Basic Engineering Package

50 MLD STP at Vellore

Based on C-Tech SBR Technology

End User

Vellore City Municipal Corporation, Vellore

Submitted by

M/s. P&C Constructions (P) Ltd.

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SFC-A4-D631-BEP-C-Tech-R0

Technology Provider

SFC Environmental Technologies Pvt Ltd

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ABBREVIATIONS

BOD_5	:	5 Day Biochemical Oxygen Demand (at 20°C)
COD	:	Chemical Oxygen Demand
TSS	:	Total Suspended Solids
VSS	:	Volatile Suspended Solids
NH_4-N	:	Ammoniacal Nitrogen (as N)
TKN	:	Total Kjeldhal Nitrogen (as N)
NO_3-N	:	Nitrate Nitrogen (as N)
TP	:	Total Phosphorous (as P)
SVI	:	Sludge Volume Index
SRT	:	Solids Retention Time
MLSS	:	Mixed Liquor Suspended Solids
MLVSS	:	Mixed Liquor Volatile Suspended Solids
RAS	:	Return Activated Sludge
SAS	:	Surplus Activated Sludge
W	:	Working
S	:	Standby
SS	:	Store Standby

INTRODUCTION

Vellore City Municipal Corporation, Vellore has placed an order on M/s. P&C Constructions (P) Ltd. for Design, Supply, Construction, Installation, and Commissioning of 50.0 MLD capacity Sewage treatment plant using Sequential Batch Reactor (SBR) Technology at Vellore.

M/s. P&C Constructions (P) Ltd. is sourcing the Cyclic Activated Sludge Technology (C-Tech) component of the STP from SFC Environmental Technologies Pvt. Ltd. SFC is a global wastewater treatment technology company. It has it's headquarter in Mumbai with group companies in various parts of the world. SFC holds the patent rights of C-Tech process. This technology is extensively used for treatment of domestic sewage and industrial wastewater to highest possible quality at a very low cost of treatment and by using minimum space. There are numerous plants working worldwide and in India based on this technology.

This is the Basic Engineering Package for the C-Tech system.

DESIGN BASIS

A BASIS OF DESIGN

1 Flow

a	Average Flow	=	50.00	MLD
		=	2083.33	m^3/hr
		=	0.579	m^3/sec
b	Peak Factor	=	2.25	
c	Peak flow = a x b	=	4687.50	m^3/hr
		=	1.303	m^3/sec

2 RAW SEWAGE CHARACTERISTIC

(Pre-bid Reply No. 36)

		Raw Sewage Quality	Average Design Parameters	Unit
BOD_5	=	250-325	287.5	mg/l
COD	=	400-700	550	mg/l
TSS	=	200-300	250	mg/l
TKN (as N)	=	30-45	45	mg/l
TP (as P)	=	5-10	7.5	mg/l

3 DESIGN QUALITY OF TREATED SEWAGE

BOD_5 @ 20° C	≤	10	mg/l
COD	≤	50	mg/l
TSS	≤	10	mg/l
TN (as N)	≤	10	mg/l
TP (as P)	≤	2	mg/l

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Note:

1. *Any variation in the Inlet Design Parameters as mentioned above may affect the performance of the System.*
2. *There should be no ingress of industrial effluent with the sewage.*
3. *Oil and Grease at the inlet of the C-Tech basin should be less than 10 mg/L, accordingly suitable Oil and Grease removal system should be provided before C- Tech basin.*

PROCESS DESCRIPTION

Raw sewage after primary treatment (Fine Screens and Grit Chambers) is taken to C-Tech Basins by gravity.

C-Tech is a Cyclic Activated Sludge process technology which is the latest and 4th generation of Sequential Batch Reactor (SBR) process. The C-Tech system specifically refers to the use of variable volume treatment in combination with a biological SELECTOR and OXYGEN UPTAKE RATE (OUR) control, which is operated in a fed-batch reactor mode. The Cyclic Activated Sludge process technology represents a certain technical development of a process philosophy over conventional SBR technology.

The incorporation of a multi cell biological Selector in the front – end of the System distinguishes it from all other technologies (Generic SBRs). The raw sewage enters the Selector Zone, where anoxic-mix conditions are maintained. Also, a part of the treated effluent along with activated sludge from the Aeration Zone is recycled here using Return Activated Sludge (RAS) Pump. As the microorganisms meet high BOD and low DO condition in the Selector Zone, natural selection of predominantly floc-forming microorganisms takes place. This is very effective in containing all of the known low F/M bulking microorganisms, which eliminates problems of sludge bulking and sludge foaming. This process ensures excellent settling characteristics of the biological sludge. Also, due to the anoxic / anaerobic conditions in the Selector Zone, De-nitrification and Phosphorous removal occurs.

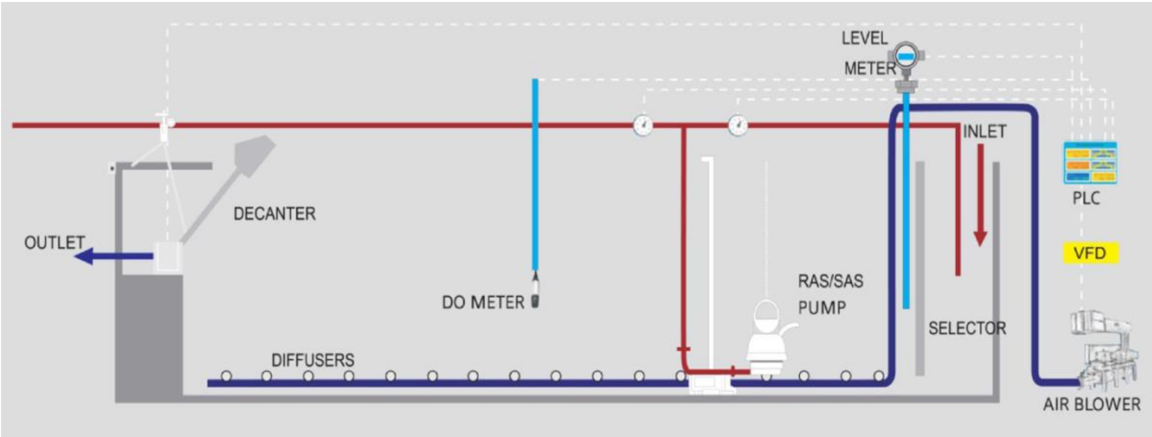


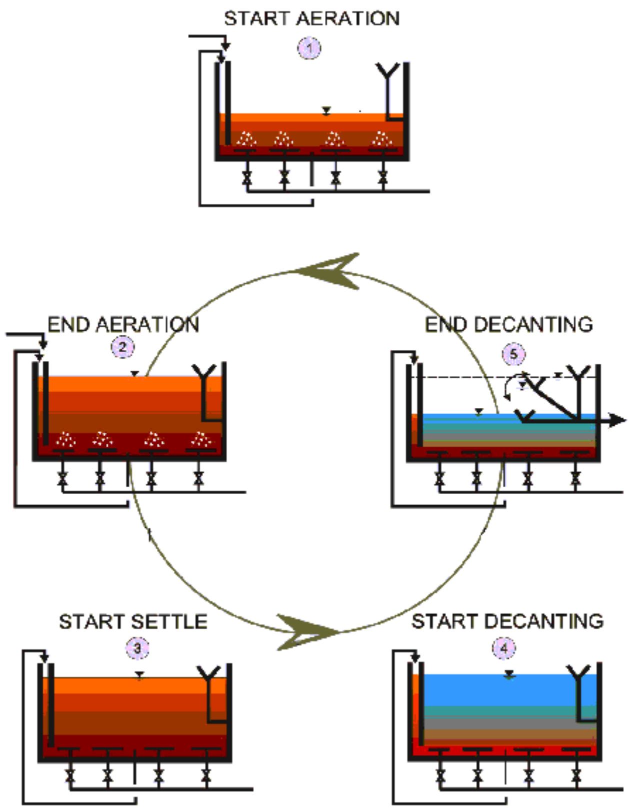
Fig 1. Components of C-Tech SBR System

There are four operating C-Tech basins in the plant. These C-Tech basins work in sequence and the influent flow is distributed using Automatic Gates provided at the Inlet Chamber of C-Tech basins. The C-Tech basins are equipped with air blowers, diffusers, Return Activated Sludge (RAS) pumps, Surplus Activated Sludge (SAS) pumps, Decanters, Auto valves, Programmable Logic Controller (PLC) etc. All cycles will be automatically controlled using PLC.

The complete biological treatment is divided into Cycles with each Cycle is of 2.5-5 hrs. (3 hrs. in present case) duration, during which all treatment steps take place. A basic Cycle comprises of the following phases which take place independently in sequence to constitute a Cycle and then gets repeated:

- Fill / Aeration (F/A)
- Settling (S)
- Decanting (D)

Cyclic Operation



Fill / Aeration (F/A):

This refers to the process loading time in the cycle. Loading occurs outside of the designated settle and decant sequences during which time influent is received into the basin through an admixture (selector) reactor. Biomass from the main aeration zone is admixed with influent load in the biological selector hydrolysis reactor. Complete-mix reaction conditions prevail in the main reaction zone during this variable volume operational sequence, being typical of a fed-batch reactor operation. Aeration can be regulated to maximize co-current nitrification-de-nitrification that takes place and to insure the aerobic uptake of phosphorus previously released during anaerobic operation. The process typically employs a nominally constant rate of recycle from the main reaction zone that is pumped to a zone at the inlet end of the admixture reactor.

Settling (S):

The air is turned off and influent to the reactor basin is stopped. During the first five minutes of this sequence, the residual mixing energy within the reaction basin is consumed. At this time, gentle bio-flocculation initially takes place and solids-liquid interface forms under partial hindered settling conditions. Rising sludge does not occur.

Decanting (D):

This sequence is an extension of the settle sequence and is also totally quiescent whereby a moving weir lowering decanter is used to take the operating liquid level in the basin to its designated bottom water level reference position. In this way supernatant is withdrawn from a subsurface position under laminar flow conditions. This allows optimum removal over the decant depth without entrainment of settled solids or floating debris. Upon completion of the supernatant liquid removal sequence, the moving weir decanter returns to its rest position located out of liquid. Completion of the decant sequence terminates the designated use of the basin as a stratified, interrupted inflow reactor. Typically, fill sequencing begins while the decanter is travelling to its upper rest position.

Excess sludge at a consistency level of approx. 0.8 % will be pumped intermittently from SAS pump to the Sludge Sump. The sludge from Sludge Sump is taken for dewatering and finally for its ultimate disposal.

BOD REMOVAL, CO-CURRENT NITRIFICATION & DENITRIFICATION AND ENHANCED PHOSPHORUS UPTAKE IN AERATION ZONE

BOD Removal

The aeration zone of C-Tech is provided with diffused aeration system to oxidize the organic matter by activated sludge.

The activated sludge in aeration zone is capable of converting most organic wastes to stable inorganic forms or to cellular mass. In this process, the soluble and colloidal organic material is metabolized by a diverse group of microorganisms to carbon dioxide and water. At the same time, a sizeable fraction of incoming organic matter is converted to cellular mass that can be separated from the effluent by settling.

Activated sludge comprises a mixed microbial culture wherein the bacteria are responsible for oxidizing the organic matter, while protozoa consume the dispersed un-flocculated bacteria and rotifers consume the unsettled small bio-flocs in the treated wastewater, performing the role of effluent polishers.

The utilization of substrate by a bacterial cell can be described as a three-step process:

1. The substrate molecule contacts with the cell wall.
2. The substrate molecule is transported into the cell.
3. Metabolism of the substrate molecule within the cell

However, as the bacteria require the molecule in the soluble form, colloidal, spherically incompatible molecules, which cannot be readily biodegradable, have to be first adsorbed to the cell surface and hydrolyzed or transformed externally to transportable fractions by exo-enzymes or wall-bounded enzymes. The organic matter will be utilized by the bacteria resulting in cell synthesis and energy for maintenance. Nutrients available in the wastewater cater to the nutrient requirements of the aerobic microorganisms and to enhance the activity of the aerobic microbes.

In addition to the nutrient requirements, the aerobic microbes require oxygen to sustain their microbial activity. Oxygen functions as a terminal electron acceptor in the energy metabolism of the aerobic heterotrophic organisms indigenous to the activated sludge process. In other words, a portion of the organic material removed is oxidized to provide energy for the maintenance function and the synthesis function.

The following reactions best describe the organic substrate utilization by the aerobic bacteria:

1. **Oxidation**

   $COHNS + O_2 + Bacteria \rightarrow CO_2 + NH_3 +$ other End Products + Energy

2. **Synthesis**

   $COHNS + O_2 + Bacteria \rightarrow C_5H_7O_2N$ (New Bacterial Cell)

3. **Endogenous Respiration**

   $C_5H_7O_2N + 5O_2 \rightarrow 5CO_2 + NH_3 + 2H_2O +$ Energy

It is to be noted that the activated sludge in C Tech reactor operates in extended aeration mode. An extended aeration activated sludge process operates in the endogenous respiration phase of the growth curve where the microorganisms are forced to metabolize their own protoplasm due to the limited availability of food or substrate. During this phase, the nutrients remaining in the dead cells diffuse out to furnish the remaining cells with food. This system has been developed for application where minimum bio-solids production is desirable. Less solids production is achieved by using a larger fraction of the entering organic material for energy rather than for synthesis. This means that more oxygen will be consumed per unit mass of organic material removed.

Nitrification

Extended Aeration system, with high sludge retention time (θ_c) and DO > 2.0 mg/L ensures uniform nitrification. Nitrification results from the oxidation of ammonia present in the sewage by Nitrosomanas to nitrite and the subsequent oxidation of the nitrite to nitrate by Nitrobacter. The nitrifying organisms are strict aerobes and require more than 2 mg/L DO in the C-Tech basin to avoid oxygen limitation. The nitrification of ammonia can be represented as given below:

$$2\,NH_4^+ + 3O_2 \xrightarrow{\text{NITROSOMONAS}} 2NO_2^- + 2\,H_2O + 4\,H^+ + \text{New Cells}$$

$$2\,NO_2^- + O_2 \xrightarrow{\text{NITROBACTOR}} 2NO_3^- + \text{New Cells}$$

The diffused aeration system is sized in such a way that sufficient oxygen is provided for carbonaceous oxidation, sludge stabilization, nitrification by maintaining the DO at the specified level of 2 mg/L. The capacity of diffused aeration in each C-Tech basin will be sufficient to ensure good and uniform mixing conditions during Fill - Aeration phase of the cycle of operation.

Denitrification:

The process of denitrification of nitrates is represented as:

$$NO_3^- + BOD \rightarrow N_2 + CO_2 + H_2O + OH^- + \text{cells}.$$

Denitrification releases nitrogen which escapes off as an inert gas to the atmosphere.

Co-Current Nitrification and denitrification

A balanced process is achieved and regulated by online-measuring of the specific oxygen uptake rate in the basin in such a way that the floc reaction profile allows for nitrification at the peripheral sections and denitrification at the inner parts of the floc as shown in Figure below.

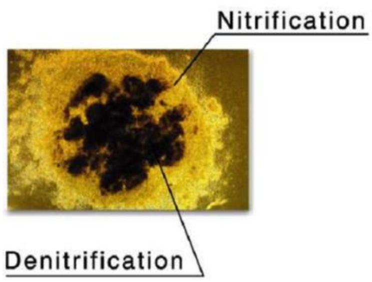


Fig.: Representative view of a sludge floc under a light microscope with suggested zones for co-N/DN

Nitrate penetration is governed by its rate of diffusion which is of the order of ten times that of dissolved oxygen. Under aerated conditions there is typically no nitrate limitation in the interior zone of the floc. Sufficient carbon provision for denitrification is achieved through the carbon storage (biosorption) mechanism and the proportional DO demand regulation which minimizes the use of substrate carbon by oxic metabolization. The process can be regulated such that during the aeration phase there is nitrification and also denitrification taking place within the flocs. Denitrification also takes place during settling phase. Rising of activated sludge due to nitrogen gas bubbling does not occur as during the relatively short time cycles only low concentrations of nitrate nitrogen have to be denitrified in each cycle.

Process control using in-basin respiration enables a direct control over biological phosphorus removal.

Enhanced Phosphorous Uptake

In aerobic zone PHB metabolized, providing energy from oxidation and carbon for new cell growth. The energy released from PHB oxidation to form polyphosphate bonds in cell storage so that soluble orthophosphate is removed from solution and incorporated into polyphosphates within the bacterial cell. As biomass is wasted after settling, stored phosphorus is removed from the reactor for ultimate disposal with the waste sludge.

PROCESS DESIGN CALCULATIONS

1.0 Basis of Design

a.	No. of Basins	=	4	Nos.
b.	MLSS	=	4500	mg/L

As per CPHEEO Manual (Pg. no. 5-198) value is 3500 to 5000 mg/L.

c.	F/M	=	0.135	**d^{-1}**

As per CPHEEO Manual (Pg. no. 5-198) F/M of SBR system varies from 0.05 to 0.3 d-1

d.	Sewage Temperature	=	25	°C

Considering the Geographic location and Climatic conditions at site, the minimum sewage temperature of 25°C is considered for design of STP

e.	MLVSS/MLSS ratio	=	0.7	
f.	DO in basin	=	2	mg/L
g.	Altitude of site	=	216	m
h.	Humidity	=	75	%
i.	Ambient Air Temperature	=	45	^{O}C

2 C-Tech Operating Cycle

a.	Filling and Aeration Phase (T_{FA})	=	1.5	hrs.
b.	Settling phase (T_S)	=	0.75	hrs.
c.	Decant Phase (T_D)	=	0.75	hrs.
d.	Total Cycle Time (T_C) = a + b + c	=	3	hrs.

For the design of present STP, a Cycle time of 3 hrs. is considered as design basis. As per CPHEEO Manual (Pg. no. 5-198) standard cycle time lies in the range of is 2.5–6 hrs.

e.	No of Cycles Per day/basin = 24/d	=	8	Nos.
f.	Hours of aeration time/day/basin = a x e	=	12	hrs.
g.	No. of basins receiving flow simultaneously	=	2	Nos.
h.	No. of basins aerating simultaneously	=	2	Nos.
i.	No. of basins decanting simultaneously	=	1	Nos.
j.	Average flow rate	=	2083.33	m^3/hr.
k.	Average flow rate to each basin = j/g	=	1041.67	m^3/hr.

C-Tech Basin Operating Sequence

Time, Hrs. →												
	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
Basin - 1	F/A	F/A	F/A	F/A	F/A	F/A	S	S	S	D	D	D
Basin - 2	S	S	S	D	D	D	F/A	F/A	F/A	F/A	F/A	F/A
Basin - 3	D	D	D	F/A	F/A	F/A	F/A	F/A	F/A	S	S	S
Basin - 4	F/A	F/A	F/A	S	S	S	D	D	D	F/A	F/A	F/A

F/A	Fill and Aeration Phase
S	Settling phase
D	Decanting Phase

3.0 Calculation of SBR Volume & HRT

3.1 Calculation of SBR Volume

a.	Daily flow	=	50000	m^3/d
b.	Inlet BOD_5	=	287.5	mg/L
c.	MLSS	=	4500	mg/L
d.	MLVSS/MLSS ratio	=	0.7	
e.	MLVSS = c × d	=	3150	mg/L
f.	F/M	=	0.135	
g.	Total volume of basins = (a×b)/(e×f)	=	33803.64	m^3
h.	No. of basins provided	=	4	Nos.
i.	**Volume of single basin required= g/h**	**=**	**8450.91**	**m^3**

3.2 Fill Volume and C-Tech Area Requirement

a.	Peak Flow rate	=	4687.50	m^3/hr
b.	No. of basins receiving flow simultaneously	=	2.00	Nos.
c.	Flow rate per basin = a/b	=	2343.75	m^3/hr
d.	Fill/Aeration Time	=	1.50	hrs.
e.	Fill volume per basin =c × d	=	3515.63	m^3
f.	Decant depth Considered	=	**2.40**	m
g.	Basin surface area required for assumed decant depth = e/f	=	1464.84	m^2
h.	Length Provided	=	**45.00**	m
i.	Width required = g/h	=	32.55	m
j.	Width provided	=	**33.00**	m
k.	Area of single basin provided = h × j	=	1485.00	m^2
l.	No. of basins provided	=	4.00	Nos.
m.	Total Basin area provided = k × l	=	**5940.00**	m^2

Peak Flow Handling Capacity of C-Tech SBR Basins

As presented in above calculation, the C-Tech basins are designed to take care of flow variations like peak flow, average flow and lean flow spanning over a day. SBR basins have variable water level with varying levels between TWL (Top Water Level) and BWL (Bottom Water Level). The maximum water level of the basin is achieved when the plant receives peak hydraulic capacity. The peak flow is preceded and succeeded by lean flow. As per flow variations in the feed to SBR basins, the water varies between TWL & BWL. As SBR is a batch process, whatever flow enters the basin; it is contained within the basin (as there is no outflow during inlet/filling time) and treated over a longer period. Therefore, the decanting system decants only at average flow in any cycle. Each SBR basin is equipped with level transmitter and each decanter mechanism is equipped with position sensor and level sensor. Based on the signals received from level transmitter, position sensor and level sensor, the decanting rate is controlled through PLC system to discharge at average flow.

3.3 Calculation of SWD

a.	Volume of Basin Required	=	8450.91	m^3
b.	Area of Basin Provided	=	1485.00	m^2
c.	SWD of Basin required = a/b	=	5.69	m
d.	SWD of Basin Provided	=	**5.70**	**m**

3.4 Provided Volume of SBR

a	Length of SBR Provided	=	45.00	m
b	Width of SBR Provided	=	33.00	m
c	Depth of SBR Provided	=	5.70	m
d.	Total volume of basin provided = a × b × c	=	8464.50	m^3
e.	No. of Basins	=	4.00	Nos.
f.	Total volume of basins provided = d x e	=	33858.00	m^3

3.5 Calculation of HRT

a.	Total volume of basins provided	=	33858.00	m^3
b.	Daily flow	=	50000.00	m^3/d
c.	**HRT = a/b × 24**	**=**	**16.25**	**hrs.**

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IMPORTANCE OF BIOLOGICAL SELECTOR

The incorporation of a biological SELECTOR in the front zone of the C-Tech Systems distinguishes it from all other technologies. This is very effective in containing all of the known low F/M bulking microorganisms, eliminates problems of bulking and foaming. This process ensures excellent settling characteristics of the sludge. SVI < 100 is achieved in all seasons. The figure below shows the experience with SVI developments in a C-Tech plant with municipal sewage with SVI in the range of 25 to 60 mL/g that is observed over a period of over 240 days. Due to the anaerobic conditions in the SELECTOR zone, phosphorous release also occurs.

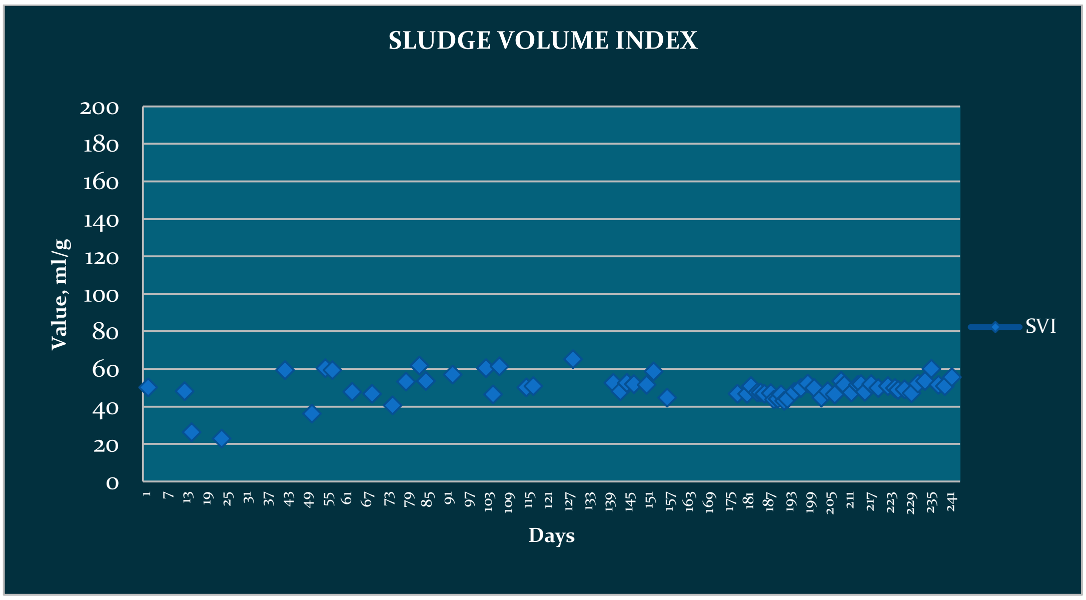

Fig: SVI of a C-TECH plant

Selector Functioning

The wastewater enters into the selector zone from the front end of the C-Tech reactor, where anoxic/anaerobic conditions are maintained. In addition, return sludge from the aeration basin is also recycled using RAS pumps. As microorganisms meet high BOD, low DO conditions in the selector zone, natural selection of Phosphate Accumulating Organisms (PAOs) and floc-forming microorganisms takes place. This is very effective in containing all of the known low F/M bulking microorganisms and eliminates the problems of bulking and surface foaming. Also, due to the anoxic/anaerobic conditions in the selector zone, phosphorous release occurs. During anaerobic conditions, acetate is produced by fermentation of organic matter in the wastewater. Using the energy available from stored polyphosphates, the phosphorus accumulating organisms (PAOs) assimilate acetate and produce intracellular Polyhydroxybutyrate (PHB) storage products. Concurrent with the acetate uptake is the release of phosphate. The PHB content in the PAOs increases while the polyphosphate decreases. Simultaneously with the phosphorus release some denitrification also takes place in selector.

4.0 RECIRCULATION FLOW REQUIREMENT AND SELECTOR SIZING

4.1 RECIRCULATION FLOW

1	Recirculation Flow			
a	Recirculation Ratio provided	=	25.0%	of Feed Flow per Basin
b	Feed Flow to each Basin	=	1041.67	m^3/hr
c	Recirculation Flow required = b x a	=	260.42	m^3/hr
d	Capacity of Return Activated Sludge (RAS) Pump provided	=	**265.00**	**m^3/hr**

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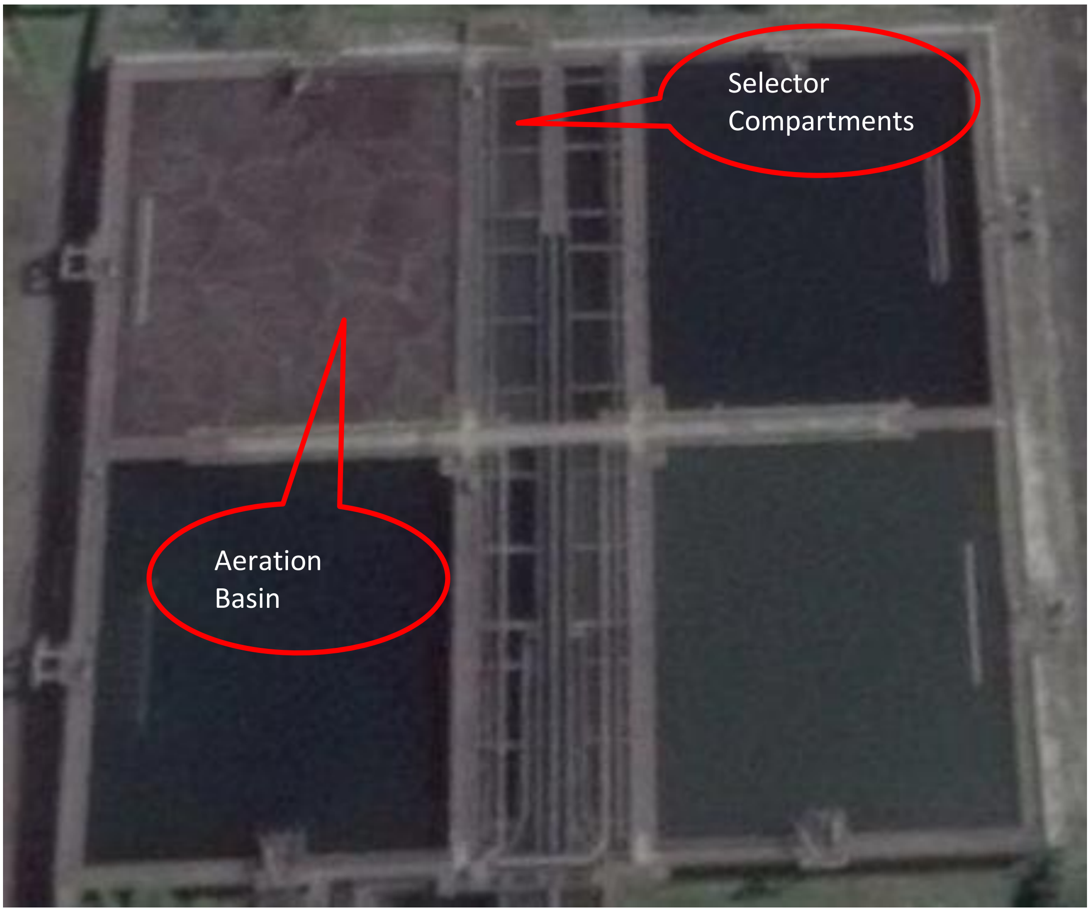
4.2 SELECTOR ZONE

A	Design Flow = Feed Flow + Recirculation Flow	=	1306.67	m^3/hr
	As per Metcalf & Eddy, Wastewater Engineering Treatment and Reuse, pg. no, 701, Selector retention time varies from 20 to 60 min.			
B	Hydraulic Retention Time HRT) provided at Design Flow	=	55.0	min
C	Volume required = (A x B) / 60	=	1197.78	m^3
D	No. of Sub-Compartments provided per Basin	=	**6**	No.
E	Side Water Depth (SWD) provided	=	**5.70**	m
F	Length provided	=	**45.00**	m
G	Width required = C / (F x E)	=	4.67	m
H	Width provided	=	**5.00**	m
I	Volume provided = F x H x E	=	1282.50	m^3



SLUDGE GENERATION

5.0 Total Sludge Generation

5.1 Biological Sludge Generation

A	Specific Sludge Yield	=	0.59	Kg/Kg BOD removed
B	BOD removed	=	13,875	Kg/day
C	Biological Sludge generated = B x A	=	8,186	Kg/day

5.2 Phosphorous Removal

a.	Plant Flow	=	50.00	MLD
b.	Influent Phosphorous	=	7.5	mg/L
c	Phosphorous in effluent	=	2	mg/L
d.	Daily phosphorous load = a × b	=	375.00	Kg/d
e	Phosphorous assimilation in biomass	=	2.5%	Inlet BOD_5
f.	BOD Removal	=	277.5	mg/L
g.	Biological Phosphorous removal = e × f	=	6.90	mg/L
h.	Phosphorous remaining = b – g	=	0.6	mg/L
		≤	2.0	mg/L

5.3 Total Sludge Generation

a.	Biological Sludge generated	=	8,186	Kg/day

5.4 Calculation of SAS pump Capacity

a.	Total Sludge Produced	=	8,186	Kg/day
b.	No. of Basins provided	=	4	Nos.
c.	Sludge to be Wasted per Basin = a / b	=	2,047	Kg/day
d.	No. of Cycles	=	8.0	Cycles/day/ Basin
e.	Sludge to be Wasted per Cycle per Basin = c / d	=	256	Kg/day
f.	Solids Consistency in the Wasted Sludge	=	0.80%	
g.	Specific gravity of sludge	=	1.05	
h.	Volume of Sludge to be Wasted per Cycle per Basin = e / (f X g x 1000)	=	30.5	m^3
i.	Considering Running Time of Surplus Activated	=	10	min

	Sludge (SAS) Pump per Cycle			
j.	Capacity of SAS Pump required= (h x 60) / i	=	182.7	m^3/hr
k.	Capacity of SAS Pump provided	=	**185**	**m^3/hr**

5.5	**Calculation of SRT**			
a	Total Volume of SBR	=	33858	m^3
b	MLSS	=	4500	mg/L
c	Sludge Generated	=	8186	Kg/day
d	Solids Retention Time (SRT) provided = (a x b) / (c x 1000)	=	**18.70**	**days**

DESIGN OF AERATION SYSTEM

Fine Bubble Diffusers for Aeration

The aeration system can be thought of as the heart of the C Tech system. The system uses high quality fine bubble membrane diffusers for aeration. The system has highest oxygen transfer efficiency which can yield substantial cost savings and the membrane material is advanced quality PU which promotes extended diffuser life.

6.0 Oxygen Calculation:

A	Volume of sewage treated	=	50000.00	m^3/d
B	Theoretical Kg O_2 required per Kg BOD	=	1.20	-
C	Inlet BOD_5	=	287.50	mg/l
D	Outlet BOD_5	=	10.00	mg/l
E	BOD_5 removed = C - D	=	277.50	mg/l
F	Kg of BOD removed in a day = A x E / 1000	=	13875.00	kg/d
G	KgO_2 reqd. for BOD load = B x F	=	16650.00	kg/d
H	Inlet Total Kjeldhal Nitrogen	=	45.00	mg/l
I	Outlet Ammoniacal Nitrogen	=	0.70	mg/l
J	Nitrogen assimilated during BOD removal = (5/100) x E	=	13.88	mg/L
K	Outlet Nitrate Nitrogen	=	3.00	mg/l
L	NH3-N removed in a day = H – I – J	=	30.43	mg/l
M	Kg O_2 required per Kg of NH_3-N	=	4.56	-
N	Kg of NH_3-N removed in a day = A x L/1000	=	1522.00	kg/d
O	KgO_2 reqd. for NH_3-N removal = M x N	=	6940	kg/d
P	KgO_2 released per Kg of Nitrate-Nitrogen during denitrification	=	2.86	-
Q	Kg of Nitrate-Nitrogen generated = A x L / 1000	=	1521.30	kg/d
R	Kg of Nitrate Nitrogen in the Treated Sewage = A x K / 1000	=	150.00	kg/d
S	Quantity of Nitrate Nitrogen available for Denitrification = Q - R	=	1371.30	kg/d
T	**Assuming Denitrification as % of available Nitrate Nitrogen**	=	75%	

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U	Quantity of Nitrate Nitrogen that is denitrified = S x T	=	1028.48	kg/d
V	KgO_2 released during Denitrification = P x U	=	2941.50	kg/d
W	**Total KgO_2 required/d = G + O – V**	**=**	**20648.9**	**kg/d**

7.0 STANDARD OXYGEN TRANSFER REQUIREMENT (SOTR) CALCULATIONS

A	Actual Oxygen Transfer Rate (AOTR) under field conditions	=	20,648.9	Kg/day

B As per Equation 5-55, Pg No 429, Wastewater Engineering - Treatment and Reuse, Metcalf & Eddy….. **Standard Oxygen Transfer Rate (SOTR) in Tap Water at 20 ^{0}C and Zero Dissolved Oxygen: = AOTR ÷ [(($\beta C'_{S,T,H}$ – C_L) ÷ $C_{S,20}$) x $1.024^{(T-20)}$ x α x F]**

Where,

AOTR = Actual Oxygen Transfer Rate under field conditions	=	20,648.9	Kg/day

As per Pg No 429, Wastewater Engineering - Treatment and Reuse, Metcalf & Eddy…..

$C'_{S,T,H}$: Average Dissolved Oxygen Saturation Concentration in Clean Water in Aeration Tank at Temperature 'T' and Altitude 'H'

= $C_{S,T,H}$ x (1/2) x ((P_d / $P_{atm,H}$)+O_t/21))

T = Sewage Temperature	=	25	^{0}C
H = Altitude of Site	=	216.00	m

As per Equation B-2, Pg No 1738, Wastewater Engineering - Treatment and Reuse, Metcalf & Eddy…..

$C_{S,T,H}$ = Oxygen Saturation Concentration in Clean Water at Temperature 'T' and Altitude 'H':

$C_{S,T,H}$ = $C_{S,T}$ x exp(-(g x M x (z_b - z_a)) / (R x T))

Where,

$C_{S,T}$ = Oxygen Saturation Concentration in Clean Water at Temperature 'T' (Table D, Appendix D Pg No 1745)	=	8.24	mg/l
g = Acceleration due to Gravity	=	9.81	m/s^2
M = Mole of Air	=	28.97	Kg/Kg-mole
z_b = Elevation (Altitude 'H')	=	216.00	m
z_a = Elevation (Altitude Zero)	=	0	m
R = Universal Gas Constant	=	8,314	Nm/Kg-mole.K
T = Sewage Temperature	=	298.15	Kelvin

	Hence, $C_{S,T,H}$	=	**8.04**	mg/l

As per Equation B-2, Pg No 1738, Wastewater Engineering - Treatment and Reuse, Metcalf & Eddy.....

$$\mathbf{P_{atm,H} = P_a \times exp(-(g \times M \times (z_b - z_a)) / (R \times T))}$$

Where,

	P_a = Pressure at Zero Altitude	=	10.33	mWC
	g = Acceleration due to Gravity	=	9.81	m/s^2
	M = Mole of Air	=	28.97	Kg/Kg-mole
	z_b = Elevation (Altitude 'H')	=	216.00	m
	z_a = Elevation (Altitude Zero)	=	0	m
	R = Universal Gas Constant	=	8,314	Nm/Kg-mole.K
	T = Sewage Temperature	=	298.15	Kelvin
	Hence, $P_{atm,H}$	=	**10.08**	
	P_d = Pressure at the Depth of Air Release **= $P_{atm,H}$ + Effective Aeration Depth**	=	14.33	mWC
	O_t = % Oxygen Concentration leaving Tank	=	19.00	
	Hence, $C'_{S,T,H}$	=	**9.35**	mg/l
	C_L: Operating Oxygen Concentration	=	2.00	mg/l
	$C_{S,20}$: Dissolved Oxygen Saturation Concentration in Clean Water at 20^0 C and 1 atm (Table D, Appendix D Pg No 1745)	=	9.08	mg/l
	α: Oxygen Transfer Correction Factor	=	0.65	
	β: Salinity - Surface Tension Correction Factor	=	0.95	
	F: Fouling Factor	=	0.90	
	Hence, SOTR	=	**41,358**	Kg/day
	SOTR per basin per day	=	**10,339.50**	Kg/day/basin
	SOTR per basin per hr.	=	**861.63**	Kg/hr/basin
C	No. of Basins	=	4	Nos.
D	Standard O2 required at Field Conditions per Basin	=	10,340	Kg/day/Basin

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	= B / C			
E	Top Water Level (TWL) in C-Tech Basins	=	5.70	m
F	Bottom Water Level (BWL) in C-Tech Basins	=	3.30	m
G	Aeration Depth	=	4.50	m
H	Height at which Diffusers are kept	=	0.25	m
I	Effective Aeration Depth = G - H	=	4.25	m
J	SOTE for the above Effective Aeration Depth	=	23.30	%
K	Fraction of O_2 in Air	=	23.18	%
L	Density of air at Standard Condition	=	1.293	Kg/m^3
M	Air required at Field Conditions per Basin = D / (J x K x L)	=	1,48,058	Nm^3/day/Basin
N	Hours of Aeration per Basin per day	=	12	hr/day/Basin
O	Air required per hour per Basin = M / N	=	12,338	Nm^3/hr/Basin
P	No. of Operating Air Blowers per Basin	=	**2**	Nos.
Q	Capacity of Air Blowers required = O / P	=	6,169	Nm^3/hr
R	Capacity of Air Blowers provided (at 0 °C & 1 atm.)	=	**6,200**	Nm^3/hr
S	Number of Basins per set of Air Blowers	=	2	Nos.
T	Number of Basins	=	4	Nos.
U	Number of Operating Air Blowers = P x T / S	=	**4**	Nos.
V	Number of Standby Air Blowers	=	**2**	Nos.

8.0 Calculation of Air Flow Requirement for Actual Field Condition.

Air flow	=	6,200	Nm^3/h
Field Temperature, T	=	45	Deg.C
Field Temperature, T	=	318	K
Relative humidity, RH	=	75	%
Altitude, H	=	216	m
Molar mass of water, MH_2O	=	18.02	g/mol
Molar mass of dry air, M_{dry}	=	28.96	g/mol
Water vapour saturation pressure, p_{ws}	=	$e^{(77.3450+0.0057T-7235/T)}/T^{8.2}$	Pa
	=	9482.5	
Atmospheric pressure at given altitude, P	=	exp(-9.81*28.97*Altitude / (8314*(273.15+Field temp.)))*10.33	

	=	10.10	mWC
	=	99046.66	Pa
Partial pressure of water vapour in moist air, p_w	=	$(RH/100)*p_{ws}$	Pa
	=	7111.90	
Humidity ratio, x	=	$0.62198*p_w/(p_a-p_w)$	
	=	0.05	kg/kg
Density of dry air at temp T & altitude H	=	P*9.81/100*28.97/8314/(273.15+T) *10^5	
	=	1.09	kg/m^3
Density of moist air at T & H	=	Density of dry air(1+x)/(1+1.609x)	
	=	1.06	
Air flow at field conditions	=	7567.96	m^3/h
	=	7570.00	m^3/h

DECANTATION

The clear supernatant is removed from the basin using a stainless-steel Decanter. During decanting, there is no inflow to the basin. The moving weir DECANTER is motor driven and travels slowly from its "park" position to a designated bottom water level. Variable frequency drives are provided to control the rate of movement of the Decanters. After the required level of supernatant is removed, the Decanter is returned to its "park" position through reversal of the drive. The basin is now ready for the next cycle to begin. Stainless steel fabrication ensures resistant to corrosion, long equipment life without any/no maintenance.

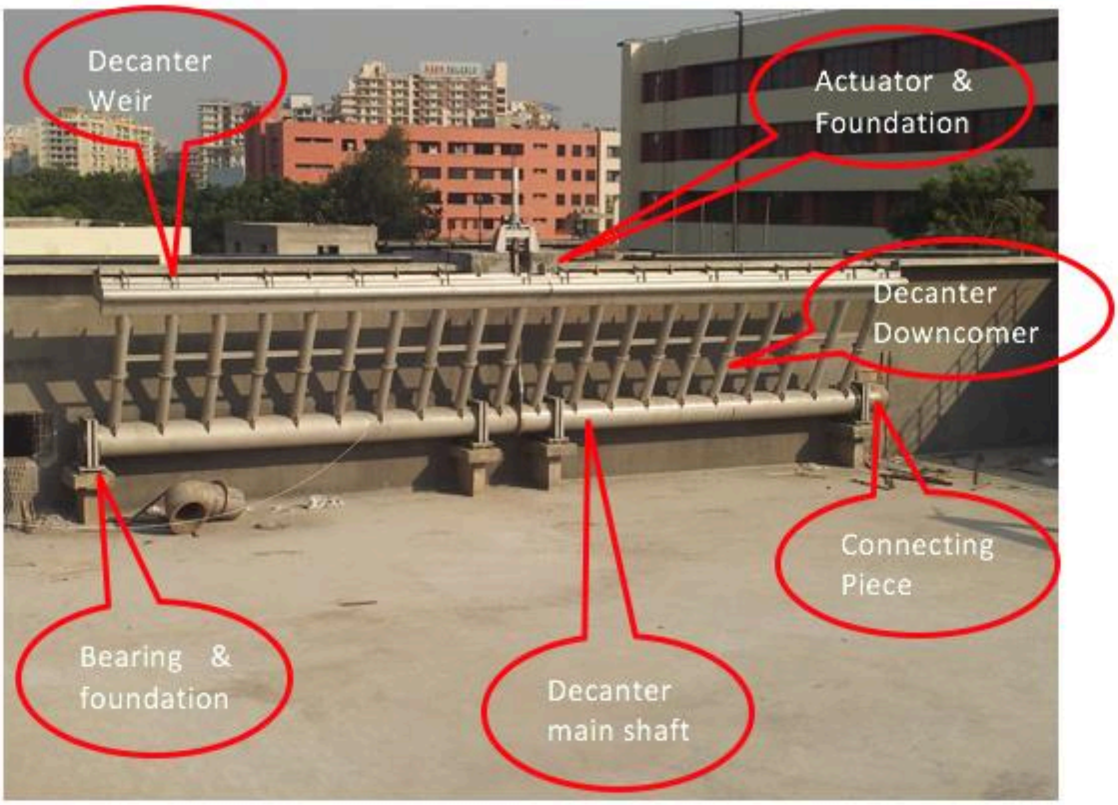

Fig. Pictorial view of Decanter (Image for reference only)

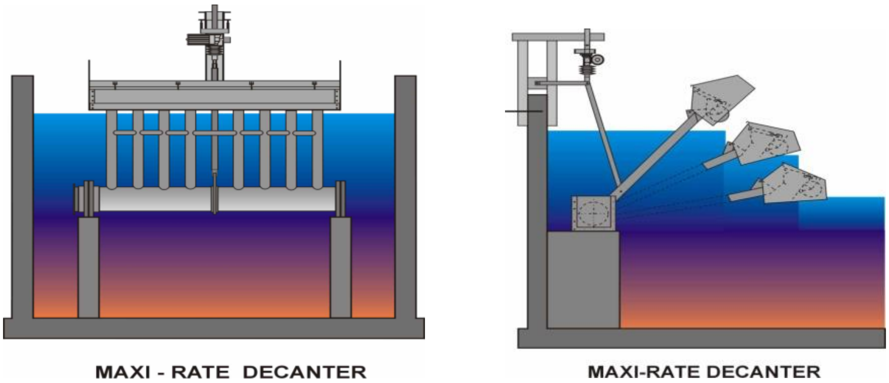

Fig. DECANTER of the C-TECH process

9.0 Decant Flow

Decanting volume shall be equivalent to average fill volume only i.e Decanting will be carried out at average flow rate only.

a.	Average fill volume per basin / cycle = (Avg. flow rate × fill time) / no of basins filling simultaneously.	=	1562.5	m^3
b.	Decanting volume per basin/cycle	=	1562.5	m^3
c.	Decant time	=	0.75	Hr.
d.	Decant Flow = b/c	=	2083.3	m^3/hr

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DESIGN SUMMARY

Parameters		As per BEP	As per Tender/ CPHEEO Manual	Unit
Daily Flow	=	50000	50000	m^3/d
Peak Factor	=	2.25	2.25	
Each Basin Volume	=	8464.50	-	m^3
No. of Basins	=	4.00	-	Nos.
Total Basin Volume	=	33858.00	-	m^3
Total Cycle Time	=	3	2.5-6	Hrs.
HRT	=	16.25	-	Hrs.
MLSS	=	4500	3,500-5,000	mg/L
SRT (θc)	=	18.70	-	days
F/M	=	0.135	0.05-0.3	d^{-1}
Sludge Yield	=	0.59	-	Kg / Kg BOD removed
Total sludge generation per day	=	8,186	-	Kg/d

INSTRUMENT AND CONTROL PHILOSOPHY

The Biological system based on C-Tech Technology will be fully controlled and automatic. Various operations in the basins will be controlled by PLC as follows:

i) Auto - Valve Operation

a) **C-Tech Basin Inlet Gates:** Will on/off automatically based on input from PLC to the Gate to allow inflow of wastewater in the selected basin. Based on the pre-decided cycle time, PLC will command one of the inlet Gates to open and receive the influent for a specified time.

b) **Main Air Header Valves:** Will on/off automatically based on input from PLC to the Valve to allow inflow of air in the Aerating basin. Based on the pre-decided cycle PLC will command one of the valves to open and supply air to the basin for a specified time. This valve will remain open throughout the entire filling and aeration phase of the basin and will remain closed during other phases of the basin.

c) **Selector Air Header Valves:** Will on/off automatically based on input from PLC to the Valve to allow inflow of air in selector area of the basins. Based on the pre-decided cycle PLC will command one of the valves to open and supply air to the basin's selector for a specified time. The valve will be under open condition only when main Air Header Valve is open and will be open for the same basin only.

ii) Instruments

a. **Level Transmitter:** Provides input to PLC about the fill and decanted volume. Also regulates the speed of decanter based on the depth of water to be decanted by controlling the VFD connected to Decanter.

b. **DO analyzer:** Analyses the DO levels in the tank on continuous basis based on which Air Blower rpm is automatically adjusted through connected VFD with help of PLC to maintain set point DO value in the basin.

c. **Decanter Level Positioner:** Limits the upward / downward movement of decanter while basin is under decantation.

d. **Decanter Level Sensor:** Monitors and controls the downward movement of decanter while basin is under decantation.

iii) Equipment

a. **Return Activated Sludge (RAS) Pump:** On / off of the pump is regulated by PLC. The pump starts for the basin, which is receiving the influent in the basin and stops only when aeration cycle for the basin is completed. The pump does not operate during Settling and Decanting phase of the cycle.

b. **Surplus Activates Sludge (SAS) Pump:** On / off of the pump is regulated by PLC for a specified duration in a treatment cycle, during the decanting phase of the cycle.

EQUIPMENT LIST FOR C-TECH SYSTEM

Sr. No.	Description	Specification	Nos.
1.	Inlet Gate to C-Tech basin	Auto Gate	4 Nos.
2.	Air blowers	6200 Nm^3/hr @ 0.67 Kg/cm^2 (At 0 °C & 1 atm.) 7570 m^3/hr @ 0.67 Kg/cm^2 (At Actual Field Condition)	6 Nos. (4W+2SB)
3.	VFD for air blower	Suitable	2 Nos.
4.	Soft Starter for air blower	Suitable	4 Nos.
5.	Diffuser assembly	Fixed Type	1 lot
6.	Decanters with positioner and Drive	Suitable	4 Nos.
7.	VFD for auto rate control of decanters	Suitable	4 Nos.
8.	RAS Pumps	265 m^3/hr @ 5 m. head	6Nos. (4W+2SS)
9.	SAS Pumps	185 m^3/hr @ 10 m. head*	6Nos. (4W+2SS)
10.	Piping and Valves	Suitable	1 Lot
11.	Main Air Header Valve	Auto Butterfly	4 Nos.
12.	Selector Air Header Valve	Auto Butterfly	4 Nos.
13.	Selector Down Comers Valve	Manual Ball	24 Nos.
14.	SAS Pump Discharge	Motorised Knife Gate Valve	4 Nos.
15.	SAS Pump Discharge	Manual Knife Gate Valve	1 No.
16.	Instrumentation and Controls		
a)	PLC and control panel	-	1 No.
b)	DO Transmitter	Fixed Type Optical	4 Nos.
c)	Level Transmitter	Hydrostatic Type	4 Nos.

*** Head to be decided as per actual location of Sludge Sump & Hydraulic**

ANNEXURE I – SOTE CURVE