin(s) Sludge content : 250.0 kgDS/day Required area : 4.17 m2/basin Depth : 4.0 m Diameter : 2.3 m ⑥ Sludge Dewatering Type : Centrifugal type Sludge content : 250.0 kgDS/day Sludge moisture rate : 97.0 % (Thickened sludge) Sludge volume : 8.33 m3/day Unit number : 2 unit(s) (including 1 stand-by) Operation time : 8.0 hr/day Required capacity : 1.0 m3/hr
(3)Required surface area	① Grit Chamber : 2.8 m2 ② Oxidation ditch : 208.3 m2 ③ Sedimentation Basin : 50.0 m2 ④ Disinfection Tank : 10.4 m2 ⑤ Sludge Thickening Tank : 8.3 m2 ⑥ Sludge Dewatering : 100.0 m2 (as building) 379.9 m2
(4)Required area	Required area = Required surface area × 3.0 (for maintenance space) Approximately : 1,139.6 m2

2. Design Flow = 2,500 m3/day (Daily average flow)

(1)Basic conditions

・Daily average flow = 2,500 m3/day
・Peak flow = 7,500 m3/day (Daily average×3.0)
・Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 3.47 m2
Unit number : 2 unit(s) , including 1 Bypass
Width : 0.4 m/unit
Length : 8.7 m
Depth : 0.3 m

② Oxidation Ditch
Type : Endless ditch flow type
Hydraulic retention time : 15.0 hours
Required volume : 1,563 m3/day
Depth : 3.0 m
Unit number : 2 basin(s)
Width : 4.0 m
Length : 65.1 m

③ Sedimentation Basin
Type : Circular tank with sludge collector
Sueface load : 20.0 m3/m2/day
Unit number : 2 basin(s)
Required area : 62.5 m2/basin
Depth : 4.0 m
Diameter : 8.9 m/basin

④ Disinfection Tank
Type : Chlorination type
Retention time : 15.0 min
Required volume : 26.0 m3
Width : 1.0 m
Depth : 1.0 m
Length : 26.0 m

⑤ Sludge Thickening Tank
Type : Circular tank with sludge collector
Dry solid load : 30.0 kgDS/m2/day
Unit number : 2 basin(s)
Sludge content : 625.0 kgDS/day

Required area : 10.42 m2/basin
Depth : 4.0 m
Diameter : 3.6 m

⑥ Sludge Dewatering
Type : Centrifugal type
Sludge content : 625.0 kgDS/day
Sludge moisture rate : 97.0 % (Thickened sludge)
Sludge volume : 20.83 m3/day
Unit number : 2 unit(s) (including 1 stand-by)
Operation time : 8.0 hr/day
Required capacity : 2.6 m3/hr

(3)Required surface area

① Grit Chamber : 6.9 m2
② Oxidation ditch : 520.8 m2
③ Sedimentation Basin : 125.0 m2
④ Disinfection Tank : 26.0 m2
⑤ Sludge Thickening Tank : 20.8 m2
⑥ Sludge Dewatering : 100.0 m2 (as building)
799.7 m2

(4)Required area

Required area = Required surface area × 3.0 (for maintenance space)

Approximately : 2,399.0 m2

3. Design Flow = 5,000 m3/day (Daily average flow)

(1)Basic conditions

・Daily average flow = 5,000 m3/day
・Peak flow = 12,500 m3/day (Daily average×2.5)
・Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 5.79 m2
Unit number : 2 unit(s)
Width : 0.4 m/unit
Length : 7.2 m
Depth : 0.3 m

② Oxidation Ditch
Type : Endless ditch flow type
Hydraulic retention time : 15.0 hours

Required volume : 3,125 m3/day
Depth : 3.0 m
Unit number : 2 basin(s)
Width : 4.0 m
Length : 130.2 m

③ Sedimentation Basin
Type : Circular tank with sludge collector
Sueface load : 20.0 m3/m2/day
Unit number : 2 basin(s)
Required area : 125.0 m2/basin
Depth : 4.0 m
Diameter : 12.6 m/basin

④ Disinfection Tank
Type : Chlorination type
Retention time : 15.0 min
Required volume : 52.1 m3
Width : 1.2 m
Depth : 1.2 m
Length : 36.2 m

⑤ Sludge Thickening Tank
Type : Circular tank with sludge collector
Dry solid load : 30.0 kgDS/m2/day
Unit number : 2 basin(s)
Sludge content : 1,250.0 kgDS/day
Required area : 20.83 m2/basin
Depth : 4.0 m
Diameter : 5.2 m

⑥ Sludge Dewatering
Type : Centrifugal type
Sludge content : 1,250.0 kgDS/day
Sludge moisture rate : 97.0 % (Thickened sludge)
Sludge volume : 41.67 m3/day
Unit number : 2 unit(s) (including 1 stand-by)
Operation time : 8.0 hr/day
Required capacity : 5.2 m3/hr

(3)Required surface area

① Grit Chamber : 5.8 m2
② Oxidation ditch : 1041.7 m2
③ Sedimentation Basin : 250.0 m2
④ Disinfection Tank : 43.4 m2
⑤ Sludge Thickening Tank : 41.7 m2
⑥ Sludge Dewatering : 100.0 m2 (as building)

1,482.5 m2

(4)Required area

Required area = Required surface area × 3.0 (for maintenance space)

Approximately : 4,447.6 m2

4. Design Flow = 10,000 m3/day (Daily average flow)

(1)Basic conditions

·Daily average flow =	10,000	m3/day	
·Peak flow =	22,500	m3/day	(Daily average×2.25)

·Design water quality

Item	Influent	Effluent	Removal Rate(%)
BOD(mg/l)	250	30	88.0
SS(mg/l)	350	100	71.4

(2)Outline of major facilities

① Grit Chamber

Type	:	Parallel flow rectangular	
Surface load	:	2,160	m3/m2/day
Required area	:	10.42	m2
Unit number	:	2	unit(s)
Width	:	0.6	m/unit
Length	:	8.7	m
Depth	:	0.3	m

② Oxidation Ditch

Type	:	Endless ditch flow type	
Hydraulic retention time	:	15.0	hours
Required volume	:	6,250	m3/day
Depth	:	3.0	m
Unit number	:	4	basin(s)
Width	:	4.0	m
Length	:	130.2	m

③ Sedimentation Basin

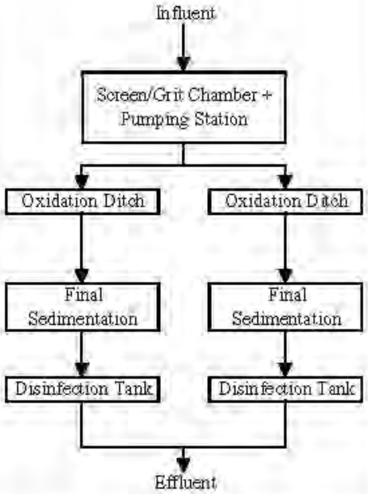
Type	:	Circular tank with sludge collector	
Sueface load	:	20.0	m3/m2/day
Unit number	:	4	basin(s)
Required area	:	125.0	m2/basin
Depth	:	4.0	m
Diameter	:	12.6	m/basin

④ Disinfection Tank

Type	:	Chlorination type	
Retention time	:	15.0	min
Required volume	:	104.2	m3
Width	:	1.5	m
Depth	:	1.2	m
Length	:	57.9	m

	⑤ Sludge Thickening Tank Type : Circular tank with sludge collector Dry solid load : 30.0 kgDS/m2/day Unit number : 2 basin(s) Sludge content : 2,500.0 kgDS/day Required area : 41.67 m2/basin Depth : 4.0 m Diameter : 7.3 m ⑥ Sludge Dewatering Type : Centrifugal type Sludge content : 2,500.0 kgDS/day Sludge moisture rate : 97.0 % (Thickened sludge) Sludge volume : 83.33 m3/day Unit number : 2 unit(s) (including 1 stand-by) Operation time : 8.0 hr/day Required capacity : 10.4 m3/hr
(3)Required surface area	① Grit Chamber : 10.4 m2 ② Oxidation ditch : 2,083.3 m2 ③ Sedimentation Basin : 500.0 m2 ④ Disinfection Tank : 86.8 m2 ⑤ Sludge Thickening Tank : 83.3 m2 ⑥ Sludge Dewatering : 100.0 m2 (as building) 2,863.9 m2
(4)Required area	Required area = Required surface area × 3.0 (for maintenance space) Approximately : 8,591.7 m2

Appendix M62.5 Detailed Comparison of Four Treatment Methods (1/5)

<table>
<tr><th>Comparison Item</th><th>Oxidation Ditch Method
(OD)</th><th>Aerated Lagoons Method
(AL)</th><th>Sequencing Batch Reactor Method
(SBR)</th><th>UASB + Trickling Filter Methods
(UASB + TF)</th><th>Remarks</th></tr>
<tr><td>(1)Basic conditions</td>
<td>・Daily flow = 10,000 m3/day
Peak flow = Daily flow × 2.25
・Peak flow = 22,500 m3/d
・Design water quality
<table><tr><th>Item</th><th>Influent</th><th>Effluent</th><th>Removal Rate(%)</th></tr><tr><td>BOD(mg/l)</td><td>300</td><td>30</td><td>90.0</td></tr><tr><td>SS(mg/l)</td><td>250</td><td>100</td><td>60.0</td></tr></table></td>
<td>・Daily flow = 8,000 m3/day (Daily average)
Peak flow = Daily average × 2.50
・Peak flow = 20,000 m3/d
・Design water quality
<table><tr><th>Item</th><th>Influent</th><th>Effluent</th><th>Removal Rate(%)</th></tr><tr><td>BOD(mg/l)</td><td>300</td><td>30</td><td>90.0</td></tr><tr><td>SS(mg/l)</td><td>250</td><td>100</td><td>60.0</td></tr></table></td>
<td>・Daily flow = 10,000 m3/day
Peak flow = Daily flow × 2.25
・Peak flow = 22,500 m3/d
・Design water quality
<table><tr><th>Item</th><th>Influent</th><th>Effluent</th><th>Removal Rate(%)</th></tr><tr><td>BOD(mg/l)</td><td>300</td><td>30</td><td>90.0</td></tr><tr><td>SS(mg/l)</td><td>250</td><td>100</td><td>60.0</td></tr></table></td>
<td>Same as Left</td>
<td>・Effluent water quality shall clear the average of target water quality
BOD = 30 mg/l
SS = 100mg/l</td></tr>
<tr><td>(2)Flow chart
1)Sewage</td>
<td>
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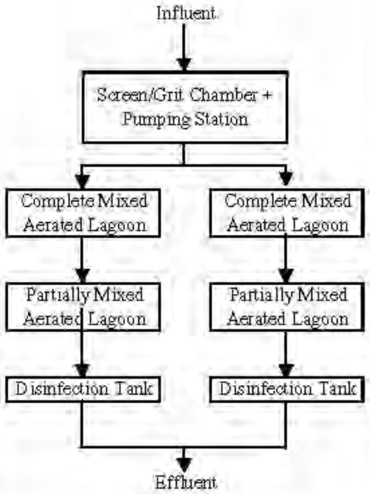
<td>
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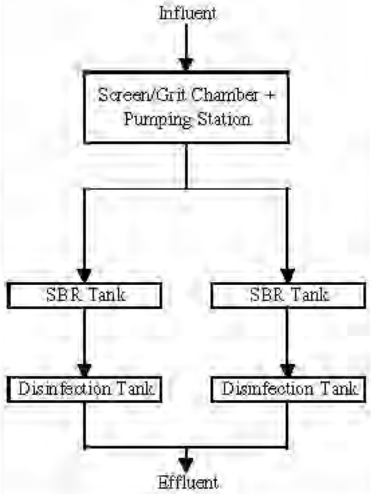
<td>
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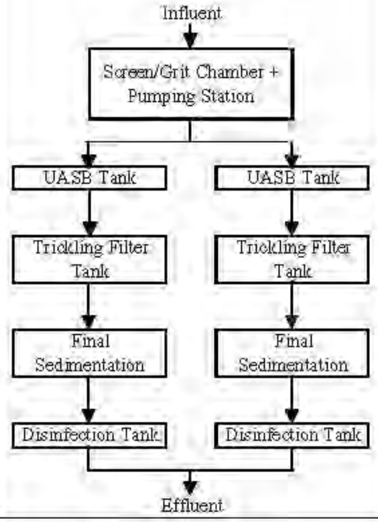
<td>
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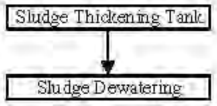
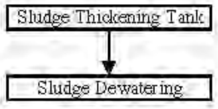
<td></td></tr>
<tr><td>2)Sludge</td>
<td>
</td>
<td>No need the sludge treatment facilities because of use the lagoons as sludge drying bed</td>
<td>
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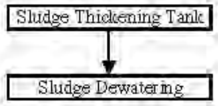
<td>
</td>
<td></td></tr>
<tr><td>(3)Outline of major facilities</td>
<td>① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 10.42 m2
Unit number : 2 unit(s)
Width : 0.6 m/unit
Length : 8.7 m
Depth : 0.3 m</td>
<td>① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 9.26 m2
Unit number : 2 unit(s)
Width : 0.6 m/unit
Length : 7.7 m
Depth : 0.3 m</td>
<td>① Grit Chamber
Type : Parallel flow rectangular
Surface load : 2,160 m3/m2/day
Required area : 10.42 m2
Unit number : 2 unit(s)
Width : 0.6 m/unit
Length : 8.7 m
Depth : 0.3 m</td>
<td>① Grit Chamber
Type :: Parallel flow rectangular
Surface load :: 2,160 m3/m2/day
Required area :: 10.42 m2
Unit number :: 2 unit(s)
Width :: 0.6 m/unit
Length :: 8.7 m
Depth : 0.3 m</td>
<td></td></tr>
</table>

(2/5)

Comparison Item	Oxidation Ditch Method (OD)	Aerated Lagoons Method (AL)	Sequencing Batch Reactor Method (SBR)	UASB + Trickling Filter Methods (UASB + TF)	Remarks
	② Oxidation Ditch Type : Circulation Channel Retention time : 15.0 hr(s) Required volum : 6,250 m3/day Depth : 3.0 m Unit number : 4 basin(s) Width : 4.0 m Length : 130.2 m	② Complete Mixed Aerated Lagoon Type : Rectangle Tank Retention time : 2.5 day Unit number : 8 unit(s) Required volum : 20,000 m3 Depth : 3.0 m Width : 30.0 m Length : 27.8 m	② SBR Tank Type : Rectangle Tank BOD-SS load : 0.30 kg/kgSS/day MLSS quality : 1,750 mg/l Cycle : 4 cycle/day Pull-out ratio : 3 - Cycle time : 6.0 hr/cycle Basin number : 2 basin(s) Aeration time : 4.6 hr/cycle Aeration time ratio : 0.76 - Required volume : 7,500 m3 Depth : 4.0 m Width : 25.0 m Length : 37.5 m	② UASB Tank Type : Upflow Anaerobic Sludge Blanket BOD volumetric : 1.5 kg/m3/day Inlet BOD : 3,000 kg/day Required volum : 2,000 m3 Unit number : 4 basin(s) Width : 10.0 m Depth : 5.0 m Length : 10.0	
	③ Sedimentation Basin Type : Circular tank with sludge collector Sueface load : 20.0 m3/m2/day Unit number : 4 basin(s) Required area : 125.0 m2/unit Depth : 4.0 m Diameter : 12.6 m/basin	③ Partilly Mixed Aerated Lagoon Type : Rectangle Tank Retention time : 4.0 day Unit number : 12 unit(s) Required volum : 32,000 m3 Depth : 3.0 m Width : 30.0 m Length : 29.6 m	③ -	③ Trickling Filter Tank Type : High-rate Filter Areal filter load : 25.0 m3/m2/day Unit number : 4 basin(s) Required area : 100.0 m2/unit Depth : 2.0 m Diameter : 11.3 m/basin	
	④ Disinfection Tank Type : Chlorination Type Retention time : 15.0 min Required volum : 104.2 m3 Width : 1.5 m Depth : 1.2 m Length : 57.9 m	④ Disinfection Tank Type : Chlorination Type Retention time : 15.0 min Required volum : 83.3 m3 Width : 1.5 m Depth : 1.2 m Length : 46.3 m	④ Disinfection Tank Type : Chlorination Type Retention time : 15.0 min Required volum : 104.2 m3 Width : 1.5 m Depth : 1.2 m Length : 57.9 m	④ Final Sedimentation Tank Type : Circular tank with sludge collector Sueface load : 20.0 m3/m2/day Unit number : 4 basin(s) Required area : 125.0 m2/unit Depth : 4.0 m Diameter : 12.6 m/basin	
	⑤ Sludge Thickening Tank Type : Circular tank with sludge collector Dry solid load : 30.0 kgDS/m2/day Unit number : 2 basin(s) Sludge content : 1,500 kgDS/day Required area : 25.00 m2/basin Depth : 4.0 m Diameter : 5.6 m	⑤ Sludge Thickening Tank -	⑤ Sludge Thickening Tank Type : Circular tank with sludge collector Dry solid load : 30.0 kgDS/m2/day Unit number : 2 basin(s) Sludge content : 1,500 kgDS/day Required area : 25.00 m2/basin Depth : 4.0 m Diameter : 5.6 m	⑤ Disinfection Tank Type : Chlorination Type Retention time : 15.0 min Required volum : 104.2 m3 Width : 1.5 m Depth : 1.2 m Length : 57.9 m	
	⑥ Sludge Dewatering Type : Centrifugal type Sludge content : 1,500 kgDS/day Sludge moisture rate : 97.0 % Sludge volume : 50.00 m3/day Unit number : 2 unit(s) (including 1 stand-by) Operation time : 8.0 hr/day Required capacity : 6.3 m3/hr	⑥ Sludge Dewatering -	⑥ Sludge Dewatering Type : Centrifugal type Sludge content : 1,500 kgDS/day Sludge moisture rate : 97.0 % Sludge volume : 50.00 m3/day Unit number : 2 unit(s) (including 1 stand-by) Operation time : 8.0 hr/day Required capacity : 6.3 m3/hr	⑥ Sludge Thickening Tank Type : Circular tank with sludge collector Dry solid load : 30.0 kgDS/m2/day Unit number : 2 basin(s) Sludge content : 975 kgDS/day Required area : 16.25 m2/basin Depth : 4.0 m Diameter : 4.5 m	(UASB) Digestion rate : 0.5 Organic solid rate : 0.7 Sludge = (0.3+(0.5×0.7)) = 0.65 ∴ 1,500×0.65 = 975 kgDS/day
				⑦ Sludge Dewatering Required capacity : 4.1 m3/hr	

(3/5)

Comparison Item	Oxidation Ditch Method (OD)	Aerated Lagoons Method (AL)	Sequencing Batch Reactor Method (SBR)	UASB + Trickling Filter Methods (UASB + TF)	Remarks
(4)Required site Surface area	① Grit Chamber : 10.4 m2 ② Oxidation Ditch : 2,083.3 m2 ③ Sedimentation Basi : 500.0 m2 ④ Disinfection Tank : 86.8 m2 ⑤ Thickening Tank : 50.0 m2 ⑥ Sludge Dewatering : 100.0 m2 (Total) : 2,830.6 m2	① Grit Chamber : 9.3 m2 ② Complete Mixed Lagoon : 6,666.7 m2 ③ Partially Mixed Lagoon : 10,666.7 m2 ④ Disinfection Tank : 69.4 m2 ⑤ Thickening Tank : - m2 ⑥ Sludge Dewatering : - m2 (Total) : 17,412.0 m2	① Grit Chamber : 10.4 m2 ② SBR Tank : 1,875.0 m2 ③ - : - m2 ④ Disinfection Tank : 86.8 m2 ⑤ Thickening Tank : 50.0 m2 ⑥ Sludge Dewatering : 100.0 m2 (Total) : 2,122.2 m2	① Grit Chamber : 10.4 m2 ② UASB Tank : 400.0 m2 ③ Trickling Filter : 400.0 m2 ④ Final Sedimentation : 500.0 m2 ④ Disinfection Tank : 86.8 m2 ⑤ Thickening Tank : 32.5 m2 ⑥ Sludge Dewatering : 100.0 m2 (Total) : 1,529.7 m2	
Required site area	Surface area × 4.5 : 12,738 m2 Approximately : 12,800 m2	Surface area × 4.5 : 78,354 m2 Approximately : 78,400 m2	Surface area × 4.5 : 9,550 m2 Approximately : 9,600 m2	Surface area × 4.5 : 6,884 m2 Approximately : 6,900 m2	
(5)Retention time	① Oxidation Ditch : 15.0 hrs ② Sedimentation : 4.8 hrs ③ Disinfection Tank : 0.3 hrs (Total) 20.1 hrs	① Complete Mixed : 60.0 hrs ② Partially Mixed : 96.0 hrs ③ Disinfection Tank : 0.3 hrs (Total) 156.3 hrs	① SBR tank : 18.0 hrs ② Disinfection Tank : 0.3 hrs (Total) 18.3 hrs	① UASB Tank : 4.8 hrs ② Trickling Filter : 1.9 hrs ③ Final Sedimentation : 4.8 hrs ④ Disinfection Tank : 0.3 hrs (Total) 11.8 hrs	
(6)Required load	① Pumping Station Sewage lift pump 25.0 kw × 3 units = 75.0 kw ② Oxidation Ditch Aerator (4units/basin) 22.0 kw × 8 units = 176.0 kw ③ Return Sludge Pump 3.7 kw × 4 units = 14.8 kw ④ Excess Sludge Pump 3.7 kw × 4 units = 14.8 kw ⑤ Sludge Collector (thickening tank) 0.75 kw × 2 units = 1.5 kw ⑥ Thickened Sludge Pump 1.5 kw × 2 units = 3.0 kw ⑦ Sludge Dewatering 5.5 kw × 1 unit = 5.5 kw (Sub-Total) 290.6 kw (176.0+1.5)+(75.0+14.8+14.8+3.0)×12/24+ 5.5×8/24 = 233.1 kw Miscellaneous Equipment 233.1 kw × 20 % = 46.6 kw (Total) 279.8 kw ↓ 280 kw	① Pumping Station Sewage lift pump 25.0 kw × 3 units = 75.0 kw ② Complete Mixed Lagoon Aerator 32 units (4units/basin) 3.0 kw × 32 units = 96.0 kw ③ Partially Mixed lagoon Aerator 48 units (4units/basin) 2.2 kw × 48 units = 105.6 kw (Sub-Total) 276.6 kw (96.0+105.6)+75.0×12/24 = 239.1 kw Miscellaneous Equipment 239.1 kw × 5 % = 23.9 kw (Total) 263.0 kw ↓ 270 kw	① Pumping Station Sewage lift pump 25.0 kw × 3 units = 75.0 kw ② SBR Tank Aerator (6units/basin) 22.0 kw × 12 units = 264.0 kw ③ Decanter for Treated Water 5.5 kw × 2 units = 11.0 kw ④ Excess Sludge Pump 3.7 kw × 4 units = 14.8 kw ⑤ Sludge Collector (thickening tank) 0.75 kw × 2 units = 1.5 kw ⑥ Thickened Sludge Pump 1.5 kw × 2 units = 3.0 kw ⑦ Sludge Dewatering 5.5 kw × 1 unit = 5.5 kw (Sub-Total) 374.8 kw 1.5+(75.0+14.8+3.0)×12/24+5.5×8/24 +264.0×16/24+11.0×4/24 = 227.6 kw Miscellaneous Equipment 227.6 kw × 20 % = 45.5 kw (Total) 273.1 kw ↓ 280 kw	① Pumping Station Sewage lift pump 25.0 kw × 3 units = 75.0 kw ② UASB Tank - kw × - units = - kw ③ Trickling Filter Tank Lift (4units) and return water pumps (4units) 11.0 kw × 8 units = 88.0 kw ④ Sludge Collector (Sedimentation Tank) 3.7 kw × 4 units = 14.8 kw ⑤ Sludge Collector (thickening tank) 0.75 kw × 2 units = 1.5 kw ⑥ Thickened Sludge Pump 1.5 kw × 2 units = 3.0 kw ⑦ Sludge Dewatering 5.5 kw × 1 unit = 5.5 kw (Sub-Total) 187.8 kw (14.8+1.5)+(75+88+3.0)×12/24+5.5×8/24 = 101.1 kw Miscellaneous Equipment 101.1 kw × 30 % = 30.3 kw (Total) 131.5 kw ↓ 135 kw	· Major equipment only · Loads values are assumed based on the experience · Pump specification 200mm×5.2m3/min ×15m×25kw×4(1)

(4/5)

Comparison Item	Oxidation Ditch Method (OD)	Aerated Lagoons Method (AL)	Sequencing Batch Reactor Method (SBR)	UASB +Trickling Filter Methods (UASB + TF)	Remarks
(7) Treatment characteristics					
・BOD removal rate	・Target treatment water quality can be easily cleared by this high level method ・BOD removal rate = 90 - 95 %	・Same as Left ・BOD removal rate = 70 - 90 %	・Same as Left ・BOD removal rate = 90 - 95 %	・It is possible to clear the effluent quality standard by combining the UASB with TF methods (BOD : 300 mg/l →30 mg/l) ・BOD removal rate = 80 - 90 %	
・Stability and flexibility of treatment	・Stable for load flactuations by long retention time	・Stable for load flactuations by long retention time	・Unstable for load flactuations by shorter retention time	・Unstable for load flactuations by shorter retention time	
・Sludge treatment	・Excess sludge at sedimentation tank must be treated by thickening tank and dewatering facility	・Sedimented sludge must be removed after discharging the lagoon water	・Sedimented sludge at SBR must be drawn and treated by thickening tank and dewatering facility	・Excess sludge at sedimentation tank must be treated by sludge treatment processes	
(8) Operation and maintenance					
・Laborer for O & M	・Moderate numbers of staff and fewer numbers than the Conventional Activated Sludge Method	・Fewer numbers than other two alternatives	・Moderate numbers of staff and fewer numbers than the Conventional Activated Sludge Method	・More numbers of stuffs than other three alternatives	
・Technical level	・Mean level in the Activated Sludge Process	・Low level in the Activated Sludge Process	・Mean level in the Activated Sludge Process	・Mean level in the Activated Sludge Process	
・Biochemical management	・Biochemical management is necessary	・Same as Left	・Same as Left	・Biochemical management is necessary	
・Maintenance work	・Moderate numbers of equipment and maintenance work items	・Few numbers of equipment and maintenance work items	・Moderate numbers of eauipment and maintenance work items	・Many numbers of equipment and maintenance work items	
・Operation of equipment	・Every equipment should be operated properly	・Same as Left	・Every equipment, especially decanter, should be operated properly	・Every equipment should be operated properly	
(9) Environmental Impact					
・Odor	・Odor at screen&grit chamber, sludge thickening tank and sludge from dewatering facility	・Odor at screen&grit chamber	・Odor at screen&grit chamber, sludge thickening tank and sludge from dewatering facility	・Odor at screen&grit chamber, UASB tank, Trickling filter, sludge thickening tank and sludge from dewatering facility	
・Injurious insect	・None	・Same as Left	・Same as Left	・Many flies and mosquitoes are generated frequently	
(10) Initial Cost					
① Construction cost	12.00 Rs crore	5.62 Rs crore	10.70 Rs crore	14.50 Rs crore	・refer to Appendix
② Land acquisitio cost	・Unit price of lanc : 2,083 Rs/m^2 ・Acquisition cost : 26,662,400 Rs Total cost : 14.67 Rs crore (100 %)	・Unit price of lanc : 2,083 Rs/m^2 ・Acquisition cost : 163,307,200 Rs Total cost : 21.95 Rs crore (150 %)	・Unit price of lanc : 2,083 Rs/m^2 ・Acquisition cost : 19,996,800 Rs Total cost : 12.70 Rs crore (87 %)	・Unit price of land : 2,083 Rs/m^2 ・Acquisition cost : 14,372,700 Rs Total cost : 15.94 Rs crore (109 %)	

(5/5)

Comparison Item	Oxidation Ditch Method (OD)	Aerated Lagoons Method (AL)	Sequencing Batch Reactor Method (SBR)	UASB +Trickling Filter Methods (UASB + TF)	Remarks
(11) O&M Cost ① Chlorine cost ・Expense for Chlorine	Type : Chlorine Dosage rate : 3.0 mg/l Required volume : 10,000 × 3.0 × 10^{-3} = 30.0 kg/day ・30.0 × 365 × 18.50 = 202,575 Rs/year	Same as Left = 202,575 Rs/year	Same as Left = 202,575 Rs/year	Same as Left = 202,575 Rs/year	・Unit price of chlorine 18.50 Rs/kg
② Polymer cost ・Expense for Chlorine	Type : Polymer Dosage rate : 5.0 kg/DS ton Required volume : 1,500 × 5.0 × 10^{-3} = 7.5 kg/day ・7.5 × 365 × 500.00 = 1,368,750 Rs/year	-	Type : Polymer Dosage rate : 5.0 kg/DS ton Required volume : 1,500 × 5.0 × 10^{-3} = 7.5 kg/day ・7.5 × 365 × 500.00 = 1,368,750 Rs/year	Type : Polymer Dosage rate : 5.0 kg/DS ton Required volume : 975 × 5.0 × 10^{-3} = 4.9 kg/day ・4.9 × 365 × 500.00 = 889,688 Rs/year	・Unit price of polymer 500.0 Rs/kg
③ Electric charge ・Consumed electricity ・Electric charge	・280 × 24 × 365 = 2,452,800 kwh/year ・2,452,800 × 3.0 = 7,358,400 Rs/year	・270 × 24 × 365 = 2,365,200 kwh/year ・2,365,200 × 3.0 = 7,095,600 Rs/year	・280 × 24 × 365 = 2,452,800 kwh/year ・2,452,800 × 3.0 = 7,358,400 Rs/year	・135 × 24 × 365 = 1,182,600 kwh/year ・1,182,600 × 3.0 = 3,547,800 Rs/year	・Unit cost of electric charge = 3.0 Rs/kwh
④ Labor cost	・Chief : 1 × 15,000 × 12 = 180,000 Rs/year ・Technitian : 2 × 10,000 × 12 = 240,000 Rs/year ・Operator : 5 × 7,500 × 12 = 450,000 Rs/year ・Laborer 15 × 4,000 × 12 = 720,000 Rs/year 1,590,000 Rs/year	・Chief : 1 × 15,000 × 12 = 180,000 Rs/year ・Technitian : 1 × 10,000 × 12 = 120,000 Rs/year ・Operator : 3 × 7,500 × 12 = 270,000 Rs/year ・Laborer 6 × 4,000 × 12 = 288,000 Rs/year 858,000 Rs/year	・Chief : 1 × 15,000 × 12 = 180,000 Rs/year ・Technitian : 2 × 10,000 × 12 = 240,000 Rs/year ・Operator : 5 × 7,500 × 12 = 450,000 Rs/year ・Laborer 15 × 4,000 × 12 = 720,000 Rs/year 1,590,000 Rs/year	・Chief : 1 × 15,000 × 12 = 180,000 Rs/year ・Technitian : 3 × 10,000 × 12 = 360,000 Rs/year ・Operator : 8 × 7,500 × 12 = 720,000 Rs/year ・Laborer 20 × 4,000 × 12 = 960,000 Rs/year 2,220,000 Rs/year	・Labor cost (Rs/month) Chief = 15,000 Technitian = 10,000 Operator = 7,500 Laborer = 4,000
⑤ Repair cost, others (Σ①-④)×15%	(Σ①-④)×15% 1,547,573 Rs/year	(Σ①-④)×10% 835,128 Rs/year	(Σ①-④)×15% 1,547,573 Rs/year	(Σ①-④)×15% 998,623 Rs/year	・For minor equipment repairing, drop of oil and exchange of spare parts
⑥ Total cost	・Chemical cost : 202,575 Rs/year ・Polymer cost : 1,368,750 Rs/year ・Electric charge : 7,358,400 Rs/year ・Labor cost : 1,590,000 Rs/year ・Repair cost, others : 1,547,573 Rs/year 12,067,298 Rs/year (100 %)	・Chemical cost : 202,575 Rs/year ・Polymer cost : 0 Rs/year ・Electric charge : 7,095,600 Rs/year ・Labor cost : 858,000 Rs/year ・Repair cost, others : 835,128 Rs/year 8,991,303 Rs/year (75 %)	・Chemical cost : 202,575 Rs/year ・Polymer cost : 1,368,750 Rs/year ・Electric charge : 7,358,400 Rs/year ・Labor cost : 1,590,000 Rs/year ・Repair cost, others : 1,547,573 Rs/year 12,067,298 Rs/year (100 %)	・Chemical cost : 202,575 Rs/year ・Polymer cost : 889,688 Rs/year ・Electric charge : 3,547,800 Rs/year ・Labor cost : 2,220,000 Rs/year ・Repair cost, others : 998,623 Rs/year 7,858,686 Rs/year (65 %)	

Note: Design Sewage Flow of AL Method

AL method is usually designed less sewage flow than OD or SBR, such as daily average flow for AL and daily maximum flow for OD/SBR, because AL's longer hydraulic retention time mitigates sewage inflow fluctuation. In this project, sewage treatment plants are designed by daily average flow for any treatment method though, AL was calculated by smaller flow such as 8,000 m^3/day as usual comparison with OD/SBR. Consequently construction cost of AL in this comparison becomes smaller than necessary capacity, however, AL was not evaluated advantageous considering with other factors.

Appendix M62.6 Selection of Sludge Treatment Method

The commonly used methods to treat and to dispose sludge are listed in Table 62.6.1.

Table M62.6.1 Sludge Treatment and Disposal Methods

Unit process	Function
1. Thickening process	
(1) Gravity thickening	Volume reduction
(2) Flotation thickening	Volume reduction
(3) Centrifugal thickening	Volume reduction
(4) Rotary drum thickening	Volume reduction
2. Stabilization process	
(1) Digestion	
- Anaerobic digestion	Stabilization, mass reduction
- Aerobic digestion	Stabilization, mass reduction
(2) Composting	Stabilization
3. Dewatering	
(1) Mechanical Dewatering	
Vacuum filter	Volume reduction
Centrifuge	Volume reduction
Belt press	Volume reduction
(2) Sludge drying beds	Volume reduction
4. Sludge disposal	
(1) Landfill	Final disposal
(2) Land reclamation	Final disposal
(3) Reuse as land application	
Agriculture, Green space, Forest, etc.	Final disposal
(4) Chemical fixation	Final disposal, beneficial use

Sludge treatment method shall be suitable for the proposed sludge disposal methods. Table M62.6.2 shows the relationships between disposal methods and possible sludge conditions.

Table M62.6.2 Sludge Conditions and Possible Disposal Methods

Item	Digested sludge	Dewatered sludge	Composted sludge
Land fill		○	○
Land reclamation		○	○
Agriculture reuse	○	○	○
Green space reuse	○	○	○

Appendix M62.7 Study on STP Cost for Comparison of Treatment Methods

(1) Study on Preliminary Cost Estimates for the Proposed STPs

1 References for Cost Estimation

① Final Report on Water Quality Management Plan for Ganga River, 2005
② Study reports conducted by the Goa State
③ Others (photographs, etc.)

2 Applicable Sewage Treatment Processes

- Oxidation Ditch (OD) Process
- Aerated Lagoon (AL) Process
- Sequencing Batch Reactor (SBR) Process
- Upflow Anaerobic Sludge Blanket (UASB) Process + Trickling Filter (TF) Process

3 Comparison of the Unit Construction Cost of Sewage Treatment Plant in the Ganga Project and the Goa Project

The unit construction cost of STP per sewage flow (MLD) is compared for the same treatment process.

Compared process : Stabilization Ponds Process
Unit construction cost in Ganga Project (refer to the Ganga Report page 5-22)
: 1.6 million Rs/MLD
Unit construction cost in Goa Project (refer to the Mapusa F/S Report)
: 4.5 million Rs/MLD

Unit cost comparison : 4.5 / 1.6 = 2.81
Therefore, the unit cost in the Goa Project is 2.81 times higher than that of the Ganga Project.

4 Unit Construction Cost of the Oxidation Ditch Process

The unit construction cost will be based on the "F/S Report for Sewage System at North Coastal Belt".

Design Flow : 5,300 m3/day
Cost Estimates : 635 Rs lakhs = 63,500,000 Rs
Unit cost : 63,500,000 / 5,300 = 12.0 million Rs/MLD

The above unit cost is based on the cost of the extended aeration process, and it could be applied for OD process based on the following reasons.

- The reactor tanks of both processes have the same volume because the calculated retention time of the extended aeration is the same as the time of the OD process.
- Both processes are composed of the similar unit process

5 Unit Construction Cost of the Aerated lagoon Process

The unit construction cost per sewage flow (MLD) is calculated based on the Ganga Report and the above Section 3.

Unit cost in the Ganga Project : 2.5 million Rs/MLD
Price deference between Ganga and Goa : 2.81 times
Unit cost in the Goa Project : 2.5 × 2.81 = 7.03 million Rs/MLD

6 Unit Construction Cost of the SBR Process

The unit construction cost per sewage flow (MLD) is calculated based on the price which was shown on the signboard at the construction period at the Panaji STP.

Construction cost : 133,252,100 Rs

Design flow : 12,500 m3/day
Unit construction cost : 133,252,100 / 12,500 = 10.7 million Rs/MLD

7 Unit Construction Cost of the (UASB + TF) Process

The unit construction cost of the UASB Process per sewage flow (MLD) is calculated based on the Ganga Report.

UASB Process : 2.5 Rs million/MLD (refer to the Ganga Report)

The unit cost of TF is calculated based on the construction cost of the DHS (Downflow Hanging Sponge) Process proposed in the Ganga Project, taking into account the water surface loading.

Design flow : 1,000 m3/day
Tank diameter : 5.5 m
Section area : 23.75 m2
Therefore, the water surface area in DHS
1,000 / 23.75 = 42.11 m3/m2/day
Water surface area in TF : 25.0 m3/m2/day

The unit construction cost of TF Process is presented as shown below.

Unit cost of DHS Process : 4.5 million Rs/MLD
Unit cost of TF Process : 4.5×(25.0/42.11) = 2.67 million Rs/MLD

Unit construction cost of the UASB and TF Processes in the Ganga Pr :
2.5 + 2.67 = 5.17 million Rs/MLD
Unit construction cost of the UASB and TF Processes in the Goa Proje :
5.17×2.81 = 14.5 million Rs/MLD

8 Proportion of Civil Works Costs to Mechanical and Electrical (M&E) Works Costs

The cost ratio between civil works and M&E works are estimated based on the Ganga Report.

Ganga Report in case of the AL process
= C : M&E = 80% : 20%
In case of the activated sludge process
= C : M&E = 60% : 40%

Therefore, the cost composition of STP is shown below.

	OD Process	AL Process	SBR Process	(UASB+TF) Process
Civil works	60%	80%	60%	65%
M&E works	40%	20%	40%	35%

9 Preliminary Cost Estimates for the Proposed STPs

Construction costs of the proposed STP are estimated based on the daily maximum flow (10,000m3/day). Due to its long retention time, AL Process is designed for daily average flow.

Daily average : Daily Maximum = 0.8 : 1.0
= 8,000 m3/day : 10,000 m3/day

Treatment Process	Unit cost million Rs/MLD	Design flow m3/day	Civil Crore Rs	M&E Crore Rs	Total Crore Rs
OD Process	12.00	10,000	7.20	4.80	12.00
AL Process	7.03	8,000	3.37	2.25	5.62
SBR Process	10.70	10,000	6.42	4.28	10.70
(UASB+TF) Process	14.50	10,000	8.70	5.80	14.50

10 Land Acquisition Cost

Unit price for land acquisition cost is presented below based on the information provided by the PWD about the proposed six STP sites.

(Rs/m2)

St. Crus	Porvorim	Ponda	Mapusa	Colva	Baga
2,500	2,000	1,500	2,000	1,500	3,000

Average Unit Price of Land : 2,083 Rs/m2

Land acquisition Cost for Proposed Treatment Processes

Treatment Process	Required Land Area (m2)	Unit cost Rs/m2	Land acquisition Cost (Rs)
OD Process	12,800	2,083	26,666,667
AL Process	78,400		163,333,333
SBR Process	9,600		20,000,000
(UASB+TF) Process	6,900		14,375,000

(2) Study on the Unit Cost of the Construction Cost for the New STP Facilities in Goa

1 Study Report for the Mapusa Proposed STP

Design Flow : 12,000 m3/day
Treatment Process: Oxidation Ponds (Stabilization Pond)
Cost : 51,000,000 × (1.05+1.02) = 54,570,000 Rs
Unit Cost : 54,570,000/12,000 = **4,548 Rs/m3**

"Consultancy Services for Preparation of Feasibility Report on Sewerage System for Mapusa Town, Feasibility Study, April 2002"

2 Study Report for the Porvorim Proposed STP

Design Flow : 4,500 m3/day
Treatment Process: Activated sludge
Cost : 965,000 euro = 53,075,000 Rs (1euro = 55Rs)
Unit Cost : 53,075,000/4,500 = **11,794 Rs/m3**

"Prefeasibility Study, Goa/Porvorim, Wastewater Treatment Plant / Sewer System"

3 North Coastal Belt Proposed STP

Design Flow : 5,300 m3/day
Treatment Process: Extended Aeration
Cost : 63,500,000 Rs
Unit Cost : 63,500,000/5,300 = **11,981 Rs/m3**

"Feasibility Report for Sewage System at Calangute and Candolim of North Goa"

4 Panaji STP (SBR Method)

Construction Cost : 1,332 Lakhs
Design Flow : 12,500 m3/day
Unit Cost : 132200000/12,500 = **10,656 Rs/m3**

"Construction cost is referred to the picture which was standing near the SBR Plant."

(3) Study on the Required Electricity in the Aerated Lagoon Process

1 Standard Mixing Requirement According to the CPHEEO Manual (P.237)

Fully Aerobic Tank : 12-14 => 13.0 kwh/person/year
Facultative Aerobic Tank : 12-15 => 14.0 kwh/person/year

2 Required Electricity According to the CPHEEO Manual

Design flow : 8,000 m3/day
Unit sewage flow : 150 l/person/day
Design population : 8,000/0.15 = 53,333 persons
Required electricity for the complete mixed lagoon : 53,300×13.0/(365×24) = 79.1 kw
Required electricity for the partial mixed lagoon : 53300×14.0/(365×24) = 85.2 kw

3 Required Electricity for the Aerator Equipment

Complete Mixed Lagoon : unit number = 32 units 79.1 / 32 = 2.5 kw
2.5 → 3.0 kw × 32 units = 96 kw
Partial Mixed Lagoon : unit number = 48 units 85.2 / 48 = 1.8 kw
1.8 → 2.2 kw × 48 units = 105.6 kw

(4) Chemical (Polymer Coagulant) Cost for the Sludge Treatment Process

1 Chemical Dosage

Polymer dosage for the centrifugal dewatering : Dosage ratio = 5.0 kg/DS ton

2 Sludge Generation

Incoming and effluent quality in the OD and SBR process : Inlet SS Quality = 250 mg/l
Treated SS Quality = 100 mg/l
Sludge volume : 10,000 × (250-100) × 10^{-3} = <u>1,500 kgDS/day</u>

Sludge volume in the (UASB+TF) process : Inlet SS Quality = 250 mg/l
Treated SS Quality = 100 mg/l
In the UASB process, anaerobic digestion decreases sludge volume.
Organic matter percents in the sewage : 70 %
Digestion (volume reduction) ratio : 50 %
Sludge volume :
10,000 × (250-100) × (0.3+(0.7×0.5)) × 10^{-3} = <u>975 kgDS/day</u>

3 Required Chemical Volume

OD and SBR processes : 1,500 × 5.0 / 1,000 = 7.5 kg/day
(UASB+TF) process : 975 × 5.0 / 1,000 = 4.9 kg/day

4 Chemical (Polymer) Cost

Unit chemical cost : 500 Rs/kg (Polymer price in India)
Chemical cost
OD and SBR processes : 7.5×500×365 = 1,368,750 Rs/year
(UASB+TF) process : 4.9×500×365 = 889,688 Rs/year