Performance Evaluation and Cost Optimization of Sewage Treatment Plants (SBR-based) in Kolhapur City

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Abstract- Biological treatment of raw sewage in a sewage treatment plant can be achieved by multiple methods which include aerobic as well as anaerobic processes. The SBR process is one such treatment technique where specialized instrumentation and control automation is used to convert the conventional activated sludge process from a continuous mode to a batch mode with combined unit operations taking place within the same set of civil units like tanks.
The success of this process relies significantly on the efficient use of sequential operational modes to achieve the desired results. The extensive use of instrumentation and automation also gives it a certain level of flexibility to cater to change in the hydraulic and / or organic load of the incoming raw sewage. Since this is an aerobic process, it requires significant energy input in the form of process air blowers. The waste / excess sludge generated by this processesare lesser in quantity compared to extended aeration, thereby reducing the load on downstream solids handling units.
Analysis of the historical and current performance of existing treatment plants based on SBR which are in operation provides an interesting opportunity to explore and evaluate the process with respect to sustainability in terms of energy efficiency, process robustness, capability to handle future variations in loads while remaining cost effective over a long-term horizon.
Keywords- Sewage Treatment Plant, Performance Evaluation, Cost Optimization, SBR

I. INTRODUCTION

The city of Kolhapur is situated in the south-west corner of Maharashtra on the bank of river Panchaganga. Kolhapur is also famous for one of the complete Shakti peeth "Shree Mahalaxmi" temple. It is renowned as 'DakshinKashi' since ancient times and is a holy place which was historically known for being the capital of the 'Kolhapur Sansthan'.
Kolhapur city is divided into four major sewerage zones:
1. Jayanti nalla zone2. Dudhali nalla zone3. Line Bazar nalla zone4. Bapat Camp nalla zone
Initially the city had one operational sewage treatment plant (STP) of capacity 43.5 million litres per day (MLD) at Kasba Bawada based on conventional treatment which was commissioned around 1973-74. Currently, two STPs are in operation within the city limits of Kolhapur:
1. Under the NRCD project, a STP of treatment capacity 76 MLD is under operation where the sewage from Jayanti Nallah, Line Bazaar Nallah and Bapat Camp Nallah is being treated.
2. Under Maharashtra Suvarna Jayanti Nagarotthan Maha Abhiyan, the STP of capacity 17 MLD catering to the sewage collected in the Dudhali nallah basin is under operation.

Figure 1: Bird's eye view of 17MLD STP at Dudhali nalla, Kolhapur

After the commissioning of 76 MLD STP (SBR-based) in 2014 and 17 MLD STP (SBR-based) in 2018, all the major nallas have been tapped and the sewage is being treated and discharged into river Panchaganga. The effluent is also utilized for agriculture in fields along the alignment of the discharge line. Author summarizes the performance evaluation and cost optimization of the 76 MLD STP and 17 MLD STP at Kasaba Bawada and Dudhali nalla respectively.

II. Literature Review

1) Analyze and evaluate current operation & maintenance practices at both existing STPs and to suggest steps for achieving performance as well as cost optimization. This project also aims to optimize energy consumption at the STPs.
2) The treatment process employed at both the STPs under evaluation is Sequential Activated Batch reactor (SBR) technology offered by C-Tech. It operates based on a set of three phases / operations i.e. (1) Fill and aeration, (2) Settling and (3) Decanting and the nominal duration of the complete cycle is 3 hours.

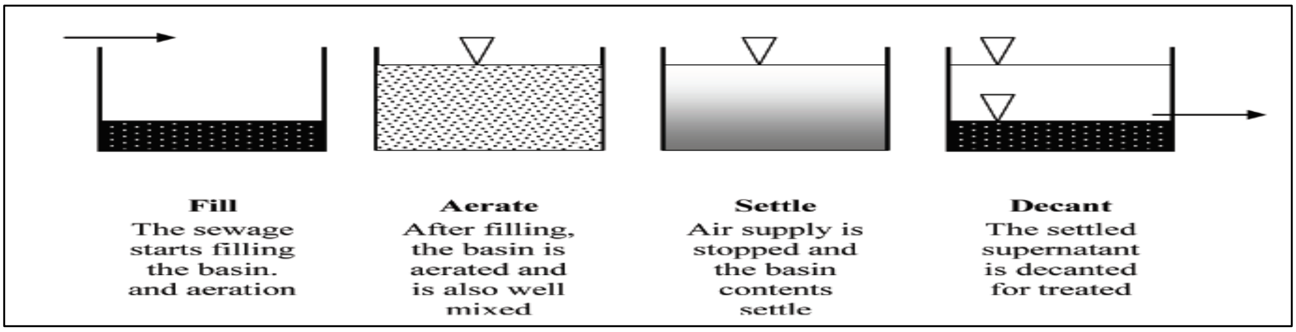


Figure 2: Illustrative scheme of SBR operation in the same basin*Source: CPHEEO Manual, 1993*

3) This paper gives a brief general description of the different phases comprising one cycle:
   a) Fill and Aeration Phase:- This is the initial phase in which the tank is filled and the contents are simultaneously aerated via submerged diffusers using air blowers. This is an automated process.
   b) Settling Phase: - In this phase the activated sludge is allowed to settle for the design period. This settled sludge is partly recycled as Recycle Activated Sludge (RAS) and excess sludge is wasted / sent to thickening as Surplus Activated Sludge (SAS).
   c) Decanting Phase:- In this phase the supernatant from the basins passes over the decanter weir in laminar flow conditions. After removal of supernatant the decanter returns to its designated position.
4) In the SBR tank biological treatment occurs when active microbial biomass is put into contact with wastewater allowing removal of organic pollutants. These microorganisms in the presence of oxygen, convert biodegradable organic compounds into carbon dioxide, water, more cell material and other inert products. The basic ingredients needed for biological treatment are the mixed microbial population, oxygen, nutrients (Phosphates and Nitrogen components), favorable temperature and pH. Aerobic heterotrophic bacteria found in these processes are able to produce extra cellular biopolymers that result in the formation of biological floc that can be separated from the treated liquid by gravity settling with relatively low concentration of free bacteria and suspended solids.
5) The efficiency of the SBR process derives from a capacity to maintain good sludge settling through batch settling. Nitrogen removal by biological nitrification-de-nitrification as also biological phosphorous removal by upstream anaerobic processes can also be built into the SBRs.
6) Advantages of this process
   a) One single reactor basin provides all of the unit operations and processes that require two separate basins in a conventional activated sludge plant configuration that can provide an effluent quality suitable for reuse. Equalization, primary clarification (in most cases), biological treatment, and secondary clarification can be achieved in a single reactor vessel.
   b) This process can be operated and controlled with flexibility for efficient removal of organic matter, suspended solids, nitrogen, and phosphorus under all loading conditions. Provides enhanced organic phosphorus removal with or without chemical augmentation.
   c) This process can control the growth of filamentous bacteria and hence prevent bulking of activated sludge.
   d) This process saves capital cost by eliminating final sedimentation tanks. As secondary sedimentation tanks are not required in this process, footprint area needed is also minimal as simultaneous multiprocessing takes place in a single reactor basin (approximately 100m2 / 1000m3 only needed for SBR Tanks).
   e) Can be used with primary clarifiers and power generation configurations where the ratio of VSS:TSS is high.
   f) Allows for easy modular expansion for population growth, modular configurations and cyclic operation is easily managed to provide continuous inflow and outflow hydraulic profiles, dispensing with the need for outflow hydraulic balancing.
7) Limitation of this process
   a) Compared to the conventional activated sludge system, a higher level of sophistication and maintenance can be associated with more automated switches and valves.
   b) In small single stream SBR systems approximately less than 10 MLD, effluent flow balancing may be needed for downstream processing, such as filtration or disinfection.
   c) Larger capacity aeration system, relative to aeration time per cycle and per day, is required compared as to conventional activated sludge system.

d) The potential for discharging floating or settled sludge during the decant phase with certain SBR configurations.
e) Potential plugging of aeration devices during selected operating cycles depending on the aeration system used by the manufacturer.
f) All the SBR plants must be designed to cater to the peak flows. A minimum of two tank system is required.

With proper anticipations in the design stage, the SBR process can be installed with good flexibility to adapt to future regulatory changes for effluent parameters such as for nutrient removal.

III. METHODOLOGY

Analysis and evaluation of the existing SBR process will entail evaluation of the process components that combine together to produce the desired result i.e. treated sewage complying with guarantee parameters.

The SBR system as a whole runs on multiple inter-linked and inter-dependent unit operations and processes that include but not limited to:

- Aeration blowers
- Sludge recycle pumps & sludge wasting pumps
- Decanter mechanism
- Level & flow measuring instruments
- PLC program with software interlocks
- Valves & gates
- Hydraulic gradients in channels and civil units

System evaluation & optimization therefore implies carrying out the exercise for all of these contributing components / factors.

IV. NEED OF THE STUDY

The aeration stage in a sewage treatment plant is often the most energy intensive unit operation and is responsible for up to 50% of the total average energy consumption during the operation of the plant. It is also the “heart” of the treatment process where maximum reduction in pollutant load is achieved. Analysis of this process along with other associated unit processes and operational parameters provides an insight to the governing factors that affect the process control driving the treatment technique under consideration i.e. SBR.

Knowledge of such key data points and an understanding of the degrees of freedom for each parameter will aid in the analysis of the overall process beginning from preliminary treatment to disinfection and thus lead to implementable recommendations for gradual improvements and changes to achieve higher performance efficiency and cost optimization.

V. FUTURE SCOPE

Sewage treatment, recycle and reuse is fast becoming an essential aspect of urban infrastructure planning thanks to the increased awareness among policy makers, planning authorities, ULBs as well as the urban populace regarding the long-term adverse effects on public health and overall community well-being as a result of discharging untreated sewage into water bodies such as lakes, rivers which serve as sources of drinking water. The negative impact of untreated sewage on the immediate ecology and aquatic flora-fauna is also now a point of concern in the public domain.

The Union government as well as several State governments have formulated strict guidelines for sustainable management of urban sewage and have implemented or are in the process of implementing STPs catering to significantly dense urban agglomerations. The discharge standards set for these planned and upcoming STPs are much more stringent than earlier. It therefore becomes imperative to have STPs that are not just designed to achieve stringent quality standards but are also energy efficient during their lifecycle of 15-20 years on an average.

In addition to continuous monitoring for performance, periodic review and evaluation of critical parameters will therefore definitely impart value to the efforts taken to maintain the efficiency of an STP at desired levels and will consequently result in cost optimization in the course of its natural lifecycle.

VI. FIELD OBSERVATIONS

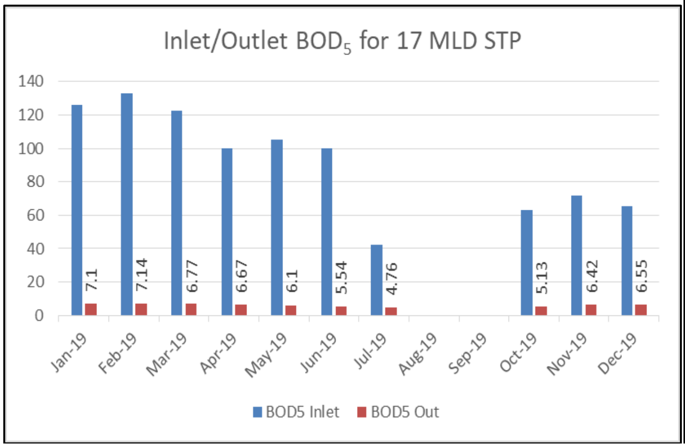
For the STPs under consideration, it is observed from the available results that the design inlet parameters of raw sewage have not yet been achieved due to multiple factors. The inlet parameters are currently around 40-50% of design load.

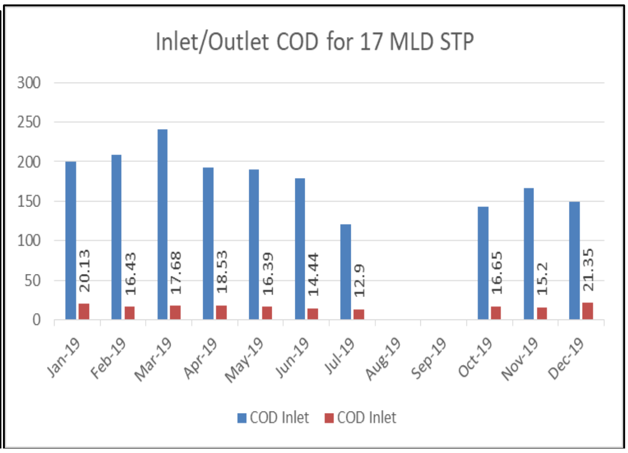
Analysis of treated sewage as presented in the bar charts below indicate that the liquid treatment scheme at both STPs is performing satisfactorily and meeting the discharge quality requirements on a consistent basis.

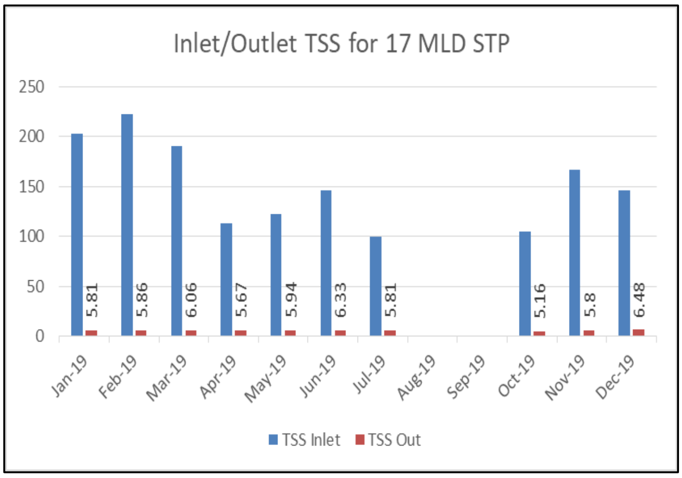
Since the incoming raw sewage is currently lean with reference to the design basis, studying the effect of an eventual increase in organic loading on the treatment process is important to ascertain the feasibility and consequence of implementing performance optimization techniques to the treatment plant. Similarly, the plant can also handle higher hydraulic loads if the concentration of raw sewage remains low as at present.

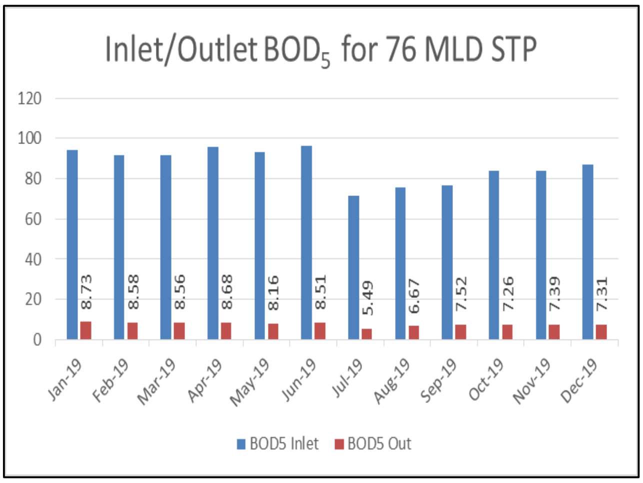
As regards the solid stream, the excess sludge from the biological treatment process is currently dewatered in a decanter centrifuge to about 22% dry solids content by weight. However, since there is no current provision or

immediate plan for recycle-reuse of sludge, it is temporarily stored within the plant premises and left to dry under ambient conditions.
This sludge does not undergo any treatment and thus has significant volatile matter along with high concentration of pathogens. It is therefore unfit for direct or indirect reuse involving manual handling.
Further treatment using well-established and economically feasible techniques can help in converting this waste to reusable product.
Following observations are summarized from the preliminary data:



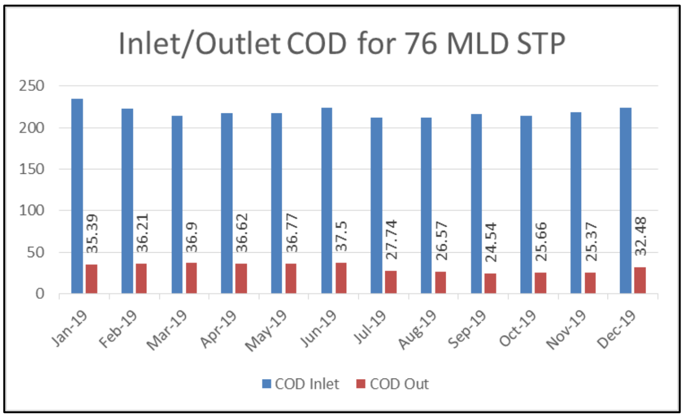


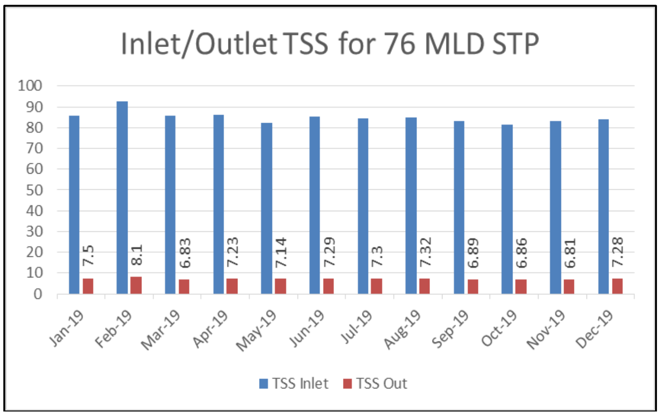




Bar charts-1- Inlet/Outlet parameters for sewage at 17& 76 MLD STP

** 17mld STP Plant was shut down from August 2019 to Sept 2019 due to flooding*





Bar charts-1- Inlet/Outlet parameters for sewage at 17& 76 MLD STP

VII. CONCLUSION

As the inlet parameters are within limit, the hydraulic load can be gradually increased beyond the design capacity i.e.17 MLD; so that the cost of treatment per ML will be reduced and consequently more raw sewage will be treated. For this to happen, certain key modifications will be required in the cycle time and some units need to be augmented for handling excess sludge (SAS) from SBR basins.

The units to be upgraded during the preliminary stage of optimization are sludge thickener and dewatering centrifuge. These unit operations i.e. thickening and dewatering will be directly affected once the incoming load is increased.

The liquid treatment scheme can be optimally improved by addition of primary clarifiers to lessen the organic load on the secondary treatment process in the event of an increase in the raw sewage concentration.

Sludge stabilization using anaerobic digesters will be recommended to provide effective solids management and generate a reusable, environmentally sustainable product.

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