CYCLIC ACTIVATED SLUDGE TECHNOLOGY: C-TECH STATE of the ART SBR

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INTRODUCTION

Activated sludge processing using a single reactor basin with repeated cyclic sequencing for biological treatment, gravitational solids liquid separation and effluent removal (supernatant decanting) within a variable volume and depth operating boundary is by convention called sequencing batch reactor (SBR) technology (Wilderer, Irvine and Goronszy, 2001). The C-TECH SBR is by definition a true SBR in that inflow during its settle and decant sequencing is interrupted. Together with its fill and or fill-aeration sequencing, C-TECH offers a simple and most reliable method of activated sludge wastewater treatment that produces a tertiary quality effluent at the price of secondary treatment including nutrient removal. Simplifying factors which select C-TECH against other and conventional sequencing batch reactors are:

- The inclusion of a multi cell initial biomass influent admixture reactor volume for the purpose of sequestering soluble COD through enzymatic transfer reactions, hence less energy/kg COD removed.
- Simultaneous nitrification denitrification during aeration sequencing.
- Absence of formal anoxic/anaerobic mixing sequences, hence less equipment.
- Reaction results obtained using shorter time cycles, hence less reactor volume.
- Simplified kinetic and metabolic filamentous sludge bulking control, hence deeper operating decant depth.
- Deeper decant depth and smart decanter operation, hence less footprint.
- Operates as a fed batch reactor.
- Balanced OUR/ORP methodology.

This paper summarizes important aspects of the technology with examples of case histories. The technology, being modular based, is applicable for use over the full spectrum of plant sizes including multi MLD loadings. By way of example a four basin module of 100-125 MLD hydraulic and process capacity (25,000 – 31,250 kg BOD/d) on a footprint of circa 100 m^2/1000 m^3 provides a simple, practical and demonstrated basis for multiple modular replications. Simple flow distribution and modular base multipliers of 2, 3, 4, N are easily applied in practice.

ALL SBRs ARE NOT EQUAL.

A number of systems/variants are offered in the market place under the Sequencing Batch Reactor (Acronym SBR) umbrella, the more common of which are known as (generic, conventional or true) SBR, Cyclic Activated Sludge Technology (Acronym C-TECH), Intermittently Decanted Extended Aeration

Table 1: All SBRs are not equal-a quick snapshot

Sr. No.	Feature	Acronym IDEA	Acronym ICEAS	Acronym C-TECH
1	Year of invention	1969- Outdated	1978-3 Decades Old	1999 - Contemporary
	PROCESS COMPARISON			
2	Influent	Continuous	Continuous	True Batch
3	Discrete process steps to ensure perfect settling and "starving" conditions	Absent	Absent	Present
4	Cycle time	High	High	Low
5	Inbuilt equalization to handle peak flow variations	Absent	Absent	Present
	RAS Pump	Absent	Absent	Present
6	OUR/ORP Control	Absent	Absent	Present
7	Multi Cell Selector	Absent	Absent	Present
8	Level of automation	Low	Medium	High
9	Decant Depth	Low (1.0 m)	Low (1.5 m)	High (2.5 - 3.0 m)
10	Decanter Design	Outdated	3 decades old	Contemporary with intelligent control
11	Diffuser Design	Variable mechanical aerators, tubular & disc	EPDM / Silicon disc diffusers - outdated	Polyurethane Mini Panel /Tubular - most suitable for SBR on - off operation
12	Basin Fill Ratio	0.25	0.30	0.45
	OUTLET PARAMETERS			
13	Performance efficiency	Low	Medium	High
14	Co current Nitrification, De Nitrification and Bio Phosphorous removal	Absent	Absent	High
15	Outlet Quality of treated domestic sewage	BOD <20 mg/L, TSS < 30 mg/L	BOD <20 mg/L, TSS < 30 mg/L	BOD ~5 mg/L, TSS ~10 mg/L
16	SVI_{60} m^3/ kg	150 - 250	150-200	50-80
	OTHER			
17	Land Requirement	High	Medium	Low
18	Power consumption	High	High	Low
19	Operating Cost	High	High	Low
20	Capital cost	High	Medium	Low
21	No. of Installations	Few - Mostly In 1970s To 1980s	Many- Mostly From 1980s To 1995	Many - From 1999 To 2010

(Acronym IDEA), Intermittently Decanted Aerated Lagoon (Acronym IDAL), Intermittent Cycle Extended Aeration System (Acronym ICEAS), Variable Volume Activated Sludge (Acronym VVAS), Cyclic Activated Sludge System (Acronym CASS), Continuously Fed and Intermittently Decanted Activated Sludge (Acronym CFID), all of which cannot be regarded as equal as is often presented (Goronszy, 2010).

Some variants are historically wedded to continuous or semi continuous inflow protocols and typically need to adopt longer cycles and higher retention times for a same level of treatment (generic SBR, IDEA, ICEAS, CASS, IDAL, CFID) as the C-TECH SBR. Others adhere to true batch operation and interrupt inflow for settle and decant sequencing (true SBR, C-TECH). Some have purpose and advanced engineering and development of the decanters (C-TECH). Others additionally include highly efficient multi cell selectors in their configuration (C-TECH), which result in tangible savings in land, power use, containment of filamentous sludge bulking and operational simplicity over other variant and generic SBRs. All of which are major factors in any process selection procedure which has made C-TECH more suited to medium to large scale application (> 100 MLD). Most of all, the absence of nuisance and other mal odors are typically a feature of these facilities.

THE SELECTOR

Together with the ORP/OUR process based methodology, the multi cell “selector" plays a very important role in the C-TECH SBR configuration. A selector is defined as the initial part of a bioreactor, designed to remove soluble COD and provide micro organism selectivity, which assists in enhanced biodegradation. Operation with continuous fill in the settle and decant sequencing of a batch reactor, as in IDEA, ICEAS, IDAL, is more an efficient or reliable method of selecting for the growth of filamentous micro organisms.

In the "selector" a pumped flow of biomass from the main basin is exposed to a high substrate concentration during each fill sequence. It is specifically designed and sized (Goronszy 1987) to ensure that floc forming micro organism growth is not disadvantaged by limited substrate availability in the SBR operation. This feature enables optimization of cycle time aeration and ensures a favourable growth environment for floc forming micro organisms under all diurnally (substrate) varying conditions. Pumped biomass or RAS is essential as it rapidly entraps the particulate and colloidal material in the wastewater and converts soluble organics to biologically mediated storage compounds (e.g. poly-B-hydroxybutyric acid; PHB). A plug flow hydraulic regime is provided in the selector with baffles which eliminate the use of mechanical mixers. The "selector" is an essential and differentiating component of the biological process in the C-TECH SBR configuration.

SLUDGE CLOUD PHENOMENA IN CONTINUOUS INFLOW SBR‘s

Sludge cloud phenomena (flow of entrained settled solids through underflow partial baffle wall transport or other diffuser pipe work towards the decanter) are typical issues associated with ICEAS SBRs and others that feature cyclic operation with influent flow during settle and decant sequences. Systems operating with inflow during settle and decant are typically disadvantaged by lesser effluent quality, basin dimensioning and/or lower decant depths and rate of effluent removal.

DECANTING

The design and capacity of the decanter has a major influence on the rate at which treated effluent can be removed from a basin. Clearly a basin design that is governed by a shallow decant depth has to be less efficient in the use of plant footprint than a design that is not similarly limited. Irrespective of other design issues, a decant limited effective depth of less than circa one metre, including submerged or fixed position decanters, will result in at least a doubling of the basin footprint when compared with other more efficient designs. For the same or similar quality of final effluent, shallow depth decanting is not considered suitable for modern medium to large scale SBR systems in which the typical operating decant depth needs to be significantly deeper than two metres. C-TECH SBR configuration fulfils this role.

The C-TECH decanter is specifically designed to be positively free of entrained settled and surface (floating) solids at all times. It has a variable speed and decreasing rate of discharge at lower depths allowing the decant operation to be up to 3 m depths. At 500-1,0000 m^3/m, these are the most successfully efficient decanter designs currently available and operate as a rotating drum shaft connected to a shaped weir trough via multiple downcomers. Programming logic and PLC / SCADA controls allow synchronous operation of multiple decanters resulting in enhanced configuration benefits.

C-TECH CASE HISTORIES

Influent/effluent data, as mean monthly average values, are summarized in Tables 2, 3, and 4 and show representative information at approximate design hydraulic loading conditions. The STPs in Table 2 have been operating for close to six months. Tables 3 and 4 demonstrate the performance of a four basin module in its third and fourth year of operation over a range of volumetric loadings 0.43-0.77 kg BOD/m^3; reflecting mean loadings of 16,000 to 29,000 kg BOD/d for which the design ADWF basis was 90,000 m^3/d, BOD 22,500 kg/d and a TWL volumetric loading of 0.6 kg BOD/m^3.

CONCLUSIONS

Currently a number of SBR variants are available in the market, each having different designs which were suitable for the time and purpose for which they were designed. When making an optimum process selection the various aspects as highlighted in this summary article should be considered to achieve the required result and basic purpose on any effluent or sewage treatment facility. The principle and advantage of better sludge settling leading to deeper available decant depth (volume) and a smaller basin foot print is obvious. Through innovation, the failings of the generic SBR have been corrected in a way in the new age C-TECH SBRs that simplifies the whole operation of SBR activated sludge processing allowing the use of shortened cycles. Data as presented represents mean monthly loading conditions. This methodology achieves best performance generating a typical SVI of circa 50-80 m^3/ kg. The treatment uncertainty factor in such systems (C-TECH) is minimized as the high outlet quality of BOD < 5 mg/L, COD <30 mg/L, TSS<10 mg/L, NH_3N< 2mg/L, TN<10 mg/L and phosphorus < 1 mg/L as reported in this paper demonstrates.

ABOUT THE AUTHOR

Mervyn Goronszy, Specialist Consultant and the author of this paper, has wide experience in the research, development and application of Sequencing Batch Reactor Technologies since 1969. This material is taken from an invited paper for the Mumbai Indian Institute of Technology. His pioneering and innovative contributions to the waste water treatment industry and SBRs are well known.

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Figure 1: KAHRGHAR STP 4 BASIN MODULE, 25 MLD design

Figure 2: NERUL STP 3 X 2 BASIN MODULES, 100 MLD design

Table 2: Mean monthly influent effluent summary for three selected Indian C-Tech plants under approximate design hydraulic loading

30 MLD BANER STP,PUNE

	MONTH 1		MONTH 2		MONTH 3		MONTH 4		MONTH 5	
FLOW (m^3/d)	23,480		20,430		20,440		25,330		25,365	
	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff
BOD (mg/L)	121	5	110	5	109	5	86	5	78	5
COD(mg/L)	323	22	287	16	286	16	234	20	211	17
TSS(mg/L)	204	7	210	6	210	6	187	6	180	6
T ^{0}C	28		28		28		26		27	

25 MLD KAHRGHAR STP,NAVI MUMBAI

	MONTH 1		MONTH 2		MONTH 3		MONTH 4		MONTH 5	
FLOW (m^3/d)	25,225		25,685		24,390		24,840		25,250	
	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff
BOD (mg/L)	125	3	124	3	116	3	134	3	86	3
COD(mg/L)	315	33	315	36	298	34	339	35	216	26
TSS(mg/L)	180	7	173	7	176	7	178	7	146	6
NH_3N (mg/L)	11	1	12	1	11	1	11	1	9	0
T ^{0}C	27		29		30		31		30	

45 MLD MUNDHWA STP,PUNE

	MONTH 1		MONTH 2		MONTH 3		MONTH 4		MONTH 5	
FLOW (m^3/d)	44,160		36,820		43,510		36,940		30,130	
	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff	Inf	Eff
BOD (mg/L)	130	7	136	7	120	8	119	9	119	8
COD(mg/L)	322	27	311	27	244	30	269	31	261	29
TSS(mg/L)	251	10	191	10	141	9	125	10	156	9
T ^{0}C	26		27		30		27		27	

Table 3: Summary of mean monthly influent parameters for 4 basin module; design basis 22,500 kg BOD/d and 90,000 m^3/d

Parameter	Jul-3rd year	Aug-3rd year	Sep-3rd year	Oct-3rd year	Nov-3rd year	Dec-3rd year	Feb-4th year	Mar-4th year	Apr-4th year	May-4th year	Jun-4th year	Jul-4th year
BOD, mg/L	180	205	195	180	145	145	162	193	269	238	222	173
COD, mg/L	340	360	315	320	290	275	330	359	431	406	437	325
TSS, mg/L	180	195	155	165	155	140	177	207	277	259	260	155
NH_3-N, mg/L	22.4	23.2	21.4	23.1	22.4	22.1	26.8	25	24.5	22.1	25.6	27.1
NO_3-N, mg/L	2.5	3.1	2.8	2.9	2.5	2.6	3.1	2.9	3.2	2.5	2.5	2.7
Oil and Grease, mg/L	8.4	8.6	8.2	8.5	9.0	8.0	8.6	8.5	8.9	10.1	9.7	10.9
TP, mg/L	6.7	9.8	8.1	7.7	7.6	6.8	6.7	5.1	9.3	5.9	6.2	5.6
pH	6.3 - 7.0	6.2 - 7.2	6.5 - 7.2	6.5 - 7.4	6.5 - 7.2	6.5 - 7.2	6.6 - 6.7	6.6 - 6.8	6.6 - 6.8	6.6 - 6.8	6.5 - 7.2	6.5 - 7.1
Flow m3/d	102790	98090	85710	101790	-	-	98850	111580	110310	97750	-	-

Figure 3: JELUTONG STP 3 x 4 BASIN MODULES; 22,500 kg BOD/d and 90,000 m^3/d EACH MODULE DESIGN

Table 4: Summary of mean monthly effluent parameters for 4 basin module; design basis 22,500 kg BOD/d and 90,000 m^3/d

Parameter	Jul-3rd year	Aug-3rd year	Sep-3rd year	Oct-3rd year	Nov-3rd year	Dec-3rd year	Feb-4th year	Mar-4th year	Apr-4th year	May-4th year	Jun-4th year	Jul-4th year
BOD, mg/L	5.1	4.4	5.3	6.0	6.6	4.7	5.3	3.9	4.6	4.3	6.0	6.5
COD, mg/L	16	16	14	19	18	17	21	18	17	20	21	21
TSS, mg/L	8.0	5.6	4.4	5.7	5.3	5.4	8.0	4.8	5.5	7.4	8.0	6.7
NH_3-N, mg/L	0.7	1.4	1.2	1.1	1.4	1.0	1.4	0.6	0.6	0.9	0.7	1.3
NO_3-N, mg/L	2.5	2.2	1.9	2.1	3.2	3.3	2.2	2.7	2.4	2.2	2.6	3.1
TP, mg/L	0.3	0.2	0.2	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.3
Oil and Grease, mg/L	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
pH	6.3 - 7.0	6.4 - 7.2	6.5 - 7.2	6.3 - 7.5	6.4 - 7.3	6.5 - 7.3	6.6 - 6.7	6.6 - 6.6	6.5 - 6.6	6.5 - 6.7	6.4 - 7.3	6.4 - 7.7