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ANALYSIS OF DESIGN AND OPERATIONAL APPROACH OF SEWAGE TREATMENT PLANT: A CASE STUDY

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Abstract: Almost 80%-85% of the water supplied for domestic use gets converted into the wastewater. Wastewater containing high organic matter, nitrogen, phosphorus leads to numerous problems like eutrophication, consumption of oxygen, toxicity to the environment. To remove these contaminants; physical, chemical and biological wastewater treatments are adopted. A Sewage treatment Plant (STP) can be express as the factory, which prevents the environment from waste produced by human beings. When the waste produced is beyond the limit of environment to decompose, STP is only the solution. The present STP reduces the waste, produces manure & energy and helps us to keep our rivers, ponds clean. Various types of STPs are introducing each day, according to the requirement and economic view. The SBR is one of the potential options for treatment of wastewater. SBR is a fill and draw system for aerobic wastewater treatment. In this system, wastewater is added to a single "batch" reactor, treated to remove undesirable components, and then discharged. Equalization, reaction/aeration, and clarification can all be achieved using a single batch reactor. SBR systems have been successfully used to treat both municipal and industrial wastewater (Mahvi, 2008). For further improvement in the performance, the attempt was made to study the 245 MLD existing sewage treatment plant at Kabitkhedi, Indore and identify the bottlenecks in the system to make it more suitable for Indian conditions.

***Index Terms* - Sewage, Wastewater, Treatment Plants, Treatments Technologies**

I.INTRODUCTION

The treatment of domestic wastewater is a major and complicated issue regarding the environmental pollution; hence one can have the better solution in the form of SBR. The wide variety of wastewaters can be treated using SBR as can be concluded from the literature review. The process modification is very easy due to flexible nature of the SBR. The cycles, HRTs, SRTs can be changed and hence it provides wide scope for treatment that too in a single reactor which is most advantageous factor.

Although, SBR gives good performance in average conditions, it fails to deliver the same output in peak hours. The quality of treated water is affected in peak hours due to reduction in the reaction time of SBR basin. Whereas the consideration of higher peak factor makes it uneconomical due to increase in sizes of basin and other processing units. These drawbacks can be detected by studying and analyzing the design approach, operation and maintenance of existing STP and wastewater collection system. Further rectification in the existing system and process modification can be proposed for better functioning of the overall system.

India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population. Total utilizable water resource in the country has been estimated to be about 1123 BCM (690 BCM from surface and 433 BCM from ground), which is just 28% of the water derived from precipitation (Kaur et al). Insufficient capacity of waste water treatment and increasing sewage generation pose big question of disposal of waste water. As a result, at present, significant portion of waste water being bypassed in STPs and sold to the nearby farmers on charge basis by the Water and Sewerage Board or most of the untreated waste water end up into river basins and indirectly used for irrigation. It has been reported that irrigation with sewage or sewage mixed with industrial effluents results in saving of 25 to 50 per cent of N and P fertilizer and leads to 15-27 % higher crop productivity, over the normal waters (Anonymous, 2004). In India, there are 234 Sewage Water Treatment plants (STPs). Most of these were developed under various river action plans (from 1978-79 onwards) and are located in (just 5% of) cities/ towns along the banks of major rivers (CPCB, 2005a). Batch Operation of the activated sludge process is nothing new. During the early development of the activated sludge process in the United Kingdom by Arden and Lockett around 1914, plants were operated using fill-and-draw or batch feed methods. These researchers firmly established the concept of operating a single reactor basin using repetitive cycles of aeration, settlement and discharged of treated effluent. Around 1956, during the development of oxidation ditch technology, Pasveer incorporated interrupted and continuously fed batch treatment principles. Further advancements to the oxidation ditch fed-batch treatment then took place by incorporating a rectangular basin configuration.

II.SEQUENTIAL BATCH REACTOR (SBR)

Sequential batch reactor is a type of biological treatment system in which stabilization of organic matter, flocculation of generated cells and settling of cells occur in a safe tank. In its operations, the cycle processes FILL-REACT, REACT, SETTLE DRAW are controlled by time to achieve the objectives of the operation. Each process is associated with particular reactor conditions (turbulent/Quiescent, Aerobic/Anaerobic) that promote selected changes in the chemical and physical nature of the waste water. These changes lead ultimately to a fully treated effluent.

III.PROCESS DESCRIPTION

A treatment plant utilizing the SBR concepts has only one type of process unit, the batch reactor tank. It is possible and even preferable in many cases, to link several identical reactors in a multiple tank configuration, to limit the size of Individual units and increased flexibility. There are no units dedicated to a single process, such as equalizing basin, aeration chambers, and clarifiers, as continuous flow systems. In its simplest form, a batch reactor consists of single tank equipped with an inlet for raw waste water; air diffusers, with associated compressors and piping for aeration; a sludge draws off mechanism at the bottom of waste sludge; a decant mechanism to remove the supernatant after settling; and a control mechanism to time and sequence the processes. Various suppliers of SBR systems include different modifications to the basic system, such as the installation of a baffle near the inlet to provide a pre react chamber separated from the aerated portion of the basin. Many decant structures are marketed with features designed to limit the discharge of floating solids and settled sludge. Air diffuser design and construction also varies among suppliers, but many SRBs use jet aerators or mechanical aeration to accomplish aeration and/or mixing with a single device. The heart of the SBR system is the control unit and automatic switches and valves that sequence and time the different operations. The advent of reliable microprocessors at reasonable cost, used in conjunction with modern limit/level switches and automatic valves, has been a major factor in the recent development of SBR technology. The ability to control the processes in time rather than space is crucial in SBR Concept.

IV.BOD, NITROGEN AND PHOSPHORUS REMOVAL MECHANISM

More than 95% removal of BOD is noted in SBR. An important advantage of the SBR system is the control the operator can maintain over microorganism selection. Within a complete treatment cycle, the microorganism selection pressures are highly variable and severe. These pressures include oxygen availability, which ranges from anaerobic through anoxic to high DO conditions, and substrate availability, which ranges from famine to feast conditions. While certain of these selection pressures can occur in some conventional continuous flow systems, the SBR system provides the ability to easily select and extend or limit preferred conditions through time, allowing the preferential growth of desirable microorganisms. Two observations have been documented that illustrate the beneficial effects of this control ability. Firstly, in an SBR system more microorganisms are capable of processing a greater quantity of substrate at a greater rate than in a conventional system. Secondly, it has been reported that a properly selected aeration strategy can result in the minimizing of the growth of filamentous microorganisms. These microorganisms, whose presence in quantity leads to problems with sludge bulking and foaming, are undesirable in the activated sludge floc in excessive numbers, and their control is an asset to system performance. Nitrogen removal can be achieved in the SBR system without additional equipment or chemicals. Nitrogen enters the system in the raw waste water in the form of organic nitrogen and ammonia (NH_4). It is removed from the system in the form of organic nitrogen gas. Phosphorus removal by microbiological methods in SBR systems is well documented. The additional of chemical coagulant to the reactor that precipitates phosphorus into the sludge is a common phosphorus removal process applicable to both conventional continuous flow and SBR systems. The microbiological removal of phosphorus first requires an anaerobic period (absence of dissolved Oxygen and Oxidation nitrogen) during which substrate (raw waste) is present. This period should be followed by an aerobic period (high DO) that promotes the uptake of excess phosphorus by the sludge mass. Excess sludge should be removed from the reactor in suitable quantities before the onset of next anaerobic period. In term of SBR operation anaerobic conditions and aeration must be available during FILLREACT period for phosphorus release and uptake by biomass. These conditions can also available in selector by recirculation of sludge. Fig.1 shows a Typical SBR Cycle for BOD, SS and COD, SS, T-N and T-P Removal.

V.PERFORMANCE COMPARISON

The performance of SBRs is typically better to conventional activated sludge system and depends on system design and site-specific criteria. Depending on their mode of operation, SBRs can achieve good BOD and nutrient removal. For SBRs the BOD removal efficiency is generally 85 to 95 percent. SBR manufactures will typically provide a process guarantee to produce an effluent of less than: (i) 10 mg/L Biochemical Oxygen Demand (ii) 10 mg/L Total Suspended Solids (iii) 5-8 mg/L Total Nitrogen (iv) 1-2 mg/L Total Phosphorus (EPA, 1995). The advantages of Sequential Batch Reactor over conventional system are:

1. Control system provides high flexibility. The control system automatically coordinates equipment operation through various phase of SBR cycle. This feature offers a high degree of flexibility allowing adaptation of the process cycle to meet the changing influent conditions through simple changes in control set points.
2. No primary and secondary settling tanks, no return sludge pumping, hence lesser area requirement and ease in operation & maintenance.
3. It is a proven process, which enhances the standard system through strategic cost, operating and biological advantage.
4. Improved effluent quality: extended aeration mode, a special ability to handle extremely high organic and hydraulic shock loads, no washout of biomass, reliable performance. More than 95% BOD removal, advantage aeration processes.
5. The process is also recommended for small-scale sewage treatment in CPHEEO manual, but due to the advancement in technology in last decade, these plants are very favourable for medium and largescale sewage treatment applications.

It is a proven process all over the world for sewage treatment. Many large-scale plants working efficiently around the globe.

6. Nitrified effluent (no ammonia is present), doesn't consume further oxygen for nitrification and much beneficial for irrigation and fisheries.
7. Expansion potential: Simplified expansion- Each unit forms a modular treatment unit. All basins have been built with common wall construction. This can be achieved by maintaining the same length for all tanks and increasing the width appropriately. The blower equipment is also sized proportionally to the capacity of each basin such that the same blowers are used before and after expansion.

VI. SEWAGE TREATMENT PLANT DETAILS

From main pumping station Raw water supply to inlet of STP (for treatment purpose). Where water passes through 6mm bar screen. Here 6mm and above particles retain and removed. After removal of 6mm particles water passes through GRIT mechanism. In GRIT mechanism 0.5 mm and above particles are retained and removed. Then water passes through partial flumes for measurement of flow. After pre-treatment water enter into the SBR.

Figure 1: Photographic view of Sewage Treatment Plant, Kabitkhedi, Indore

VII. OBSERVATIONS AND ANALYSIS

The sequential batch reactor is operated in cycles of 3 hrs. Scheduling of all six basins is done considering the inflow in the system.

8.1 Basin Operation Sequence

SBR batch operations are operated as follows,

Table 1 : Operation 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	D	D	D	D
Basin-2	S	S	D	D	D	D	F/A	F/A	F/A	F/A	F/A	F/A
Basin-3	D	D	F/A	F/A	F/A	F/A	F/A	F/A	S	S	D	D
Basin-4	F/A	F/A	S	S	D	D	D	D	F/A	F/A	F/A	F/A
Basin-5	D	D	D	D	F/A	F/A	F/A	F/A	F/A	F/A	S	S
Basin-6	F/A	F/A	F/A	F/A	S	S	D	D	D	D	F/A	F/A

F/A: Filling and aeration phase, **S**: Settling phase, **D**: Decanting phase

8.2 Average Inflow and Treated Water Flow

Average inflows and outflows from STP are shown in figure 2;

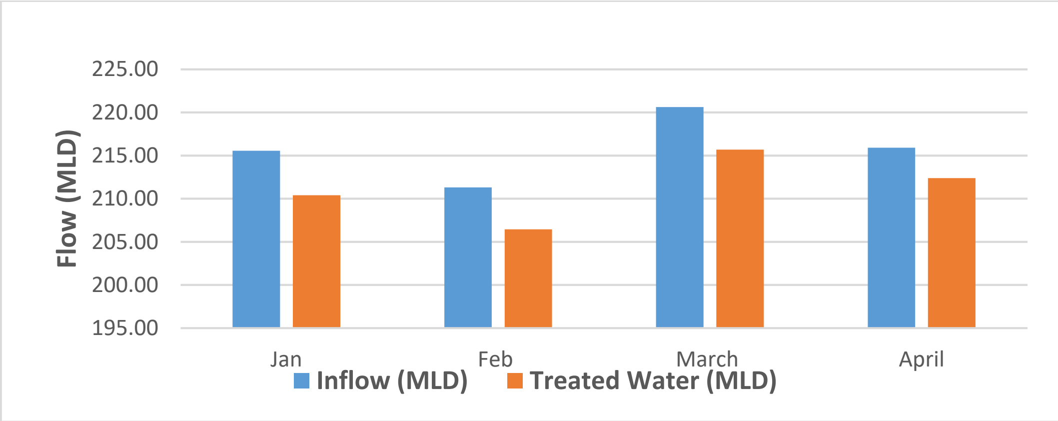

Figure 2: Average Inflow and Treated water flow

8.3 Wastewater Generation Patterns

The wastewater generation during a day is not constant throughout the day. It changes every hourly. The typical domestic wastewater generation pattern used to design STP is as shown in figure below;

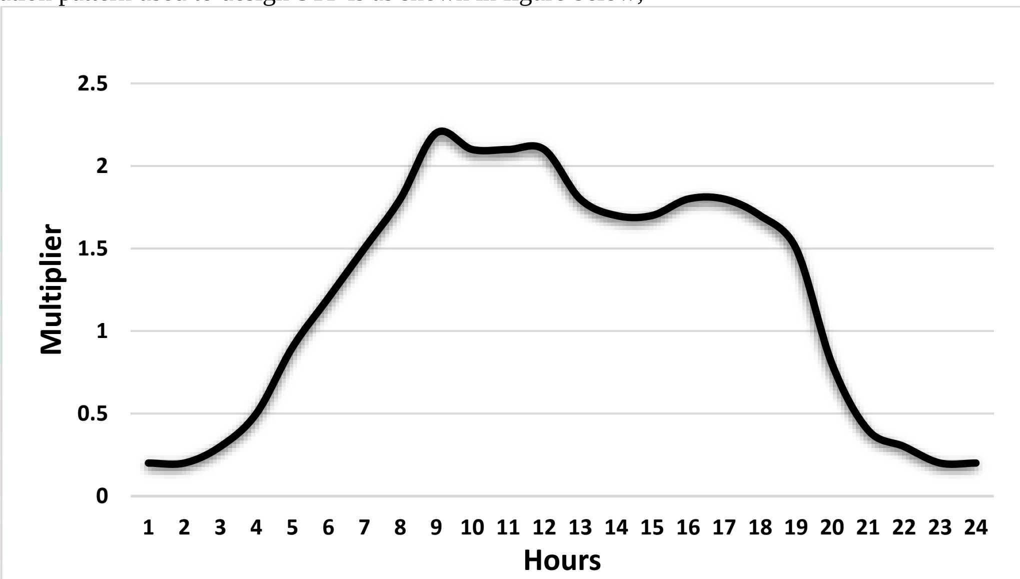

Figure 3: Wastewater Generation Pattern Used for Design

But the wastewater generation in Indian scenarios is not found as per the pattern used for the design. The actual wastewater generation pattern observed on field is as shown in figure below;

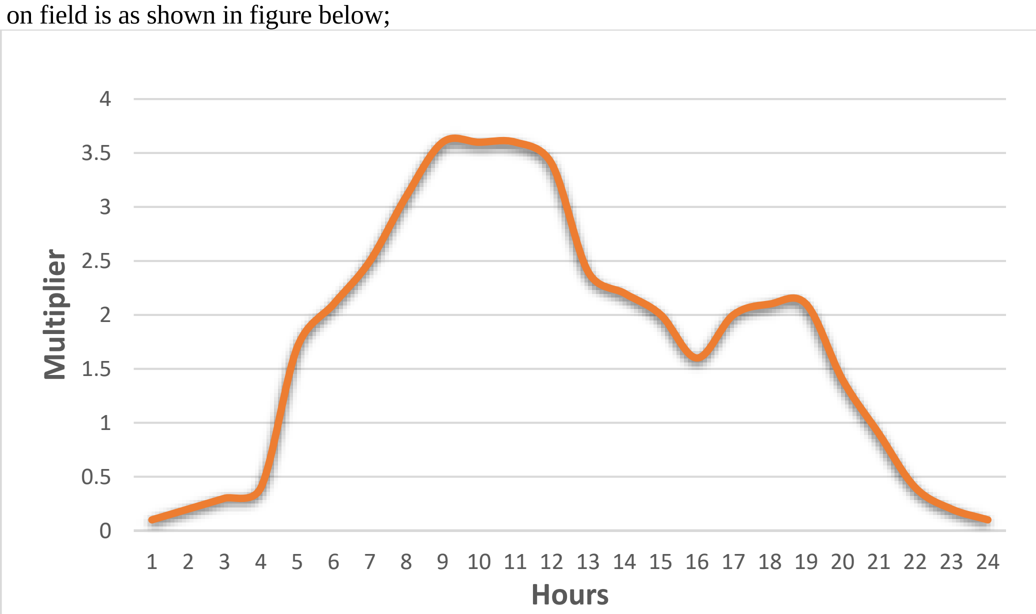

Figure 4: Wastewater Generation Pattern Observed on Field

8.4 Comparison between wastewater generation pattern used for design, wastewater generation pattern observed on field and operational peak factor in STP

The peak factor used while designing the STP was 2.5, the same factor is used while designing the SBR in general conditions. The peak factor of 2.5 was used considering the ideal wastewater generation pattern. But the data observed on the field was not matching to the data considered during design. The comparison between wastewater generation pattern used for design, wastewater generation pattern observed on field and operational peak factor in STP is shown in figure below;

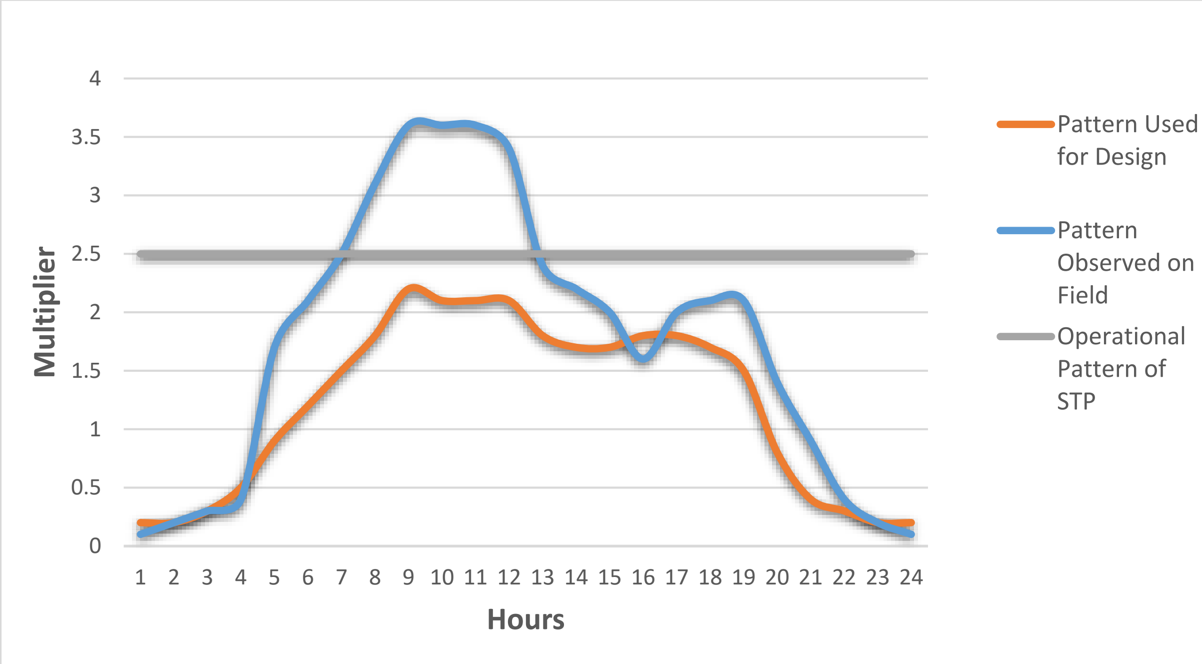

Figure 5: Comparison between wastewater generation pattern used for design, wastewater generation pattern observed on field and operational peak factor in STP

VIII. CONCLUSIONS

The study was conducted to understand the design and operation approach of sewage treatment plant at Kabitkhedi, Indore of capacity 235 MLD. After detailed analysis of design and operational considerations following conclusions are made;

1. The wastewater generation pattern adopted for STP designing in India is not suitable for Indian conditions.
2. During peak hours the incoming flow in STP exceeds the operational capacity of STP which raises the issue of storage of excess inflow at STP.
3. As STP cannot take flow more than its operational capacity, the remaining wastewater remains in the primary sewerage lines which causes problems like surcharging the primary lines and overflowing the manholes.
4. These problems can be tackled either by providing larger wet wells or designing the STP basins for higher peak factor.

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