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### A Study on 20 MLD Sewage Treatment Plant using Sequential Batch Reactor (SBR) process at Old Somalwada, Nagpur, India

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**ABSTRACT:** The present study was carried out to evaluate the performance of 20 MLD Sewage Treatment Plant using Sequential Batch Reactor (SBR) process at Old Somalwada, Nagpur, India. The present study investigates the performance of a pilot-scale Sequencing Batch Reactor (SBR) process for the treatment of wastewater quality parameters, including turbidity, total suspended solids (TSS), total solids (TS), nitrogen (ammonia (NH3–N), nitrite (NO2 –), and nitrate (NO3 –), phosphate (PO4 3–), the chemical oxygen demand (COD), and the 5-day biological oxygen demand (BOD5), from municipal wastewater. Two scenarios, namely, pre-anoxic denitrification and post-anoxic denitrification, were investigated to examine the performance of a pilot-scale SBR on the wastewater quality parameters on the performance of the SBR system. The results revealed that the post-anoxic denitrification scenario was more efficient for higher qualify effluent than the first scenario. The effluent concentrations of the targeted wastewater quality parameters obtained for the proposed SBR system were below those of the local standards, while its performance was better than that of the North Sewage Treatment Plant, Dharan, Eastern province, Kingdom of Saudi Arabia (KSA), in terms of the BOD5, COD, TN, and PO4 3- treatment efficiencies. These results indicated the suitability of SBR technology for wastewater treatment in remote areas in the KSA, with a high potential of reusability for sustainable wastewater management.

KEYWORDS :- Sequencing Batch Reactor, Nitrification, Denitrification, Temperature, Domestic Wastewater,

#### I. INTRODUCTION

astewater discharged from residences, institutions and commercial establishments is termed as sewage. The composition of wastewater is a refection of the life styles and technologies practiced in the producing society (Edwin Wet al. 2014; Gray 1989). Normally, domestic/municipal wastewater is composed of 99.9% water and remaining 0.1% suspended, colloidal and dissolved solids, mainly organic in nature, as it consists of larger proportion of carbon compounds such as human excreta, paper, vegetable matter and microorganisms (Gautam et al. 2013). Three quarters of organic carbon in sewage are present as carbohydrates, fats, proteins, amino acids and volatile acids. The inorganic constituents include large concentrations of sodium, calcium, potassium, magnesium, chlorine, sulfur, phosphate, bicarbonate, ammonium salts and heavy metals (Chen et al. 2018: Horan 1990; Lim et al. 2011). In order to minimize the environmental and health hazards (Singh et al. 2015; Jafarinejad 2017; Khudair and Jasim 2017; Kominko et al. 2018), these constituents need to be brought down to permissible limits. Therefore, removal of the nutrients, organic contaminants and pathogens from wastewater is of paramount importance in order to prevent eutrophication, oxygen depletion and toxicity (Najar and Khan 2011, 2012, 2013; Najar 2017; Ajala et al. 2018). Further, there are some strict criteria for discharging efuents containing nitrogen and phosphorus, especially in environmentally sensitive areas.

Sequencing batch reactor (SBR) as compared to traditional or conventional treatments is an easily obtainable, on timescale, highly operational, fexible technology for newer and varied pollutants (Popple et al. 2016; Dutta and Sarkar 2015); Kulkarni 2013). The SBR systems have many advantages such as lower operational cost, less bulking and higher fexibility to combine nitrification and denitrification phases into one reactor (Lim et al. 2011) with good removal efficiency for nitrogen, phosphorus and chemical oxygen demand (Khan et al. 2017; Ding et al. 2011).



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Nagpur Improvement Trust (NIT) has placed an order on M/s. Vishvaraj Infrastructure Ltd. for Constructing, Erecting and Commissioning of 20.0 MLD capacity Sewage treatment plant at Old Somalwada, Nagpur.

M/s. Vishvaraj Infrastructure 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 worldwide 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.

The aim of this research is to investigate study the performance of Sequencing Batch Reactor (SBR) for domestic wastewater treatment in Old Somalwada, Nagpur, India.

#### **SBR** Operating Principle:



#### **Benefits of Advanced SBR:**

- Consistent good quality treated water for reuse applications (BOD < 15).
- Handle varying flow and organic loadings.
- No need of Settling Tank. No need of Sludge Recycling system. Less Foot Print.
- Low Sludge production. Retrofits on Existing Tanks.
- No clogging, cleaning and free from common treatment problems.
- Simultaneous Nitrate and Phosphate removal.
- Easier to control Filamentous Growth and Settling



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Schematic Advanced SBR Flow Diagram:



#### **II. LITERATURE REVIEW**

The Sequencing Batch Reactor (SBR) is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. The major differences between SBR and conventional continuous flow, activated sludge system is that the SBR tank carries out the functions of equalization aeration and sedimentation in a time sequence rather than in the conventional space sequence of continuous-flow systems. In addition, the SBR system can be designed with the ability to treat a



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wide range of influent volumes whereas the continuous system is based upon a fixed influent flow rate. Thus, there is a degree of flexibility associated with working in a time rather than in a space sequence (Norcross, 1992, Mace and Mata-Alvarez, 2002, Wisaam S. Al-Rekabi et al., 2008).

In recent years, the use of sequencing batch reactors (SBRs) in the biological treatment of wastewater has been widely extended from lab-scale studies to real WWTPs (wastewater treatment plants) (Mace and Mata-Alvarez, 2002, Steinmetz et al., 2002). While lab-scale SBRs have been used for research on carbon and nutrient removal and the development of urban/industrial wastewater biodegradability assays, real plant applications are still mainly focused on carbon removal. Nevertheless, when operating real plant SBRs the efficiency of nitrogen removal sometimes turns out to be better than the legally required effluent standards (Teichgraber et al., 2001).

Ros and Vrtovsek (2004) also found that the removal of N was not dependent on initial P concentration, but P removal was related to P concentration in the original wastewater by using SBR laboratory pilot plant used in the study consisted of a 70 L rectangular reactor and operation of the pilot plant is monitored by five on-line measurements, i.e. PH, Redox potential (ORP), Dissolved oxygen (DO) concentration, Temperature (T), and water level. All experiments were carried out with synthetic wastewater.

Two bench scale SBR's were used by Keller et al. (1997) to investigate the effect of pretreatment abattoirs and process variations on the BNR (Biological Nutrient Removal) capacity. The reactors were operated at room temperature  $(20\pm2oC)$  the maximum operating volume of the reactors was approximately 5 liters. The overall removal efficiency of the incoming carbon was very good, particularly in terms of the effluent BOD which reached very low values during the whole reactor operation. The remaining COD has to be regard as nonbiodegradable. This fraction in fact quite small, representing around 2% of the COD initially present in the wastewater.

Kargi and Uygur (2003) operated laboratory SBR to Nutrient removal from synthetic wastewater by sequencing batch operation was studied at different specific nutrient loading rates (SNLR).Nutrient removal in a sequencing batch reactor (SBR) was a five-step process consisting of anaerobic (An), anoxic (Ax), oxic (Ox), anoxic (An) and oxic (Ox) phases with hydraulic residence times (HRT) of 2/1/4.5/1.5/1.5 h, respectively. The settling step used at the end of the operation was 45 min for all experiments. The initial COD concentration was varied between 600 and 4800 mg/l at eight different levels with constant COD/N/P ratio of 100/3.33/0.7. Effects of SNLRs on COD, NH+4-N and PO4-P removal were investigated. Percent nutrient removals decreased and effluent nutrient levels increased with increasing nutrient loading rates. The highest COD (99%), NH+4-N (99%) and PO4-P (97%) removal efficiencies were obtained with the initial COD concentration of 600 mg/l at COD loading rate of nearly 40 mg COD /(g biomass)/ h. However, the sludge volume index (SVI) decreased with increasing COD loading rate resulting minimum SVI of 46 mg/l at COD loading rate of nearly 86 mg COD /(g biomass)/ h. Biomass concentration increased with increasing SNLR resulting in biomass concentration of 3.84 mg/l at COD loading rate of 86 mg COD /(g biomass) /h.

#### III. PROPOSED METHODOLOGY

**Design Basis:** 

Average Sewage Flow : 20.0 MLD Peak Factor : 1.50 Peak flow : 30.0 MLD

#### **Inlet Parameters**

S. No.	Parameters	Units	Value
1.	Biochemical Oxygen Demand (BOD <sub>5</sub> )	mg/L	200
2.	Chemical Oxygen Demand (COD)	mg/L	400
3.	Total Suspended Solids	mg/L	400
4.	Ammonical Nitrogen	mg/L	20
5.	Total Kjeldahl Nitrogen (TKN)	mg/L	35
6.	Total Phosphorus (TP)	mg/L	5



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#### **Outlet Parameters**

S. No.	Parameters	Units	Outlet
1.	Biochemical Oxygen Demand (as BOD <sub>5</sub> )	mg/L	≤ <b>10</b>
2.	Chemical Oxygen Demand (COD)	mg/L	$\leq 50$
3.	Total Suspended Solids	mg/L	$\leq 10$
4.	Total Nitrogen (as N)	mg/L	$\leq 10$
5.	Total Phosphorus as (P)	mg/L	$\leq 2$

#### **Treatment Philosophy:**

Raw sewage after primary treatment (Fine Screens and Grit Chambers) is taken to C-Tech Basins by gravity. There are three 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. Excess sludge at a consistency level of approx 0.8% - 1.0% 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. The treated effluent from the C-Tech Basins will then pass through Chlorination tank where it is disinfected before its ultimate discharge.

#### **Process Description and Process Chemistry:**

#### **Process Description:**

The raw sewage free from floating debris and grit shall be taken up for Biological treatment for the removal of organics, nitrogen and phosphorus. The activated sludge process configuration is designed using Cyclic Activated Sludge Technology which operates on extended aeration activated sludge principle for BOD reduction, Nitrification, Denitrification as well as biological phosphorous removal, using energy efficient fine bubble membrane diffused aeration system, with automatic control of oxygen uptake rate, resulting in 20 - 30% power savings. The practice of manipulating activated sludge reaction environments to obtain maximum nitrogen and phosphorous removal has been optimized using cyclic activated sludge technology by simultaneous nitrification-denitrification and biological phosphorus removal.

The C-TECH system operates in a batch reactor mode, which eliminates all the inefficiencies of the continuous processes. A batch reactor is a perfect reactor, which ensures 100% treatment. Four tanks are provided to ensure continuous operation; however, complete process takes place sequentially in each single reactor. The system makes use of the variable volume treatment in combination with a biological Selector and operated in a batch-fed reactor mode. The complete biological operation is divided into various cyclic modes. Each basic cycle comprises of:

• Fill – Aeration

Decantation
Sedimentation

Generally, each cycle is of 2.5 hrs. - 5 hrs duration (3.0 hours as design basis), during which all treatment steps take place.



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During the period of fill-aeration, the liquid volume inside the Reactor increases from a set operating low water level up to the high water level. Mixed liquor from the aeration zone is also recycled into the Selector during the Fill-Aeration sequence. Aeration ends at apredetermined period of the cycle to allow the biomass to flocculate and settle under quiescent conditions. After a pre-determined settling period, the treated supernatant is decanted using a moving weir electromechanical Decanter. After decanting, the liquid level in the Reactor is returned to the bottom water level after which the cycle is repeated. Solids are wasted from the reactor during the decanting phase. In its simplest form, the sequences of fill, aeration, settling and decant are consecutively and continuously operated all in the same tank, allowing up to 30-40% space saving. No secondary clarifier system is required to separate and concentrate the sludge.



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Features of C Tech Reactor: The C Tech system comprises the following features:



Biological Selector zone - No bulking, No Foaming, Denitrification, Phosphorus release for Biological Phosphorus removal 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 < 120 is achieved in all seasons. The figure below shows the experience with SVI developments in parallel operations with a wastewater that traditionally favours sludge settling. Due to the anaerobic conditions in the SELECTOR zone, phosphorous release also occurs.



Fig: Comparison of the SVI of a conventional Activated Sludge plant & a C-TECH plant

at parallel operation (Grossarl WWTP)

Oxygen Uptake Rate (OUR) based Dissolved Oxygen Control - Energy Savings The C Tech reactor process uses measurement of Oxygen Uptake rate (OUR) and Dissolved Oxygen (DO) levels in the basin to enhance treatment



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efficiency and optimise power consumption. The OUR and DO values in the basin are continuously monitored by a DO sensor. Once OUR and DO levels are measured in the basins, aeration intensity is regulated automatically according to actual demands of the process through PLC andvariable frequency drive connected to air blower to maintain desired DO levels in the basin. This methodology provides a true in-basin method for the efficient use of energy and ensures 20 - 30% power savings.

#### Co Current Nitrification and De nitrification, Phosphorous removal

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 oxicmetabolization. The process can be regulated such that during the aeration phase there is nitrification and also 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.

#### Fully PLC Based Intelligent Control - Operational Simplicity

The complete C-Tech plant operation is controlled automatically through a PLC system, which is a major factor in reducing operating costs. All key functions like, RAS, sludge wasting, aeration intensity, cycle time control, decanting rate etc. are automatically controlled along with data logging. Complete historical records of plant operation are available on touch of a button.

Stainless Steel Decanter - Corrosion Resistant and Long life.

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



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#### Fine Bubble Diffusers for Aeration:

Essentially, 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.

#### Return sludge (RAS) recycle and Surplus Sludge (SAS) Pumps for Sludge Wasting:

Submersible RAS and SAS pumps are placed in the C Tech reactor itself. It reduces external pumping space requirements.

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

1. Oxidation

COHNS +  $O_2$  + Bacteria  $\rightarrow$  CO<sub>2</sub> + NH<sub>3</sub> + other End Products + Energy

2. Synthesis

COHNS +  $O_2$  + Bacteria  $\rightarrow$  C<sub>5</sub>H<sub>7</sub>O<sub>2</sub>N (New Bacterial Cell)

#### 3. Endogenous Respiration

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



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**Process Design and Unit Sizing Calculations:** 

i	Design Basis adopted for calculations		
Α.	Inlet Flow	20000	m3/day
B.	Peak Factor	1.50	-
C.	Inlet BOD	200	mg/L
D.	Outlet BOD	≤ 10	mg/L
E.	Inlet COD	400	mg/L
F.	Outlet COD	≤ 50	mg/L
G	Inlet TKN	35	mg/L
H.	Outlet Total Nitrogen	≤ 10	mg/L
I.	Inlet suspended solids	400	mg/L
J.	Outlet suspended solids	≤ 10	mg/L
K.	Inlet Phosphorous	5	mg/L
L.	Outlet Phosphorus	$\leq 2$	mg/L

ii	Treatment Sequence		
Α	Volume of sewage treated in a day	20000.00	m <sup>3</sup>
В	Aeration Phase	1.500	Hrs.
С	Fill Phase	1.000	Hrs.
D	Settling Phase	0.500	Hrs.
Е	Decanting Phase	1.000	Hrs.
F	Total Cycle Time = $B + D + E$	3.00	Hrs.
G	No. of Cycles per day/basin = 24 / F	8.00	Nos.
Н	Hours of aeration time/day/basin = $B \times G$	12.00	Hrs.
Ι	No. of basins receiving flow simultaneously	1.00	Nos.
J	No. of basins Aerating simultaneously	2.00	Nos.
K	No. of basins Decanting simultaneously	1.00	Nos.
L	Flow rate = $A / 24$	833.33	m <sup>3</sup> /h
Μ	Flow rate to each basin = $L / I$	833.33	m <sup>3</sup> /h



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#### **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									3.00			
Basin - 1	F/A	F/A	F/A	F/A	Α	Α	S	S	D	D	D	D
Basin - 2	D	D	D	D	F/A	F/A	F/A	F/A	Α	Α	S	S
Basin - 3	Α	Α	S	S	D	D	D	D	F/A	F/A	F/A	F/A

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

#### **Equipment Specification for C-Tech System:**

Sl. No.	Description	Specification	Nos.
1.	Inlet Gate to C-Tech basin	Auto Gate	3 nos.
2.	Air blowers	4400 Nm <sup>3</sup> /hr @ 0.70 Kg/cm2	3 nos. (2W+1S)
3.	VFD for air blower	Suitable	3 nos.
4.	Diffuser assembly	Fixed Type	1 lot
5.	Decanters with positioner and Drive	Suitable	3 nos.
6.	VFD for auto rate control of decanters	Suitable	3 nos.
7.	RAS pumps	195 m <sup>3</sup> /hr @ 5 m. head	4 nos. (3W+1SS)
8.	SAS pumps	125 m <sup>3</sup> /hr @ 10 m. head*	4 nos. (3W+1SS)
9.	Piping and Valves	Suitable	1 Lot
10.	Main Air Header Valve	Auto Butterfly	3 nos.
11.	Selector Air Header Valve	Auto Butterfly	3 nos.
12.	Selector Down Comers Valve	Manual Ball	18 nos.
13.	SAS Pump Discharge	Non Return Valve	3 nos.
14.	SAS Pump Common Discharge Header	Manual Knife Gate Valve	1 No.
15.	Instrumentation and Controls		
a)	PLC and control panel	-	1 no.
b)	DO Transmitter	Fixed Type	3 nos.
c)	Level transmitter	Hydrostatic Type	3 nos.
d)	Pressure gauge	Bourdon Type	3 nos.



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#### **IV. RESULTS AND DISCUSSIONS**

Figure.4.1 Variations of (a) nitrogen (NH3–N), (b) nitrate-nitrogen (NO3–N), (c) total nitrogen (TN), and (d) pH.



Figure 4.2. Variations and removal efficiencies of (a) the chemical oxygen demand (COD), (b) the 5-day biological oxygen demand (BOD5), and (c) phosphate (PO4 3–).



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#### V. CONCLUSION

The correlation statistics results revealed that treatment efficiencies of NH3-N, TN, PO4 3–, COD, and BOD5 were significantly improved by increasing the aeration time fraction in the total SBR runtime, while increasing the total anoxic period in the total SBR runtime improved the NO3-N removal efficiency. The treatment efficiencies of turbidity, TSS, and TS indicated very strong and positive correlations with the ratio of the settling period to total batch runtime. The post-anoxic denitrification scenario resulted in the maximum treatment efficiencies of NH3-N (99.9%), TN (92.0%), PO4 3– (90.0%), COD (99.1%), BOD5 (89.3%), turbidity (97.9%), TSS (98.8%), and TS (98.4%) when the filling, aeration, sedimentation, and decanting times were set to 0.58, 6.0, 6.0, and 0.20 h, respectively. The effluent concentrations of the targeted wastewater quality parameters computed for the proposed SBR system were below the local standards, and the performance of the proposed SBR system was better than that of NSTP in terms of the BOD5, COD, TN, and PO4 3– treatment efficiencies. Hence, the tested and proposed SBR process is a simple, efficient, flexible, cost-effective, and successful technology for the treatment of municipal wastewaters. The SBR process can be employed in remote areas in arid regions of KSA for wastewater treatment and reuse for sustainable water management.

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