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UPGRADING OF SMALL SEWAGE TREATMENT PLANTS FOR AMMONIA REMOVAL - CASE OF A UNIVERSITY CAMPUS

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ABSTRACT

Fourteen small sewage treatment plants (STPs) are constructed to treat the sewage generated from the International Islamic University Malaysia (IIUM) Gombak campus. These plants are required to fulfil the effluent Standard B of the revised environmental quality act of Malaysia. Effluent quality data of these plants was evaluated to check the compliance with the revised effluent quality standards set by the Department of Environment (DOE), Malaysia. Secondary data (monthly) of the STPs was analysed for this study. Performance of the STPs were evaluated in terms of ammoniacal nitrogen (AN) and biochemical oxygen demand (BOD). The statistical analyses of the data revealed that the median effluent concentration of AN from all the plants usually fails to meet the allowable concentration of 20 mg/L set for Standard B. However, all of the plants are able to meet the BOD standard of 50 mg/L. This study recommends additional aeration for extended time to reduce AN concentration from the effluents of the existing plants. Another alternate solution is to construct a centralized treatment plant, preferably a sequenced batch reactor (SBR), to provide further treatment of effluent released from the existing small plants, which are unable to meet the standard set for allowable AN concentration.

Keywords: Ammoniacal nitrogen, centralized treatment plant, effluent quality, extended aeration, sequenced batch reactor.

INTRODUCTION

Wastewaters are generally discharged into the river system which has self-purification capacity. In the past, discharging this wastewater did not pose threat to the stream as it had sufficient resilience to mitigate the effect of pollutants. However, with the increase of population and rapid urbanization the system often gets overloaded with the pollutants. As a consequence, the aquatic system becomes polluted posing threat to the environment. Majority of the organic pollutants of a river comes from sewage (Biswas 2002). Modern technologies have been emerged to treat this sewage to discharge better water to river systems. However, if the Sewage Treatment Plants (STPs) fail to treat the sewage according to the standard, the water body to which effluent is discharged will be polluted. It has been argued that in near future the standards of STP effluent will be changed and it will be set based on the recipient water body (Vanrolleghem 1996). The future of the wastewater treatment is anticipated to be dependent on the condition of the local recipient of the STP effluent and not some common effluent standards (Tyson *et al*., 1993).The River Pusu which runs through the International Islamic University Malaysia (IIUM) Gombak Campus at its downstream is currently heavily polluted with suspended solids. The suspended solids occur because of the sand mining activity at the upstream of the river. However, according to Zainuddin *et al*. (2014) the river is also polluted with Biochemical Oxygen Demand (BOD) and Ammoniacal Nitrogen (AN). An average BOD of 8 mg/L and AN of 1.6 mg/L attributes the river as a class IV river according to the Malaysian national water quality standards Zainuddin *et al.* (2014). The STPs are discharging the effluent to the River Pusu. So, to investigate the occurrence of these pollutants, it is necessary to investigate the effluent status of the STPs functioning at IIUM. So, the objective of this paper is to find out whether the STPs are maintaining the standard effluent water quality or not.

Abma *et al.* (2010) investigated the upgrading of STP with a low cost and sustainable separate treatment facility for treating industrial sewage. To make it cost effective, three conditions were chosen and applied among which enlargement of the STP facility and separate treatment of the effluent of UASB reactor and reject water were considered. However, they concluded that the proposed solutions are cost-effective and also commented that the combined use of Phospaq and one step Annamox will be more cost-effective and sustainable. A new approach to convert ammonium and nitrite to nitrogen gas is Anaerobic Ammonium Oxidation (Annamox). Physiology of Annamox was investigated by Strous *et al*. (1999). The variation of pH was from 6.7 to 8.3 and temperature was varied from 200C to 400C. Jetten *et al* (1997) discussed an efficient and sustainable municipal wastewater treatment system. New microbial process was introduced by them which could remove chemical oxygen demand (COD) too. In this process nitrogen was removed by partial oxidation. However, the sludge produced by this process had a great potential to yield methane for generation of energy. Vieno *et al.* (2005) demonstrated the effluent water quality from Aura STP, Finland. They basically detected the presence of pharmaceuticals in the effluent water and also determined the impact of the effluent on the receiving water body i.e. River Aura. In their work, they showed the seasonal variation of the occurrence of pharmaceuticals and concluded that in the

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cold seasons, the environmental impact of the pharmaceuticals can be severely detrimental. Morrison *et al.* (2001) made an assessment of the impact of the Kieskammahoek Sewage Treatment Plant (KSTP) on the Kieskamma River by monitoring the effluent water quality and the river water quality in terms of pH, COD, conductivity and other nutrients for about 1 month. They found that COD and orthophosphate limits were crossing the allowable standard of effluent quality. They attributed the COD, orthophosphate and NH4-N pollution of the river to the effluent discharged from KSTP. Xu *et al.* (2007) assessed four STPs in the Pearl River delta to determine the occurrence and elimination of antibiotics in the STPs. They commented that complete elimination of the antibiotics were not possible having the highest efficiency rate of 81%. They noted the remarkable differences of the antibiotics in the daily environmental loads. Rim-Rukeh and Agbozu (2013) measured the impact of partially treated sewage on the receiving water of Epie Creek Niger Delta. They sampled the water at four locations at the downstream of the waterbody including the STP effluent discharge point. However, they described the water quality of the creek to be fairly polluted because of the partially treated sewage. Nitschke and Schüssler (1998) determined the pollution loads of herbicides of urban and rural wastewater from wastewater treatment plant. However, they found that the herbicide loads of urban areas are also significant along with the rural areas. Bueno *et al.* (2012) monitored five STPs in different regions of Spain to detect persistence of emerging organic chemicals and major pollutant groups coming out from the effluent of the STPs. Singh *et al.* (2004) assessed the impact of wastewater toxicants discharged by STPs on the surrounding disposal environment. They judged the effect of both treated and untreated wastewater toxicants. They noted that the sludge from STPs have both positive and negative effect on the agricultural areas. The sludge contained heavy metals which is detrimental for the soil and at the same time it contained nitrogen, phosphorus and potassium which are nutrients to soil.

STUDY AREA

The study has been done on the STPs of IIUM Gombak Campus, located in Malaysia. There are fourteen STPs located in the campus area (Figure-1).

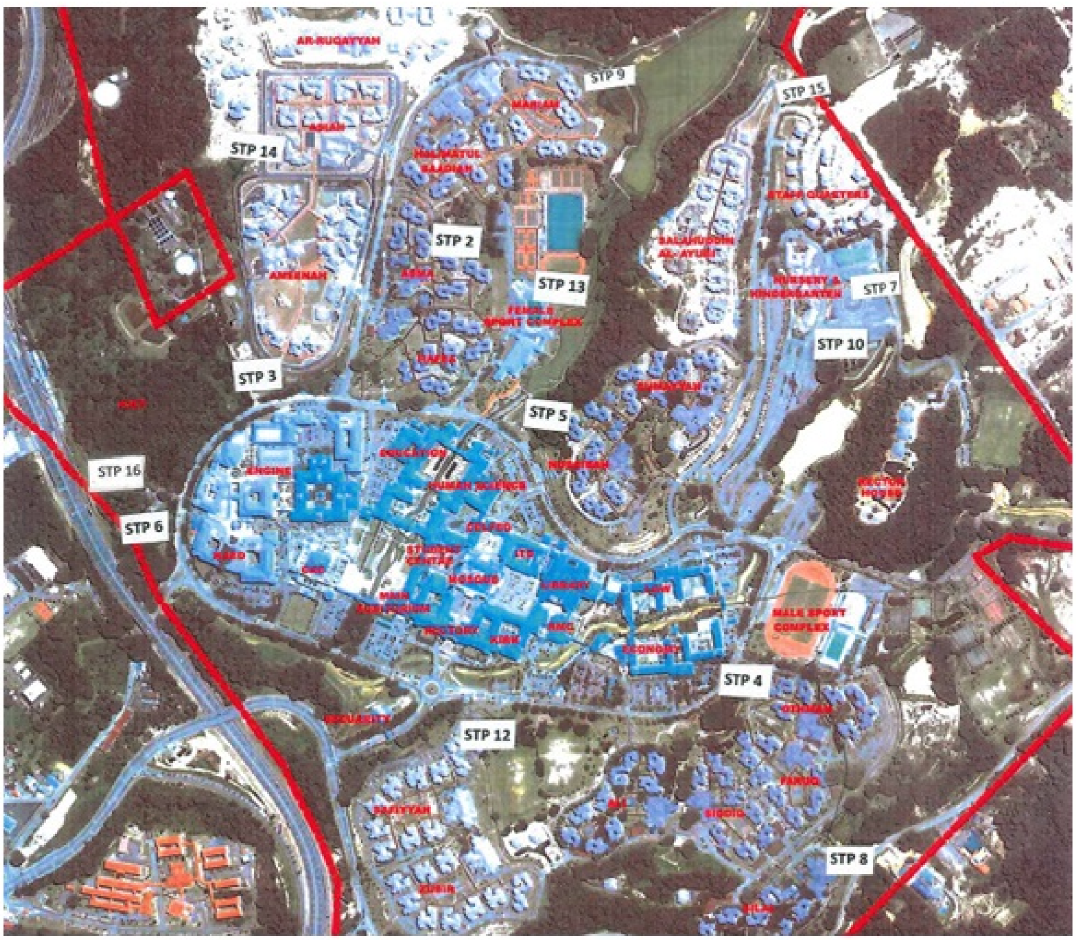

Figure-1. Locations of sewage treatment plants at IIUM (Source: IIUM).

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MATERIALS AND METHODS

The effluent quality of the STPs situated at IIUM have been checked against the allowable standard set by the Malaysian Government. There are in total fourteen STPs currently running at the university. The data of two STPs was not available. Therefore, performances of twelve STPs, out of fourteen, have been presented in a box plot to give a general overview of the condition. Data missing of the STPs are STP 3 and STP 11. The Malaysian standard for STP effluent has also been presented and the data of the STPs has been depicted in the graphs, comparing with the standard for the best and worst performing STPs. There are two standards mentioned by the Department of Environment, Malaysia. One is Standard A which refers to a high effluent water quality and applicable to the effluents discharged upstream of any existing water intake. The Standard B which indicates an inferior effluent water quality is applicable to the discharge points downstream of which there is no water intake is located. The data which has been used in this paper is of the year 2014. As per the requirements the effluent samples are tested once a month. Unfortunately, there is no data available on the influent water quality. Therefore, it is a limitation of this work that removal efficiency of the STPs could not be measured and also having one test result once in a month is a weakness in the available data. However, as the objective of this paper is to give information about the general status of the STPs regarding whether the STP standard effluent quality is maintained or not, the data provided are marginally acceptable. Two water quality parameters e.g. Biochemical Oxygen Demand (BOD) and Ammoniacal Nitrogen (AN) of the effluents have been presented in this paper. BOD5 values at 20oC are taken to represent the BOD values. Table-1 represents the STP type and population equivalent (PE) of each STP. Table-2 shows the standards of STP effluent set by Department of Environment (DOE), Malaysia.

Table-1. STP information.

STP ID	Type of Plant	Estimated Population
2	Standard Aeration	1600
4	Standard Aeration	3500
5	Standard Aeration	2900
6	Standard Aeration	800
7	Hi Kleen	500
8	Hi Kleen	900
9	Hi Kleen	1000
10	Hi Kleen	550
12	Hi Kleen	2400
13	Hi Kleen	350
14	Hi Kleen	2100
15	Hi Kleen	2600
	Total =	19,200

Table-2. Malaysian standards of sewage effluent.

Parameter	Unit	Standard	
		A	B
Temperature	^{0}C	40	40
pH	-	6-9	5.5-9
BOD	mg/L	20	50
COD	mg/L	120	200
Suspended Solids	mg/L	50	100
Oil & Grease	mg/L	5	10
Ammoniacal Nitrogen (River)	mg/L	10	20
Nitrate Nitrogen (River)	mg/L	10	10
Phosphorus	mg/L	5	10

RESULTS AND DISCUSSION

Figure-2 and Figure-3 show the box plot of BOD and AN concentration respectively for the STPs. The data for the box plot were monthly data of the effluent quality of the STPs. From the box plot, the worst and best performing STPs in terms of BOD and AN have been identified. For BOD, STP 8 is the worst performing and STP 9 is the best performing STP. STP 6 is the worst and STP 14 is the best STP in terms of AN concentration, respectively.

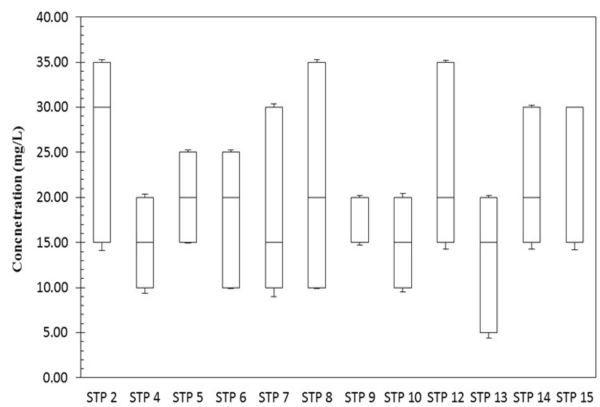

Figure-2. Box plot of BOD for the STPs.

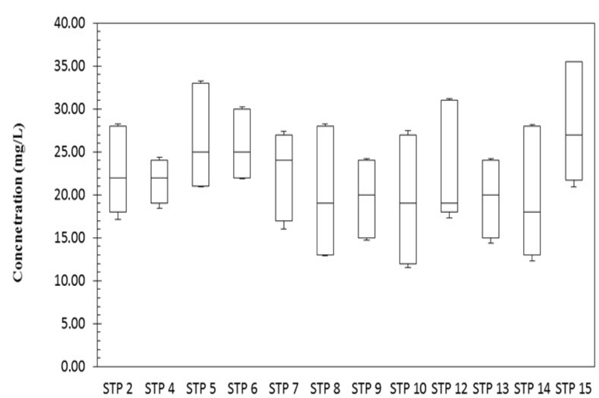

Figure-3. Box plot of AN for the STPs.

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Figure-4 and 5 show the monthly effluent quality of STP 8 and STP 9, respectively in terms of BOD. Figure 6 and 7 show the monthly effluent quality of STP 6 and STP 14 in terms of AN. From the figures it is obvious that all the STPs are failing to achieve the standard of 20 mg/L of AN concentration. However, no STP is exceeding the BOD limit of 50 mg/L.

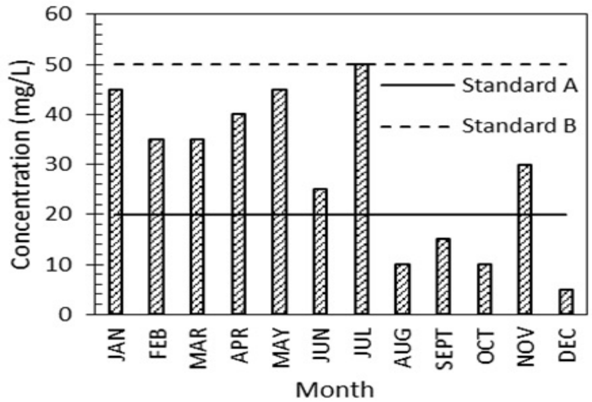

Figure-4. BOD of STP 8 effluent.

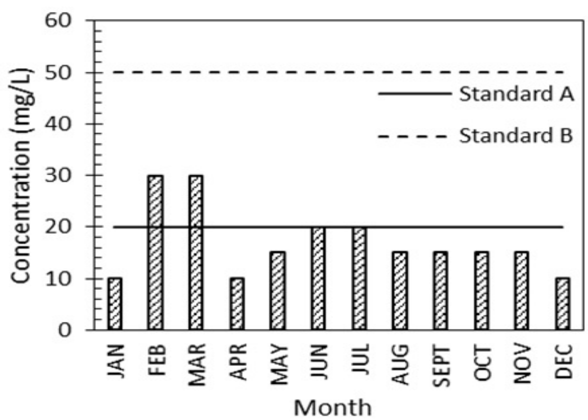

Figure-5. BOD of STP 9 effluent.

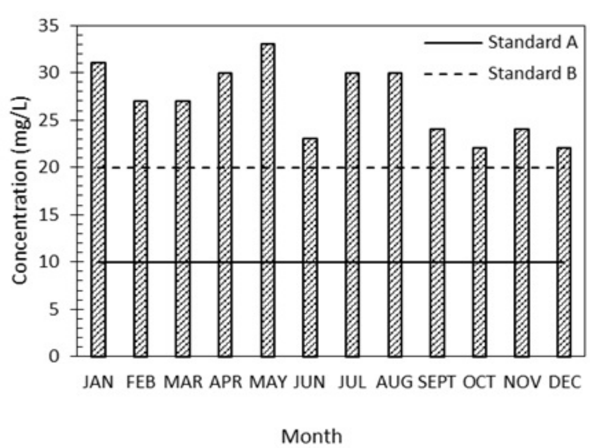

Figure-6. AN of STP 6 effluent.

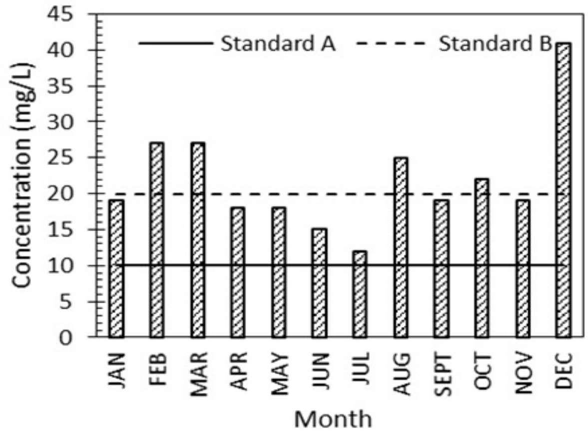

Figure-7. AN of STP 14 effluent.

The STP authority basically target to achieve Standard B effluent water quality as there is no water intake located at the downstream of the river where the effluents are discharged. It can be seen from the graphs that all the STPs are maintaining the Standard B of BOD throughout the year. The concentration of AN in the effluent is noteworthy as STPs are failing to maintain the Standard B of AN let alone Standard A. On the other hand most of the STPs are maintaining Standard A of TSS though occasionally a few months in a year it is not maintained. However, the TSS concentration is not crossing the Standard B at any time in the year. Therefore, the STPs efficiency need to be checked and adjusted according to the standard requirement of AN.

SUGGESTIONS TO REDUCE AN & BOD LEVEL

From the above graphs, it is clear that AN concentration in the effluent is noteworthy as it is beyond the allowable standards. At the same time BOD is also high in several cases. However, we discuss some of the AN and BOD removal methods of STP and suggest the best measure to be adopted by the IIUM STP operators.

Table-3. Comparison of different AN removal methods (Nye, 2010).

Method	Advantage	Disadvantage
Conventional Activated Sludge Process	Easily modifiable for biological nitrification	Initial capital cost
Extended Aeration Method	- Less Complex - Can handle different types of wastewater - High removal of AN	Requirement of large area
Sequencing Batch Reactor	Compact size	Difficulties in operation
Trickling Filter	Energy efficient	High maintenance
Membrane Bioreactor	High nitrogen removal	Expensive
Lagoon System	Cheap	Difficulties in operation

Among the above mentioned different methods (Table-3) to reduce AN and BOD from the effluent, we recommend the extended aeration method because of its feasibility and easy retrofitting into the existing facilities. It is not too expensive and at the same it has a high AN removal capacity. AN is converted to nitrate nitrogen more rapidly with the availability of more oxygen. To achieve higher AN removal, extensive aeration is required which is served by extended aeration method. So, upgrading the extended aeration component to the STPs will be able resolve the AN issue in the STP effluent. The BOD removal is also a function of aeration. The more aeration is done, the more BOD is removed. So, the suggested measure will address both AN and BOD. Figure-8 shows a typical diagram of an extended aeration process.

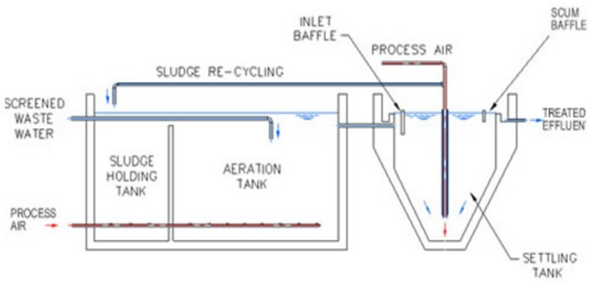

Figure-8. Typical extended aeration process.

(**Source**:http://www.slideshare.net/nadzifahghazali/assingment-1-suspended-growth-bio-treatments)

However, another potential solution can be to send the effluents from the existing STPs to a large central STP. We propose the central STP to be a Sequenced Batch Reactor (SBR) type. The network diagram of the central STP has been shown in Figure-9 and the proposed schematic diagram of the central STP system has been shown in Figure-10. SBR system has been chosen because of its advantages and suitability in the campus. SBR has an excellent flexibility with respect to effluent quality and it is very much efficient in removing nitrogen. At the same time, the power requirement for a SBR is less than the conventional STPs.

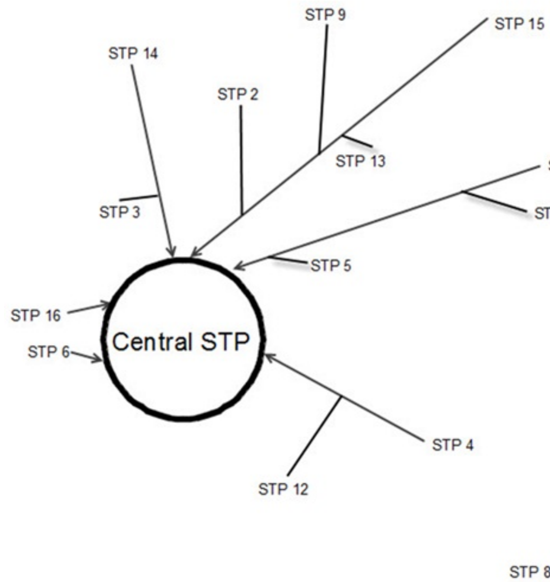

Figure-9. Proposed central STP system.

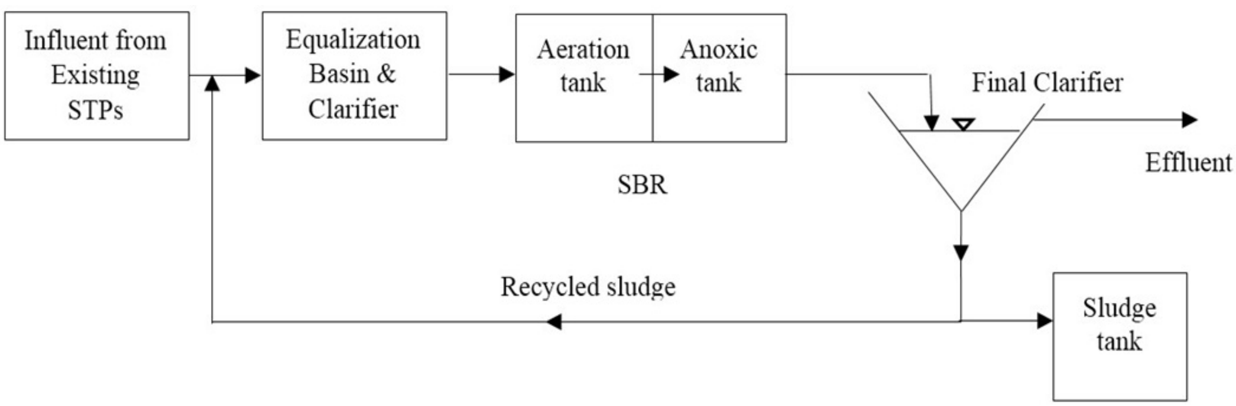

Figure-10. Schematic of the proposed sequenced batch reactor system.

CONCLUSIONS

Based on the available monthly effluent quality data available for the sewage treatment plants at IIUM Gombak Campus, it can be concluded that all the STPs are unable to meet the standard set by the DOE, Malaysia. AN concentrations in the effluents are high as the STPs are not designed to remove AN from the wastewater. On the other hand, if the BOD can be removed to some more extent, it will be beneficial for the receiving water body. However, to reduce the AN and BOD concentration in the STP effluents, two options have been presented in this paper. One is upgrading of the existing STPs with extended aeration component and the other is to construct a centralized SBR plant which will further treat the effluent from the existing STP.

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