Table AII.3.1 List of Mechanical Equipment of Braila WWTP

(1) Screening System Equipment

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output(kW)	Remarks
1	Screen channel influent gates	Cast iron made, manually operated sluice gate	1200W x 1200H	2	-	-	
2	Coarse screens	Manually screened (removable type)	Clear opening 100 mm, 1.6mW x 3.3mH, 60°	2	-	-	
3	Fine screens	Mechanically-cleaned, (intermittently operated)		0			
4	Grit chamber effluent gates	Cast iron made, manually operated sluice gate	1.2mW x 1.2mH	2	-	-	
5	Gate for pump well influent channel	Cast iron made, manually operated sluice gate	0.8mW x 0.8mH Design depth 5.0 m	1	-	-	
6	Screenings conveyors	Trough belt conveyor		0	-	-	
7	Screenings skip hoist	Wire rope operated		0	-	-	
8	Screenings hopper	Steel made, motor operated	$5m^3$	0	-	-	
9	Screening hoist	Motor operated hoist with trolley		0	-	-	
	Total motor outputs of (1)					0	kW

Note: As the lift pumping station is provided with fine bar screens, these are excluded from the WWTP pumping station.

(2) Grit Chamber, Oil Separator, Flow Measurement Equipment

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output (kW)	Remarks
1	Aeration channel Influent gates	Manually operated, cast iron made sluice gate	800mm W x 800mmH Design hydraulic depth; 2 m	8	—		
2	Blowers	Turbo blower	ϕ 125mm x $15m^3$	5 (1)	55	220	Standby excluded
3	Grit collectors	Trolley with grit lifting pump	3.8kW x 380v	2	3.8	7.6	
4	Screw conveyors	Lifting of grit from grit channel to grit hopper	2.2kW x 380v	2	2.2	4.4	
5	Aeration chamber effluent channel gates	Manually operated, cast iron made sluice gate	600mm W x 600mm H Design hydraulic depth; 2 m	4	—		
6	Flow measurement equipmen	Parshall flume	7-ft. type	1	—		
	Total motor outputs of (2)					232	kW

(3) Pumping Equipment

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	otal out put(kW)	Remarks
	I. INFLUENT PUMPS						
1	No.1 Pumps	Vertical centrifugal mixed pump	450mmΦ x 25m³/min. x 11m	4	—		
2	No.1 Pump electric motor	Vertical squirrel cage, water proof type	70kW x 4p x 380v	4	70	280	
3	Suction valves	Manually operated sluice valve	450mmΦ	4	—		
4	Check valves	Slow-closing check valve	450mmΦ	4	—		
5	Discharge valves	Motor-operated butterfly valve	450mmΦ	4	0.2	0.8	
6	No.2 Pumps	Vertical centrifugal mixed pump	600mmΦ * 50m³/min. x 11m	2 (1)	—		
7	No.2 Pump electric motor	Vertical squirrel cage, water proof type	132kW x 6p x 380v	2 (1)	132	132	Standby excluded
8	Suction valves	Manually-operated sluice valve	600mmΦ	2	—		
9	Check valves	Slow-closing check valve	600mmΦ	2	—		
10	Discharge valves	Motor-operated butterfly valve	600mmΦ	2	0.2	0.4	
11	No.3 Pumps	Vertical centrifugal mixed pump	600mmΦ * 50m³/min. x 11m	2 (1)	—		
12	No.3 Pump diesel engine	Diesel engine	198ps	2 (1)	—	-	
13	Suction valves	Manually-operated sluice valve	600mmΦ	2	—		
14	Check valves	Slow-closing check valve	600mmΦ	2	—		
15	Discharge valves	Motor-operated butterfly valve	600mmΦ	2	0.2	0.4	
16	Crane for pumps	Manually-operated crane with chain block	3.2 t x 25mH x 7mW x 19mL	1	—		Girders by building works
17	Main pumps sealing water supply unit	Unit of water supply pump with pressure tank	40mmΦ x 0.1m³/min. x 35m	1	2.2	2.2	With control panel
18	Pump room floor drain pumps	Submersible pump	65mmΦ x 0.3m³/min. x 25m	2 (1)	3.8	3.8	Standby excluded
19	Floor drain pumps	Submersible pump	65mmΦ * 0.3m³/min. x 10m	2 (1)	1.5	1.5	Standby excluded
	Total motor outputs of I.					421.1	kW
	II. EFFLUENT PUMPS						
1	No.1 Pumps	Vertical centrifugal mixed pump	450mmΦ x 25m³/min. x 5m	4	—		
2	No.1 Pump electric motor	Vertical squirrel cage, water proof type	32kW x 4p x 380v	4	32	128	
3	Suction valves	Manually operated sluice valve	450mmΦ	4	—		
4	Check valves	Slow-closing check valve	450mmΦ	4	—		
5	Discharge valves	Motor-operated butterfly	450mmΦ	4	0.2	0.8	

		valve					
6	No.2 Pumps	Vertical centrifugal mixed pump	600mmΦ * 50m^3/min. x 5m	2 (1)	—		
7	No.2 Pump electric motor	Vertical squirrel cage, water proof type	60kW x 6p x 380v	2 (1)	60	60	Standby excluded
8	Suction valves	Manually-operated sluice valve	600mmΦ	2	—		
9	Check valves	Slow-closing check valve	600mmΦ	2	—		
10	Discharge valves	Motor-operated butterfly valve	600mmΦ	2	0.2	0.4	
11	No.3 Pumps	Vertical centrifugal mixed pump	600mmΦ * 50m^3/min. x 5m	2 (1)	—		
12	No.3 Pump diesel engine	Diesel engine	90 ps	2 (1)	90		
13	Suction valves	Manually-operated sluice valve	600mmΦ	2	—		
14	Check valves	Slow-closing check valve	600mmΦ	2	—		
15	Discharge valves	Motor-operated butterfly valve	600mmΦ	2	0.2	0.4	
16	Crane for pumps	Manually-operated crane with chain block	3.2 t x 25mH x 7mW x 19mL	1	–		Girders by building works
17	Main pumps sealing water supply unit	Unit of water supply pump with pressure tank	40mmΦ x 0.1m^3/min. x 35m	1	2.2	2.2	With control panel
18	Pump room floor drain pumps	Submersible pump	65mmΦ x 0.3m^3/min. x 25m	2 (1)	3.8	3.8	Standby excluded
19	Floor drain pumps	Submersible pump	65mmΦ * 0.3m^3/min. x 10m	2 (1)	1.5	1.5	Standby excluded
	Total motor outputs of II					197.1	kW
	Total motor outputs of (3)					618.2	kW

(4) Primary Clarifiers (4 tanks)

No.	Equipment	Type	Specifications	Qt'y	Output kW/uni	Total ouput	Remarks
1	Inlet gates	Sluice gate, manual operation, cast iron, circular	φ1,000. Design hydraulic depth, 3m	4	—		
2	Sludge collectors	Rotating type scraper, center column supported	35mΦ x 2.0mH	4	0.75	3	
4	Sludge draw-off valves	Motor operated eccentric	200mmΦ	4	0.2	0.8	
5	Raw sludge pumps	Non-clog centrifugal pumps	100mmΦ x 1m³/min. x 10	3 (1)	3.7	7.4	Standby excluded
6	Bypass gates	Manually operated, cast iron made, circular sluice gate	φ2,000mm. Design hydraulic depth, 1.5m	1	—		
7	Raw sludge flow meter	Electro-magnetic flow meter	100mmΦ	1	—		
8	Raw sludge densitomete	Ultra-sonic type		1	—		In electric works
	Total motor outputs of (4)					11.2	kW

(5) Aeration Tanks (16 tanks)

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/uni	Total output	Remarks
1	Inflow control weirs	Manually operated movable weirs	400W x 600H Design hydraulic depth 1.1 m	16	—		
2	Movable weirs for control of step inflow	Cast iron made, movable weirs	400mmW x 600mmH design depth, 1.1m	96	—		
3	Return sludge inflow control weirs	Cast iron made, movable (separate type)	600mmW x 600mmH design depth 1.1m	16	—		
4	Aeration diffusers	Ceramic made diffuser (fine bubble, 300μ)	0.82m³/min. 8plates/holder header	390	—		SUS holder headers, & butterfly valves
5	Air control valves	Air operated butterfly valve	250mmΦ	16	—		Electro-magnetic box
6	Froth spray nozzles	Cast iron made movable type	15mmΦx8l/min. x 1kg/cm2	864	—		1.5 m interval 40.5/1.5=27units/tan
7	Air flow meters	Oriffice	250mmΦ	16	—		Included in electric works
	Total motor output of (5)					0	kW

(6) Final Clarifiers (4 tanks)

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output	Remarks
1	Inlet gates	Sluice gate, manual operation, cast iron	Circular, 1000mmΦ Design hydraulic depth 1.5m	4	—		
2	Sludge collectors	Rotating scraper, central column support	45mΦ x 3.5 m deep	4	0.75	3	
3	Sludge draw-off valves	Motor-operated eccentric valve	200mmΦ	4	0.2	0.8	
4	Return sludge pumps	Non-clog centrifugal	250mmΦx 6.0m³/min. x 10m	4	22	88	
5	"	"	250mmΦx 8.0m³/min. x 10m	7	30	210	5 units for additional 50 % return sludge.
6	Excess sludge pumps	"	100mmΦx 1.1m³/min. x 10m	6 (2)	3.7	14.8	Standby excluded
7	Return sludge flow meters	Electronic-magnetic flow meter	250mmΦ	4	—		Included in electric works
8	Excess sludge flow meters	Electronic-magnetic flow meter	100mmΦ	2	—		"
9	Return sludge densitometers	Ultra-sonic type	250mmΦ	4	—		"
	Total motor output of (6)					316.6	kW

(7) Chlorine Contact Tank

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output	Remarks
1	Influent gates	Manually operated, cast iron, square type	2000mmW x 2000mmH design hydraulic depth, 2 m	1	—		
2	Bypass gates	Manually operated, cast iron, square type	600mmW x 600mmH design hydraulic depth, 1.5m	1	—		
3	Hypochlorite supply pump No.1	Diaphragm pump	Discharge 6L/min.	2	0.2	0.4	
4	Hypochlorite supply pump No.2	Diaphragm pump	Discharge 13L/min.	3 (1)	0.4	0.8	Standby excluded
5	Hypochlorite storage and supply tank	FRP made	20m³ φ2.8m x 3.9m H	4	—		
	Total motor output of (7)					1.2	kW

(8) Sludge Thickeners (4 tanks)

Equipment	Type	Size and Specifications	Qt'y	Ouput kW/unit	Total output	Remarks
Sludge thickeners	Rotating scraper, with pickets	12mΦ x 4.0mH	4	0.4	1.6	
Distribution tank, movable weirs	Manually operated, cast iron weir	300mmW	4	—		
Sludge draw-off pump	Non-clog centrifugal pump	100mmΦx 1.2m3/min x 20m	3 (1)	15	30	Standby excluded
Sludge draw-off valves	Air operated eccentric valve	100mmΦ	4	0.2	0.8	
Sludge screen	Drum screen, self cleaning type	2m3/min.	1	0.4	0.4	
Total motor outputs of (8)					32.8	kW

(9) Sludge Digestion Facilities (4 digesters)

Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output	Remarks
Sludge mixer	Draft tube type	Mixing 2,300 m^3/hr or more	4	22	88	Draft tube 500mmΦ
Gas collectors	600mmΦ steel constructed dome, dry and wet seels		4	—		
Sludge feed pump valves	Motor operated eccentric valve.	150mmΦ	4	0.2	0.8	
Scum draw-off valves	Motor operated eccentric valve.	300mmΦ	4	0.4	1.6	
Digested sludge draw off telescope valves	Motor operated	200mmΦ	2	0.4	0.8	
Sludge circulation draw off valves	Motor operated eccentric valve.	200mmΦ	4	0.2	0.8	
Digested sludge draw off valves	Motor operated eccentric valve.	200mmΦ	4	0.4	1.6	
Thickened sludge pipe control valves	Motor operated eccentric valve.	150mmΦ	12	2.2	26.4	
Seed sludge pipe control valves	Non-clog sludge pump	100mmΦx 1m^3/min x 15m	2	7.5	15	
Sludge circulation pumps	Non-clog sludge pump	100mmΦx 1.4m^3/min x 15m	6	5.5	33	
Sludge heat exchangers	Spriral type		3 (1)	—		
Water circulation pump	Line pump	65mmΦ x 0.6m^3/min x 25 m	4	3.7	14.8	
Water heater	Vacuum type	800,000kg/hr.	2 (1)	8.3	8.3	Standby excluded
Gas booster fans	Turbo fan	150m^3/hr x 500mmq	2 (1)	1.5	1.5	Standby excluded
Oil service tank	Steel construction	300 L	1	—		
Oil pumps	Gear pump	15mmΦ x 10L/min. x 3kg/c	2 (1)	0.4	0.4	Standby excluded
Oil storage tank	Underground cylinder type	15,000 L	1	—		
Desulfide Gas scrubbers	Dry type	500m^3/hr.	4	—		
Gas holders	Dry seal (membrane), steel construction	2,000m^3	2	—		
Waste gas burners	Forced air combustion type	200m^3/hr.	2 1	1.5 2.2	3 2.2	Cooling fan blower
Floor drain pumps	Submersible pump	65mmΦ x 0.3m^3/min. x 10 m	2	1.5	3	
Chain block	Geared trolley	1ton	1	—		
Total motor outputs of (9)					201.2	kW

(10) Sludge Dewatering Equipment

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output	Remarks
1	Sludge storage tank mixers	Vertical paddle type	2,000mmΦ	4	7.5	30	
2	Sludge feed pumps	Positive displacement pump	100mmΦ x 20m3/hr. x 20m	9 (1)	5.5	44	Standby excluded
3	Sludge dewatering	Belt filter press	3 m effective belt width, 390 kg per hour load in dry solid basis	8	3.7	29.6	
4	No.1Cake conveyor	Trough belt	600mmW x 8,500mmL	4	1.5	6	
5	No.2 Cake conveyors	Horizontal trough belt conveyor	600w * 5500L	2	1.5	3	
6	Cake hoppers	Motor operated	10m3	2	3.7	7.4	
7	Chemical containers	Cylinder type	700 L	2	–		
8	Chemical feeders	Volumetric dry feeder	4L/min.	3	0.4	1.2	
9	Chemical dosage tank	Cylinder type	15m3 capacity	3	7.5	22.5	
10	Chemical feed pumps	Positive displacement pump	50mmΦ x 3m3/hr x 20m	15 (1)	1.5	21	Standby excluded
11	Chemical container hoists	Motor operated	1 ton	1 1	1.5 0.4	1.5 0.4	
12	Pumps for belt filter cleaning water	Centrifugal pump	50mmΦ x 0.3 m3/min. x 60 m	4 (1)	7.5	22.5	Standby excluded
13	Maintenance crane	Suspension type	2 ton	2	–		
14	Chain block	Geared trolley type	2 ton	2	–		
15	Floor drain pumps	Submersible non-clog pump	65mmΦ x 0.3m3/min. x 10 m	3	1.5	4.5	
	Total motor outputs of (9)					193.6	kW

(11) Aeration Tank Blower System

No.	Equipment	Type	Size and Specifications	Qt'y	Output kW/unit	Total output	Remarks
1	No.1 Blowers	Steel made, multi-stage turbo blower	ϕ350mm/ϕ300mm 80m^3/min.	5 (1)	–		
2	Electric motors for No.1 blowers	Horizontal squirrel cage, water proof	200kW	5 (1)	110	440	Standby excluded
3	No.1 blower valves	Electric-operated valve	ϕ250mm	5 (1)	0.4	1.6	Standby excluded
4	Dry type air filters	Self cleaning type	150m^3/min.	4	0.2	0.8	
5	Wet type air filters	Auto rolling type	150m^3/min.	4	0.2	0.8	
6	Maintenance crane	Geared trolley type	3 tons	1	–		
	Total motor outputs of (11)					443.2	kW
Grand Total of Motor Outputs						**2,050**	**kW**

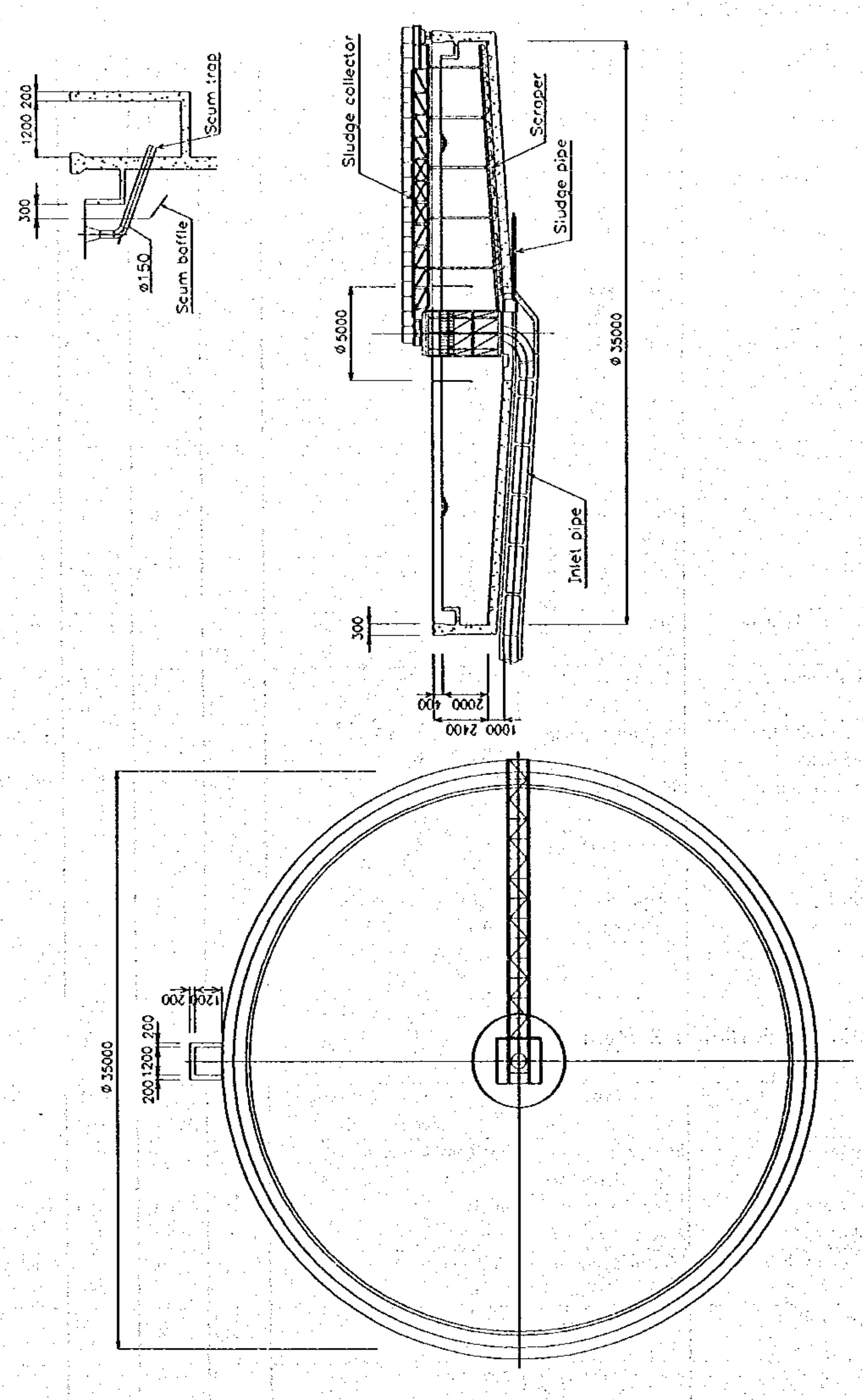


Figure AII.3.1	Primary Sedimentation Tank of Braila WWTP

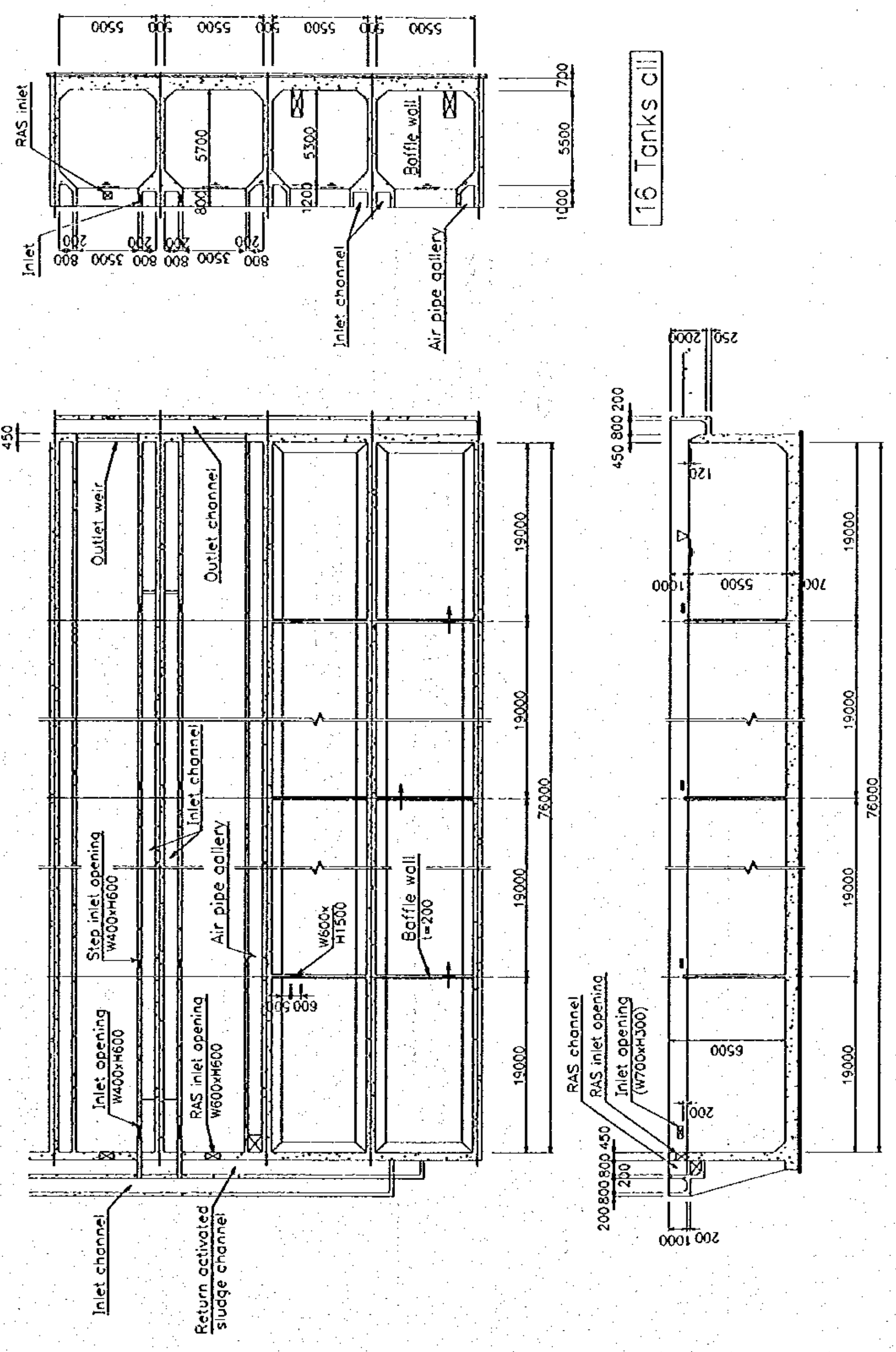


Figure AII.3.2	Aeration Tank of Braila WWTP

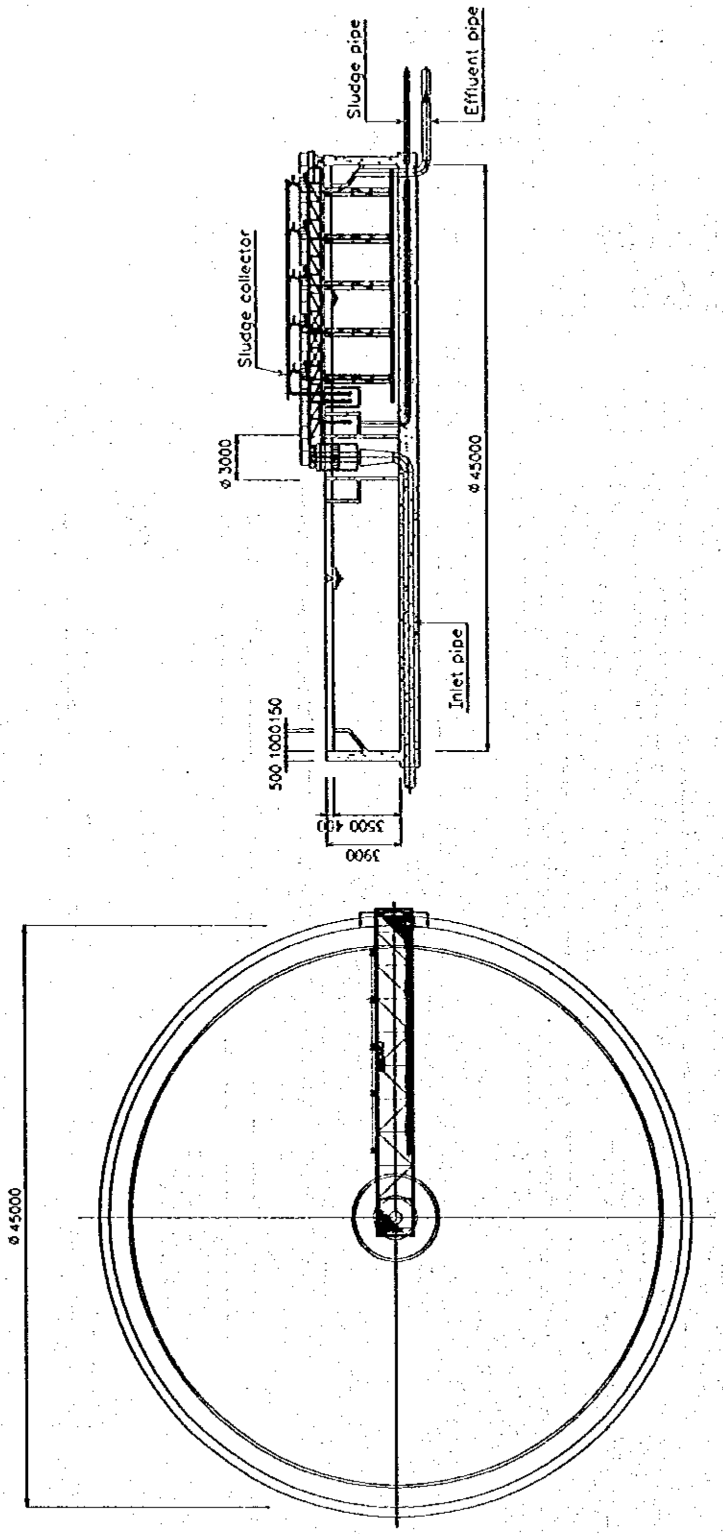


Figure AII.3.3	Final Sedimentation Tank of Braila

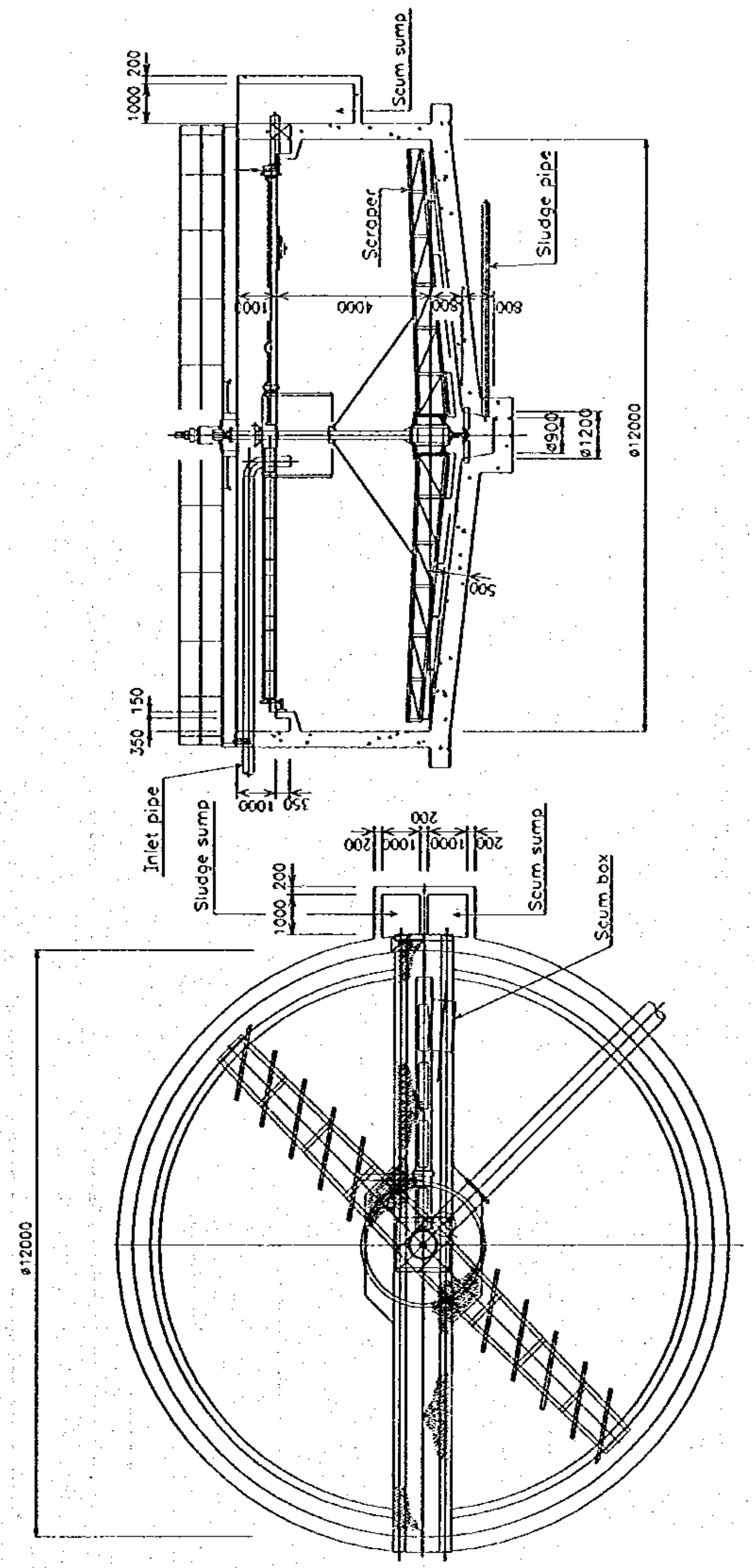


Figure AII.3.4	Sludge Thickener of Braila WWTP

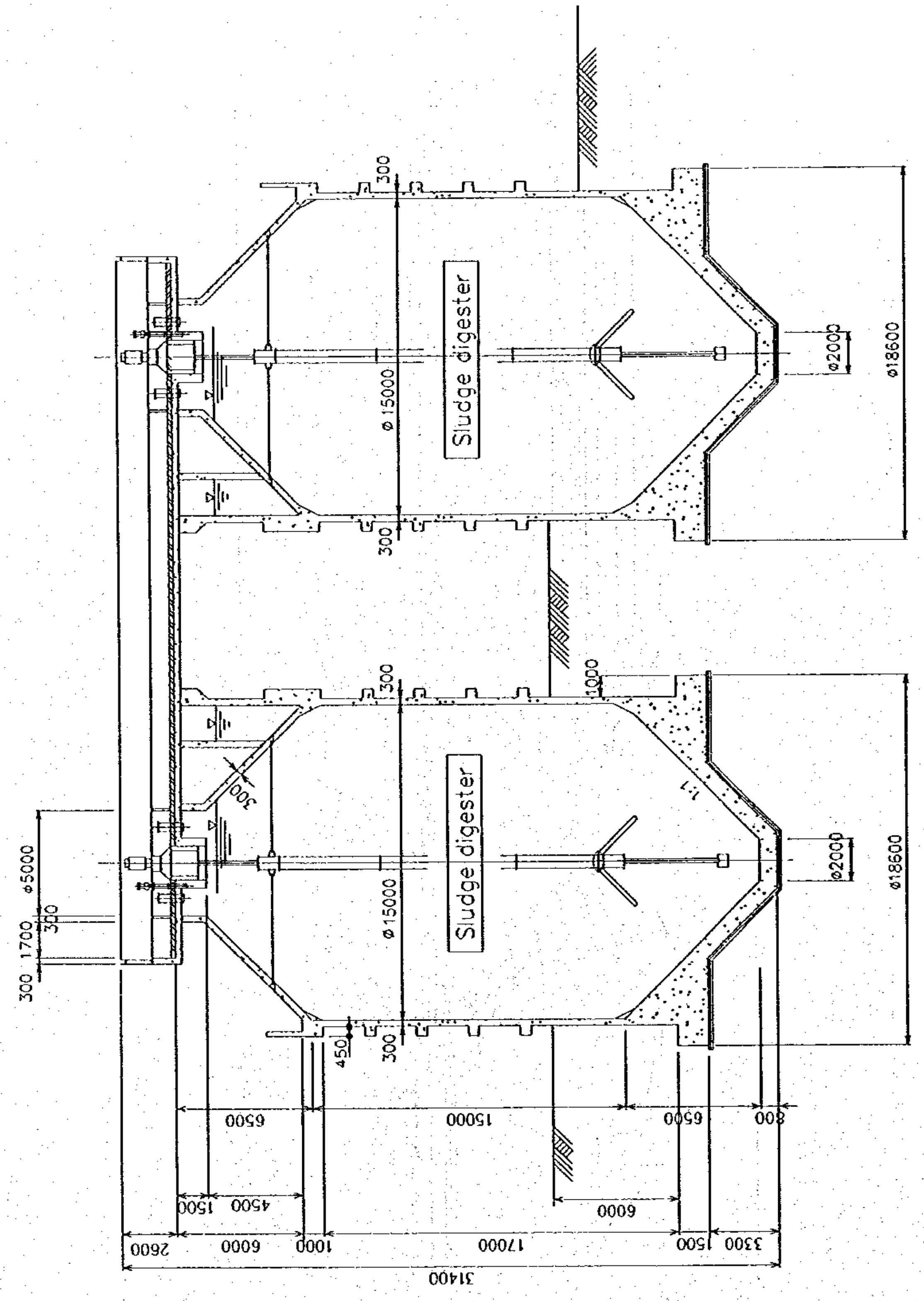


Figure AII.3.5	Sludge Digester of Bralla

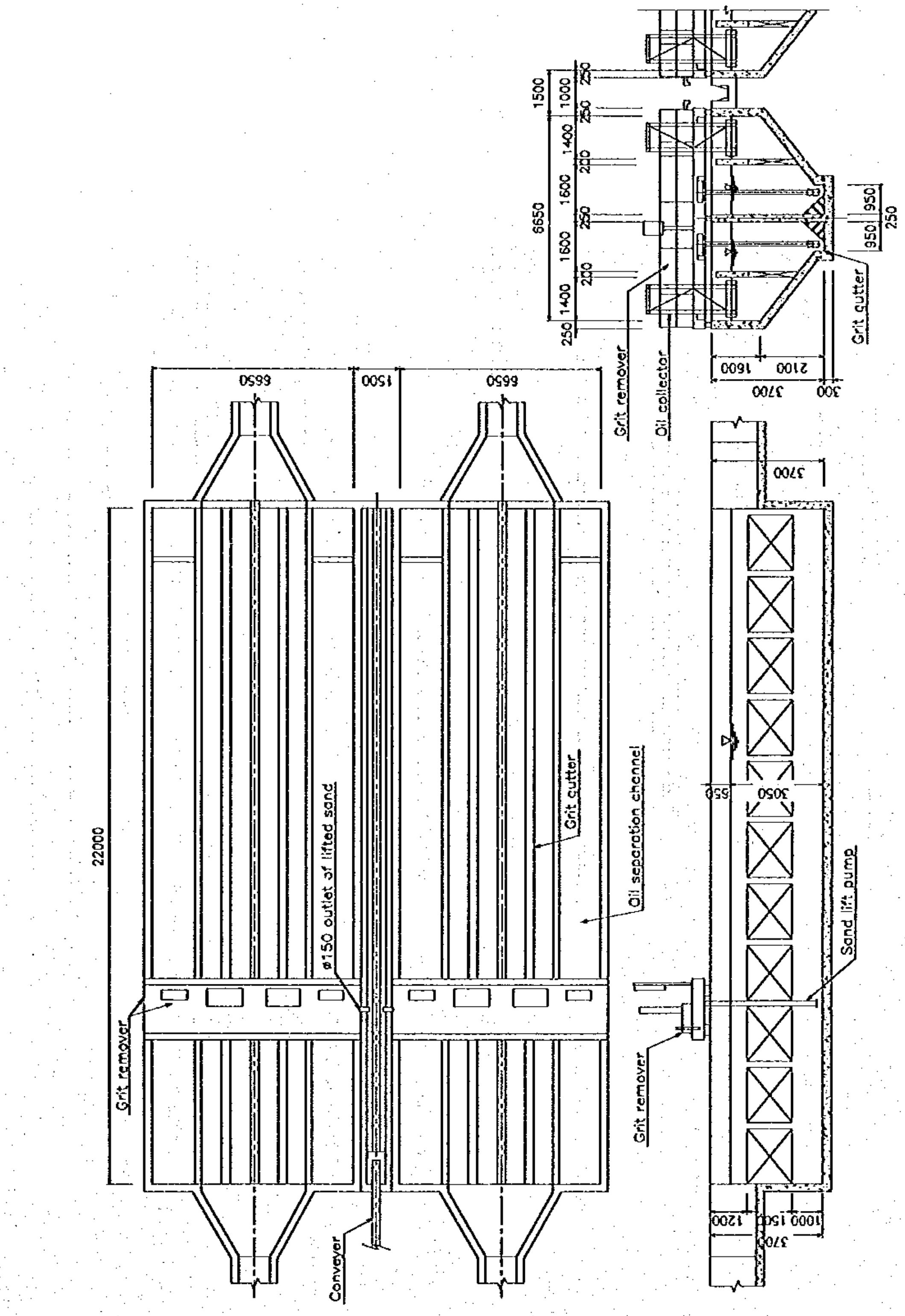


Figure AII.3.6	Grit Chamber and Oil Separator of Braila WWTP

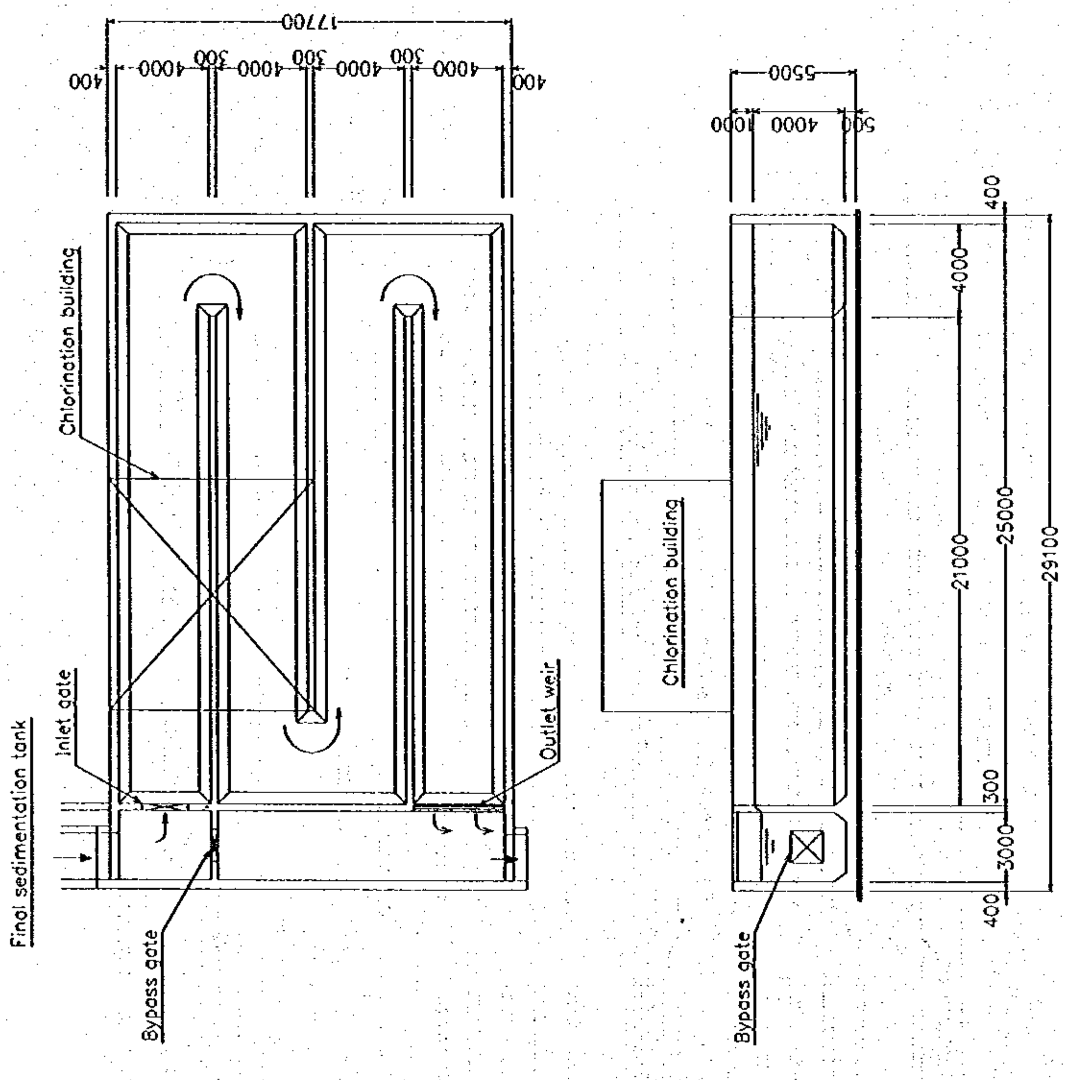


Figure AII.3.7	Chlorination Chamber of Braila WWTP

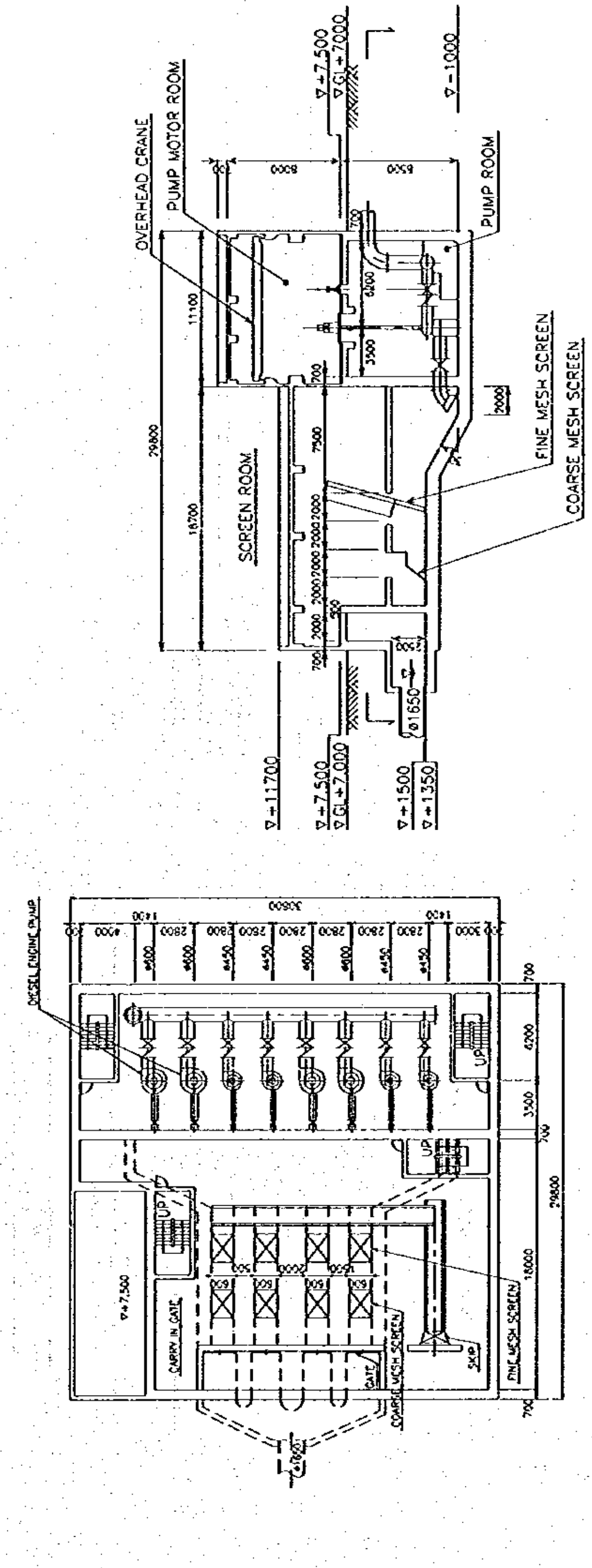


Figure AII.3.8	Screening & Pumping Station of Braila WWTP

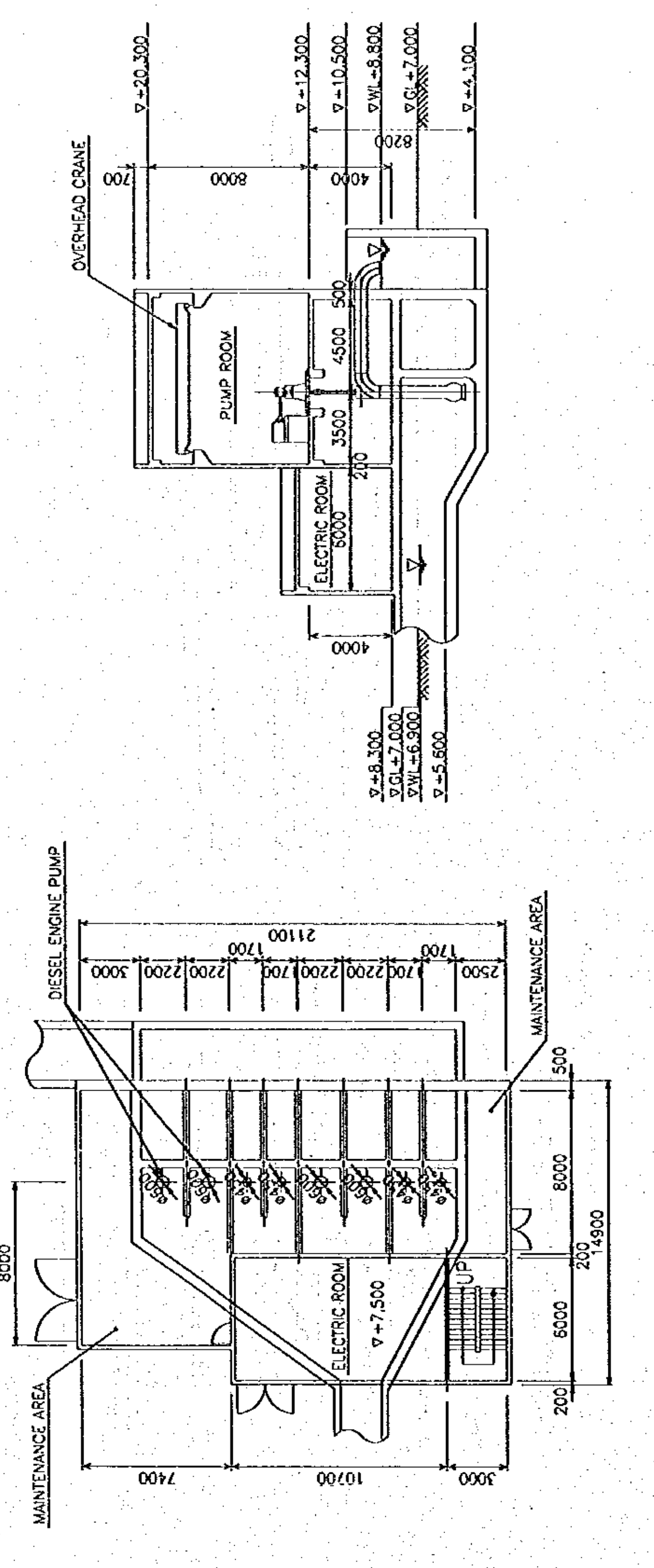


Figure AII.3.9	Effluent Pumping Station of Braila WWTP

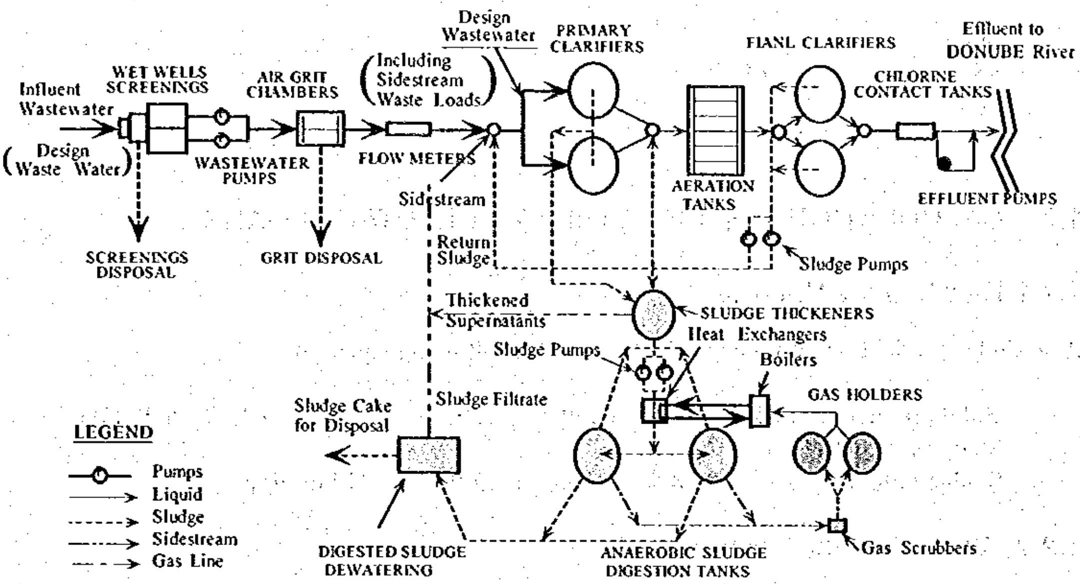
APPENDIX-4 DESIGN CALCULATIONS OF BRAILA WWTP

1. CONVENTIONAL ACTIVATED SLUDGE PROCESS

1.1 DESIGN BASIS

1.1.1 SCHEMATIC OF THE CONVENTIONAL ACTIVATED SLUDGE PROCESS

Schematic of the conventional activated sludge process is shown as follows.



1.1.2 DESIGN WASTEWATER INFLOW RATES

Design wastewater inflow rates are determined as follows.

Average daily flow	Qad	98,000 m^3/day	1,134 L/s
Maximum daily flow	Qmd	115,000 m^3/day	1,331 L/s
Maximum hourly flow	Qmh	140,000 m^3/day	1,620 L/s
Wet weather flow	Qww	280,000 m^3/day	3,241 L/day

1.1.3 DESIGN WASTEWATER QUALITY

Design wastewater quality is determined as follows.

BOD = 150 mg/L
SS = 180 mg/L

1.1.4 DESIGN WASTEWATER QUALITY (INCLUDING SIDESTREAM WASTE LOADS)

Design wastewater quality (including sidestream waste loads) is calculated as follows.

BOD = 195 mg/L
SS = 215 mg/L

Parameter	Removal Efficiency (%)			Wastewater Quality (mg/L)		
	Primary treatment	Secondary treatment	Overall removal rate	Raw waste-water	Primary effluent	Secondary effluent
BOD	30	85	89.5	195	137	20
SS	40	80	88.0	215	129	26

1.1.5 POLLUTANT DISCHARGE LIMITS BY NTPA 001

Pollutant discharge limits by NTPA 001 is regulated as follows.

BOD	<	20 mg/L
SS	<	60 mg/L
T-N	<	10 mg/L
T-P	<	1.0 mg/L

1.2 CALCULATIONS OF SIDESTREAM POLLUTANT LOADS

1.2.1 RAW SLUDGE VOLUME

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = $115{,}000 \times 180 \times 10^{-6} \times 0.4 = 8.28$ t/day
Sludge concentration 2.0 %
Sludge volume $8.28 \times 100 \div 2.0 = 414$ m^3/day

1.2.2 WASTE SLUDGE VOLUME

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency(%)
BOD	150	105	30
SS	180	108	40

Assuming that the reactor influent S-BOD is 66.7% of the total BOD; then Scc is 70.0 mg/L
Waste sludge production volume is calculated by the following equation:

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta \times XA)\ Q$$

where,

Qw	Volume of waste sludge (m^3/day)		
Xw	Average SS concentration of waste sludge (mg/L)		
Q	Influent volume to reactors (m^3/day)		115,000
XA	MLSS concentration in reactors (mg/L)		1,660
Scs	Influent soluble-BOD concentration to reactors (mg/L)		70.0
Sss	Influent SS concentration to reactors (mg/L)		108
a	Sludge yield coefficient of S-BOD(mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS(mg MLSS/mgSS)	0.9~1.00.	0.95
c	Coefficient of SS reduction due to endogeneous respiration of activated sludge micro-organisms (L/day)	0.03~0.05	0.04
θ	HRT in reactor basins (day)	6.5/24 =	0.27

therefore,

$$Qw \times Xw = (0.5 \times 70.0 + 0.95 \times 108 - 0.04 \times 0.27 \times 1660) \times Q \times 10^{-6}$$
$$= 119.63 \times Q \times 10^{-6} = 13.76 \text{ t/day}$$

Solid production = 13.76 t/day

Sludge concentration = 0.5 %

Sludge production = 13.76 × 100 ÷ 0.5 = 2,752 m³/day

1.2.3 THICKENED SLUDGE

Thickened sludge production volume is calculated by the following equation.

Sludge solids = 8.28 + 13.76 = 22.04 t/day
(Primary sludge) (Excess sludge)

Sludge volume = 414 + 2,752 = 3,166 m³/day
(2.0%) (0.5%)

Solids = 22.04 × 0.85 = 18.73 t/day

Assuming sludge concentration is 3.5 %

Sludge volume = 18.73 × 100 ÷ 3.5 = 535 m³/day

1.2.4 SLUDGE SUPERNATANT OF THICKENERS

Sludge supernatant of thickeners is calculated by the following equation.

Liquor volume = 3,166 − 535 = 2,630 m³/day

Solids weight = 22.04 × 0.15 = 3.31 t/day

BOD = 2,630 × 2000 × 10^{-6} = 5.26 t/day

BOD is assumed to be of 2,000 mg/L

1.2.5 DIGESTED SLUDGE

Digested sludge production volume is calculated by the following equation.

Digested sludge solids = 18.73 × (1−0.7 × 0.5) = 12.18 t/day

Digested sludge volume 3.0 %

= 12.18 × 100 / 3.0 = 406 m³/day

1.2.6 DEWATERED SLUDGE(SLUDGE CAKE)

Dewatered sludge production volume is calculated by the following equation.

Solids = 12.18 × 100 / 0.9 = 10.96 t/day

(Assuming 20.0 % solids concentration)

Cake volume = 10.96 × 100 / 20.0 = 55 m³/day

1.2.7 DIGESTED SLUDGE FILTRATE

Digested sludge filtrate weight is calculated by the following equation.

Filtrate volume = 535 − 55 = 480 m³/day

Dry solids weight = 12.18 × 0.10 = 1.22 t/day

BOD = 480 × 1,500 × 10^{-6} = 0.72 t/day

(Assumed BOD concentration = 1,500 mg/L)

1.2.8 Sidestream Volume and Waste Load

Sidestream volume and waste load is calculated by the following equation.

		Thickener supernatants		Sludge filtrate		
Liquor volume	=	2,630	+	480	=	3,111 m^3/day
Dry solids	=	3.31	+	1.22	=	4.52 t/day
BOD	=	5.26	+	0.72	=	5.98 t/day

1.2.9 Wastewater Quality (including all sidestreams)

Wastewater quality (including all sidestreams) is calculated by the following equation.

Overall wastewater flow = Influent + Sidestreams
Maximum daily flow = 115,000 + 3,111 = 118,111 m^3/day
Then, the design wastewater flow characteristics are;
BOD = (115,000 × 150 × 10^{-6} + 5.98) / 118,111
= 0.0001967 × 10^6 = 197 → 195 mg/L
SS = (115,000 × 180 × 10^{-6} + 4.52) / 118,111
= 0.0002136 × 10^6 = 214 → 215 mg/L

1.3 SLUDGE PRODUCTIONS

1.3.1 Raw Sludge

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = 115,000 × 215 × 10^{-6} × 0.4
= 9.89 t/day
Sludge concentration 2.0 %
Sludge volume 9.89 × 100 ÷ 2.0 = 495 m^3/day

1.3.2 Excess Sludge Volume

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency(%)
BOD	195	136.5	30
SS	215	129	40

Assuming that influent S-BOD to reactor basins is 66.7% of the raw wastewater BOD,S-BOD concentration is estimated to be; 91.0 mg/L
Waste sludge production volume is calculated by the following equation.

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta \times XA) Q$$

where,

Qw	Volume of excess sludge (m^3/day)	
Xw	Average SS concentration of waste sludge (mg/L)	
Q	Influent volume to reactors (m^3/day)	115,000
XA	MLSS concentration in reactors (mg/L)	1,667
Scs	Influent soluble-BOD concentration to reactors (mg/L)	91.0
Sss	Influent SS concentration to reactors (mg/L)	129

a	Sludge yield coefficient of S-BOD (mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS (mg MLSS/mgSS)	0.9~1.00	0.95
c	Coefficient of SS reduction due to indigeneous respiration of activated sludge micro-organisms (L/day)	0.03~0.05	0.04
θ	HRT in reactor basins (day)	6.6 / 24 =	0.27

therefore,

$Qw \times Xw = (0.5 \times 91.0 + 0.95 \times 129 - 0.04 \times 0.27 \times 1667) \times Q \times 10^{-6}$

$= 149.87 \times Q \times 10^{-6} = 17.24$ t/day

Solid production = 17.24 t/day

Sludge concentration = 0.5 %

Sludge production = 17.24 × 100 ÷ 0.5 = 3,447 m^3/day

= 2.4 m^3/min.

1.3.3 Return Sludge

Return sludge volume is calculated by the following equation.

Sludge return ratio 50 %

Return sludge volume = 115,000 × 0.5 = 57,500 m^3/day = 39.9 m^3/min.

1.3.4 Gravity Sludge Thickeners

Gravity thickened sludge production volume is calculated by the following equation.

Solids inflow = 9.89 + 17.24 = 27.13 t/day

Sludge inflow = 495 + 3,447 = 3,942 m^3/day

Thickened sludge solids = 27.13 × 0.8 = 21.70 t/day

Assume solids content to be 3.5 %

Thickened sludge volume = 21.70 × 100 / 3.5 = 620 m^3/day

1.3.5 Anaerobic Sludge Digesters

Anaerobic digested sludge production volume is calculated by the following equation.

Input solids = 21.70 t/day

Input sludge volume = 620 m^3/day

Volatile solids content of sludge 70 %

Solids destruction rate 50 %

Digested sludge solids = 21.70 × (1 − 0.7 × 0.5) = 14.11 t/day

Assume solids concentration is 3.0 %

Digested sludge volume = 14.11 × 100 / 3.0 = 470 m^3/day

1.3.6 Sludge Dewatering

Dewatered sludge production volume is calculated by the following equation.

Input solids = 14.11 t/day

Recovered solids (90%) = 14.11 × 0.9 = 12.69 t/day

Assuming solids concentration as 20.0 %

Sludge cake volume = 12.69 × 100 / 20.0 = 63 m^3/day

1.4 COMPONENT FACILITIES

1.4.1 PRIMARY CLARIFIERS

Primary clarifiers specifications are calculated by the following equation.

Average daily flow, Qad = 98,000 m^3/day
Maximum daily flow, Qmd = 115,000 m^3/day
Maximum hourly flow, Qmh = 140,000 m^3/day
Wet weather flow = 280,000 m^3/day
Hydraulic surface load rate = 35 m^3/m^2·day
Totally 2 clusters, each consisting of 2 tanks, total number of basins is 4 units
Hydraulic load on each basin is 115,000 ÷ 4 = 28,750 m^3/day/basin
Required surface area of each basin = 28,750 ÷ 35 = 821 m^2

(1) Tank Geometry (In accordance with the Romanian Standards),

Internal diameter 35 m
Effective depth 2.0 m
Number of basins 4 basins
Surface area of a basin 843 × 4 = 3,372 m^2
Hydraulic capacity of a basin 3,372 × 2 = 6,744 m^3
Check for hydraulic conditions of basins under the different flow rates.
Retention time
Qmd 6,744 × 24 / 115,000 = 1.41 hours
2Qmh 6,744 × 24 / 280,000 = 0.58 hours > 0.5
Surface load rate
Qmd 115,000 / 3,372 = 34.1 m^3/m^2·day < 35
2Qmh 280,000 / 3,372 = 83.0 m^3/m^2·day < 96

(2) Raw Sludge Pumping Equipment

The pumps will handle the mixture of primary and excess sludge having solids concentration of 2%.

Sludge solids 27.13 t/day, Solids concentration 2 %
Sludge volume 1,356 m^3/day = 0.94 m^3/min.
Pump type: Centrifugal screw pump
Pump bore size: 100 mm
Delivering capacity: 1 m^3/min.
Total dynamic head: 10 m
Number of pumps: 3 Units (including 1 standby)

1.4.2 REACTOR TANKS

Reactor tanks specifications are calculated by the following equation.

Design flow, Qmd = 115,000 m^3/day
BOD–SS load 0.30 kgBOD/kg SS day
MLSS 1,667 mg/L
Return sludge solids concentration 5,000 mg/L
Sludge return ratio = 1,667 ÷ (5,000 − 1,667) = 0.50
Inflow BOD to reactors 115,000 × 195 × 10^{-3} kg BOD/day × (1 − 0.3)
= 15,698 kg BOD/day
Reactor tanks SS = V × 1,667 × 10^{-3}kgMLSS
Required tank capacity = 15,698 ÷ 1.667 ÷ 0.30 = 31,389 m^3

Aeration time = 31,389 × 24 ÷ 115,000 = 6.6 hours

At Qmd, aeration time of 6 hours or more is secured.

Required tank capacity = 6 × 115,000 ÷ 24.00 = 28,750 m^3

Tank geometry

Width = 5.5 m

Effective depth = 5.5 m

Cross sectional area = 5.5 × 5.5 − 1/2 × 1.0^2 × 2 − 1/2 × 0.6^2 × 2

= 29 m^2

Number of tanks = 8 tanks 2 clusters 16 tanks

Capacity of one tank = 31,389 ÷ 16 = 1,962 m^3

Tank length = 1,962 ÷ 29 = 67.65 use 68 m

Tank geometry			
W	5.5 m	×	16 Tanks
L	68 m		
H	5.5 m		

Check of aeration time

Tank capacity = 29 × 68 × 16 = 31,552 m^3

Aeration time = 31,552 × 24 / 235,000 = 6.6 hours

Check for additional tank requirement to upgrade the process

Additional tank capacity required for the advanced treatment process will be provided by adding tanks to the conventional activated sludge aeration tanks. The wastewater inflow will be distributed both to the existing and additional tanks. The wastewater will be distributed in proportion to the treatment capacity of both trains.

The total retention time will be 15.4 hours.

As the retention time in the conventional treatment process is 6.6 hours, the required retention time for additional tanks is 15.4 − 6.6 = 8.80 hours

Check capacity and wastewater distribution ratio

Existing tanks 6.6 / 15.4 = 0.43

Additional tanks 8.8 / 15.4 = 0.57

Wastewater flow distribution rates

Existing tanks 115,000 × 0.43 = 49,172 m^3/day

Additional tanks 115,000 × 0.57 = 65,828 m^3/day

Additional Reactor Tanks

Required tank capacity = 115,000 × 8.8 ÷ 24 = 42,240 m^3

Number of tanks = 8 tanks 2 clusters 16 tanks

Tank capacity = 42,240 ÷ 16 = 2,640 m^3

Tank length = 2,640 ÷ 29.00 = 91.0 use 91 m

Tank geometry			
W	5.5 m	×	16 Tanks
L	91 m		
H	5.5 m		

Check retention time

Tank capacity = 29 × 91 × 16 = 42,224 m^3

Retention time = 42,224 × 24 / 115,000 = 8.8 hours

1.4.3 FINAL CLARIFIERS

Final clarifiers specifications are calculated by the following equation.

Design flow QD = 115,000 m^3/day
Surface load rate = 25 $m^3/m^2\cdot$day
2 clusters each consisting of 2 tanks, total tank number is : 4 tanks
Influent to each tank = 115,000 ÷ 4 = 28,750 m^3/day/tank
Required surface area of each tank = 28,750 ÷ 25 = 1,150 m^2

(1) Check by the Romanian Standards

Internal diameter 45 m
Effective depth 3.5 m
Tank numbers 4 units
Surface area 1,424 × 4 = 5,696 m^2
Capacity 5,696 × 3.5 = 19,936 m^3
Surface load rate 20 $m^3/m^2\cdot$day
Retention time
At Qmd 19,936 × 24 / 115,000 = 4.16 hours
Qv=Qmh + Qrmax = 140,000 + 57,500 = 197,500 m^3/day
19,936 × 24 / 197,500 = 2.42 > 2.0
Surface load rate
At Qmd 115,000 / 5,696 = 20 $m^3/m^2\cdot$day < 25
At Qv 197,500 / 5,696 = 34.7 $m^3/m^2\cdot$day < 52.8
Weir loading
Weir length L = π × 42.7 × 4 = 536 m
At Qmd 115,000 / 536 = 214 m^3/m·day
At Qv 197,500 / 536 = 368 m^3/m·day
As compared with the Japanese Standards, the weir loading appears to be high side. The weir length may be increased in detailed design.

(2) Check for Advanced Treatment

The advanced treatment will be performed through two trains, existing and advanced treatment process trains.
The wastewater will be distributed to each train in proportion to the reactor tanks hydraulic retention time.

Wastewater distribution
Existing train 49,172 m^3/day
Additional train 65,828 m^3/day
Check for additional tanks
Surface load rate 15 $m^3/m^2\cdot$day or lower
Cluster 2 with 2 tanks, then total tank number is 4 units
Flow rate to each tank 65,828 ÷ 4 = 16,457 m^3/day.tank
Required surface area of each tank = 16,457 ÷ 15 = 1,097 m^2
D = 45 − 2.3 = 42.7 m
According to Romanian Standards A = 0.785 × $(D^2 - 3^2)$ = 1,424 m^2
Diameter 45 m
Effective depth 3.5 m
Number of tanks 4 units
Water surface area 1,424 × 4 = 5,696 m^2
Capacity 5,696 × 3.5 = 19,936 m^3
Overflow rate 11.6 m^3/m^2/day

Check the existing tank overflow rate

65,828 / 5,696 = 11.6 $m^3/m^2/day$ < 15

(3) Return Sludge Pumps

Return sludge pumps are specified as follows.

Average 50 % sludge return rate is considered, but pump capacity 100 % return rate is provided to prevent and restore sludge bulking.

Return sludge volume = 57,500 m^3/day = 40 m^3/min.

60 % and 40 % of sludge will be transported by 4 and 2 pumps respectively, through double pipelines.

Pump capacity	20	×	0.2	=	3.99	use	4.0 m^3/minute/unit
"	20	×	0.15	=	2.99	use	3.0 m^3/minute/unit

By operating above pumps, the return sludge rates can be adjusted at the order of 5% to 15 %.

Pump type	No.1 Screw centrifugal	No.2 Screw centrifugal
Diameter	200 mm	200 mm
Capacity	3.0 m^3/min.	4.0 m^3/min.
TDH	10 m	10 m
Number of pumps	8 units	4 units
Motor output	11 kW	11 kW

(4) Excess Sludge Pumps

Excess sludge pumps are specified as follows.

Excess sludge volume = 3,447 m^3/day = 2.4 m^3/min

Two lines will be provided, then the capacity of a pump = 0.60 m^3/min

Type of pump	No.1 Screw centrifugal pump
Diameter	100 mm
Capacity	1.0 m^3/min
TDH	10 m
Number of pumps	6 units (2-standby)
Motor output	3.7 kW

(5) Chlorine Contact Tanks

Chlorine contact tanks specifications are calculated by the following equation.

Design flow rate = 115,000 m^3/day

Chlorine contact time = 15 minutes

Required tank capacity: 115,000 ÷ 1,440 × 15 = 1,198 m^3

Channel width: 4.0 m

Effective depth: 3.0 m

Tank length: 1,198 ÷ 4.0 ÷ 3.0 = 99.8 m -> 100 m

Number of tanks 1 unit

Chlorine contact tank geometry						
W	4 m	×	H	4.0 m	×	1 Tank
L	100 m					

1.5 ANAEROBIC SLUDGE DIGESTERS

1.5.1 SLUDGE THICKENERS

(1) Hydraulic Capacity of Tanks

Hydraulic capacity of tanks are specified as follows.

Solids input	=	27.13 t/day
Input sludge volume	=	3,942 m^3/day
Output sludge volume	=	620 m^3/day
Floor loading	=	60 kg/m^2/day
Required surface area	=	452 m^2
Tank geometry	Circular radial flow type	
Internal diameter	=	12 m
Effective depth	=	4 m
Number of tanks	=	4 units
Water surface area	3.14 / 4 × 12^2 × 4 = 452 m^2	

(2) Sludge Withdrawal Pumps

Sludge withdrawal pumps are specified as follows.

The pumps will have capacities that can send thickened sludge in around 8 hours.

Pump capacity	Q = 620 × 1 / 8 × 1/60 = 1.29 m^3/min.
Pump	Sludge pump
Diameter	100 mm
Discharge capacity	1.20 m^3/min.
TDH	20 m
Motor output	15 kW
Number of pumps	3 units(including one standby)

(3) Sludge Screens

Sludge screens are specified as follows.

Type	Rotary drum screen
Screen opening	4 mm
Capacity	2 m^3/min.
Motor output	0.4 kW
Number of screens	1 unit

Screen capacity is so determined that the sludge quantity being sent concomitantly from 2 raw sludge pumps (each q =1.0 m^3/min.) can be screened.

1.5.2 ANAEROBIC SLUDGE DIGESTION TANKS

(1) Hydraulic Capacity of Tanks

Hydraulic capacity of tanks are specified as follows.

Sludge solids input	=	21.70 t/day
Input sludge	=	620 m^3/day
Detention time		20 days
Tank temperature		35 °c
Required tank capacity		620 × 20 = 12,400 m^3

(2) Tank Geometry

Tank geometry is specified as follows.

Type	Single stage digestion
Internal diameter	15 m
Effective tank depth	26 m
Number of tanks	2 clusters × 2 tanks
Capacity	3,503 m^3/tank , 14,013 m^3 total tank capacity

1.5.3 GAS STORAGE TANKS

(1) Capacity of Tanks

Capacity of tanks are calculated by the following equation.

Total solids input to digesters = 21.70 t/day

Assuming that 70 % of the input sludge solids are volatile, and 1 kg of which produce 0.425 m^3 gas, the total gas production can be estimated as follows:

Total gas production = 21.70 × 0.7 × 10^3 × 0.425 = 6,456 m^3/day

Storage time 8 hours

Tank storage capacity = 6,456 × 8 / 24 = 2,152 m^3/day

(2) Tank Geometry

Tank geometry is specified as follows.

Type	Dry-seal type steel tanks
Number of tanks	2 units
Diameter	12.6 m
Effective height	13.3 m
Storage capacity	1,000 m^3

1.5.4 MECHANICAL SLUDGE DEWATERING

(1) Filter Capacity

Filter capacity is calculated by the following equation.

Solids input = 14.11 t/day , Input sludge volume 470 m^3/day

Belt press filter

Yields per unit length	130 kg/m/hr
Filter width	3 m
Daily operation time	6 hr
Working days/week	5 day

Solids loads per hour = 14.11 × 7 / 5 × 10^3 / 6 = 3,291 kg/hr

Required number of belt press = 3,291 / 130 / 3 = 8 use → 8 units

Type	:	Belt filter press
Filter loading rate	:	130 kg/m/hr
Filter width	:	3 m
Number of filters	:	8 unit

1.6 CHLORINE REQUIREMENTS

Required quantity of hypochlorite solution can be calculated by multiplying the dosing rate by the wastewater flow rate as shown in the following equation:

$$VR = Q \times R \times (100 / C) \times (1 / d) \times 10^{-3}$$

where

VR	Required hypochlorite solution (L / hr.)
Q	Wastewater flow rate (m^3 / hr)
R	Chlorine dosing rate(mg / L)
C	Effective chlorine concentration in chemical (%)
d	Specific gravity of hypochlorite solution (at the effective concentration of C %)

At the maximum daily flow rate, the required hypochlorite solution is:

Q = 115,000 m^3/day = 4,792 m^3/hr
R = 3 mg/L
C = 10 %
d = 1.2
$VR = Q \times 3 \times (100 / 10) \times (1 / 1.2) \times 10^{-3}$
$= 0.036 \times Q$ = 173 L/hr = 3 L/minute

At the wet weather flow (maximum hydraulic rate)

Qww = 280,000 m^3/day = 11,667 m^3/hr
R = 8 mg/L
VR = $0.012 \times 8 \times$ Qww = 1,120 L/hr = 19 L/minute

(1) Hypochlorite Solution Storage Tanks

Hypochlorite solution storage tanks are specified as follows.

8 days storage capacity for the maximum daily flow rate. Then, the capacity is:

$V = 0.1725\ m^3/h \times 24 \times 8 = 33.1\ m^3$

Tank specifications

Type	FRP made cylinder type
Internal diameter	2.8 m
Height	3.9 m
Capacity	20 m^3
Number of tanks	4 units

(2) Dosing Pumps Specification

	(No.1)	(No.2)
Type	Diaphragm	Diaphragm
Diameter	20 mm	20 mm
Discharge	6 L/min.	13 L/min.
Motor output	0.2 kw	0.4 kw
No. of unit	2 units	3 units(including 1 standby)

1.7 DIGESTER HEATING SYSTEM

1.7.1 Temperature

Lowest daily average temperature	0 °c
Soil temperature	15 °c

Input sludge temperature 10 °c
Digester tank temperature 35 °c

1.7.2 REQUIRED CALORIES FOR SLUDGE HEATING SPECIFIC HEAT 1.0 KCAL/KG.℃

Required calories for sludge heating specific is calculated by the following equation.

$$Q = 620 \times (35 - 10) \times 103 \times 1.0 = 15{,}500{,}209\ \text{Kcal/d}$$

1.7.3 HEAT LOSSES TANK INTERNAL DIAMETER 15 M

(1) Surface Area of the Digestion Tank

	Internal diameter	15	m
	r	R	h
Top slab (gas portion)	1.00	3.00	2.0
A1		38.67	m^2
Top slab(liquid portion)	3.00	7.50	4.50
A2		496.9	m^2
Side wall(above ground)	7.50	7.50	10.55
(down to 1m below ground) A3		717.1	m^2
Side wall(underground)	7.50	7.50	4.45
(up to 1m from surface) A4		209.6	m^2
Bottom slab	1.00	7.50	6.50
A5		248.5	m^2

A1 = 35.5(side) + 3.14(top, r) = 38.67
A2 = 209.8 , A3 = 496.9 , A4 = 209.6 , A5 = 245.3 + 3.14 = 248.5

(2) Overall Thermal Conductivity Coefficient (kcal/m², °C/hr)

	RC thickness (m)	Water proof motor	Insulation (polyurethane foam)	Concrete block	Spray concrete	Gas portion	Internal α 1(thermal conductivity)	External α 2(thermal conductivity)	K
	(λ=1.4)	(λ=1.2)	(λ=0.22)	(λ=1.0)	(λ=1.4)	(λ=0.48)			
Roof slab(gas portion)	0.3	0.03	0.04				20	20	0.464k1
Roof slab(liquid portion)	0.3	0.03	0.04				300	20	0.474k2
Upper side walls (1m underground or higher)	0.3		0.04	0.15		0.26	300	20	0.360k3
Lower sidewalls (1m underground or lower)	0.3						300	5	2.395k4
Bottom slab	0.8				0.1		300	5	1.182k5

The overall thermal conductivity coefficient can be calculated by the following equation:

$$1/K = 1/\alpha^1 \times \delta^1/\lambda^1 + \delta^2/\lambda^2 + 1/\alpha^2$$

where

K Overall thermal conductivity coefficient (Kcal/m²·°c·hr.)

α_1 Thermal conductivity coefficient of gas or sludge (Kcal/m²·°c·hr.)
$1/k1 = 2.16$ $k1 = 0.464$

α_2 Thermal conductivity coefficient of air or ground (Kcal/m²·°c·hr.)
$1/k2 = 2.11$ $k2 = 0.474$

λ_2, λ_2 Thermal conductivity coefficient of insulation material (Kcal/m/°c·hr.)
$1/k3 = 2.78$ $k3 = 0.360$

δ_1, δ_2 Thickness of insulators (m) $1/k4 = 0.42$ $k4 = 2.395$
$1/k5 = 0.85$ $k5 = 1.182$

(3) Overall Heat Losses

Portion of tank	Heat transfer area	Thermal conductivity coefficient	Number of tanks	Difference of temperature	Total heat losses
	(m²)	(Kcal/m²/°c/hr)	(unit)	(°c)	
Roof slab(gas portion)	38.67	0.464	4	35	2,509
Roof slab(liquid portion)	209.8	0.474	4	35	13,916
Upper sidewalls(1m under ground above)	496.9	0.360	4	35	25,047
Lower sidewalls (up to 1m below ground surface)	209.6	2,395	4	35	70,263
Bottom slab	248.5	1.182	4	35	41,111
				Total	152,847

Overall heat losses = 152,847 Kcal / hr

1.7.4 Heating System

24 hours continuous heating. A total of 20 % heat losses from pipes are considered.

15,500,209 / 24 + 152,847 × 1.2 = 829,258 Kcal / hour

Efficiency of water heater 0.9

829,258 / 0.9 = 921,398 Kcal / hour

Water heater

450,000 Kcal / hr × 3 units (including 1 standby)

1.8 ANAEROBIC SLUDGE DIGESTION SYSTEM

1.8.1 Digestion Tank

Hydraulic capacity of tanks are specified as follows.

Solids input = 620 m³/day
Detention time 20 days
Temperature 35 °c
Required tank capacity 620 × 20 = 12,400 m³

1.8.2 Tank Geometry

Tank geometry is specified as follows.

Type	single stage tank		
Internal diameter	15 m		
Effective tank depth	26 m		
Number of tanks	2 clusters	4 tanks	
	$3,503\ m^3$/tank	D1 =	15 m
	($3,100\ m^3$ / tank or larger)	D2 =	2 m
		D3 =	6 m

1.8.3 TANK CAPACITY

Tank capacity is calculated by the following equation.

Effective depth	15.0 m	Portion V1
"	6.5 m	Portion V2
"	4.5 m	Portion V3
Total	26m	

$V1 = \pi / 4 \times D1^2 \times D1$

$= \pi / 4 \times D1^3 = 2,649\ m^3$

$V2 = \pi / 4 \times D1^2 \times (D1/2) / 3 - \pi / 4 \times D2^2 \times (D2/2) / 3$

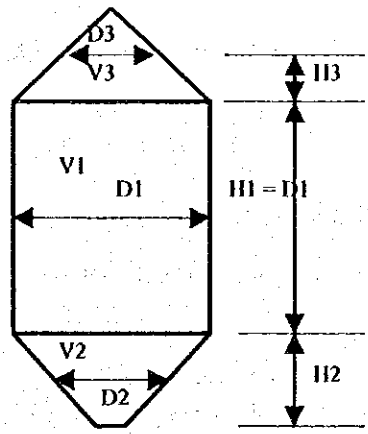
$= \pi / 4 / 6\ (D1^3 - D2^3)$

$= 441\ m^3$

$V3 = \pi / 4 / 6\ (D1^3 - D3^3)$

$= 413\ m^3$

V total $3,503\ m^3$



1.9 REQUIRED OXYGEN

Required oxygen is calculated by the following equation.

Required O_2 : OD = $OD_1 + OD_2 + OD_3$

where

OD_1 : Oxygen required for BOD oxygenation (cell synthesis)

OD_2 : Oxygen required for endogenous respiration

OD_3 : Oxygen to be utilized for maintaining required dissolved oxygen level

1.9.1 REQUIRED OXYGEN FOR BOD OXIDATION(CELL SYNTHESIS) : OD1(KGO_2/DAY)

OD1 = A(kgO_2/kgBOD) × BOD removed (kg BOD/day)

where

A : kg oxygen required to remove kg BOD (kgO_2/kgBOD), 0.5~0.7 → 0.6

Q = 115,000 m^3/day

OD_1 = 0.6 × Q × 116.0 × 10^{-3} = 0.0696 Q kgO_2/day

Influent BOD = 137 – 20 = 116.0 mg/L

1.9.2 OXYGEN REQUIRED FOR ENDOGENOUS RESPIRATION OD_2(KGO_2/DAY)

OD_2 = B(kgO_2/kgMLVSS·day) × VA(m^3) × MLVSS(kgMLVSS/m^3)

where

B : Oxygen consumption due to endogenous respiration per unit MLVSS 0.05~0.15 (kgO_2/kgMLVSS·day) 0.05

VA : Capacity of aerobic portion of reactor(m^3) Q × 6.6 ÷ 24 = 0.27 Q

MLVSS/MLSS = 0.8

OD_2 = 0.05 × 0.27 × Q × 1,500 × 10^{-3} × 0.8

= 0.0165 Q kgO_2 / day

1.9.3 Required Oxygen to Maintain Dissolved Oxygen Level: OD_3 (kgO_2/day)

OD_3 = COA × Q × 10^{-3}

where COA : Aeration tank dissolved oxygen 1.5 mg/l concentration

Return sludge ratio R 0.5

OD_3 = 1.5 × Q (1 + 0.5) × 10^{-3}

= 0.00225 Q kg O_2/day

1.9.4 Total Oxygen Requirements

OD = OD_1 + OD_2 + OD_3

= 0.0607 Q + 0.0165 Q + 0.00225 Q = 0.0795 Q (kgO_2/day)

1.9.5 Aeration Equipment (diffusers, fine bubbles, spiral flow)

Aeration equipment is calculated by the following equation.

EA = 7.5, ρ = 1.293, Qw = 0.233

Air volume (N m^3/day)

= (Required oxygen (kgO_2)) / (EA(%) × 10^{-2} × ρ (air/Nm^3) × Qw(kgO_2/kg air))

= (0.0795 Q) / (7.5 × 0.01 × 1.293 × 0.233)

= 4.00 Q = 459,920 (N m^3/day) = 319 (N m^3/min.)

Install one blower for each train

Required blower capacity 319 ÷ 4 = 80 m^3/tank・unit

Blower spec.	Cast-iron made multi-stage turbo blower
Inlet/outlet diameters	φ300 / φ300
Capacity	80 m^3/min.
Motor output	110 kW
Number of units	5 units (including 1 standby)

1.10 SCREENS AND PUMPING STATION

1.10.1 Flow Rate

Flow rate is determined as follows.

Qad	98,000 m^3/day	1,134 L/s
Qmd	115,000 m^3/day	1,331 L/s
Qmh	140,000 m^3/day	1,620 L/s
Qww	280,000 m^3/day	3,241 L/s

1.10.2 Incoming Sewer

Incoming sewer is specified as follows.

Friction formula	Manning (n= 0.013)
Size of incoming sewer	φ 1,650 mm
Sewer slope	1.3 ‰
Incoming sewer invert elevation	1.425 m above M.W.L.

Full flow rate of incoming sewer 3.241 m^3/sec
Full flow velocity in incoming sewer 1.835 m/sec

Item	Wastewater flow rates (m^3/s)	Flow velocity (m/sec)	Water depth (m)	Water surface elevation at entrance (m)	Head loss ahead of chamber	Gate chamber water elevation (m)
Average daily	1.134 0.345	0.642 0.418	0.670 0.406	2.095	0.021	2.074
Maximum daily	1.331 0.405	0.754 0.495	0.733 0.444	2.158	0.029	2.129
Maximum hourly	1.620 0.493	0.917 0.597	0.818 0.496	2.243	0.143	2.200
Wet weather flow	3.241 0.986	1.591 0.867	1.333 0.808	2.758	0.129	2.629

Note: Ratio of flow to full flow | Ratio to full velocity | Ratio to full sewer depth | From tables

1.10.3 INFLUENT GATE

Influent gate is specified as follows.

Elevation of gate bottom 1.35 M.W.L.
Gate type and size square 1.2 m

Items		Average daily flow	Max. daily flow	Max. hourly flow	Wet weather flow	Remarks
Wastewater Inflow rates (Q)	m^3/s	1.134	1.331	1.620	3.241	
No. of gates operated (n)	Unit	2	2	3	4	
Wastewater inflow to each gate	m^3/s/gate	0.567	0.666	0.540	0.810	Q/n
Wastewater elevation ahead of gate	M.W.L.	2.074	2.129	2.200	2.629	
Wastewater depth at gate (H)	m	0.724	0.779	0.850	1.279	
Wastewater flow area at gate (A)	m^2	0.869	0.934	1.021	1.44	1.2xH
Flow velocity through gate(V)	m/s	0.653	0.712	0.529	0.563	Q/nA
Head losses at gate(Δh)	m	0.033	0.039	0.021	0.024	
Water elevation after gate	M	2.041	2.090	2.179	2.605	

Total head losses at gate (Δh) $1.5 \times v^2/2g$ = $0.0765 \times v^2$

1.10.4 COARSE SCREEN

Coarse screen is specified as follows.

Channel invert elevation 1.35 m M.W.L.
Channel width 1.6 m
Screen clear opening 100 mm
No. of screens 4
Slope of screens 60 degrees from horizontal

Items		Average daily flow	Maximum daily flow	Maximum hourly flow	Wet weather flow	Remarks
Wastewater inflow rates (Q)	m^3/s	1.134	1.331	1.620	3.241	
No. of channels used (n)		2	2	3	4	
Wastewater inflow to each channel	m^3/s	0.567	0.666	0.540	0.810	Q/n
Wastewater elevation ahead of screen	m M.W.L.	2.041	2.090	2.179	2.605	
Wastewater depth ahead of screen	m	0.691	0.740	0.829	1.255	
Flow area in channel(A)	m	1.106	1.184	1.045	2.008	1.6 × H
Approaching flow velocity to screen	m/s	0.513	0.562	0.517	0.404	Q/ n A
Flow velocity in screen(V2)	m/s	0.544	0.596	0.548	0.428	
Head loss in screen(Δh1)	m	0.001	0.001	0.001	0.000	
Actual head loss in screen(Δh2)	m	0.002	0.003	0.002	0.001	3 × Δh 1
Allowable head loss at screens (Δh3)	m	0.100	0.100	0.100	0.100	Δh3>h2
Wastewater elevation after screen	m M.W.L.	1.941	1.990	2.079	2.505	Δh3

$\delta h = \beta \times (s/d)^{4/3} \times \sin\alpha = 0.0492268$

$\beta = 2.42$, $d = 150$ mm, $s = 9$ mm, $\alpha = 60°$, $\sin 60 = 0.866$

Loss by screen $= \delta h \times v^2/2g = 0.04923 \times v^2/2g$ (hv)

Flow velocity through screen $V1 \times (s+d)/d = 1.06\ V1$

1.10.5 FINE SCREEN

Fine screen is specified as follows.

Channel invert elevation	1.2 M.W.L.
Channel width	1.6 m
Bar screen clear opening	20 mm
Thickness of screen bars	8 mm
No. of units	4 units
Slope of screen	75 degrees to horizontal

Items		Average daily flow	Maximum daily flow	Maximum hourly flow	Wet weather flow	Remarks
Wastewater Inflow rate (Q)	m^3/s	1.134	1.331	1.620	3.241	
No. of channels in use (n)		2	2	3	4	
Flow rate in each channel	m^3/s	0.567	0.666	0.540	0.810	Q/n
Water elevation ahead of screen	M.W.L.	1.941	1.990	2.079	2.505	
Water depth ahead of screen	m	0.741	0.790	0.879	1.305	
Sectional area of flow in channel	m^2	1.186	1.264	1.108	2.088	1.6×H
Approaching velocity to screen (V1)	m/s	0.478	0.527	0.488	0.388	Q/nA
Flow velocity through screen(V2)	m/s	0.669	0.737	0.683	0.543	
Head loss through screen(Δh1)	m	0.016	0.019	0.016	0.010	
Actual head loss in screen(Δh2)	m	0.047	0.057	0.049	0.031	3×Δh1
Allowable maximum loss(Δh3)	m	0.100	0.100	0.100	0.100	Δh3<h2
Water surface elevation after screen	M.W.L.	1.841	1.890	1.979	2.405	Δh2

$\delta h = \beta \times (s/d)^{4/3} \times \sin\alpha = 0.688907$

$\beta = 2.42$, $d = 20$ mm , $s = 8$ mm , $\alpha = 75°$, $\sin 75 = 0.9659$
Loss by screen $= \delta h \times v^2 / 2g =$ 0.68891 $\times v^2 / 2g$ (hw)
Flow velocity through screen V1 × (s+d) / d = 1.400 V1

1.10.6 PUMPING EQUIPMENT

(1) Design Flow Rate

Flow rates are determined as follows.

Qad	98,000 m^3/day	68 m^3/minute
Qmd	115,000 m^3/day	80 m^3/minute
Qmh	140,000 m^3/day	97 m^3/minute
Qww	280,000 m^3/day	194 m^3/minute

(2) Wastewater Pumps

4 units (including 1 standby), mixed flow centrifugal type driven by electric motor.

(3) Storm Water Pumps

4 units(including 1 standby), mixed flow centrifugal type, smaller pumps driven by motor, and large pumps driven by diesel engine. Pump operation schedule is as follows:

Wastewater inflows	Wastewater inflow rates (m^3/minute)	Pump discharges					Total pump discharge m^3/minute
		Wastewater pumps		Storm water pumps			
		25	50	25	50	m^3/min/unit	
		2	2(1)	2	2(1)	No. of units	
Qad	68	25	50				75
Qmd	80	50	50				100
Qmh	97	50	50				100
Qww	194	50	50	50	50		200

(4) Pump Size:

No.1 Pumps Q = 25 m^3/minute
D = $146(Q/V)^{0.5}$ V =.5 m/sec
= 462 mm use → 450 mm
No.2 Pumps Q = 50 m^3/minute
D = $146(Q/V)^{0.5}$
= 653 mm use → 600 mm

(5) Wastewater Surface Elevations:

Suction water levels at inflow of

Qad	1.841	M.W.L.
Qmd	1.890	M.W.L.
Qmh	1.979	M.W.L.
Qww	2.405	M.W.L.

Suction water levels at outflow of

Qad	10.900	M.W.L.
Qmd	10.900	M.W.L.
Qmh	10.900	M.W.L.

Qww 10.900 M.W.L.

(6) Actual Head

Qad	10.900	–	(1.841)	=	9.059 m
Qmd	10.900	–	(1.890)	=	9.010 m
Qmh	10.900	–	(1.979)	=	8.921 m
Qww	10.900	–	(2.405)	=	8.495 m

(7) Total Head Losses at Pump Equipment

Pump size	ϕ450	ϕ600
Pump bore(m)	0.45	0.6
Pump discharge(m^3/min)	25	50
Pump discharge(m^3/sec)	0.417	0.833
Delivery bore sectional area (m^2)	0.159	0.283
Pump velocity(m/s)	2.621	2.949

(8) Loss Coefficients

Inlet		0.15	0.15	
Sluice valve		0	0	
Check valve		1.0	1.0	
Outlet		1.0	1.0	
Bend		0.25	0.25	
Friction loss	f' × L / D	1.056	0.781	
Total		3.456	3.181	F

(9) Head losses

ϕ450 = 1.211 m $F \times V^2/2g$

ϕ600 = 1.411 m

Pipe length L = 15 m

Friction loss by Darcy-Wiseback Formula

$hf = f \times L / D \times V^2 / 2g$

$f = 0.02 + 1/(2000 \times D)$ (New cast iron pipe)

For old cast-iron pipes multiply the 'f' by 1.5

	ϕ450	ϕ600
D(m)	0.45	0.6
F	0.021	0.021
f' = 1.5 × f	0.032	0.031

(10) Total Head Required

Qad	9.059	+	1.211 (ϕ450)	=	10.270 m
			1.411 (ϕ600)	=	10.470 m
Qmd	9.010	+	0.000	=	9.010 m
Qmh	8.921	+	0.000	=	8.921 m
Qww	8.495	+	1.411 (ϕ600)	=	9.907 m

The required total pump head is then 11.0 m

(11)Shaft Power of Mixed Flow Centrifugal Pumps

$$L = k \times \gamma \times Q \times H / \mu$$

where

L	Shaft power of pump
k	0.163 kW or 0.222 PS
Q	Pump discharge (m^3/min)
H	Pump total dynamic head (m)
γ	Specific gravity of water (γ = 1)
μ	Pump efficiency

Calculations for shaft power requirement

Items		φ450	φ600	φ600 Engine
Pump discharge(Q)	m^3/min	25	50	50
TDH (H)	m	11.0	11.0	11.0
Pump efficiency (μ)		0.74	0.78	0.78
Shaft power	kW	61	115	157

(12) Outputs of Pump Drives

$$P = L(1+\alpha) / \mu G$$

where

P	Pump power (kW)	
L	Pump shaft power (kW)	
α	Allowance for motor	0.15
	Allowance for engine	0.2
μG	Transmission efficiency (1.0 for direct connection)	

	φ450	φ600	φ600 Engine
Shaft power (L)	61	115	157
Allowance (α)	1.15	1.15	1.20
Efficiency of transmission (μG)	1.00	1.00	0.95
Pump drive output (P) kW	70	132	198

(13) Pump Specifications

		Vertical mixed flow centrifugal pumps		
Pump bore	mm	450	600	600
Pump discharge	m^3/min.	25	50	50
Total dynamic head	m	11	11	11
Motor/engine outputs	kW	70	132	198
Pump drive		Motor	Motor	Engine

1.11 GRIT OIL/GREASE REMOVAL EQUIPMENT

1.11.1 DESIGN WASTEWATER FLOW RATES

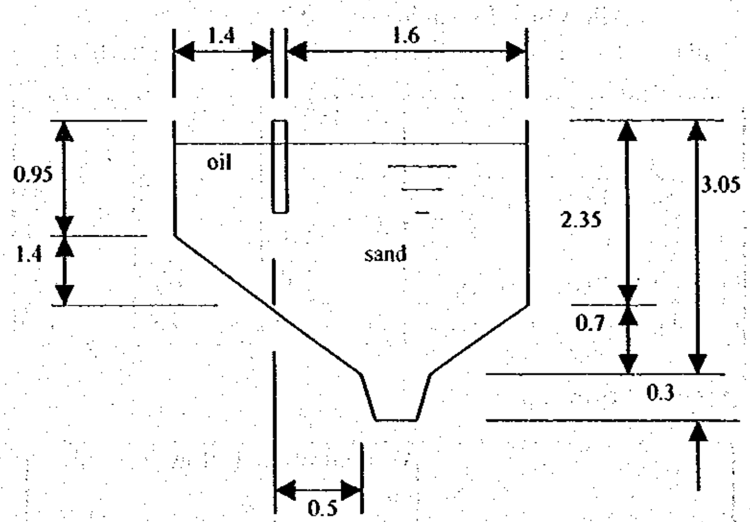
Design wastewater flow rates are determined as follows.

Qad	98,000	m^3/day	1,134	L/s
Qmd	115,000	m^3/day	1,331	L/s
Qmh	140,000	m^3/day	1,620	L/s
Qww	280,000	m^3/day	3,241	L/s

1.11.2 GRIT, OIL/GREASE SEPARATION

Grit, oil/grease separation is specified as follows.

4 trains 1 channels each, then totally 4 channels
Qww 280,000 m^3/day = 3,241 L/sec
Flow to each channel 70,000 m^3/day = 810 L/sec
Retention time 3 minutes
Capacity 280,000 × 3 ÷ 1,440 = 583.3 m^3
Section area 6.8 m^2
Length 22 m
Capacity 6.8 × 22 × 4 = 598.4 m^3
(check for flows)
At maximum daily flow Qmd 115,000 m^3/day
Retention (598.4 × 1440) / 115,000
Time = 7.5 min.



Chamber cross sectional area

1.4	×	0.95	=	1.33
1/2	×	1.4^2	=	0.98
1.6	×	3.05	=	4.88
−1/2	×	0.5^2	=	−0.13
−1/2	×	0.7^2	=	−0.25

Total 6.82 m^2 use → 6.8 m^2

Air supply volume

Romanian Standards Q = 0.3 m^3 air / m^3 water
= 0.3 × 11,667 = 3,500 m^3/hour
= 58 m^3/min

Japanese Standards Q = 0.01 m^3/sec·m × channel length/m
(0.005~0.013)
= 0.01 × 22 × 4
= 0.88 m^3/sec = 53 m^3/min

Then, the total air is 58 m^3/min
Blower equipment : 1 unit each for 1 train
then, 1 blower capacity = 58 ÷ 4 = 14.6 use → 15 m^3/min
Air blower specifications
Roots blower 5 units (including 1 standby)
ϕ 125mm 15 m^3/min
Grit volume from combined sewage: 0.001~0.02m^3 grit / 1000m^3 sewage
Then, grit volume = 0.02 / 1000 × 280,000 = 5.6 m^3/day

1.11.3 Grit Pumps

Grit pumps are calculated as follows.

Pump capacity is to remove the grit in 20 minutes. As allowances the capacity is two times of the grit quantity. Then, the pump capacity is:
5.6 m^3/day × 2 / 4 units × 20 minutes = 0.14 m^3/min.
Assuming the grit content in the withdrawn wastewater at 10 %, the required pump capacity is:
0.14 × 100 / 10 = 1.4 m^3/min.
Assume the pump velocity to be 2.5 m/sec, the pump diameter will be:
146 × $(1.4 / 2.5)^{0.5}$ = 109 use 100 mm

1.11.4 Flow Measurement

Use two units of Parshall flume

				Flow per each unit(Q / 2)
Qad	98,000 m^3/day	=	4,083 m^3/hour	2,042 m^3/hour
Qmh	115,000 m^3/day	=	4,792 m^3/hour	2,396 m^3/hour
Qmh	140,000 m^3/day	=	5,833 m^3/hour	2,917 m^3/hour
Qww	280,00 m^3/day	=	11,667 m^3/hour	5,833 m^3/hour
Select 7 ft flume, range of flow			306~ 12,380 m^3/hour	2 units

1.12 SLUDGE DIGESTER EQUIPMENT

1.12.1 Mixers

(1) Specifications

Type Up/down flow screw mixers (with a draft tube, from manufacturer's catalogue)
Capacity 1,200 m^3/hour
Draft tube diameter 400 mm
Motor output 11 kW
Quantity 4 units

(2) Sludge Mixing Capacity

Sludge turn over rate (mixing the whole sludge volume 8 ~ 12 times/day)
Q = (8~12) × 3,503 (Tank volume = 3,503m^3) / 24
= 1,168 ~ 1,752 m^3/hour use → 1,200 m^3/hour

1.12.2 TANK APPARATUS(ON ROOF TOP)

Tank apparatus are specified as follows.

Gas collectors(steel made)	ϕ600 mm × 1 unit	
Gas relief valve (wet type)	ϕ200 mm × 1 unit	
Gas relief valve (dry type)	ϕ200 mm × 1 unit	(including valve and flame arrester)
Quantity	Total 4 units	

1.12.3 WATER HEATERS

(1) Specifications

Type	Vacuum type water heater	
Heater capacity	450,000 Kcal/hr.	
Heater transfer area	9.9 m^2	
Fuel	Sludge gas and oil	
Electric motors	Burner motor	1.5 kW
	Oil pump	0.4 kW
	Oil heater	1.0 kW
	Fan	1.5 kW
Quantity	3 units (1standby)	

(2) Nominal Heat Output

Total required heat = 892,258 Kcal/hr

Nominal heater capacity Q = (892,258) / (2 × 0.9)

= 460,699 Kcal / hr. → 450,000 Kcal / hr

(Heater efficiency 0.9) (No. of units:2)

1.12.4 OIL SERVICE TANKS

(1) Specifications

Type	Steel made rectangular tank
Tank capacity	150 L
Quantity	1 unit

(2) Tank Capacity

Store oil of more than one hour consumption

q = (450,000 × 2) / (10,200 × 0.85) = 104 L / hr. use → 150 L

β :Heating value of A-diesel oil 10,200 kcal / kg

γ :Specific gravity of A-diesel oil 0.85 kg/L

1.12.5 OIL PUMPS

(1) Specifications

Type	Gear pump
Size	ϕ 15 mm
Discharge	5 L/min.
Discharge pressure	3 kg/cm^2
Electric motor	0.4 kW
Quantity	2 units (including 1 standby)

(2) Pump Discharge

Capable of supplying a 300-liter capacity tank within 30 minutes

$Q = 150 / 30 = 5$ L/minute

1.12.6 OIL STORAGE TANK

(1) Specifications

Type	Underground cylinder type
Storage capacity	7,500 L
Quantity	1 unit

(2) Tank Capacity

Store more than 3-day oil consumption.

$V = 104 \times 24 \times 3 = 7{,}474$ L use → 7,500 L

1.12.7 GAS BOOSTER FANS

(1) Specifications

Type	Turbo fan
Capacity	81.8 m^3/hr.
Pressure (static pressure in water column)	500 mm Aq
Electric motor	1.5 kW
Quantity	2 units (including 1 standby)

(2) Capacity

Sludge gas consumption

$q = 450{,}000 / 5{,}500 = 81.8$ m^3/hr.

(Sludge gas heat value 5,500 kcal/m^3)

Check for gas consumption

Required energy	Kcal/day	9,902,195
Heater operation time	Hour	22.1
Gas production	m^3/day	6,456
Gas consumption	m^3/day	1,809

Required heat energy	829,258 Kcal/hr.
Heater output	450,000 Kcal/hr.
No. of units	2 units

1.12.8 HEAT EXCHANGE

(1) Specifications

Type	Spiral type heat exchanger				
Heat transfer area		15 m^2			
Water temperature	Inlet	35 °c,	Outlet	40 °c	
	"	70 °c,	"	60 °c	
Quantity	Total Nos.	4 units			

(2) Energy Transfer

Provide an exchanger to each digester

Required energy per unit, M = 19,902,195 × 1 / 4 = 4,975,549 Kcal/day
= 207,315 Kcal/hr.

(3) Required Heat Transfer Area

A = (M × 1.2) / (K × Δtm) = (207,315 × 1.2) / (600 ×27.4)
= 15.1 m^2 use 15 m^2

M = Heat transfer 207,315 Kcal/hr.
K = Overall heat transfer coefficient 600 Kcal/m^2 hr. °c
Δtm Logarithmic average of temperature difference
= (Δt1–Δt2) / (ln Δt1 / Δt2)
= (30 – 25) / (ln (30/ 25) = 27.4 °c
Δ1 = 70 – 40 = 30 °c
Δ2 = 60 – 35 = 25 °c

(4) Sludge Recirculation

Q 1 = M / (C × Δt× γ × 60) = 207,315 / (1 × 5 × 1,000 × 60)
= 0.69 m^3/min.

C Sludge specific heat 1 Kcal/kg·°c
Δt Temperature difference between inlet and outlet sludge
40 – 35 = 5 °c
γ Unit weight of sludge 1,000 kg/m^3

(5) Water Recirculation

Q 2 = 207,315 / (1 × 10 × 1,000 × 60) = 0.35 m^3/min.
Δt Difference of temperature between inlet and outlet
70 – 60 = 10 °c

1.12.9 SLUDGE CIRCULATION PUMPS

(1) Specifications

Type	Sludge pump with suction screw
Size	100 mm
Discharge	0.7 m^3/min.
TDH	15 m
Motor output	5.5 kW
No. of units	4 units

(2) Capacity

Sludge circulation rate Q = 0.69 m^3/min use → 0.7 m^3/min.

(3) Head

Total head = Actual head + pipe losses + losses in heat exchanger (10m)
= 15 m

(4) Motor Output

P_m = 0.163 × 0.7 × 15 × (1 + 0.2) / 0.4 = 5.13 kW use → 5.5 kW

1.12.10 Hot Water Circulation Pumps

(1) Specifications

Type	Line pump
Size	65 mm
Capacity	0.34 m^3/min.
TDH	25 m
Motor output	3.7 kW
Quantity	4 units

(2) Capacity

Return from exchanger, Q = 0.35 m^3/min.

(3) Head

Total heads = Actual head + pipe losses + losses in heat exchanger (20m)
= Use 25 m

(4) Motor Output

Pm = $(0.163 \times 0.4 \times 25 \times (1 + 0.2) / 0.6$ = 3.26 kW use → 3.7 kW

1.12.11 Gas Holder

(1) Specifications

Type	Steel made dry seal type
Capacity	1,100 m^3
Size	12.6m $\phi \times$ 13.3mH
No. of tanks	2 units

(2) Capacity

Gas generation	6,456 m^3/day	
Retention time	8 hr.	
Storage capacity	$6,456 \times 8 / 24 / 2$	= 1,076 m^3 use → 1,100 m^3

1.12.12 Gas Scrubbers

(1) Specifications

Type	Dry type (intermittent) scrubbers
Capacity	150 m^3/hr.
Size	1,800 mm × 4,200 m H × 2 units
No. of units	2 × 1,800 mm × 4,200 m H × 2 units 2 units

(2) Capacity

Treat all the gas produced

Q = $6,456 \times 1 / 24 / 2$ = 134 m^3/hr use → 150 m^3/hr.

(3) Diameter of Towers

Velocity of gas flow 1 m/min.

D = $(4 \times 150 / 60 / 3.14 / 1)^{0.5}$ ≒ 1.785 mϕ, use → 1800 mmϕ

(4) Chemical Consumption

Inflow and outflow gas H2S concentrations are 100 ppm and 10 ppm, respectively.

$V1 = 0.235 \times 10^{-3} \times Q \times \mu$

$= 0.235 \times 10^{-3} \times 150 \times 24 \times 0.9 = 0.761$ L/day

(μ Removal efficiency = 90%)

$VO = V1 / (C0 \times 0.8) = 0.761 / (100 / 1,000) \times 0\ 8$

= 9.5 L/day

C0 : Chemical requirements to absorb 100 kg hydrogen sulifide= 1000 kg

γ : Nominal specific gravity of chemical 0.8

(5) Life of Chemical

$T = (V \times 10^3) / V0 = (5 \times 10^3) / 9.5 = 525$ days

V = Volume 5 m^3

1.12.13 WASTE GAS BURNERS

(1) Specifications

Type	In furnace
Capacity	300 m^3/hr.
Size	3,600 mm × 4,200 mm H
Motor	Cooling fan
"	Gas blower
No. of units	2 units

(2) Treatment Capacity

Capacity: all produced gas

$Q = 6,456 \times 1/24 \times 2.0 \times 1/2$

= 269 m^3/hr use → 300 m^3/hr.

1.12.14 SLUDGE SEED PUMPS(SLUDGE SEEDING / WITHDRAW)

(1) Specifications

Type	Sludge pumps with suction screw
Size	100 mm
Capacity	1 m^3/min.
T.H.L	15 m
Motor output	7.5kW
No. of units	2 units

(2) Capacity

Q = 1 m^3/min.

(3) Total Dynamic Head

H = 15 m

(4) Motor Output

$Pm = 0.163 \times 1 \times 15 \times (1 + 0.2) / 0.4$

= 7.34 kW use → 7.5 kW

1.13 APPARATUS FOR SLUDGE DEWATERING EQUIPMENT

1.13.1 SLUDGE STORAGE TANK MIXER

(1) Specifications

Type	Vertical paddle type
Shape	Approximately 6,000mm ×11,500mm × 2,500mmH
Capacity	170 m^3
Blade size	1,500 mmϕ
Motor output	5.5 kW
No. of units	3 units

(2) Tank Capacity

Store average one-day sludge production

V = 470 × 1 / 3 = 157 m^3 use 170 m^3

1.13.2 SLUDGE SUPPLY PUMP

(1) Specifications

Type	Single-axis screw pump
Size	ϕ 100 mm
Capacity	20 m^3/hour
TDH	20 m
Motor output	5.5 kW
No. of units	9 units

(2) Discharge Capacity

One pump to each dewater equipment (one-standby pump for all dewatering Equipment)

$$Q1 = 130 \times 3 \times 10^{-3} \times 100 / (3 \times 1.5)$$
$$= 19.5\ m^3/hour \quad use \rightarrow 20\ m^3/hour \quad 0.33\ m^3/minute$$

Filter velocity 1	30 kg/m·hr.
Filter width	3 m
Sludge solid concentration	3 %
Allowance	1.5

(3) Electric Motor Output

$$Pm = 0.163 \times 20 \times 0.33 \times (1 + 0.3) / 0.3$$
$$= 4.71\ kW \quad use \rightarrow 5.5\ kW$$

1.13.3 CHEMICAL FEED PUMP

(1) Specifications

Type	Single-axis screw pump
Size	ϕ 50 mm
Capacity	3 m^3/hour
TDH	20 m
Motor output	1.5 kW
No. of units	9 units (including one standby)

(2) Discharge Capacity

One pump to each dewater equipment (one standby pump for all dewatering Equipment)

Q1 = 130 × 3 × 10^{-3} × 0.01 × 100 / 0.2 × 1.5

= 2.925 m^3/hour → 3 m^3/hour 0.05 m^3/min.

Filter velocity	130 kg/m·hr.
Filter width	3 m
Solid concentration of sludge	0.2 %
Allowance	1.5

(3) Electric Motor Output

Pm = 0.163 × 20 × 0.05 × (1+0.3) / 0.25

= 0.85 kW use → 1.5 kW

1.13.4 CHEMICAL SOLUTION TANKS

(1) Specifications

Tank type	Steel made cylinder type
Tank capacity	14 m^3
Approx. size	2,300 mmϕ × 3,000mmH
Electric motor output	5.5 kW (for mixer)
No. of tanks	2 units

(2) Sludge Storage Tank Capacity

Dosing rate 14.11 × 10^3 × 0.008 × 7/5 = 157.98 kg/day

Dewatered solids 14.11 t/day

Chemical dosing rate (Polymer) 0.8 %/kg·ds

(5 days/week operation)

Storage capacity. 2 hours of design sludge volume

2 tanks (alternately used)

V = (158 × 100) / (0.2× 2 / 6 / 2)

= 13,165 L use → 14,000 L

Chemical solution concentration 0.2 %

Operation time a day 6 hours

Retention time 2 hours

1.13.5 CHEMICAL FEEDERS

(1) Specifications

Type	Chemical pump
Supply rate	3 L/min.
Electric motor output	0.4 kW
Quantity	2 units

(2) Supply Rate

One feeder is attached to each solution tank, supplying chemical in 15 to 20 minutes.

Q = 14,000 × 10^3 × 0.2 / 100 × 1/(15 ~ 20) × 1 / 0.5

= 3.7 ~ 2.8 → 3 L/min.

Apparent specific gravity of polymer 0.5

1.13.6 CHEMICAL CONTAINERS

(1) Specifications

Type	Stainless steel made, cylinder container
Effective capacity	400 L
Quantity	2 units

(2) Capacity

Provide 2 tanks (alternately used), with capacity of 7-day chemical consumption.

V = 157.98 × 7/5 × 0.5 × 7 × 1/2

= 387 L use → 400 L

1.13.7 FILTER CLOTH WASHING PUMPS

(1) Specifications

Type	Multi-stage centrifugal pump
Size	ϕ 50 mm
Discharge	0.3 m^3/min.
Total head	60 m
Electric motor output	7.5 kW
Quantity	9 units (including 1 standby)

(2) Discharge

One pump to each dewatering machine, and one standby pump for all equipment.

Q = 100 × 3 = 300 L/min. use → 0.3 m^3/min.

Then, the pump discharge per 1 m cloth is 100 L/min.

Total dynamic head 60 m

Electric motor output

Pm = 0.163 × 60 × 0.30 × (1+0.2) / 0.5

= 7.04 k W → 7.5 kW

1.14 EFFLUENT PUMPING STATION

1.14.1 FLOW RATE

Flow rates are determined as follows.

Qad	98,000 m^3/day	1,134 L / s
Qmd	115,000 m^3/day	1,331 L / s
Qmh	140,000 m^3/day	1,620 L / s
Qww	280,000 m^3/day	3,241 L / s

1.14.2 PUMPING EQUIPMENT

(1) Design Flow Rates

Qad	98,000 m^3/day	68 m^3/minute
Qmd	115,000 m^3/day	80 m^3/minute
Qmh	140,000 m^3/day	97 m^3/minute
Qww	280,000 m^3/day	194 m^3/minute

(2) Wastewater Pumps

4 units (including 1 standby), mixed flow centrifugal type driven by electric motor.

(3) Storm Water Pumps:

4 units (including 1 standby), mixed flow centrifugal type, smaller pumps driven by motor, and large pumps driven by diesel engine. Pump operation schedule is as follows:

Wastewater inflows	Wastewater inflow rates (m³/minute)	Pump discharges					Total pump discharge (m³/minute)
		Wastewater pumps		Storm water pumps			
		25	50	25	50	(m³/min/unit)	
		2	2(1)	2	2(1)	No. of units	
Qad	68	25	50				75
Qmd	80	50	50				100
Qmh	97	50	50				100
Qww	194	50	50	50	50		200

(4) Pump Size:

No.1 Pumps Q = 25 m^3/minute
D = $146(Q/V)^{0.5}$ V = 2.5 m/sec
= 462 mm use → 450 mm

No.2 Pumps Q = 50 m^3/minute
D = $146(Q/V)^{0.5}$
= 653 mm use → 600 mm

(5) Wastewater Surface Elevations:

Suction water levels at inflow of

Qad	6.900	M.W.L.
Qmd	6.900	M.W.L.
Qmh	6.900	M.W.L.
Qww	6.900	M.W.L.

Suction water levels at outflow of

Qad	8.800	M.W.L.
Qmd	8.800	M.W.L.
Qmh	8.800	M.W.L.
Qww	8.800	M.W.L.

(6) Actual Head:

Qad	8.800	–	(6.900)	=	1.900 m
Qmd	8.800	–	(6.900)	=	1.900 m
Qmh	8.800	–	(6.900)	=	1.900 m
Qww	8.800	–	(6.900)	=	1.900 m

Total head losses at pump equipment:

Pump size	φ450	φ600
Pump bore (m)	0.45	0.6
Pump discharge (m³/min)	25	50
Pump discharge (m³/sec)	0.417	0.833
Delivery bore sectional area (m²)	0.159	0.283

Pump velocity (m/s)		2.621	2.949	
Loss coefficients				
Inlet		0.15	0.15	
Sluice valve		0	0	
Check valve		1.0	1.0	
Outlet		1.0	1.0	
Bend		0.25	0.25	
Friction loss	$f' \times L/D$	1.056	0.781	
	Total	3.456	3.181	F

(7) Head Losses

ϕ450 = 1.211 m $F \times V^2/2g$

ϕ600 = 1.411 m

Pipe length L = 15 m

Friction loss by Darcy-Wiseback Formula

$hf = f \times L/D \times V^2 / 2g$

$f = 0{,}02 + 1/(2000 \times D)$ (New cast iron pipe)

For old cast-iron pipes multiply the 'f' by 1.5

	ϕ450	ϕ600
D(m)	0.45	0.60
f	0.021	0.021
$f' =$ 1.5*f	0.032	0.031

(8) Total Head Required

Qad	1.900	+	1.211 (ϕ450)	=	3.111 m
			1.411 (ϕ600)	=	3.311 m
Qmd	1.900	+	0.000	=	1.900 m
Qmh	1.900	+	0.000	=	1.900 m
Qww	1.900	+	1.411 (ϕ600)	=	3.311 m

The required total pump head is then 5.0 m

(9) Shaft Power of Mixed Flow Centrifugal Pumps

$L = k \times \gamma \times Q \times H / \mu$

where

- L Shaft power of pump
- k 0.163 kW or 0.222 PS
- Q Pump discharge (m^3 / min)
- H Pump total dynamic head (m)
- γ Specific gravity of water ($\gamma = 1$)
- μ Pump efficiency

Calculations for shaft power requirements

Items		ϕ450	ϕ600	ϕ600 Engine
Pump discharge(Q)	m^3/min	25	50	50
TDH (H)	m	5.0	5.0	5.0
Pump efficiency(μ)		0.74	0.78	0.78
Shaft power	kW	28	52	71

(10) Outputs of Pump Drives

$$P = L(1+\alpha) / \mu \times G$$

where

P	Pump power (kW)	
L	Pump shaft power (kW)	
α	Allowance for motor	0.15
	Allowance for engine	0.2
μG	Transmission efficiency (1.0 for direct connection)	

	ϕ450	ϕ600	ϕ600 Engine
Shaft power (L)	28	52	71
Allowance (α)	1.15	1.15	1.20
Efficiency of transmission (μG)	1.00	1.00	0.95
Pump drive output (P) kW	32	60	90

(11) Pump Specifications

		Vertical mixed flow centrifugal pumps		
Pump bore	mm	450	600	600
Pump discharge	m^3/min.	25	50	50
Total dynamic head	m	5	5	5
Motor/engine output	kW	32	60	90
Pump drive		Motor	Motor	Engine

2. RECIRCURATION PROCESS

2.1 DESIGN BASIS

2.1.1 Design Wastewater Inflow Rates

Design wastewater inflow rates are determined as follows.

Average daily flow	Qad	98,000 m^3/day	1,134 L/s
Maximum daily flow	Qmd	115,000 m^3/day	1,331 L/s
Maximum hourly flow	Qmh	140,000 m^3/day	1,620 L/s
Wet weather flow	Qww	280,000 m^3/day	3,241 L/day

2.1.2 Design Wastewater Quality

Design wastewater quality is determined as follows.

BOD	=	150 mg/L
SS	=	180 mg/L
T-N	=	25 mg/L
T-P	=	4 mg/L

2.1.3 Design Wastewater Quality (Including Sidestream Waste Loads)

Design wastewater quality (including sidestream waste loads) is calculated as follows.

BOD = 170 mg/L
SS = 210 mg/L
T-N = 30 mg/L
T-P = 5.5 mg/L

Parameter	Removal Efficiency (%)			Wastewater Quality (mg/L)		
	Primary treatment	Secondary treatment	Overall removal rate	Raw waste-water	Primary effluent	Secondary effluent
BOD	30	91	93.7	170	119	11
SS	40	93	95.8	210	126	9
T-N	10	65	68.5	30	27.0	9.5
T-P	10	80	82.0	5.5	4.95	1.0

2.1.4 Pollutant Discharge Limits by NTPA 001

Pollutant discharge limits by NTPA 001 is regulated as follows.

BOD < 20 mg/L
SS < 60 mg/L
T-N < 10 mg/L
T-P < 1.0 mg/L

2.2 CALCULATIONS OF SIDESTREAM POLLUTANT LOADS

2.2.1 Raw Sludge Volume

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = 115,000 × 180 × 10^{-6} × 0.4
= 8.28 t/day
Sludge concentration 2.0 %
Sludge volume 8.28 × 100 ÷ 2.0 = 414 m^3/day

2.2.2 Waste Sludge Volume

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency (%)
BOD	150	105	30
SS	180	108	40

Assuming that the reactor influent S-BOD is 66.7% of the total BOD; then Scc is 70.0 mg/L
Waste sludge production volume can be calculated by the following equation:

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta \times XA)Q$$

where,

Qw	Volume of waste sludge (m^3/day)	
Xw	Average SS concentration of waste sludge (mg/L)	
Q	Influent volume to reactors (m^3/day)	115,000
XA	MLSS concentration in reactors (mg/L)	3,000
Scs	Influent soluble-BOD concentration to reactors (mg/L)	70.0
Sss	Influent SS concentration to reactors (mg/L)	108

a	Sludge yield coefficient of S-BOD (mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS (mg MLSS/mgSS)	0.9~1.00.	0.95
c	Coefficient of SS reduction due to indigeneous respiration of activated sludge micro-organisms (L/day)	0.03~0.05	0.04
0	HRT in reactor basins (day)	15.4 / 24	= 0.64

therefore,

$Qw \times Xw = (0.5 \times 70.0 + 0.95 \times 108 - 0.04 \times 0.643 \times 3{,}000) \times Q \times 10^{-6}$

$= 60.43 \times Q \times 10^{-6} = 6.95$ t/day

Solid production = 6.95 t/day

Sludge concentration = 0.9 %

Sludge production = 6.95 × 100 ÷ 0.9 = 772 m^3/day

2.2.3 THICKENED SLUDGE

Thickened sludge production volume is calculated by the following equation.

Sludge solids = 8.28 + 6.95 = 15.23 t/day

(Primary sludge) (Excess sludge)

Sludge volume = 414 + 772 = 1,186 m^3/day

(2.0%) (0.9%)

Solids = 15.23 × 0.85 = 12.95 t/day

Assuming sludge concentration is 3.5 %

Sludge volume = 112.95 × 100 ÷ 3.5 = 370 m^3/day

2.2.4 SLUDGE SUPERNATANT OF THICKENERS

Sludge supernatant of thickeners weight is calculated by the following equation.

Liquor volume = 1,186 – 370 = 816 m^3/day

Solids weight = 15.23 × 0.15 = 2.28 t/day

BOD = 816 × 2000 × 10^{-6} = 1.63 t/day

BOD is assumed to be of 2,000 mg/L

T-N = 816 × 700 × 10^{-6} = 0.57 t/day

T-N is assumed to be of 700 mg/L

T-P = 816 × 180 × 10^{-6} = 0.15 t/day

T-P is assumed to be of 180 mg/L

2.2.5 DIGESTED SLUDGE

Digested sludge production volume is calculated by the following equation.

Digested sludge solids = 12.95 × (1 – 0.7 × 0.5) = 8.41 t/day

Digested sludge volume 3.0 %

Sludge volume = 8.41 × 100 / 3.0 = 280 m^3/day

2.2.6 DEWATERED SLUDGE(SLUDGE CAKE)

Dewatered sludge production volume is calculated by the following equation.

Solids = 8.41 × 0.9 = 7.57 t/day

(Assuming 20.0 % solids concentration)

Cake volume = 7.57 × 100 / 20.0 = 38 m^3/day

2.2.7 Digested Sludge Filtrate

Digested sludge filtrated weight is calculated by the following equation.

Filtrate volume = 280 − 38 = 243 m^3/day
Dry solids weight = 8.41 × 0.10 = 0.84 t/day
BOD = 243 × 1,500 × 10^{-6} = 0.36 t/day
(Assumed BOD concentration = 1,500 mg/L)
T-N = 243 × 150 × 10^{-6} = 0.04 t/day
(Assumed BOD concentration = 150 mg/L)
T-P = 243 × 80 × 10^{-6} = 0.02 t/day
(Assumed BOD concentration = 80 mg/L)

2.2.8 Sidestream Volume and Waste Load

Sidestream volume and waste load is calculated by the following equation.

	Thickener supernatants		Sludge filtrate		
Liquor volume	= 816	+	243	=	1,059 m^3/day
Dry solids	= 2.28	+	0.84	=	3.13 t/day
BOD	= 1.63	+	0.36	=	2.00 t/day
T-N	= 0.57	+	0.04	=	0.61 t/day
T-P	= 0.15	+	0.02	=	0.17 t/day

2.2.9 Wastewater Quality (Including All Sidestreams)

Wastewater quality (including all sidestreams) is calculated by the following equation.

Overall wastewater flow = Influent + Sidestreams
Maximum daily flow = 115,000 + 1,059 = 116,059 m^3/day
Then, the design wastewater flow characteristics are;
BOD = (115,000 × 150 × 10^{-6} + 2.00) / 116,059
= 0.00016584 × 10^6 = 166 → 170 mg/L
SS = (115,000 × 180 × 10^{-6} + 3.13) / 116,059
= 0.000205292 × 10^6 = 205 → 210 mg/L
T-N = (115,000 × 25 × 10^{-6} + 0.61) / 116,059
= 0.000030009 × 10^6 = 30.0 → 30 mg/L
SS = (115,000 × 4 × 10^{-6} + 0.17) / 116,059
= 0.000005397 × 10^6 = 5.4 → 5.5 mg/L

2.3 SLUDGE PRODUCTIONS

2.3.1 Raw Sludge

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = 115,000 × 210 × 10^{-6} × 0.4
= 9.66 t/day
Sludge concentration 2.0 %
Sludge volume 9.66 × 100 ÷ 2.0 = 483 m^3/day

2.3.2 WASTE SLUDGE VOLUME

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency(%)
BOD	170	119	30
SS	210	126	40

Assuming that influent S-BOD to reactor basins is 66.7 % of the raw wastewater BOD,S-BOD concentration is estimated to be; 79.37 mg/L
Waste sludge production volume is calculated by the following equation.

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta XA)Q$$

where,

Qw	Volume of excess sludge (m^3/day)		
Xw	Average SS concentration of waste sludge (mg/L)		
Q	Influent volume to reactors (m^3/day)		115,000
XA	MLSS concentration in reactors (mg/L)		3,000
Scs	Influent soluble-BOD concentration to reactors (mg/L)		79.37
Sss	Influent SS concentration to reactors (mg/L)		126
a	Sludge yield coefficient of S-BOD (mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS (mg MLSS/mgSS)	0.9~1.00	0.95
c	Coefficient of SS reduction due to indigeneous respiration of activated sludge micro-organisms (L/day)	0.03~0.05	0.04
θ	HRT in reactor basins (day)	15.4 / 24	= 0.64

therefore,

$$Qw \times Xw = (0.5 \times 79.37 + 0.95 \times 126 - 0.04 \times 0.643 \times 3{,}000) \times Q \times 10^{-6}$$
$$= 82.20 \times Q \times 10^{-6} = 9.45 \text{ t/day}$$

Solid production = 9.45 t/day
Sludge concentration = 0.9 %
Sludge production = 9.45 × 100 ÷ 0.9 = 1,050 m^3/day
= 0.73 m^3/min.

2.3.3 RETURN SLUDGE

Return sludge volume is calculated by the following equation.

Sludge return ratio 50 %
Return sludge volume = 115,000 × 0.5 = 57,500 m^3/day
= 40 m^3/min.

2.3.4 GRAVITY SLUDGE THICKENERS

Gravity thickened sludge production volume is calculated by the following equation.

Solids inflow = 9.66 + 9.45 = 19.11 t/day
Primary sludge Excess sludge
Sludge inflow = 483 + 1,050 = 1,533 m^3/day
Thickened sludge solids = 19.11 × 0.8 = 15.29 t/day
Assume solids content to be 3.5 %

Thickened sludge volume = 15.29 × 100 / 3.5 = 437 m^3/day

2.3.5 Anaerobic Sludge Digesters

Anaerobic digested sludge production volume is calculated by the following equation.

Input solids = 15.29 t/day
Input sludge volume = 437 m^3/day
Volatile solids content of sludge 70 %
Solids destruction rate 50 %
Digested sludge solids = 15.29 × (1 – 0.7 × 0.5) = 9.94 t/day
Assume solids concentration is 3.0 %
Digested sludge volume = 9.94 × 100 / 3.0 = 331 m^3/day

2.3.6 Sludge Dewatering

Dewatered sludge production volume is calculated by the following equation.

Input solids = 9.94 t/day
Recovered solids (90%) = 9.94 × 0.9 = 8.95 t/day
Assuming solids concentration as 20.0 %
Sludge cake volume = 8.95 × 100 / 20.0 = 45 m^3/day

2.4 COMPONENT OF FACILITIES

2.4.1 Design Basis

Design wastewater inflow rate is determined as follows.

Average daily flow Qin = 98,000 m^3/d
(Maximum daily flow in winter season)
Maximum daily flow Qin max = 115,000 m^3/d

Design wastewater quality : Influent wastewater quality to reactor tank is calculated As follows.

BOD	119	mg/L
SS	126	mg/L
T-N	27	mg/L

(S-BOD is 80.92 mg/L) 68 % (SBOD/BOD)

Design discharge wastewater quality :
Design effluent wastewater quality from final sedimentation tank (average quality) is Determined as follows.

Removal efficiency

BOD	9	mg/L	92.4	%	110
SS	8	mg/L	93.7	%	118
T-N	10	mg/L	63.0	%	17

T-N condition of Treated water is NOT-N 8.3 mg/L Removal efficiency
K-N 1.7 (T-N)60~70%
Design water temperature 10 °c

2.4.2 DESIGN CALCULATION

(1) Recircuration Ratio(R)

Recircuration ratio (R) is calculated by the following equation.

Influent concentration of T-N to reactor tank CTN. in = 27 mg/L
(effluent water quality from final sedimentation tank)

NOT-N concentration, Cnox·eff = 8.3 mg/L, Assuming that nitrogen ratio which concerned about nitrification in CTN·in is $\alpha = 0.7$, recircuration ratio R is

$$R = \alpha \times CTN{\cdot}in / CNOX{\cdot}eff - 1$$

$$R = 0.7 \times 27 / 8.3 - 1 = 2.28 - 1 = 1.28 \rightarrow 1$$

(2) MLSS Concentration

MLSS concentration is calculated by the following equation.

Assuming that MLSS concentration at reactor tank 3,000 mg/L (2,000~3,000MLSS) and return sludge concentration 9,000 mg/l, so that return sludge ratio R r is

$$9000\,R\,r = 3000 \times (1 + R\,r)$$

$$R\,r = (3{,}000) / (9{,}000 - 3{,}000) = 0.5$$

Recircuration flow Qc and return sludge flow Qr are respectively

$$R - R\,r = 1 - 0.5 = 0.5$$

$$Qr = Qin \times 0.5 = 49{,}000\ m^3/day$$

$$Qc = Qin \times 0.5 = 49{,}000\ m^3/day$$

(3) A - SRT

Retention time at aerobic tank is calculated by the following equation.

Assuming that complete nitrification, and to consider daily and seasonally change of water quantity and quality, A-SRT(d) is

δ = 1.5 (Assuming)

T = 10 °c (Assuming)

$$0XA = \delta \times 20.6 \times \exp(-0.0627 \times T) - 0.627$$

$$= 1.5 \times 20.6 \times 0.534192 = 16.5\ day$$

(4) Aerobic Tank Capacity VA(m^3)

Aerobic tank capacity is calculated by the following equation.

$$VA = (Q\,in \times 0XA \times (a \times C_S\text{-}BOD{\cdot}in + b \times SS{\cdot}in)) / (1 + c \times 0XA) \times X$$

0XA	=	Aerobic solids retention time	16.5 day
a	=	Gross yield coefficient of dissolved BOD(0.5~0.6)	0.55 gMLSS/gS-BOD
Cs-BOD	=	Dissolved BOD concentration of influent flow	80.92 mg/L
B	=	Gross yield coefficient of SS (0.9~1.0)	0.95 gMLSS/gSS
C	=	Autolysis coefficient of sludge (0.025~0.035)	0.03 L / d
X	=	MLSS concentration	3,000 mg/L

$$VA = 98{,}000 \times 16.51 \times 164 / 4{,}486 = 59{,}218\ m^3$$

$$A \times C_S\text{-}BOD{\cdot}in + b \times SS{\cdot}in = 0.55 \times 80.92 + 0.95 \times 126 = 164$$

$$(1 + c \times 0XA) \times X = (1 + 0.03 \times 16.5) \times 3{,}000 = 4{,}486$$

(5) Biological Reaction Tank Capacity V(m^3)

Biological reaction tank capacity is calculated by the following equation.

Assuming BOD-SS load(LBOD/x) is 0.06 kgBOD/kgMLSS/day (0.05~0.1)

V = (BOD·in × Qin) / (LBOD/x × X)

= (119 × 98,000) / (0.06 × 3,000) = 64,789 m^3

(6) Anoxic Tank Capacity VDN m^3

Anoxic tank capacity VDN m^3 is calculated by the following equation.

VDN = V − VA = 64,789 − 59,218 = 5,571 m^3

(7) Capacity Ratio of Anoxic Tank and Aerobic Tank

VDN : VA = 5,571 : 64,789 = 1 : 11.6

(8) Speed Constant of Denitrification KDN (mgN/ g MLSS/h)

Speed constant denitrification KDN is calculated by the following equation.

KDN = (LNOX.DN × 10^3) / (24 VDN × X)

Here

CNOX.A = α·CTN·in × 1 / (1+R)

= (0.7 × 27 × 1) / (1 + 1) = 9.5 mg/L

LNOX.DN = CNOX.A × (Qr + Qc) × 10^{-3}

= 9.5 × (49,000 + 49,000) × 10^{-3} = 926 kg/d

KDN = (916 × 10^3) / (24 × 5,571 × 3)

= 2.309 (mgN/gMLSS/h) > 0.872 OK

Check of denitrification speed

Less than(y') is NO y' = 6.2 × 0.06 + 0.5 = 0.872

More than (y') is OK

Calculate	Vdn	=		926	×	10^3			
back			24	×	0.872	×	3		
							=	14,751	m^3

VD : VA = 1 : 4.01

V = 14,751 + 59,218 = 73,968 m^3

(9) Biological Reaction Tank Capacity and Retention Time

Biological reaction tank capacity and retention time is calculated by the following equation.

Retention time at biological reaction tank in winter season, t(h) is

t = (24 × 73,968) / 98,000 = 18.1 h

Retention time at aerobic tank in winter season, tA(h) is

t = (24 × 59,218) / 98,000 = 14.5 h

Retention time for daily maximum flow at biological reaction tank in winter season, t(h) is

t = (24 × 73,968) / 115,000 = 15.4 h

(10) Necessary Oxygen Demand ΣD (kg/d)

Necessary oxygen demands is calculated by considering of oxidation of carbonic organic matter, necessary oxygen for endogenous respiration and nitrification reaction of microorganisms in activated sludge, and necessary oxygen for maintain a dissolved oxygen.

OD = OD1 + OD2 + OD3 + OD4

Here

OD	Necessary oxygen demands (kgO_2/day) (AOR)	
OD1	Necessary oxygen for oxidation of carbonic organic matter	(kgO_2/day)
OD2	Necessary oxygen for endogenous respiration	(kgO_2/day)
OD3	Necessary oxygen for nitrification reaction	(kgO_2/day)
OD4	Necessary oxygen for maintain a dissolved oxygen	(kgO_2/day)

OD1 = A(kgO_2/kgBOD) × {Removal BOD(kgBOD/day) – Denitrification volume (kgN/day) × K (kgBOD/kgN)}

Here A : Necessary oxygen for removal of BOD (0.5~0.7)

K : BOD consumption for denitrification(2.86)

OD2 = B(kgO_2/kgMLVSS·day) × VA(m3) × MLVSS(kgMLVSS/m^3)

Here B : Oxygen consumption by endogenous respiration at MLSS unit (0.05~0.15)

VA : Reaction tank capacity at aerobic part

OD3 = C (kgO_2/kgN) × Nitrificated Kj-N volume(kgN/day)

Here C : Nitrificated oxygen at nitrification reaction (4.57)

Nitrificated Kj-N (Inflow Kj-N) – (Outflow Kj – N volume) – (Removal volume of Kj -N by excess sludge)

OD4 = Q × DO concentration of reaction tank

Here DO : Dissolved oxygen concentration at end point of aerobic tank 1.5mg/L

(Design flow = 98,000 m^3/day)

BODin = 119 mg/L, T-N = 27 mg/L

BODout = 9 mg/L, VA = 59,218 m^3

The results of calculation is shown in table bellow.

		unit		note	
Necessary oxygen demands for oxidation of BOD (OD1)	(1) Q	m^3/day	98,000		
	(2) BODin	mg/L	119		
	(3) BODout	mg/L	9		
	(4) $\{(2)-(3)\}\times(1)\times10^{-3}$	kg/day	10,780		
	(5) ΔDN (denitrification volume)	kg/day	926		
	(6) k×(5)	kg/day	2,649	k =	2.86
	OD1= A×{(4)−(6)}	kg/day	488	A =	0.06
Necessary oxygen demands for endogenous respiration (OD2)	(1) MLSS	mg/L	3,000		
	(2) VA	m^3	59,218		
	(3) $(1)\times(2)\times10^{-3}$	kg/day	177,653		
	OD2 = B × (3)	kg/day	17,765	B =	0.1
Necessary oxygen demands for nitrification reaction (OD3)	(1) α (nitrification ratio)		0.7		
	(2) T-Nin	mg/L	27.0		
	(3) Q	m^3/day	98,000		
	OD3= $4.57\times(1)\times(2)\times(3)\times10^{-3}$	kg/day	8,465	C =	4.57
Necessary oxygen demands for maintain dissolved oxygen (OD4)	(1) DO concentration at reaction tank	mg/L	1.5		
	(2) Q	m^3/day	98,000		
	(3) Qr+Qc	m^3/day	147,000		1.5
	(4) {(2)+(3)}	m^3/day	245,000		
	OD4 = $(1)\times(4)\times10^{-3}$	kg/day	368		
Necessary oxygen(OD) demands	OD= OD1+OD2+OD3+OD4	kg/day	27,085		
			0.276 Q		

Design of air diffuser (Assuming that diffused air aeration、fine bubble、spiral flow)

EA = 7.5 , ρ = 1.293

Qw = 0.233 (Assuming)

Supplied air (N m^3/day) =

(Necessary oxygen demands(kgO_2)) / EA(%) × 10^{-2} × ρ (Air/Nm^3) × Ow(kgO_2/kgAir)

= (0.276 × Q) / (7.5 × 0.01 × 1.293 × 0.233)

= 12.23 Q = 1,198,718 (N m^3/day) = 832 (Nm^3/min)

2.4.3 MEASURE FOR ADVANCED TREATMENT

Way of thinking

Changing from conventional activated sludge process to advanced treatment process (T-N,T-P removal)
Calculate a necessary treatment capacity of advanced treatment process and evaluate a capacity of conventional activated sludge process.
Extend a necessary ponds and equipment in the future.

Necessary treatment capacity of advanced treatment process	−	Treatment capacity of conventional activated sludge process	=	Extend or remodeling of treatment about shortage of capacity

Explanation of measures for advanced treatment

Here showing a treatment capacity of two processes in table below.

* Conventional activated sludge process
* Advanced treatment process (Recircuration process)

Explanation of Measures for Advanced Treatment

	unit	Necessary advanced capacity	Facility and equipment for advanced treatment: Conventional activated sludge process	Facility and equipment for advanced treatment: Measures for shortage of capacity
・Primary sedimentation tank surface load	$m^3/m^2/day$	35	35	—
Facility shape			ϕ35m × 4 tanks	
・Reaction tank				
Retention time	hour	15.4	15.4	15.4
Distribution ratio of water	%		6.6/15.4×100= 43 Making a wall in reaction tank, and divided an anoxic zone and aerobic zone	100 − 43 = 57 Build an extend tank for reaction tank
Facility shape			W5.5m × H5.5m × L68m × 16 tanks	W5.5m × H5.5m × L71m × 16 tanks
・Final sedimentation Tank surface load	$m^3/m^2/day$	15	8.6	11.6
Facility shape			ϕ45m × 4 tanks	New ponds ϕ45m × 4 tanks
・Return sludge flow	%	Usually 50% (Sludge pump capacity 100%)	Same to the left	Same to the left (New pumps are necessary)
・Recircuration flow of Nitrificated water	%	50%	Provide a recircuration pumps at the outflow point of reaction tank(aerobic tank)	Same to the left
・Supplied air flow	m^3/min	832	312	520 Extend capacity
・Waste sludge volume (Inflow sludge solids of thickener) (exclude T-P removal)	t/day	19.11	27.21 (Sludge products from Conventional activated sludge process)	Not necessary a extend of capacity
(include T−P removal)		21.59		Not necessary a extend of capacity
・ T−P removal by addition of coagulant		New equipment is necessary	Same to the left	Same to the left

Waste sludge volume produced from T-P removal

Waste sludge production volume by addition of coagulant

Influent T-P concentration of reaction tank 4.95 mg/L

Additional concentration of aluminum suliface CA(mg/L) is calculated by following equation

CAL = Csp·in × m × AL / P

Here

Csp·in	Influent dissolved T-N concentration(mg/l)	4.95
P	Valence of phosphorus	31
AL	Valence of aluminum	27
m	Additional molality ratio	1 (assuming)

CAL = (4.95 × 27 × 1) / (31) = 4.3 mg/L

Assuming that waste sludge production volume by addition of coagulant is 5 times as Additional phosphorus volume.

Waste sludge production volume by addition of coagulant = QD ×5 × CAL × 10^{-6}

= 115,000 × 5 × 4.3 × 10^{-6} = 2.48 t/day

Waste sludge volume in case of removal of T-N and T-P simultaneously

= 19.11 + 2.48 = 21.59 t/day