# PERFORMANCE EVALUATION OF SEQUENCE BATCH REACTOR USING DOMESTIC AND SYNTHETIC WASTEWATER

A

PROJECT REPORT

*Submitted in partial fulfilment of the requirements for the award of the degree*

*of*

**BACHELOR OF TECHNOLOGY**

**IN**

**CIVIL ENGINEERING**

*Under the supervision*

*of*

**Mr Anirban Dhulia**

**(Assistant Professor)**

*by*

**NITESH CHANDEL (151654)**

**AMIT SINGH (151661)**

**JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY**

**WAKNAGHAT, SOLAN – 173234**

**HIMACHAL PRADESH, INDIA**

**MAY – 2019**

# STUDENT'S DECLARATION

I hereby declare that the work presented in the project report entitled **“Performance Evaluation of Sequence Batch Reactor using Domestic and Synthetic Wastewater**” submitted for partial fulfilment of the requirements for the degree of bachelor of technology in civil engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr Anirban Dhulia**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Name - Nitesh Chandel, Amit Singh

Roll no-151654, 151661

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, india

Date: 8th MAY, 2019

# CERTIFICATE

This is to certify that the work which is being presented in the project report titled **“Performance Evaluation of Sequence Batch Reactor Using Domestic and Synthetic Wastewater”** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Nitesh Chandel (151654), Amit Singh (151661)** during a period from August, 2018 to November, 2018 under the supervision of **Mr Anirban Dhulia** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement is correct to the best of our knowledge.

The above statement made is correct to the best of our knowledge.

Date:-…………………………………

| | | |
|---|---|---|
| Signature of supervisor | Dr. Ashok Kumar Gupta | External |
| Mr. Anirban Dhulia | Professor & Head of | Examiner |
| Assistant Professor | Department | |
| Department of Civil | Department of Civil | |
| JUIT Waknaghat | JUIT Waknaghat | |

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I would like to thank our project coordinator and all other faculty members and technical staff of Department of civil engineering of Jaypee University of Information Technology for providing valuable input throughout the course of this work.

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# LIST OF ABBREVATIONS

| | |
|---|---|
| BOD | Bio Chemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| SBR | Sequencing Batch Reactor |
| TSS | Total suspended Solids |
| TDS | Total dissolved solids |
| ASP | Activated sludge process |
| TS | Total Solids |
| HRT | Hydraulic Retention Time |
| SRT | Sludge Retention Time |
| EPS | Extracellular Polymeric Substance |

# ABSTRACT

Sequence batch reactor is a modified version of conventional ASP also it requires less space and less cost. In Sequence batch reactor separate settling tank is not needed settling or clarification can be done in a single tank and also separate aeration tank is not needed aeration is given in the single tank only. Sequence Batch Reactor requires less space than conventional ASP as an additional settling tank is not there in a Sequence Batch Reactor. In Sequence Batch Reactor separation of sludge from the wastewater happen in a single reactor. This study aims to compare firstly the performance and treatment capability of two lab scale Sequencing Batch Reactor (SBR) fed domestic and synthetic wastewater under different case of operations for total solids, total suspended solids, total dissolved solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and also to analyse the response of two lab scale SBRs feed with synthetic and domestic wastewater. In this work domestic and synthetic wastewater is treated in a single batch reactor. The outcome of this work shows competent results having removal rates for TDS, TS, TSS COD, BOD in domestic wastewater was 87 %, 84 %. 73 %, 86 %, 86 % respectively analysed for 20 days of reactor operation having 8hr cycle time. Also synthetically prepared wastewater is analysed in a different reactor and removal rates for TDS, TS, COD was found to be 83 % 83 % 88 % and 84 % 84 % 89 % and 85 % 85 % 91 % for 4hr, 6hr, 8hr respectively analysed for 30 days.

# CHAPTER 1

# INTRODUCTION

In the past few years there is increase in awareness of the negative impact that wastewater discharges have on the aquatic life i.e. eutrophication when the wastewater is discharged in ponds lakes etc. that has led to the introduction of more strict legislation for controlling the effluents quality that is discharged from wastewater treatment plants. So to satisfy with these more stringent effluent quality standards, new wastewater treatment techniques have been introduced or the older techniques have been improved. The purpose of wastewater treatment is to lessen the unfavourable impacts of pollutants present in the wastewater on the nature and human health. Initially treatment of wastewater focused on the removal of contaminants such as suspended solids (SS), chemical oxygen demand, COD, and biochemical oxygen demand, BOD). Later the importance of the nutrient (N and P) nitrogen and phosphorous removal was recognised.

Wastewater treatment process consists consist of 3 – 4 stages of treatment.

- Preliminary treatment-This process focuses on removing large particles from the wastewater to prevent damage and also hinders efficiency treatment operations.
- Secondary treatment- In secondary treatment process biodegradable organic matter are removed which is either dissolved or suspended.
- Tertiary treatment- In this process residual SS are removed and disinfection is done.

The treatment of wastewater is done by four methods namely. In first method i.e. Physical methods tanks etc. are used for the removal of impurity from wastewater. In second i.e. Mechanical treatment we use machines for wastewater treatment. Third is biological method if we use bacteria and other micro-organisms for removal of pollutants from wastewater. For removal of pollutants from wastewater biological methods is used because it is more advantageous than other method used for wastewater treatment. The last method is Chemical this is used to increase the productivity of various phases in the treatment process. A sequencing batch reactor (SBR) is a fill-and-draw process (Secondary treatment process) for wastewater treatment. In this we use bacteria and micro-organisms for treatment of wastewater that is considered as biological methods of wastewater treatment. In SBR the treatment of wastewater is done in a reactor which is a fill and draw reactor commonly known as batch reactor to eliminate pollutants from wastewater. These are widely used in the chemical and pharmaceutical industries. Sequencing batch reactor means the sequence of steps reactor under- goes as it receives wastewater. In this all operations are performed in a single tank. It means that SBR performs equalization, aeration and clarification steps in a single reactor. The conventional activated sludge process used for wastewater treatment was first made as a batch system, but due to certain problems like clogging of aeration diffusers and high operating time the system was changed to continuous flow system. During the past decades, due to advancement in technology electronic and mechanical timers, level sensors, jet aerators are being made which solves the problems which has encountered earlier in a batch system led to the reintroduction of batch treatment system. In recent years, SBRs have gained popularity for treatment of wastewater due recent technological advancement, which makes it more efficient than conventional activated sludge systems. In this it is very simple to increase the efficiency of treatment wastewater by changing the time duration of each phase.

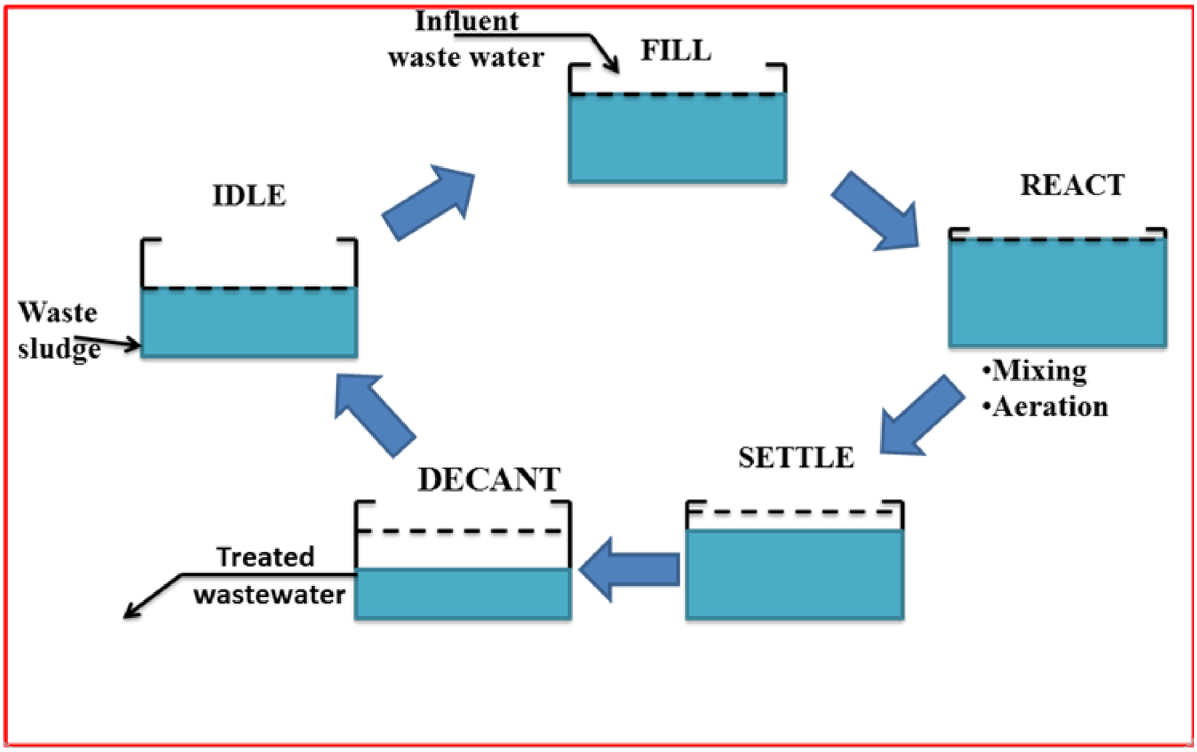

Figure1.1 Schematic diagram of SBR Process

## 1.1 OBJECTIVES

- To study the performance of SBR for parameters Total Suspended Solids, Total Dissolved Solids, Total solids, COD, BOD.

- To analyse the response of two lab scale SBRs feed with synthetic and domestic wastewater for different cycle times.

## 1.2 NEED FOR STUDY

Conventional activated sludge process because it require separate clarifier or a settling tank so it space and cost requirement is more and sequence batch reactor .In SBR we can modify cycle time such as cycle of 4h,6h,8h according to pollutants present in the wastewater. If the pollutants present in the wastewater is more so more cycle time is given in the treatment process so that the effluent meets effluent discharge standards set by various environmental authorities. Potential cost of an SBR system is low as separate clarifiers are not used because equalisation, primary clarification and secondary clarification can be achieved in single tank due to which its potential cost decreases. In this we have Cyclic operations by which data gathering become very SBR system has very low operational costs than conventional system SBR can handle large variations in organic loadings as compared to conventional activated sludge process. As in this we have a settling period so we can easily identify problems of bacteria growth and settling problems and also can correct and control them. SBRs also perform well under shock loadings and varying influent flow rates.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 SEQUENCING BATCH REACTOR

During the early 19th century, for biological treatment of wastewater is done by activated sludge process is used and this process is developed by Ardern Locket and Flower. These analysts used crude sewage in the sequence batch reactor and later came up with an idea of sequence batch reactor which can be operated in a single tank or reactor with different phases such as filling of influent wastewater, reaction of influent wastewater by proper mixing and aeration, settling of sludge, decanting of treated wastewater so that. The treated effluent which was taken from the SBR treatment for testing different parameters had found to be of good quality but it experiences many functional problems such as clogging of aerators pores which advocate the development of continuous-flow ASP which has two tanks, one is known as aeration tank and another is equalization tank. After that Further advancement in the process of sequence batch reactor process happened in 1950's when a researcher named Pasveer and associates of his repeatedly used concepts of batch treatment in their varying volume ASP. After that in 1970's major advancement took place in the SBR technology in countries like US and Australia with the help of Environment Protection Agency (EPA). EPA also published design manuals for design of Sequence Batch Reactor in 1986 and 1992 which leads to broad scale implementation of the Sequence Batch Reactor. Due to technological advancement the operational difficulties experienced prior has been resolved, especially the use of jet aerators which solve the problem of clogging of pores of aerators and also good microprocessor control system. In today's time SBR has found its implementation on a large scale applicability (earlier there is a question mark on large scale applicability) which is due to technological modifications in the Sequence Batch Reactor treatment process, which will leads to greater efficiency of existing wastewater treatment facilities. The removal efficiency of Sequence batch reactor is generally high than ASP but it will also depend on the design of SBR and the manner of its working. Sequence Batch Reactor can attain good Biological Oxygen Demand removal capacity. Biological Oxygen Demand removal capacity is 85 % for ASP to 93-95 % for SBR. In SBR BOD discharge limits is smaller than 20 mg/L and thus can be achieved consistently. TKN levels of smaller than 8 mg/L can be accomplished by successive anoxic phase in which reformation of $NH_3$ to nitrates with the help of nitrifying bacteria which is also called nitrification phase and anaerobic phase conversion of nitrates to nitrogen gas with the help of denitrifying bacteria which is also called the denitrification phase. Low phosphorus levels which is smaller than 1- 2 mg/L can be accomplished by employing a conjunction of biological treatment and chemical agents such as aluminium in treatment cycle.

## 2.2 BACTERIAL GROWTH IN A BATCH REACTOR

In a batch reactor if more and more mechanical mixing is provided EPS (Extracellular polymeric substances) is released in the system by microorganisms present in the system. The EPS excreted by the microorganisms in the wastewater leads to decrement in affinity of cell towards water and also changes charges on the surface of the cell which leads to better bacterial growth and better adherence of microbial cells and granulation by which large diameter granules are formed and ultimately leads to large bacteria growth in the system. Initially there is flocs of sludge in the system but as reactor runs continuously these flocs are converted large diameter granules having an average diameter of 0.2mm. These granules are formed due to interaction by inter particle bridging process among EPS, microbial cell, and ions. Bacteria can reproduce by binary fission, either by sexual mode or by budding. In a batch reactor food comes in terms of organic matter when we fed it with wastewater and sludge is inoculated which has microorganisms in it. These microorganisms reproduce by binary fission as more and more organic matter comes in they reproduce and there population becomes very large with time. These microorganisms when food supply is over these microorganisms eat their own protoplasm and at final stage of treatment process microorganism concentration decreases. Bacteria growth in reactor takes place in 4 phases.

- The Lag Phase: In Bacterial physiology lag phase is the phase which is essential so that bacteria cells will adapt to new environment. In this phase size of the bacteria increases but bacteria concentration is almost constant.

- The log phase: This phase is also known as exponential phase. During this phase growth in bacteria population takes place in an exponential manner means its number increases in an exponential manner and bacteria cells division takes place as fast as possible if the organic matter is readily available to them.

- The Stationary Phase: During this phase, bacteria growth is limited due to depletion of organic matter essential food is not available for microorganism bacteria concentration remains relatively constant as growth rate of bacteria is equal to death rate of bacteria. Bacterial growth is constant.

- The Death Phase: In the death phase, due to non-availability of food i.e. organic matter microorganisms eat their own protoplasm due to which death of these microorganisms will takes place. No bacteria growth will take place in this phase.

## 2.3 NITRIFICATION

Nitrification is the process of change of $NH_3$ into $NO_2$- and then it goes from $NO_2$- to $NO_3$- for this conversion from ammonia to nitrite a special type of bacteria is used commonly known as autotrophic bacteria which leads to completion of nitrification process

Majority of the organic nitrogen immediately gets converted to $NH_3$ and high percentage of this $NH_3$ instantly gets converted into ionic $NH_{3.}$ The ionic and gaseous form of ammonia are also influenced by amount of $H^+$ ions in the water. More acetic solution favour the ionic form ammonia and basic solution favours gaseous form ammonia as the PH of waste water ranges from (6 to 9) almost all the ammonia present in ionic form.

The Nitrification process is a two stage process and the microorganisms present in nitrification activity are known as nitrifying bacteria named as Nitrosomonas and Nitrobacter. These microorganisms are known as autotrophs as these microorganisms obtain their energy for their maturation from the oxidation of nonorganic resources such as carbon dioxide ($CO_2$ compounds) and alkaline bicarbonate. These nitrifiers are highly dependent upon temperature, dissolved oxygen and PH lower the DO lesser will be the activity of nitrifier and higher temperature promotes the growth of nitrifier. The oxidation of $NH_3$-N to $NO_2$-N can only be done by Nitrosomonas bacteria, while the oxidation of $NO_2$-N to $NO_3$-N is done by nitrobacter bacteria. The conversion of ammonia nitrogen to nitrite nitrogen occurs in a two-step reaction listed below:

$NH_4^+ + 1.5\ 0_2 \rightarrow 2H^+ + H_2O + NO_2^-$ (Nitrosomonas) (2)

$NO_2^+ + 0.5\ 0_2 \rightarrow NO_2^-$ (Nitrobacter) (3)

Combining Equations (2) and (3):

$NH_4^+ + 20_2 + NO_3- + 2H^+ + H_2\ O$ (4)

For the above reaction to happen, 4.56 mg of $0_2$ are needed per milligram ammonium nitrogen.

## 2.4 BIOLOGICAL DENITRIFICATION MECHANISM

After nitrification $N_2$ is still there in the water as nitrates it is not as toxic as ammonia but still is harmful so the complete removal of nitrogen from the system is called denitrification. In this process the nitrate is converted into nitrogen gas (N2) with the help of heterotrophic bacteria. These bacteria needs food and to oxidize that food they need oxygen if DO is not present they use nitrate which is useful for denitrification. After that nitrate is converted into nitrogen gas and released from the system

## 2.5 FACTORS AFFECTING SBR PERFORMANCE

- pH: PH is plays a very important role in the good BOD,COD,TS,AMMONIA removing efficiency of the SBR .optimum pH condition is required for the growth of bacteria . For the removal of nitrogen pH should be between 6 to8, because the nitrifiers are dependent upon the pH, high pH will lead to decrease the functioning of nitrifiers.

- Temperature: Growth of bacteria depend upon the temperature very low temperature will decrease the growth and also decrease the removal efficiency of SBR. The sludge settlement became worse when the temperature decreases because of the less growth of bacteria the nitrification and denitrification effect was almost lost and seriously affected. Autotrophic bacteria growth depend upon temperature high temperature will lead faster growth and lower temperature will lead to slower growth. These bacteria is essential for the nitrification.

- Dissolved oxygen: DO is one of the most important factor in the performance of SBR Bacteria uses DO for the removal of microorganisms present in the wastewater also DO is very important in the nitrification process or we can say that DO is very essential for the nitrogen removal. DO is controlled and supplied by the aerators , if DO concentration decreases the efficiency to remove ammonia decreases so aeration time should be selected to achieve full nitrification for the best results.

- Cycle time: The cycle in SBR is bifurcated into five phases: First phase is fill phase second is react third is settle followed by draw and idle phases as shown above. There are many types of fill and react phases, which depend upon aeration and mixing processes. By changing the cycle time we can conclude that at which cycle time the best removal efficiency is achieved. by changing the cycle time for example is mixing and aeration increases the nitrification processes improves because of the availability of good amount of DO for the autotrophs to remove nitrogen.

Mixing: mixing improves the biomass settling and the reactor performance . A stirrer is used to provide mixing for proper dispersion of sludge in the reactor and also so that sludge remain suspended in the reactor the stirring rate used is 1500-3000rpm and it mounted above the reactor. The removal efficiency of COD increases at this mixing rate .

## 2.6 USES OF SBR

Sequence batch reactor is very useful in the treatment of wastewater. SBR treats the wastewater by the process discussed earlier with the help of sludge and providing aeration and proper mixing.

- In a sequence batch reactor single tank is used we have no separate tank for settling so settling, mixing and aeration can be attained in a single tank.
- Effluent quality of discharge water meets the requirement of BOD, COD, TS, TDS, TSS for surfaces discharge.
- Power consumption of SBR is less than the conventional plant with better power savings at lower flows.
- High rate removal of total solids, BOD, COD and nitrogen which makes SBR highly efficient.
- Required less space and cost than that of conventional plant.
- SBR can be used for various types of wastewater like domestic , synthetic wastewater , brewery wastewater , swine wastewater etc.

## 2.7 SUMMARY RELATED TO SBR

A summary of various studies involving use of SBR is presented in Table 2.1.

Table 2. 1 Summary of Studies Related to SBR

| Sl. No. | Title | Journal Name (Year) | Author | Methodology | Conclusion |
|---|---|---|---|---|---|
| 1 | The key role of inoculated sludge in fast start-up of sequencing batch reactor for the cultivation of aerobic granular sludge. | Journal of environmental Sciences. (2019) | Wang, Xiao-chun, Zhong-lin Chen, Jing Kang, Xia Zhao, Ji-min Shen, and Liu Yang. | In this two inoculation sludge is taken one is granular sludge which is stored sludge and another is activated sludge. | It is seen that when granular sludge which is stored is fed in the reactor this sludge generate fully grown granular after 20 days of operation and has more bacteria concentration as compared to when activated sludge is used. |
| 2 | A sequential treatment of intermediate tropical landfill leachate using a SBR and coagulation. | Journal of Environmental Management. (2018) | Zi Jun Yong, Mohammed J.K. Bashir, Choon Aun NG, Sumathi SethuPathi | In this research 6 reactors were used with a capacity of 1.5 litre made from polypropylene. | Study was done to treat COD, BOD. $NH_3$-N, TSS and other parameters using SBR followed with coagulation |

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| | | | | SRT and HRT were fixed at 30 and 20 days. Sludge was added in a ratio of 1:9. Sludge was from palm oil mill. | using Alum in it. The efficiency of treatment of wastewater is found to be 85.99 %, 95.25 %, 92.82 % and 87.81 % for chemical oxygen demand, ammonia nitrogen and total suspended solids. |
| 3 | Use of magnetic powder to effectively improve the performance of sequencing batch reactors (SBRs) in municipal wastewater treatment. | Bioresource Technology. (2018). | Liu, Yi, Jixiang Li,WenshanGuo, HuuHao Ngo, Jiajun Hu, and Min-tianGao. | In this research magnetic powder is added in an SBR and its consequence is studied. | Study shows that, by adding magnetic powder in SBR had 8.98 % and 5.76 % higher removal efficiencies than that of the conventional for ammonia and chemical |

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| | | | | | oxygen demand. |
| 4 | Roles of bacterial and epistylis populations in aerobic granular SBRs treating domestic and synthetic wastewaters | Chemical Engineering Journal. (2018) | Liu, Jun, Jun Li, Sarah Piché-Choquette, and Balasubramanian Sellamuthu. | In this study two SBRs are used having same sludge is fed with domestic or synthetic wastewater. | The SBR which is fed with domestic wastewater has fully grown aerobic granules hence more bacterial growth than synthetic waste water and also has greater treatment efficiency. |
| 5 | Organic micro pollutants removal in sequential batch reactor followed by nanofiltration from municipal wastewater treatment. | Bioresource Technology. (2018) | Wei, C.H., Wang, N., HoppeJones, C., Leiknes, T., Amy, G., Fang, Q., Hu, X. and Rong, H. | The expulsion of 27 (OMPs) in municipal synthetic wastewater was analysed by using batch reactor which is of aerobic type and a batch reactor accompanied by nanofiltration. | The experimental results indicated that 9 (organic micro-pollutants) shows good organic removal which is over 60 %, six OMPs shows average biotic |

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| | | | | | removal having efficiency of about (30 – 70 %) and Ten OMPs showed low Organic removal which is less than 40 %. |
| 6 | A sequential treatment of intermediate tropical landfill leachate using a SBR and coagulation. | Journal of Environmental Management. (2018) | Zi Jun Yong, Mohammed J.K. Bashir, Choon Aun NG, Sumathi SethuPathi | Six sequence batch reactor is used made up of polypropylene having 1.5 litres of capacity parameters such as COD, Ammonia, and total suspended solids are tested after that alum is used for coagulation. | The outcome of the study shows good removal efficiencies chemical oxygen demand, total suspended solids, and ammonia nitrogen having values 84 %, 92 % and 94 % respectively. |
| 7 | Evaluation of dairy processing wastewater bio | Biotechnology Reports. (2018) | Beatriz Gil-Pulido, Emma Tarpey, Eduardo L.Almeida, | sequence batch reactor is used made up of | The outcome of the study shows good removal |

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| | treatment in an IASBR system: aeration rate impacts on performance and microbial ecology. | | William Finnegan, Xinmin Zhan, Alan D.W. Dobson, Niall O'Leary. | polypropylene having 1.5 litres of capacity and six such reactors are used parameters such as COD, Ammonia, and total suspended solids are tested after that alum is used for coagulation. | efficiencies chemical oxygen demand, total suspended solids, and ammonia nitrogen having values 84 %, 92 % and 94 % respectively. |
| 8 | Effect of cadmium on the performance of partial nitrification using sequencing batch reactor. | Chemospher. (2018) | Liqiu Zhang, Jingjing Fan, HangN. Nguyen, Shugeng Li, Debora F. Rodrigues. | sequence batch reactor having 5 L working volume is used for the treatment of landfill leachate which contains hefty metals. | Partial nitrification activity in presence of cadmium are studied and it is found that partial nitrification are not affected when concentration of cadmium is less than 5mg\l but when it above |

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| | | | | | 10 mg\L PN is affected its removal rate gets decreased by 30 %. |
| 9 | Development of aerobic granules from Slaughterhouse wastewater in treating real dyeing wastewater by Sequencing Batch Reactor. | Journal of Environmental Chemical Engineering. (2018) | Batoul Bashiri, Narges Fallah, Babak Bonakdarpour, Shilan Elyasi. | In this research two wastewater is used one is synthetically prepared and another is collected from dyeing industry. | Outcome of this study showed that chemical oxygen demand maximal removal efficiency was found to be 87 % while maximum removal efficiency for dyeing is 43 % only. It is also seen that if concentration of dyeing wastewater is increased to hundred percent the aerobic granules gets destroyed. |

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| 10 | Evaluation of colour and COD removal by Fenton from Biologically (SBR) pre-treated pulp and paper wastewater. | Process Safety and Environmental Protection. (2018) | Abedinzadeh, N., Shariat, M., Monavari, S. M., & Pendashteh, A. | Sequence Batch Reactor is used having 3.5 litres working volume and a wastewater sample from a pulp paper industry. | Fenton oxidation used in this leads higher removal rates for chemical oxygen demand and colour by this the total chemical oxygen demand removal efficiency was found 97.9 % and colour removal efficiency of 93.8 % respectively. |
| 11 | Effects of carbon sources on sludge performance and microbial community for 4-chlorophenol wastewater treatment in sequencing batch reactors. | Bioresource Technology. (2018) | Zhao, J., Li, Y., Chen, X. and Li, Y. | Two 4-L sequence batch reactor were taken by the researchers and fed with synthetic wastewater. One SBR is fed with starch which act as a | The result shows that by using different carbon sources in the two reactor doesn’t affect efficiency and bacterial growth in the reactor means the two |

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|  |  |  |  | carbon source, and in another reactor sodium acetate act as a carbon source. | reactor has same contaminants removal efficiency. |
| 12 | Effect of different salinity adaptation on the performance and microbial community in a sequencing batch reactor. | Biotechnology Reports. (2018) | Yuanyuan Zhao, Hee-Deung Park Jeong-Hoon Park , Fushuang Zhang , Chen Chen Xiangkun Li , Dan Zhao Fangbo Zhao. | Three similar batch reactor were used having a capacity of 8l. Three reactors used are having dissimilar aeration scheme having values of 0.6, 0.8, 0.9 litres per minute. | This study used IASBRs for treatment of dairy wastewater and the wastewater is analysed for chemical oxygen demand, N and P. It is seen that aeration scheme 0.6 L\min is most efficient giving 93 % efficiency. |
| 13 | Efficiency of sequencing batch reactor for removal of organic matter in the | Data in brief (2018) | Abdolkazem Neisi, Shirin Afshin, Yousef Rashtbari, Ali Akbar Babaei, Yusef Omidi | Study of biodegradation of Methyl Tertiary Butyl Ether was the aim using | Showed that the mixed microbial mass degrades the high concentration |

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| | effluent of petroleum Wastewater. | | Khaniabadi, Anvar Asadi , Mohammad Shirmardi,<br>Mehdi Vosoughi. | SBR at a pilot scale.<br>The reactor was made of thick glass cylinder (3mm) with internal diameter of 12 cm and 60 cm height. | of methanol (250 mg/L), and concentration of MTBE up to 70 mg/L in a 24 h cycle. Analysis also proved that the mixed microbial mass helps to biodegrade the COD up to 1350 (mg/L) in effluent. Aerobic SBR can be used for biological treatment of the petroleum wastewater containing pollutants named as Methanol, MTBE with good efficiency. |
| 14 | Influence of temperature on an Anammox sequencing | Journal of Bio resource Technology. (2018) | Quan Li, Shaopo Wang, Pengda Zhang, Jingjie Yu, Chunsheng Qiu, | Here the lab scale sequence batch reactor of working | According to results the nitrogen removal |

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|  | batch reactor (SBR) under lower nitrogen load. |  | Jianfeng Zheng. | volume 14 L was used. The synthetic wastewater was fed in the bioreactor with the help of the pump along with controlling temperature. A mechanical mixer, a valve and switches for controlling parameters are used. | efficiency and anammox was lower under lower temperature .The Anammox bacteria shifted from Ca. Brocadia to Ca when the temperature decreases from 34 °C to 15 °C. |
| 15 | Improving municipal wastewater nitrogen and phosphorous removal by feeding sludge fermentation products to SBR. | Bioresource Technology (2016) | Yue Yuan, Jinjin Liu, Bin Ma, Ye Liu,Bo Wang, Young Zhen Peng | Two SBR which were compared and one was fed with sludge alkaline fermentation product as carbon source and other without the sludge. | In this it was seen that removal efficiency of TN and phosphorous were found to be 82.9 % and 96 % in sludge fed reactor and without fed was 55.9 % (Total Nitrogen) and 61 % |

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|  |  |  |  |  | (phosphorous). Compared with other Biological Nutrient Removal the sludge fed reactor could be more efficient and reduces the sludge per day. |
| 16 | High frequency ultrasound-induced sequence batch reactor as a practical solution for high rate wastewater treatment. | Journal of Environmental Chemical Engineering. (2015) | Zinadini, Sirus, MasoudRahimi, Ali Akbar Zinatizadeh, and Zahra ShaykhiMehrabadi. | Two SBR were used one having ultrasound in it another one having no ultrasound in it. | The one having ultrasound (1.8 MHz) which is of high frequency led to increase in settling ability with no harmful effect on bacterial growth hence treatment efficiency is increased. |
| 17 | Use of sequencing batch reactor | Journal of environmental engineering | Alemayehu Mekonen,Pradeep Kumar, and | In this research removal | The nitrate removal efficiency was |

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| | for biological Denitrification of high nitrate-containing water. | (2015) | Arvind Kumar. | efficiency of SBR for drinking water is accessed in terms of nitrate concentration. | remarkably high and was in the range of 88.7 – 92.3 %. Aerobic phase time of 4, 6, and 8 h were generally required to bring nitrate conc. in water to allowable limits. |
| 18 | Response of a sludge-minimizing lab-scale BNR reactor when the operation is changed to real primary effluent from synthetic wastewater. | Water Research. (2015) | Pei Huang, Ramesh Goel | Two lab scale SBR were used, one in sludge minimising mode and other as conventional activated sludge mode for more than 300 days. Firstly, both were started using synthetic wastewater and then the effluent. | Stage1 (Synthetic for 63 days), stage 2 (mixture of real and synthetic), Stage 3 (only effluent). It is seen that the modified sequence batch reactor yielded 66 % less biomass as compared to activated sequence batch reactor and also |

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| | | | | | modified sequence batch reactor generates 50 % smaller biomass than control-sequence batch reactor when there is change from synthetic wastewater to original wastewater. |
| 19 | Temperature effects on physiology of biological Phosphorus removal. | Journal of environmental engineering (2014) | Damir Brdjanovic, Mark C. M. van Loosdrecht, Christine M. Hooijmans,3 Guy J. Alaerts, and Josef J. Heijnen. | This study shows that sludge were inoculated at 21 °C in an anoxic-oxic acetate fed reactor. | It is seen that the effect of temperature on the kinetics of the processes were very strong under anoxic as well as oxic phase. The anoxic acetate uptake or we can say that phosphorous release rate showed a maximum at |

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|---|---|---|---|---|---|
|  |  |  |  |  | 21 °C. However, a continuous increase was seen in the temperature gap of 6 - 31 °C for the conversion rates under the oxic phase. |
| 20 | Cultivation of aerobic granular sludge for rubber wastewater treatment. | Bioresource Technology (2013) | Rosman, Noor Hasyimah, Aznah Nor Anuar, Inawati Othman, Hasnida Harun, Muhammad Zuhdi Sulong, Siti Hanna Elias, Mohd Arif Hakimi Mat Hassan, Shreesivadass Chelliapan, and Zaini Ujang . | In this rubber wastewater is used in SBR for treatment having cycle time of 3 h and aerobic granular sludge is cultured in the reactor at 26 °C and at pH of 7.5. | A chemical oxygen demand removal rate of 97.5 % and NH3 removal rate of 95.8 %, TKN removal rate of 88.9 % were observed. |

## 2.10 SUMMARY DISCUSSION

1. The seed sludge was taken from an aeration tank of wastewater treatment plant which will lead to bacterial growth in SBR for decomposition of organic matter present in influent wastewater these bacteria needs oxygen for decomposition of organic matter present in the waste water so aerators are used for that.
2. Aerobic granular sludge is used. A well-developed spherical shaped aerobic granules formed within 20 days by which there is better microbial activity and better growth of

bacteria which will enhance the performance of the reactor also the domestication time for these granules is less i.e. 22 days while in case of activated sludge formation of mature granules take about 70 days so aerobic granular sludge effectively shortens the domestication time and increases settling ability and microbial activity.

3. Due to formation of aerobic granules as discussed above a chemical oxygen demand removal rate of 97.5 % was achieved and NH3 removal rate of 95.7 % was observed. In addition TKN removal rate of 88.9 % were observed in the batch reactor for treatment of wastewater.
4. It is seen that if we use high frequency ultrasound it will make the system more reliable by increasing the settling velocity without having any adverse effect on microbial activity and its growth.
5. If we use magnetic powder in sequencing batch reactor it will give us higher removal efficiencies for ammonia and chemical oxygen demand i.e.(7.76 % and 4.76 % higher) as compared to conventional SBR (without magnetic powder).

# CHAPTER 3

# METHODOLOGY

## 3.1 EXPERIMENTAL SETUP

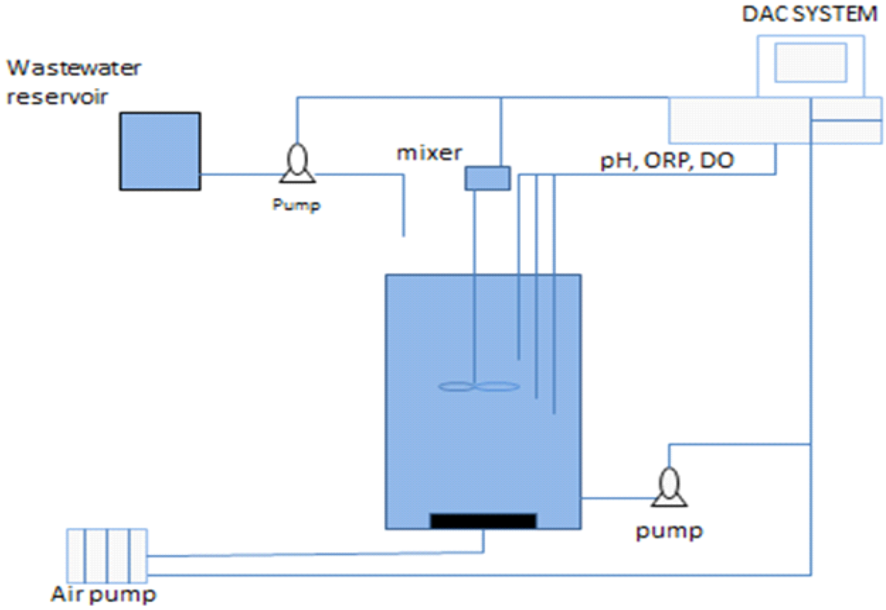

Figure 3. 1 Schematic diagram of SBR

**Reactor-**A reactor (fig 2.1) is constructed in which influent wastewater comes in and gets treated having working volume of 3L and total volume of 6l having three openings.

**Mixer**-A stirrer (fig 2.1) is used for proper dispersion of sludge in the reactor and also so that sludge remain suspended in the reactor the stirring rate used is 1500-3000rpm and it mounted above the reactor.

**Air Pumps-**These are used to give aeration (fig 2.1) in the reactor which is necessary for microorganisms to oxidise organic matter. Aerators having capacity 1.5l\min is used.

**Pipes-**They are connected (fig 2.1) to aerator for carrying the air to the reactor for treatment process.

**Diffusers-**These are connected to aerators pipes for proper dispersion of air in the reactor for proper decomposition of biomass.

**Controllers-**They are fitted to aerator pipes to regulate the flow air going the reactors for treatment process.

## 3.2 REACTOR DESIGN

The experiment was conducted using two lab (fig 2.2) scale sequencing batch reactors (SBR), having a working volume of 3 L with a total volume 6 L (fig 2.2). The lab scale SBR system was installed at the environmental lab in Jaypee University of Information Technology. The body of the SBR was fabricated using a transparent acrylic sheet tube with an inner diameter of 190 mm and outer diameter of 200 mm and a total height of 20.6 cm having 5 cm free,5 cm for sludge retention, and remaining 10.6 cm as working height. Reactor is constructed with 3 opening one is 5 cm from top another 5cm from bottom and one at the middle of the reactor as shown in the figure above. The whole system consisted of the body of the reactor, for feeding and discharging of influent and effluent respectively two peristaltic pumps are used and 3 probes are used for the measurement of temperature dissolved oxygen content (DO) and ph. Aerators was used for air supply into the reactor and two stone diffusers are used for proper dispersion of air. Mixing was provided by mechanical mixers.

## 3.3 WASTEWATER SAMPLES

There are two types of wastewater samples used in this operation one is domestic wastewater The domestic wastewater is collected from wastewater treatment plant of Jaypee University of Information Technology Waknaghat, Solan and another is synthetic wastewater which is prepared synthetically in the lab whose composition is given in table 3.1 given below, The domestic wastewater is collected from wastewater treatment plant on regular basis for 3months and fed regularly in the reactor while the synthetic wastewater is prepared in the lab. Regularly for another 3 months and also fed regularly into the reactor, In the reactor after treatment of domestic and synthetic wastewater parameters such as BOD, COD, TSS, TDS, TS and DO are checked on regular basis.

## 3.4 COLLECTION OF SLUDGE

The sludge is collected from the aeration tank of wastewater treatment plant of Jaypee University of Information Technology Waknaghat Solan. Which is stored in the dark at 4 ℃

so that no bacteria growth takes place in that sludge. The seed sludge in 1:5 is inoculated i.e. one part of sludge in 5 parts of wastewater. The sludge collected is aerobic granular sludge which is having high settling velocity and also high bacteria richness. Bacteria richness is due to conversion flocs of sludge to aerobic granules of sludge which is of spherical shape and large diameter as diameter of aerobic granules increased during granulation process epistylis bacteria stick to surface of granules formed by aerobic granulation process which led to rise in efficiency and effectiveness of water treatment process. Sludge plays a very important role in the reactor operation as it contains microorganisms which is necessary for the treatment of wastewater.

## 3.5 REACTOR OPERATION

Data are collected at a liquid temperature of 25 ± 2 °C. In this we use two SBR which was filled with 3 L (fig3.1) of influent wastewater. In which seed sludge in 1:5 is inoculated. First SBR is filled with domestic wastewater and another with synthetic wastewater. The operating cycle of SBR consists of five phases, FILL, REACT, SETTLE, DECANT and IDLE. In this we perform three cycles of 5 phases having time duration of 6h, 8h, 4h. When the fill stage starts, the influent wastewater comes in the reactor body. After that react phase consists an aerobic and anaerobic process. The wastewater in the reactor body was mixed by a 4 bladed stirrer blades having radius of 2 cm and air was supplied at the rate of 1.5 L/min with aerators fitted with air diffusers during the aerobic phase in the reactor basin and porous diffusers are used for proper dispersion of air. During settle period a layer of thick sludge was formed at the bottom which was removed during the idle phase. During draw stage clear water is obtained at the top as sludge gets settled down the clear water at the top is known as which was then supernatant was removed with peristaltic pumps. The effluent decanted was collected and sample analysis is done.

Table 3.1 Cycle and phase durations

| **Cycle Time (h)** | **Fill Time (h)** | **React Time (h)** | **Settle Time (h)** | **Decant Time (h)** |
|---|---|---|---|---|
| 4 | 0.5 | 2 | 2 | 0.5 |
| 6 | 0.5 | 3 | 3 | 0.5 |
| 8 | 0.5 | 4 | 4 | 0.5 |

## 3.6 PARAMETERS TO BE ANALYSED

The influent and the effluent wastewater water are analysed for various parameters listed below

- Biochemical oxygen demand
- Chemical oxygen demand
- Suspended solids
- Dissolved solids
- Total solids
- Dissolved Oxygen
- pH

The BOD, COD, TSS, TDS, TS were measured as per standard method according to (APHA, 2005).DO is measured using DO meter and pH using pH strips.

# CHAPTER 4

# DATA ANALYSIS

## 4.1RESULTS AND DISCUSSION

### 4.1.1 BOD REMOVAL EFFICIENCY

The $BOD_5$ value in wastewater is used to know how much organic matter is removed in the treatment process. our experiment started by filling 3L of raw influent wastewater into the lab scale SBR basin, having an average influent $BOD_5$ 151 mg\l. As seen in fig-4.1 effluent $BOD_5$ concentrations in the first 5 to 7 days had high values and reactor efficiency is almost constant (65%) and very less after that reactor efficiency increases upto 86% and there is decrement in effluent concentration this is due to reason that bacteria growth rate becomes higher due to conversion flocs of sludge to aerobic granules of sludge which is of spherical shape and large diameter due to increase in diameter of aerobic granules and because of its spherical shape bacteria stick to the surface of granules which led to increases efficiency which is also seen in the graph as efficiency increases towards the end.

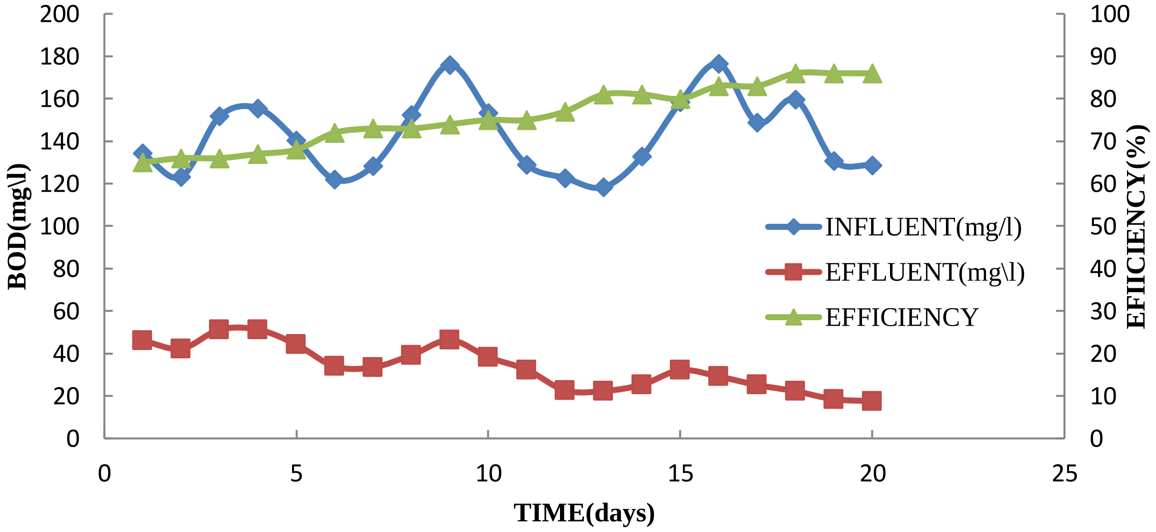

Figure 4. 1 BOD Removal Domestic Wastewater 8hr Cycle Time

### 4.1.2COD REMOVAL EFFICIENCY

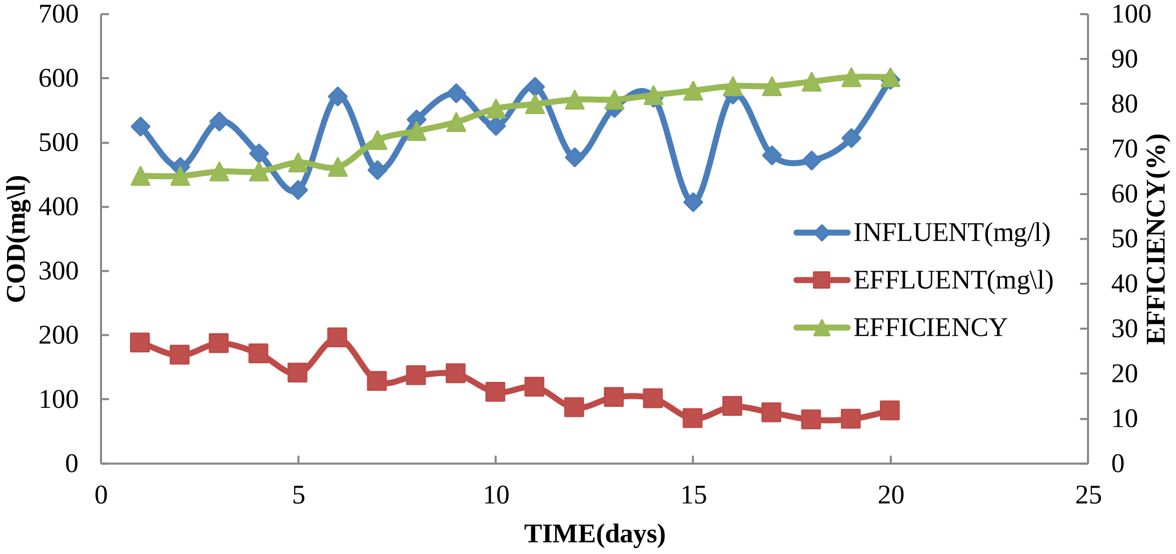

Figure 4. 2 COD Removal Domestic Wastewater 8hr Cycle Time

In the water treatment process during its first few days, the COD concentration decrement was unsatisfactory which is due to acclimatizing process of the microorganisms with the wastewater present in the bioreactor. after 5-7 days of operation aerobic granulation process starts in the reactor leading to better efficiency. In the first few days COD removal efficiency was about (fig-4.2) 65 % but later aerobic granulation process starts and removal efficiency increases up to (fig-4.2) 86 % which gives satisfactory results.

### 4.1.3 DISSOLVED OXYGEN CONCENTRATION VARIATION IN THE REACTOR

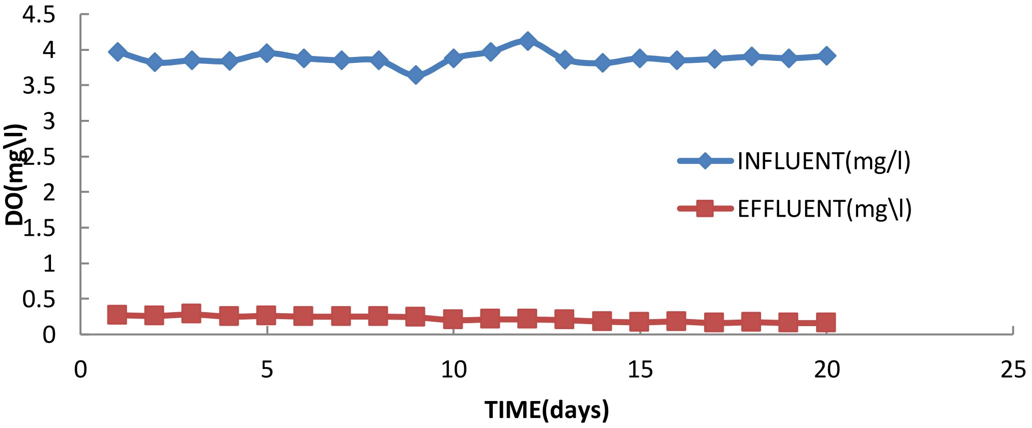

Figure 4. 3 Variation of DO with Time Domestic Wastewater 8hr Cycle Time

In the batch reactor the influent DO concentration was around (fig-4.3) 3.88 mg/L microorganisms present in the batch reactor reproduce itself by binary fission as more and more organic matter comes in the basin they reproduce and there population becomes very large with time. These microorganisms present in the reactor require oxygen to breakdown organic matter that's why DO concentration decreases at effluent level to approximately 0.22 mg/L when food supply is over these microorganisms eat their own protoplasm and at final stage of treatment process microorganism concentration decreases at the end of process.

### 4.1.4 TSS, TS, TDS REMOVAL EFFICIENCY

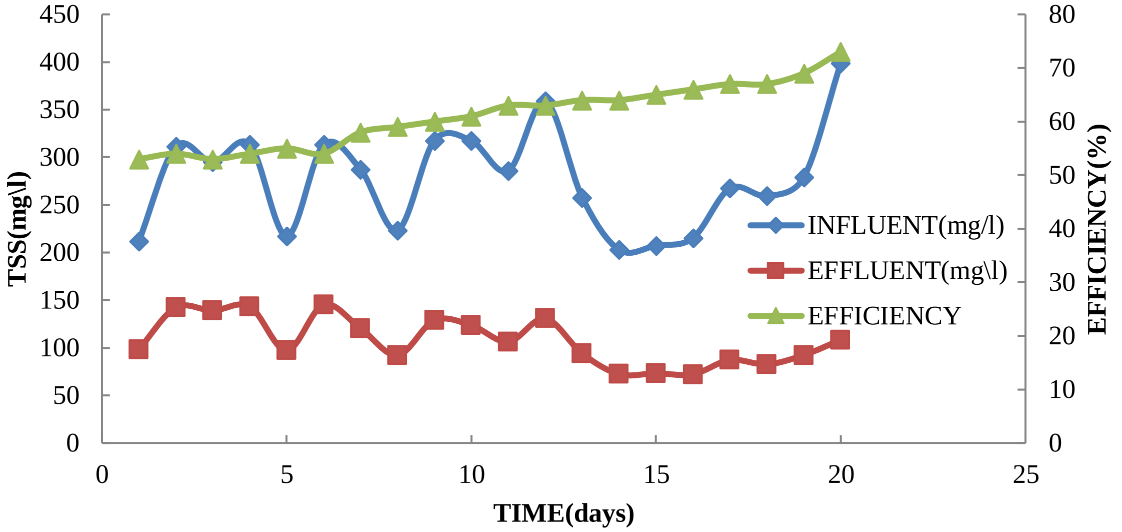

Figure 4. 4 TSS Removal Domestic Wastewater 8hr Cycle Time

Total suspended solids (TSS) vary from the influent concentration range of (fig-4.4) 211 - 398 mg/L to effluent concentration range of (fig-4.4) 72 - 145 mg/L giving an average removal efficiency of 55 % in the first 5 - 7 days after that removal efficiency increases to 73 % at the end of the 20th day which is due to bacteria growth which led to increased bacteria concentration or we can say that microbial growth in the bioreactor which led to increased efficiency and settling ability of the sludge so there is good separation of sludge from the treated effluent thus a clear effluent is obtained at the top in the batch reactor due to well settling granules.

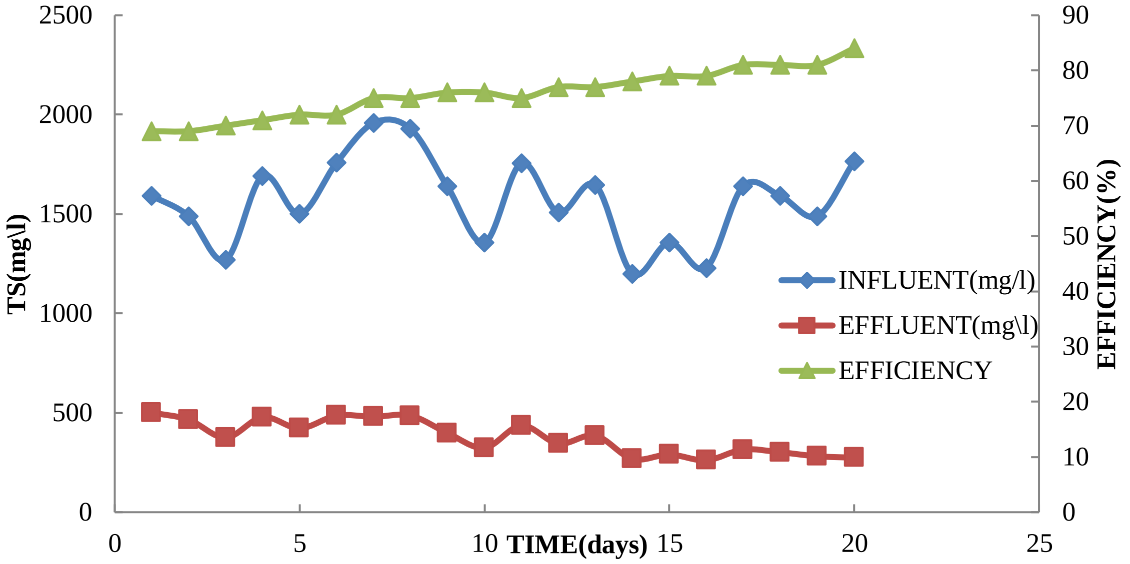

Figure 4. 5 TS Removal Domestic Wastewater 8hr Cycle Time

Total solids (TS) varied from the initial value in the range of (fig-4.5) 1500 - 1958 mg/L to effluent value in the range of (fig-4.5) 237 - 617 mg/L at the end of 20th day of the experiment and the average removal rate initially in first few days was about 70 % but as number of days increases its efficiency increases up to 84 % the reason behind that is our HRT and SRT are very less. So at the start of the experiment SRT and HRT are less so microbial population is less after few days of operation aerobic granulation process starts due to which bacteria population increases and efficiency increases.

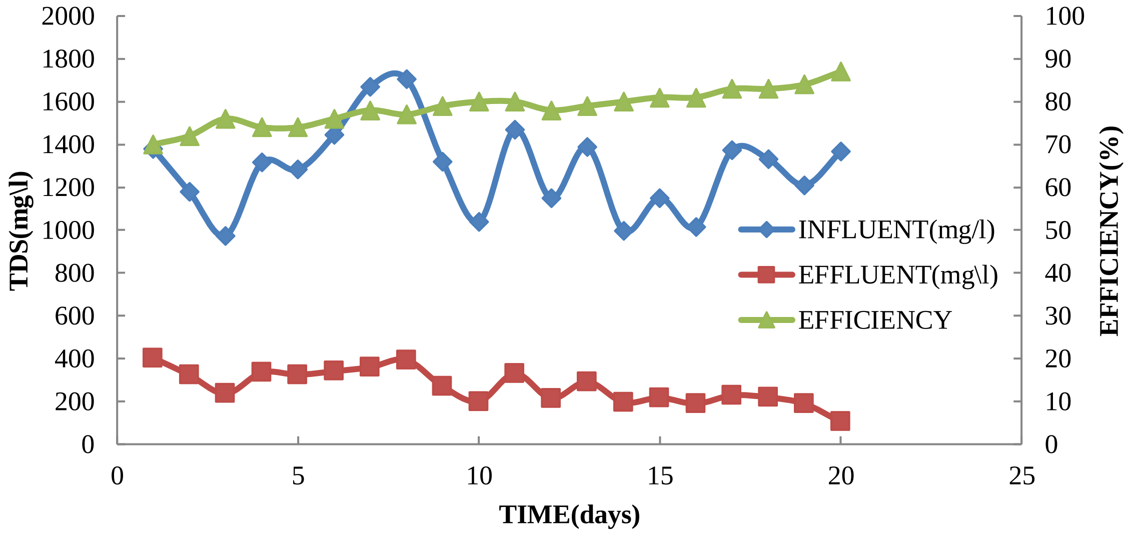

Figure 4.6 TDS Removal Domestic Wastewater 8hr Cycle Time

Total dissolved solids (TDS) influent concentration vary in the range from (fig-4.6) 900 - 1734 mg/L to (fig-4.6) 140 - 461 mg/L effluent concentration. In this the same pattern has been followed having low efficiency in first few days and efficiency increases after that. As aerobic granulation process starts after running the reactor for first few days which leads to better biomass growth and better bacteria concentration in the reactor parameters such as nitrogen, phosphates etc. decreases which decreases TDS concentration in the reactor.

### 4.1.5 BOD REMOVAL EFFICIENCY

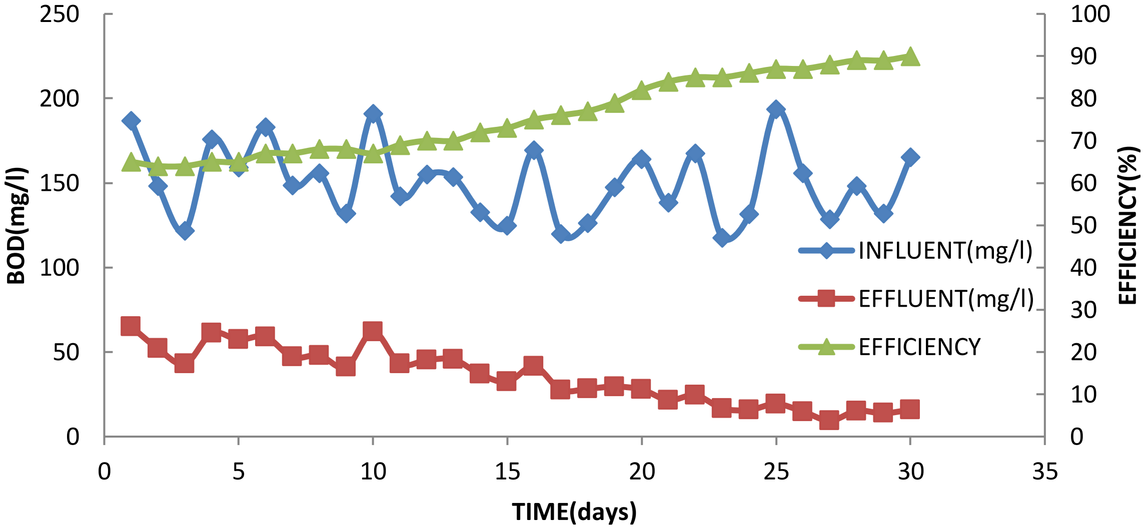

Figure 4.7 BOD Removal Domestic Wastewater 6hr Cycle Time.

The $BOD_5$ value in wastewater is used to know how much organic matter is removed in the treatment process. our experiment started by filling 3 L of raw influent wastewater into the lab scale SBR basin, having an average influent $BOD_5$ 154 mg\L. As seen in fig-4.7 effluent $BOD_5$ concentrations in the first 5 to 7 days had high values and reactor efficiency is almost constant (64 %) and very less after that reactor efficiency increases up to 90 % and there is decrement in effluent concentration this is due to reason that bacteria growth rate becomes higher due to conversion flocs of sludge to aerobic granules of sludge which is of spherical shape and large diameter due to increase in diameter of aerobic granules and because of its spherical shape bacteria stick to the surface of granules which led to increases efficiency which is also seen in the graph as efficiency increases towards the end.

### 4.1.6 COD REMOVAL EFFICIENCY

In the water treatment process during its first few days, the COD concentration decrement was unsatisfactory which is due to acclimatizing process of the microorganisms with the wastewater present in the bioreactor. After 5-7 days of operation aerobic granulation process starts in the reactor leading to better efficiency. In the first few days COD removal efficiency was about (fig-4.8) 65 % but later aerobic granulation process starts and removal efficiency increases up to (fig-4.2) 91 % which gives satisfactory results.

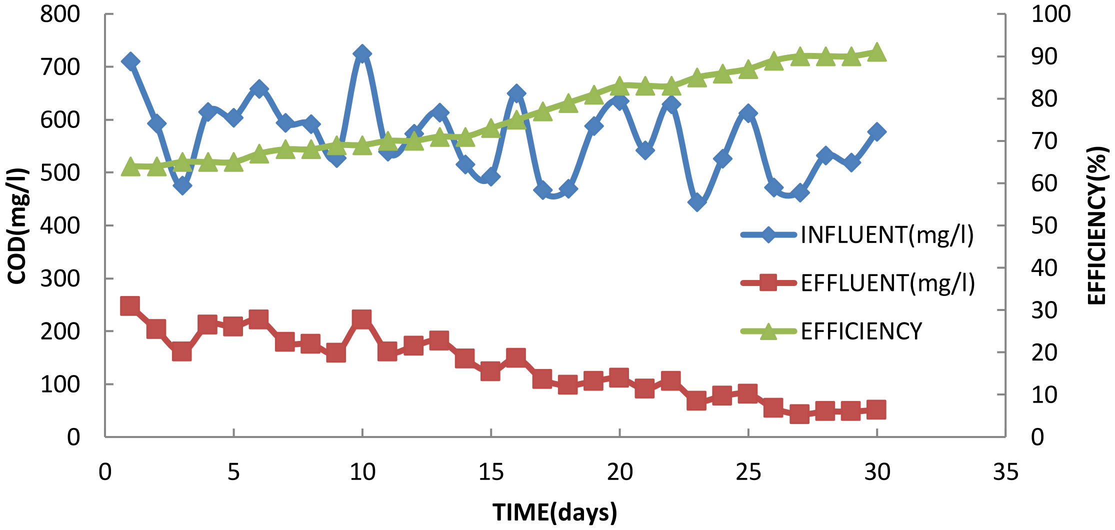

Figure 4.8 COD Removal Domestic Wastewater 6hr Cycle Time

### 4.1.7 DISSOLVED OXYGEN CONCENTRATION VARIATION IN THE REACTOR

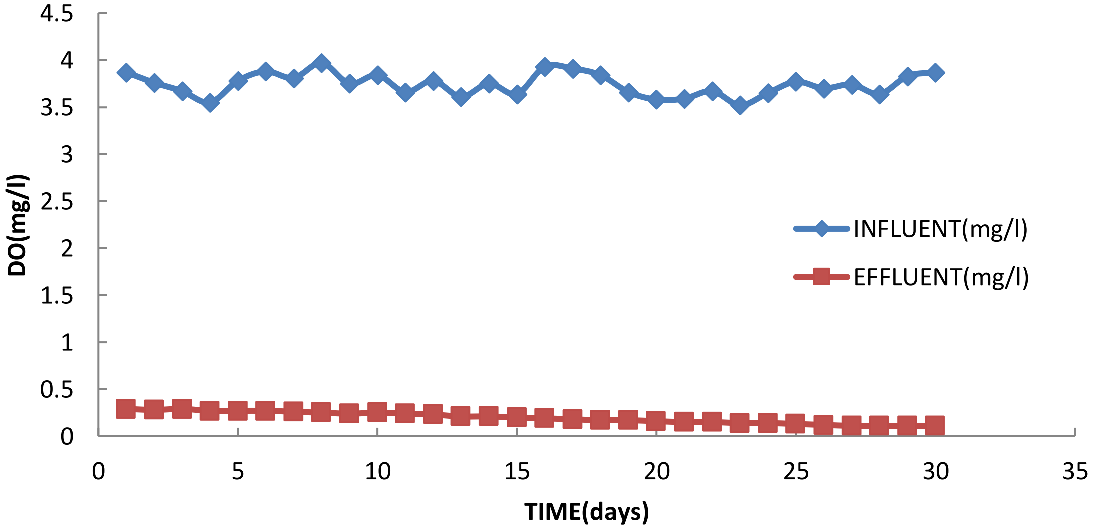

Figure 4.8 Variation of DO with Time Domestic Wastewater 6hr Cycle Time

In the batch reactor the influent DO concentration was around (fig-4.9) 3.87 mg/l microorganisms present in the batch reactor reproduce itself by binary fission as more and more organic matter comes in the basin they reproduce and there population becomes very large with time. These microorganisms present in the reactor require oxygen to breakdown organic matter that's why DO concentration decreases at effluent level to approximately 0.22mg/l when food supply is over these microorganisms eat there own protoplasm and at final stage of treatment process microorganism concentration decreases at the end of process.

### 4.1.8 TSS, TS,TDS REMOVAL EFFICIENCY

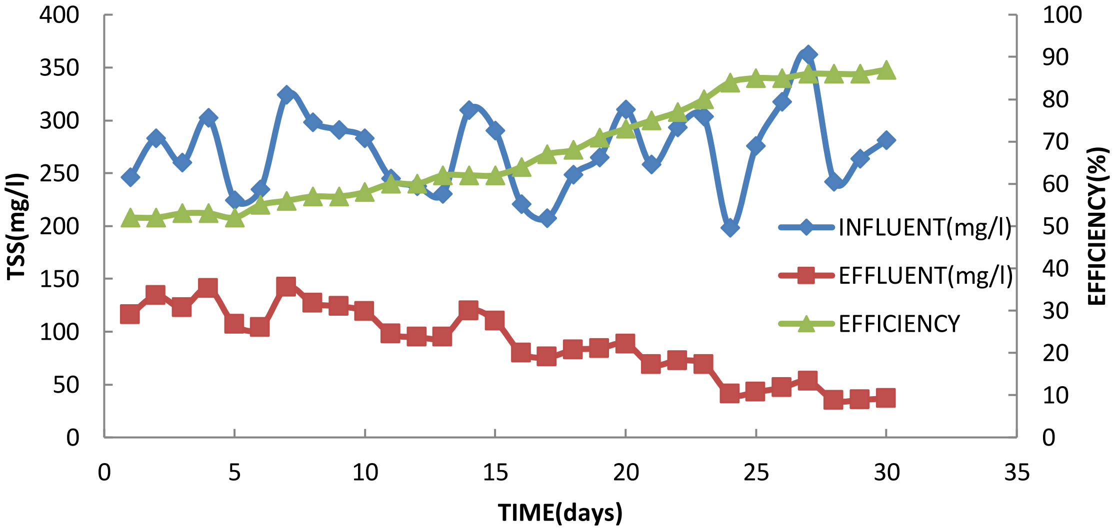

Figure 4.9 TSS Removal Domestic Wastewater 6hr Cycle Time

Total suspended solids(TSS) vary from the influent concentration range of (fig-4.10) 198-363mg/l to effluent concentration range of (fig-4.10) 35-145mg/l giving an average removal efficiency of 52% in the first 5-7 days after that removal efficiency increases to 87 % at the end of the 30th day which is due to bacteria growth which led to increased bacteria concentration or we can say that microbial growth in the bioreactor which led to increased efficiency and settling ability of the sludge so there is good separation of sludge from the treated effluent thus a clear effluent is obtained at the top in the batch reactor due to well settling granules.

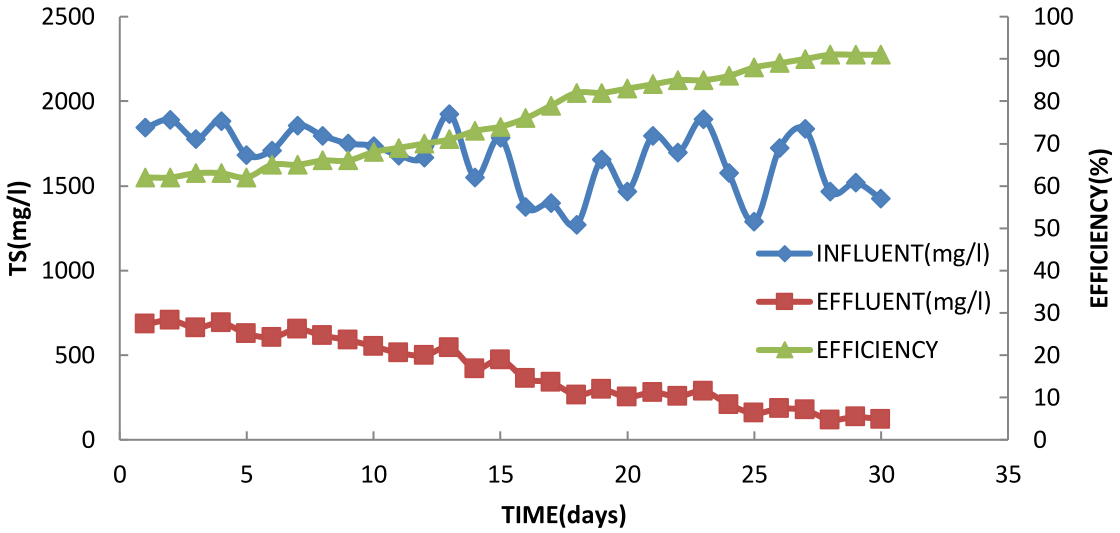

Figure 4.10 TS Removal Domestic Wastewater 6hr Cycle Time

Total solids (TS) varied from the initial value in the range of (fig-4.11) 1288-1923 mg/l to effluent value in the range of (fig-4.11) 118-622mg/l at the end of 20th day of the experiment and the average removal rate initially in first few days was about 62% but as number of days increases its efficiency increases upto 91% the reason behind that is our HRT and SRT are very less. So at the start of the experiment SRT and HRT are less so microbial population is less after few days of operation aerobic granulation process starts due to which bacteria population increases and efficiency increases.

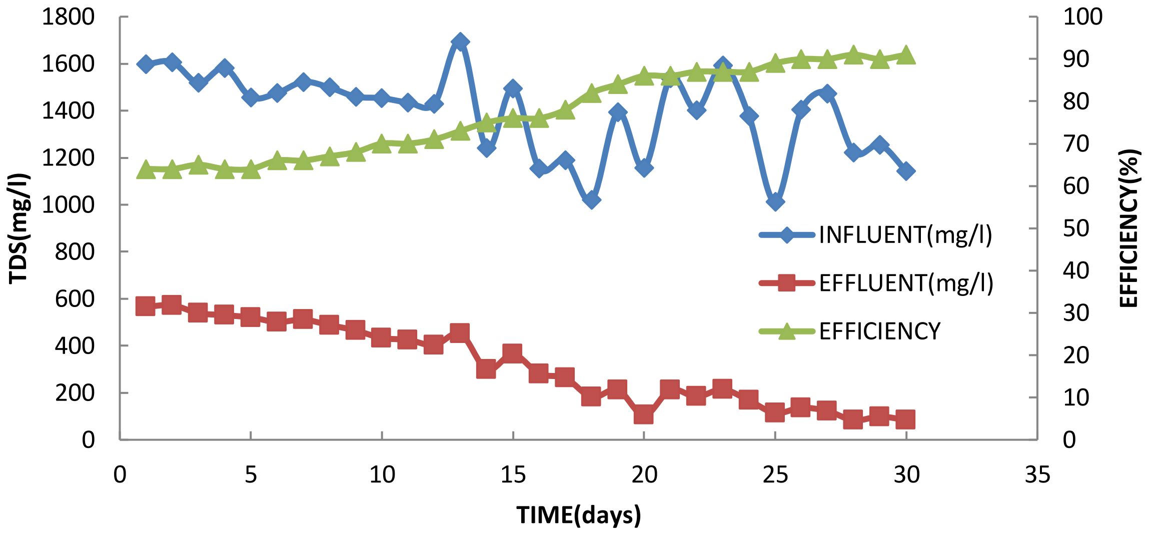

Figure 4 11 TDS Removal Domestic Wastewater 6hr Cycle Time

Total dissolved solids (TDS) influent concentration vary in the range from (fig-4.12) 1000-1700mg/l to (fig-4.6) 83-572mg/l effluent concentration. In this the same pattern has been followed having low efficiency in first few days and efficiency increases after that. As aerobic granulation process starts after running the reactor for first few days which leads to better biomass growth and better bacteria concentration in the reactor parameters such as nitrogen, phosphates etc. decreases which decreases TDS concentration in the reactor.

### 4.1.9 BOD REMOVAL EFFICIENCY

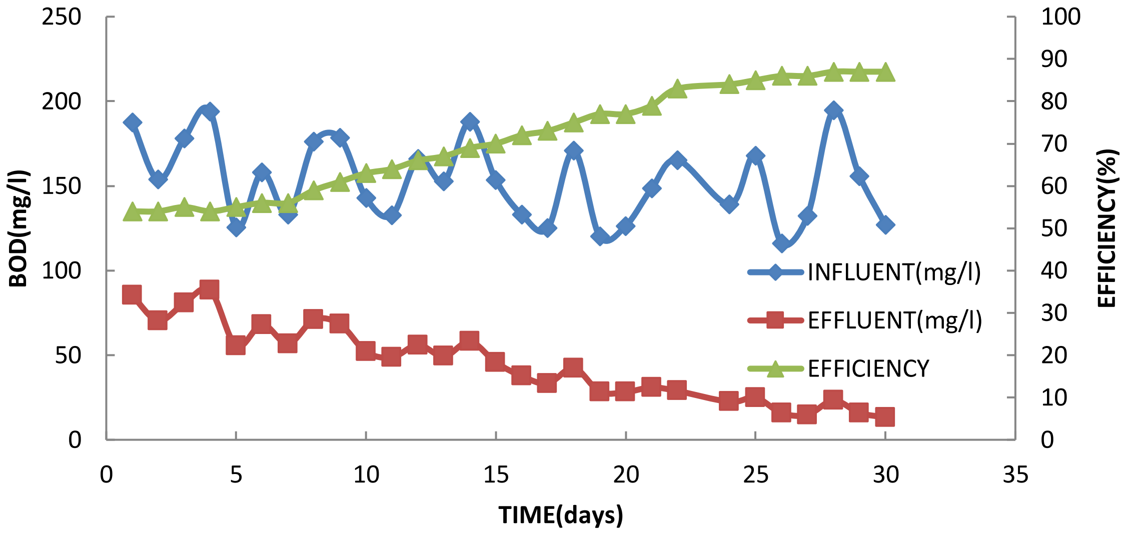

Figure 4.12 BOD Removal Domestic Wastewater 4hr Cycle Time

The $BOD_5$ value in wastewater is used to know how much organic matter is removed in the treatment process. our experiment started by filling 3L of raw influent wastewater into the lab scale SBR basin, having an average influent $BOD_5$ 154 mg\l. As seen in fig-4.13 effluent $BOD_5$ concentrations in the first 5 to 7 days had high values and reactor efficiency is almost constant (54%) and very less after that reactor efficiency increases upto 87% and there is decrement in effluent concentration this is due to reason that bacteria growth rate becomes higher due to conversion flocs of sludge to aerobic granules of sludge which is of spherical shape and large diameter due to increase in diameter of aerobic granules and because of its spherical shape bacteria stick to the surface of granules which led to increases efficiency which is also seen in the graph as efficiency increases towards the end.

### 4.1.10 COD REMOVAL EFFICIENCY

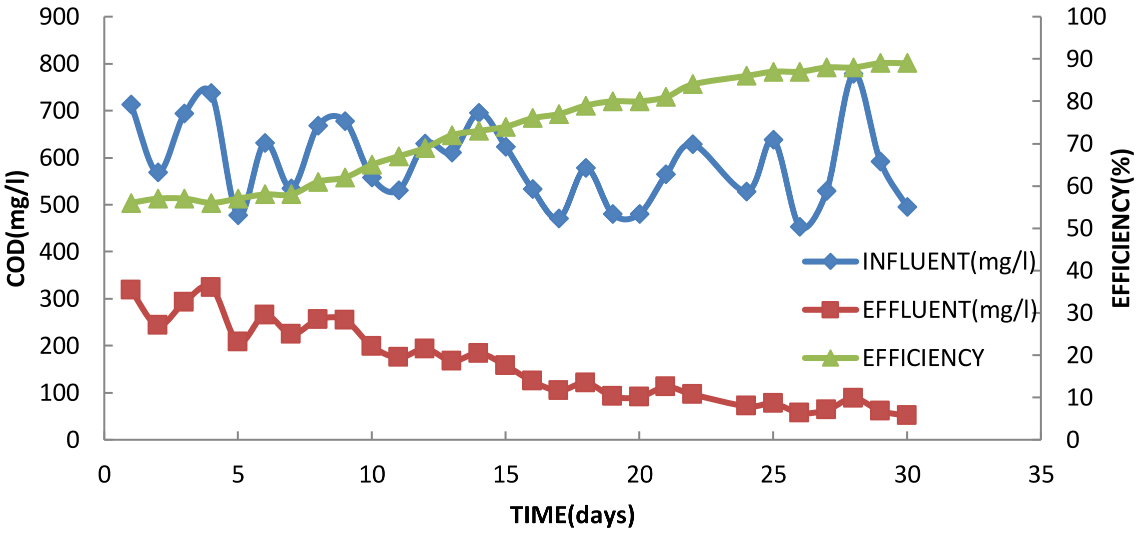

Figure 4.13 COD Removal Domestic Wastewater 4hr Cycle Time

In the water treatment process during its first few days, the COD concentration decrement was unsatisfactory which is due to acclimatizing process of the microorganisms with the wastewater present in the bioreactor. after 5-7 days of operation aerobic granulation process starts in the reactor leading to better efficiency. In the first few days COD removal efficiency was about (fig-4.14) 56% but later aerobic granulation process starts and removal efficiency increases upto (fig-4.14) 89% which gives satisfactory results.

### 4.1.11 DISSOLVED OXYGEN CONCENTRATION VARIATION IN THE REACTOR

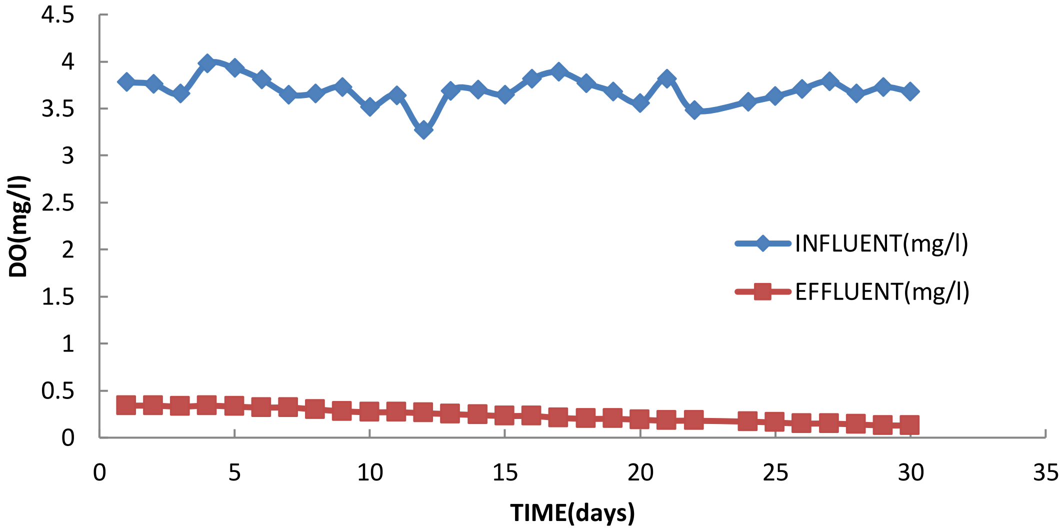

Figure 4.14 DO variation Domestic Wastewater 4hr Cycle Time

In the batch reactor the influent DO concentration was around (fig-4.15) 3.98 mg/l microorganisms present in the batch reactor reproduce itself by binary fission as more and more organic matter comes in the basin they reproduce and there population becomes very large with time. These microorganisms present in the reactor require oxygen to breakdown organic matter that's why DO concentration decreases at effluent level to approximately 0.13mg/l when food supply is over these microorganisms eat their own protoplasm and at final stage of treatment process microorganism concentration decreases at the end of process

### 4.1.12 TSS,TS.TDS REMOVAL EFFICIENCY

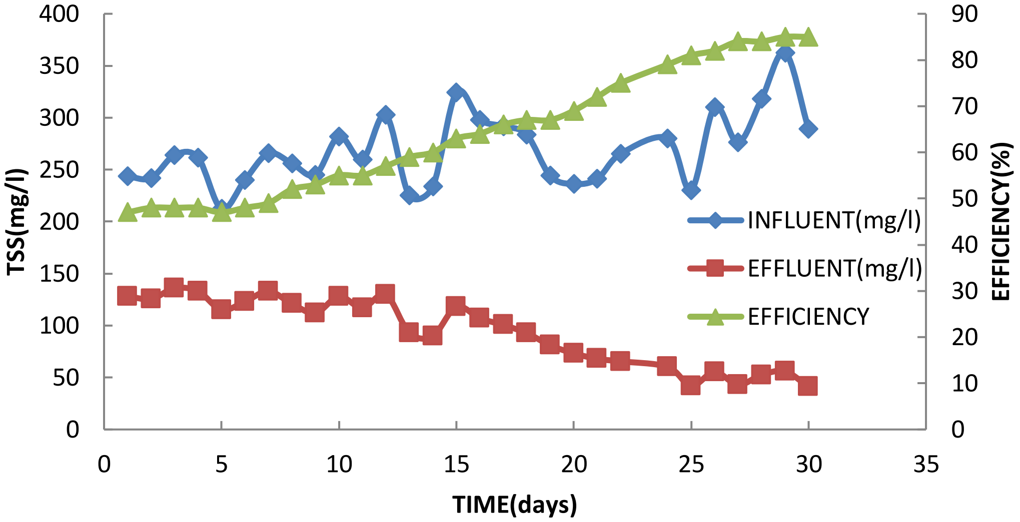

Figure 4.15 TSS removal Domestic Wastewater 4hr Cycle Time

Total suspended solids(TSS) vary from the influent concentration range of (fig-4.16) 198-363mg/l to effluent concentration range of (fig-4.16) 35-145mg/l giving an average removal efficiency of 47% in the first 5-7 days after that removal efficiency increases to 85 % at the end of the 30th day which is due to bacteria growth which led to increased bacteria concentration or we can say that microbial growth in the bioreactor which led to increased efficiency and settling ability of the sludge so there is good separation of sludge from the treated effluent thus a clear effluent is obtained at the top in the batch reactor due to well settling granules.

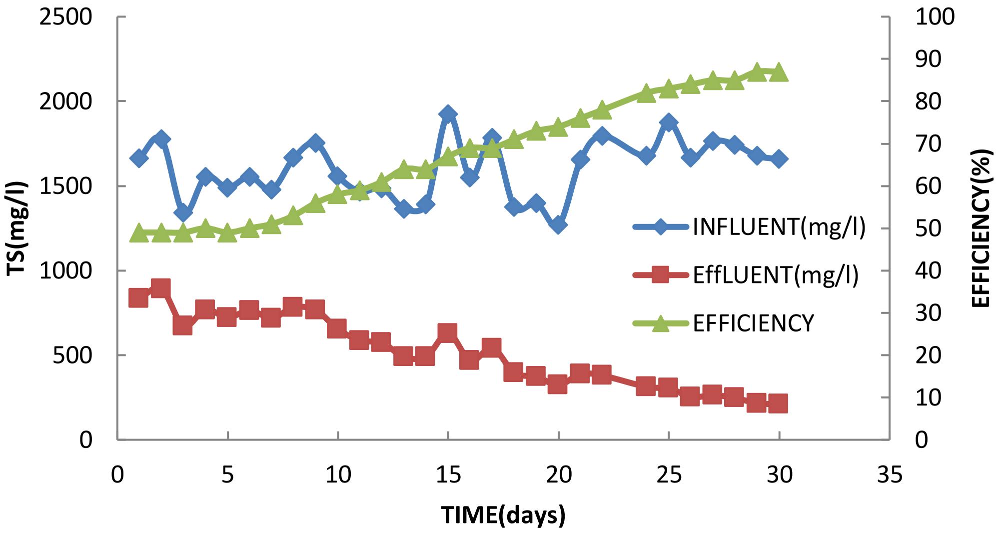

Figure 4.16 TS removal Domestic Wastewater 4hr Cycle Time

Total solids (TS) varied from the initial value in the range of (fig-4.17) 1288-1821 mg/l to effluent value in the range of (fig-4.17) 208-892mg/l at the end of 20th day of the experiment and the average removal rate initially in first few days was about 62% but as number of days increases its efficiency increases upto 91% the reason behind that is our HRT and SRT are very less. So at the start of the experiment SRT and HRT are less so microbial population is less after few days of operation aerobic granulation process starts due to which bacteria population increases and efficiency increases.

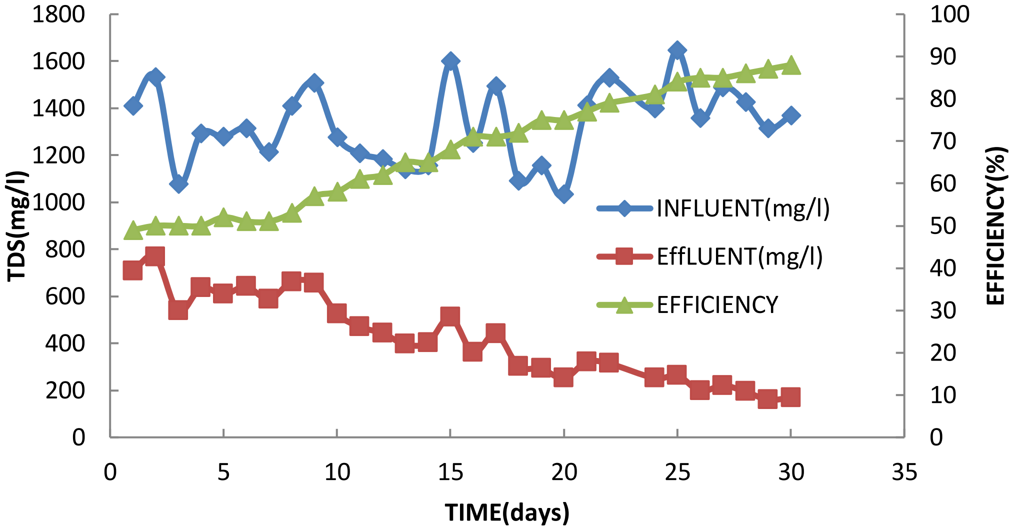

Figure 4.17 TDS removal Domestic Wastewater 4hr Cycle Time

Total dissolved solids (TDS) influent concentration vary in the range from (fig-4.18) 1000-1700mg/l to (fig-4.18) 150-710mg/l effluent concentration. In this the same pattern has been followed having low efficiency in first few days and efficiency increases after that. As aerobic granulation process starts after running the reactor for first few days which leads to better biomass growth and better bacteria concentration in the reactor parameters such as nitrogen, phosphates etc. decreases which decreases TDS concentration in the reactor.

### 4.1.13 TS,TDS REMOVAL EFFICIENCY

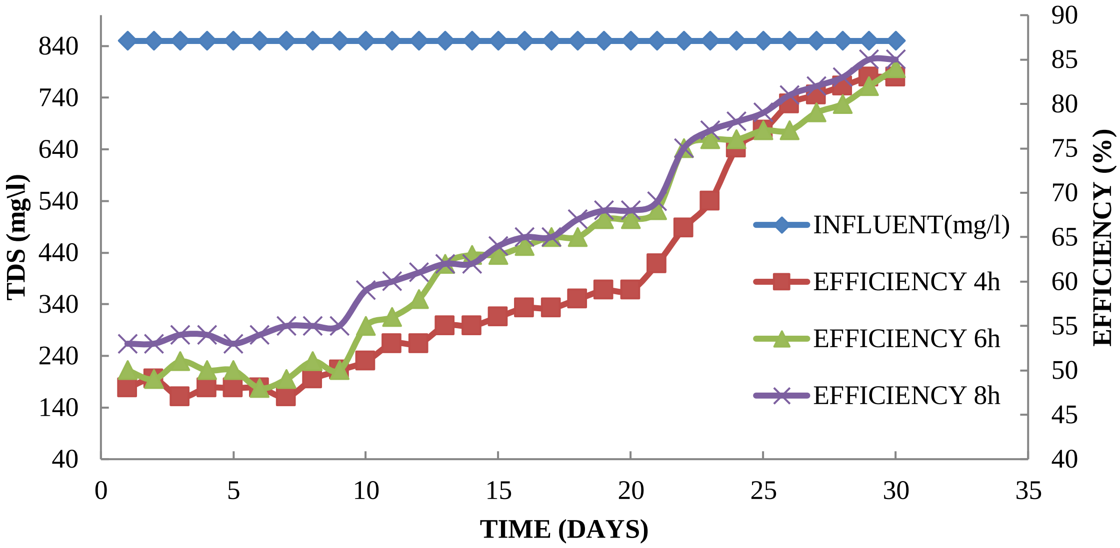

Figure 4.18 TDS Removal Synthetic Wastewater

Total dissolved solids (TDS) influent concentration was constant (fig-4.19) i.e. 850mg/l because it is synthetically prepared water so influent concentration remain constant. In every cycle it is observed that during first 10 days efficiency is less and unsatisfactory. Efficiency increases later because after that microorganisms gets acclimatize in wastewater during first 8-10 days. As aerobic granulation process starts after running the reactor for first 10 days which leads to better biomass growth and better bacteria concentration in the reactor which increases removal efficiency. At the end of 22nd day there is a rapid increase or kink in the graph which is due to formation of mature aerobic granules by which parameters such as nitrogen, phosphates etc. decreases which decreases.

If we compare the graphs of different cycles it is observed that removal efficiency of 4hr is lowest equal to 48 % in the first 8-10 days which is due to less aeration time and settling time in 4hr cycle. In 6hr cycle it is found that efficiency is slightly higher having an average value of 50 % and 8hr cycle having highest removal efficiency of 55 % which is highest among all three cycles compared in first 8-10 days which is due to better granules formed in 8 hr cycle as it is having higher reaction time. At later stages after 30 days of reactor operation efficiency for 4h,6h,8h are 83 %, 84 %, 85 respectively. After 30 days of reactor operation similar trend is seen in efficiency that 8 hr cycle having maximum efficiency among other two cycles because of better granulation process in 8hr cycle.

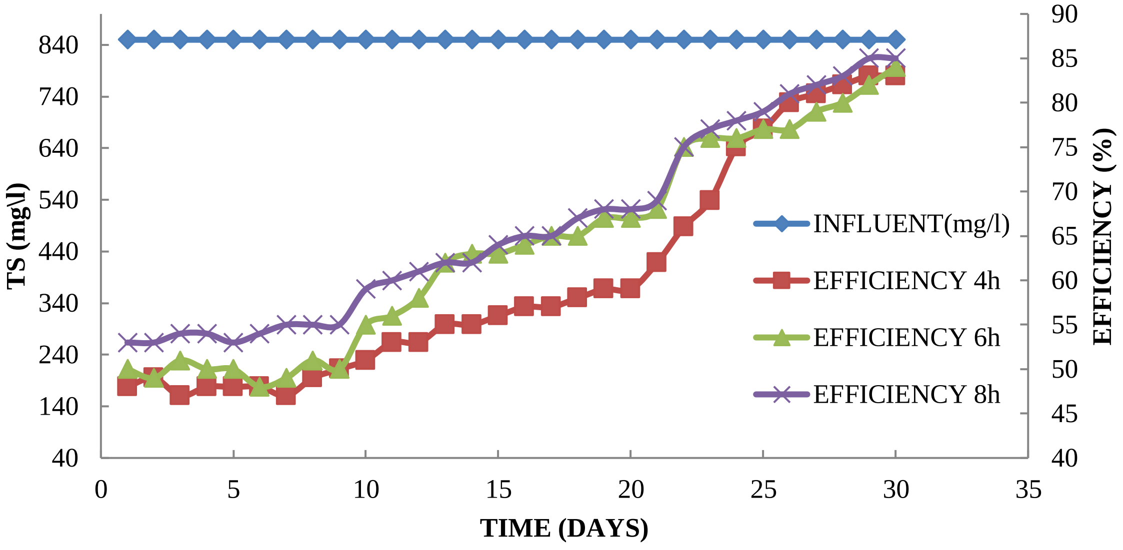

Figure 4.19 TS Removal Domestic Wastewater.

TDS and TS graph is having similar variation of graph as it is synthetically prepared and having 0 % of total suspended solids concentration. Total solids (TS) influent concentration was constant (fig-4.20) i.e. 850mg/l because it is synthetically prepared water so influent concentration remain constant. In every cycle it is observed that during first 10 days efficiency is less and unsatisfactory. Efficiency increases later because after that microorganisms gets acclimatize in wastewater during first 8-10 days. As aerobic granulation process starts after running the reactor for first 10 days which leads to better biomass growth and better bacteria concentration in the reactor which increases removal efficiency. At the end of 22nd day there is a rapid increase or kink in the graph which is due to formation of mature aerobic granules by which parameters such as nitrogen, phosphates etc. decreases which decreases.

If we compare the graphs of different cycles it is observed that removal efficiency of 4hr is lowest equal to 48 %  in the first 8-10 days which is due to less aeration time and settling time in 4hr cycle. In 6hr cycle it is found that efficiency is slightly higher having an average value of 50 % and 8hr cycle having highest removal efficiency of 55 % which is highest among all three cycles compared in first 8-10 days which is due to better granules formed in 8 hr cycle as it is having higher reaction time. At later stages after 30 days of reactor operation efficiency for 4h,6h,8h are 83 %, 84 %, 85 respectively. After 30 days of reactor operation similar trend is seen in efficiency that 8 hr cycle having maximum efficiency among other two cycles because of better granulation process in 8hr cycle.

### 4.1.14 COD REMOVAL EFFICIENCY

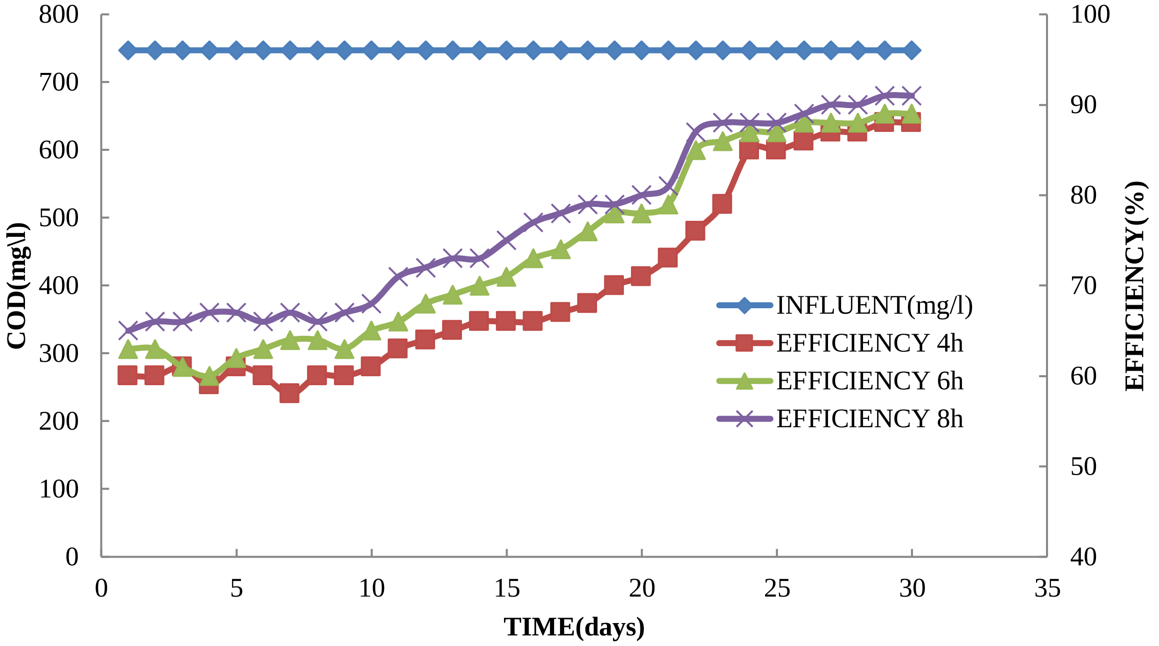

Figure 4. 20 COD Removal Synthetic Wastewater 4hr Cycle Time

In the synthetic wastewater treatment process during its first 7-10 days, the COD concentration decrement was unsatisfactory which is due to acclimatizing process of the microorganisms with the wastewater present in the bioreactor. After 8-10 days of operation aerobic granulation process starts in the reactor leading to better efficiency. Which is also seen in the graph above as after 9th day there is an upward kink in the graph . After that at the end of 23rd day fully grown aerobic granules formation takes place leading to higher removal efficiency having an average value of 87% in all three cycles.

As seen in graph of 4hr, 6hr, 8hr cycle in the first 8-10 days of reactor operation COD removal efficiency was about (fig-4.21) 60 %, 63 %, 65 % respectively. 8hr cycle having maximum removal efficiency due to better granulation. After 30 days of reactor operation similar trend is seen in efficiency that 8 hr cycle having maximum efficiency among other two cycles because of better granulation process in 8hr cycle

### 4.1.15 DO VARIATION EFFICIENCY

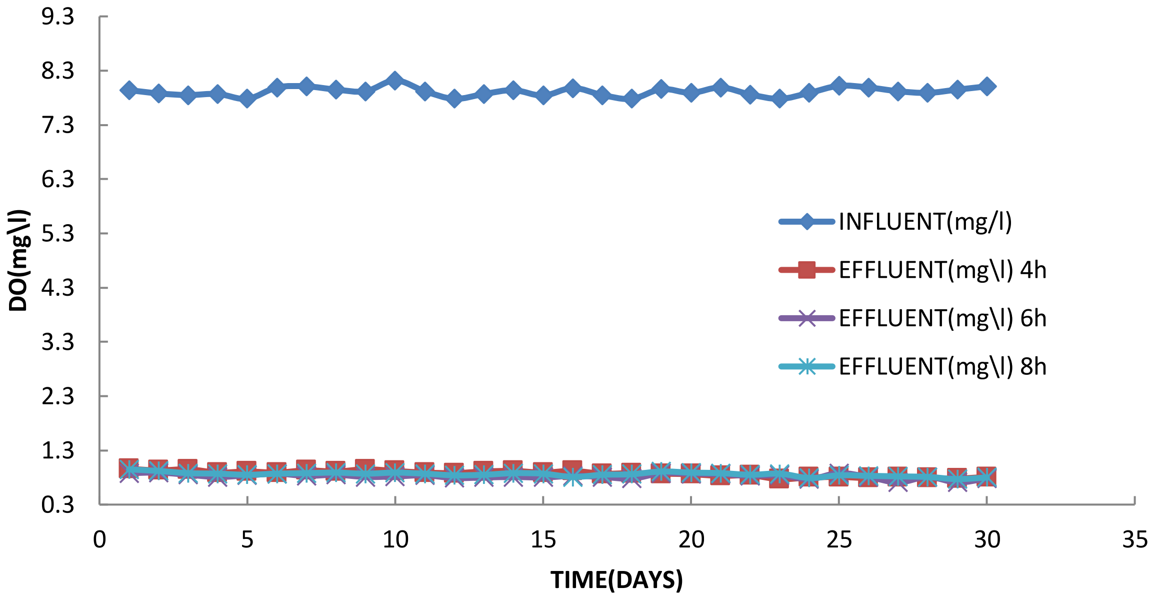

Figure 4.21 Variation of DO with Time of Synthetic Wastewater

In the process of wastewater treatment the influent DO concentration was around (fig-4.22) 8 mg\l which is generally higher than domestic wastewater this is due to the reason that in domestic wastewater microorganisms concentration are generally high which consumes DO but in synthetic wastewater there is no microorganisms initially so DO concentration is generally high but when sludge is added microorganisms growth takes place in the reactor where These microorganisms present in the reactor require oxygen to breakdown organic matter that's why DO concentration decreases at effluent level to approximately 0.92mg/l when food supply is over these microorganisms eat their own protoplasm and at final stage of treatment process microorganism concentration decreases at the end of process.

If we compare three cycles of synthetic wastewater i.e. is 4hr, 6hr, 8hr then it is observed that the variation is almost similar in all the three cycles which is a different trend to what we have seen in COD, TS, TDS. This is due to the reason that as increment in aeration time and bacteria concentration increase counterbalance each other.

# CHAPTER 6

# CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

## 6.1 CONCLUSION

The main focus of the present study was to explore the performance of sequence batch reactor using synthetic and domestic Wastewater.

On the basis of the results presented following conclusions could be made.

- In the first 7-10 days the removal efficiency of COD, BOD, TSS, TS, TDS was unsatisfactory which is due to adapting process of microorganisms with the wastewater after that aerobic granulation process starts in the reactor leading to better efficiency in the system. Also a rapid increase in removal efficiency is seen in graph after 22 days of reactor operation which is due to mature granules formation in the reactor at the end of 22nd day.

- Removal efficiency also depends upon the cycle time of reactor operation as from results, removal efficiency increases with increase in cycle time. In domestic waste water removal efficiency of 4 hour cycle of COD,BOD,TS,TSS,TDS was 88 %, 87 %, 87 %, 85 % and 88 % respectively and in 6 hour cycle was 91 %, 90 %, 91 %, 87 % and 91 % and a similar trend is observed in synthetic wastewater i.e. 8 hr cycle having maximum removal efficiency for COD, TS, TDS are 91 %, 85 % and 85 % respectively.

- Removal efficiency of domestic wastewater is comes out to be higher than the synthetic wastewater because better bacteria growth in domestic wastewater then the synthetic which leads to better granulation process.

## 6.2 SUGGESTIONS FOR FUTURE WORK

In the present study the problems faced are clogging of aeration diffusers due to sludge present in it which decreases the aeration rate of the aerator which resists microbial growth in the reactor but even then the removal efficiency of COD, BOD, TSS, TDS, TS was satisfactory. However if advance mechanism like jet aerators are used in the future the results may get better because of the better microbial growth and granulation process.

# REFERENCES

[1] Wang, X.C., Chen, Z.L., Kang, J., Zhao, X., Shen, J.M. and Yang, L., 2019. The key role of inoculated sludge in fast start-up of sequencing batch reactor for the domestication of aerobic granular sludge. *Journal of environmental sciences*, *78*, pp.127-136.

[2] Yong, Z.J., Bashir, M.J., Ng, C.A., Sethupathi, S. and Lim, J.W., 2018. A sequential treatment of intermediate tropical landfill leachate using a sequencing batch reactor (SBR) and coagulation. *Journal of environmental management*, *205*, pp.244-252.

[3] Liu, Y., Li, J., Guo, W., Ngo, H.H., Hu, J. and Gao, M.T., 2018. Use of magnetic powder to effectively improve the performance of sequencing batch reactors (SBRs) in municipal wastewater treatment. *Bioresource technology*, *248*, pp.135-139.

[4] Liu, J., Li, J., Piché-Choquette, S. and Sellamuthu, B., 2018. Roles of bacterial and epistylis populations in aerobic granular SBRs treating domestic and synthetic wastewaters. *Chemical engineering journal*, *351*, pp.952-958.

[5] Wei, C.H., Wang, N., HoppeJones, C., Leiknes, T., Amy, G., Fang, Q., Hu, X. and Rong, H., 2018. Organic micropollutants removal in sequential batch reactor followed by nanofiltration from municipal wastewater treatment. *Bioresource technology*, *268*, pp.648-657.

[6] Yong, Z.J., Bashir, M.J., Ng, C.A., Sethupathi, S. and Lim, J.W., 2018. A sequential treatment of intermediate tropical landfill leachate using a sequencing batch reactor (SBR) and coagulation. *Journal of environmental management*, *205*, pp.244-252.

[7] Gil-Pulido, B., Tarpey, E., Almeida, E.L., Finnegan, W., Zhan, X., Dobson, A.D. and O'Leary, N., 2018. Evaluation of dairy processing wastewater biotreatment in an IASBR system: Aeration rate impacts on performance and microbial ecology. *Biotechnology reports*, *19*, p.e00263.

[8] Zhang, L., Fan, J., Nguyen, H.N., Li, S. and Rodrigues, D.F., 2019. Effect of cadmium on the performance of partial nitrification using sequencing batch reactor. *Chemosphere*, *222*, pp.913-922.

[9] Bashiri, B., Fallah, N., Bonakdarpour, B. and Elyasi, S., 2018. The development of aerobic granules from slaughterhouse wastewater in treating real dyeing wastewater by Sequencing Batch Reactor (SBR). *Journal of environmental chemical engineering*, *6*(4), pp.5536-5543.

[10] Abedinzadeh, N., Shariat, M., Monavari, S.M. and Pendashteh, A., 2018. Evaluation of color and COD removal by Fenton from biologically (SBR) pre-treated pulp and paper wastewater. *Process Safety and Environmental Protection*, *116*, pp.82-91.

[11] Zhao, J., Li, Y., Chen, X. and Li, Y., 2018. Effects of carbon sources on sludge performance and microbial community for 4-chlorophenol wastewater treatment in sequencing batch reactors. *Bioresource technology*, *255*, pp.22-28.

[12] Zhao, Y., Park, H.D., Park, J.H., Zhang, F., Chen, C., Li, X., Zhao, D. and Zhao, F., 2016. Effect of different salinity adaptation on the performance and microbial community in a sequencing batch reactor. *Bioresource technology, 216*, pp.808-816.

[13] Neisi, A., Afshin, S., Rashtbari, Y., Babaei, A.A., Khaniabadi, Y.O., Asadi, A., Shirmardi, M. and Vosoughi, M., 2018. Efficiency of sequencing batch reactor for removal of organic matter in the effluent of petroleum wastewater. *Data in brief*, *19*, pp.2041-2046.

[14] Li, Q., Wang, S., Zhang, P., Yu, J., Qiu, C. and Zheng, J., 2018. Influence of temperature on an Anammox sequencing batch reactor (SBR) system under lower nitrogen load. *Bioresource technology*, *269*, pp.50-56.

[15] Yuan, Y., Liu, J., Ma, B., Liu, Y., Wang, B. and Peng, Y., 2016. Improving municipal wastewater nitrogen and phosphorous removal by feeding sludge fermentation products to sequencing batch reactor (SBR). *Bioresource technology*, *222*, pp.326-334.

[16] Zinadini, S., Rahimi, M., Zinatizadeh, A.A. and Mehrabadi, Z.S., 2015. High frequency ultrasound-induced sequence batch reactor as a practical solution for high rate wastewater treatment. *Journal of Environmental Chemical Engineering*, *3*(1), pp.217-226.

[17] Mekonen, A., Kumar, P. and Kumar, A., 2001. Use of sequencing batch reactor for biological denitrification of high nitrate-containing water. *Journal of environmental engineering*, *127*(3), pp.273-278.

[18] Mekonen, A., Kumar, P. and Kumar, A., 2001. Use of sequencing batch reactor for biological denitrification of high nitrate-containing water. *Journal of environmental engineering*, *127*(3), pp.273-278.

[19] Brdjanovic, D., Loosdrecht, M.C.V., Hooijmans, C.M., Alaerts, G.J. and Heijnen, J.J., 1997. Temperature effects on physiology of biological phosphorus removal. *Journal of environmental engineering*, *123*(2), pp.144-153.

[20] Rosman, N.H., Anuar, A.N., Othman, I., Harun, H., Sulong, M.Z., Elias, S.H., Hassan, M.A.H.M., Chelliapan, S. and Ujang, Z., 2013. Cultivation of aerobic granular sludge for rubber wastewater treatment. *Bioresource technology*, *129*, pp.620-623.

# APPENDIX A

## A.1 REACTOR OPERATION

**Figure A. 1 Mixing and Aeration in the Reactor**

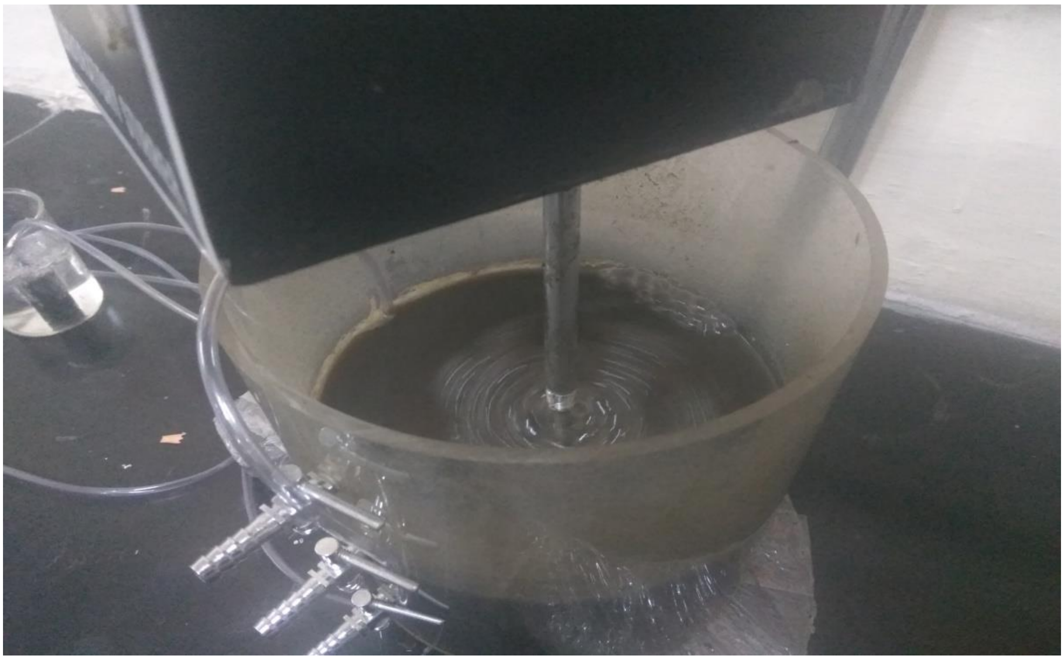

**Figure A. 2 SBR Operation taking place**.

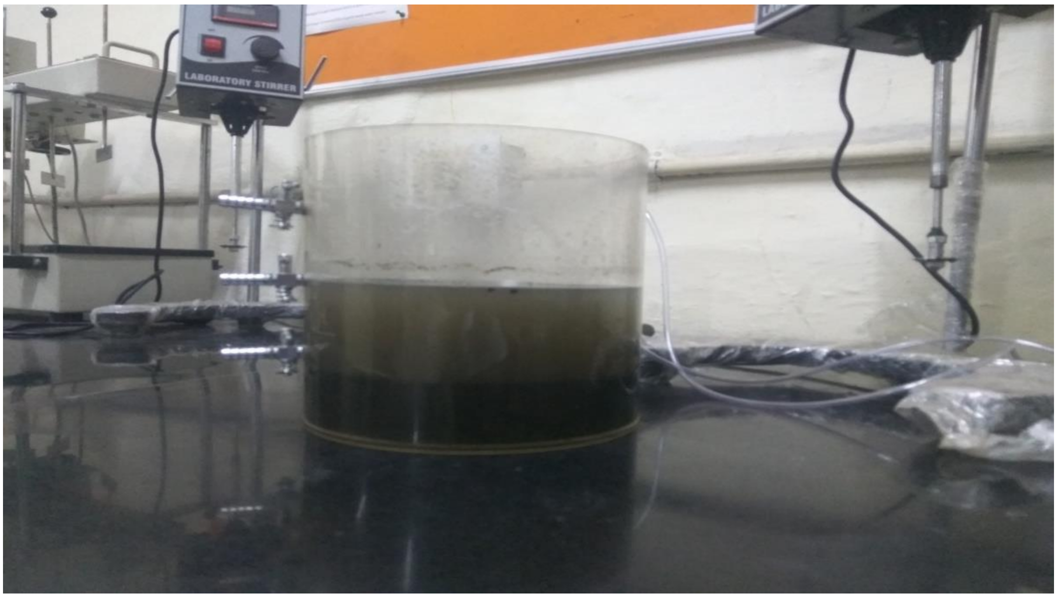

**Figure A. 3 SBR Operation taking place**

## A.2 SAMPLING

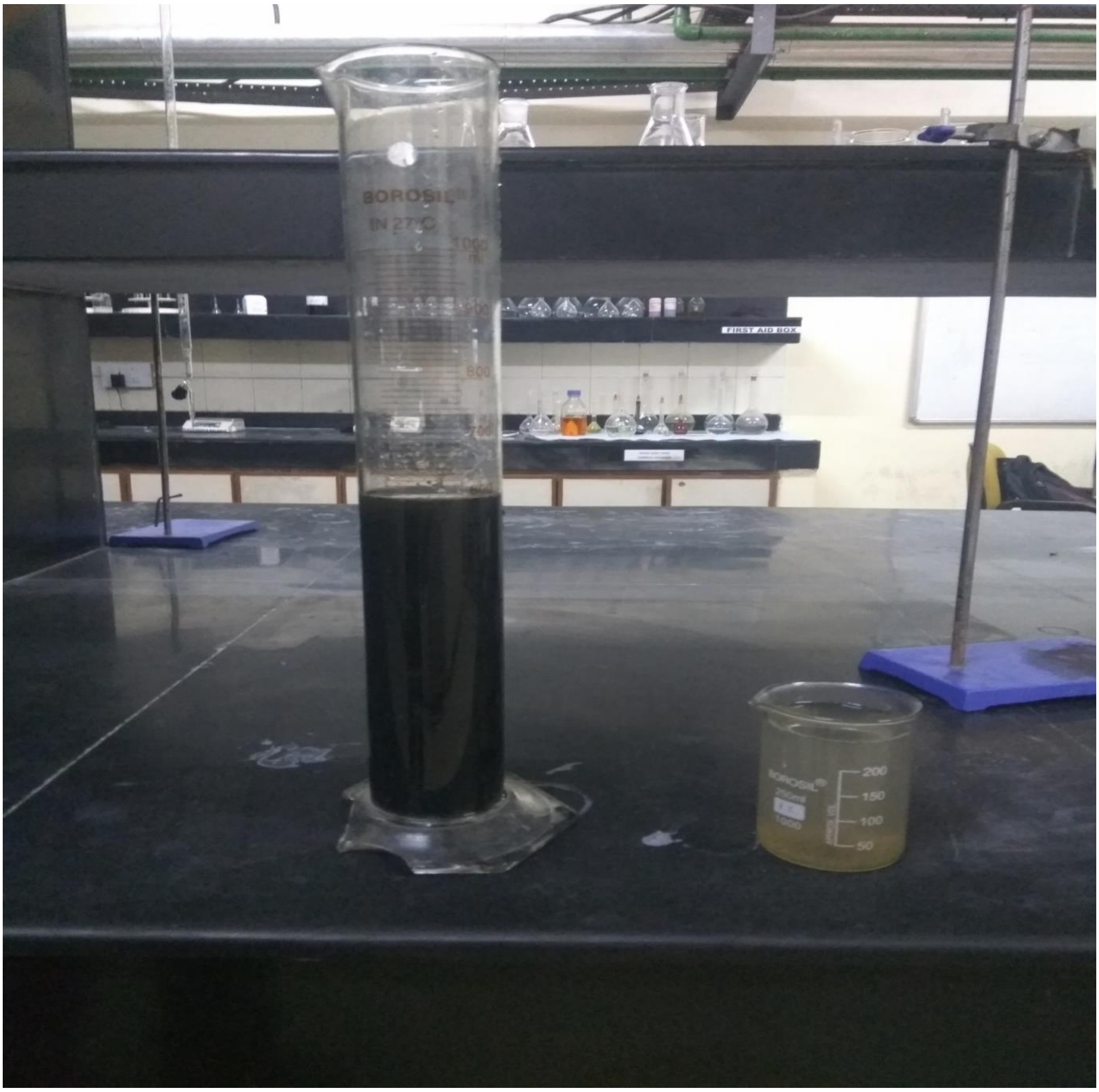

**Figure A. 4 SBR Operation taking place**

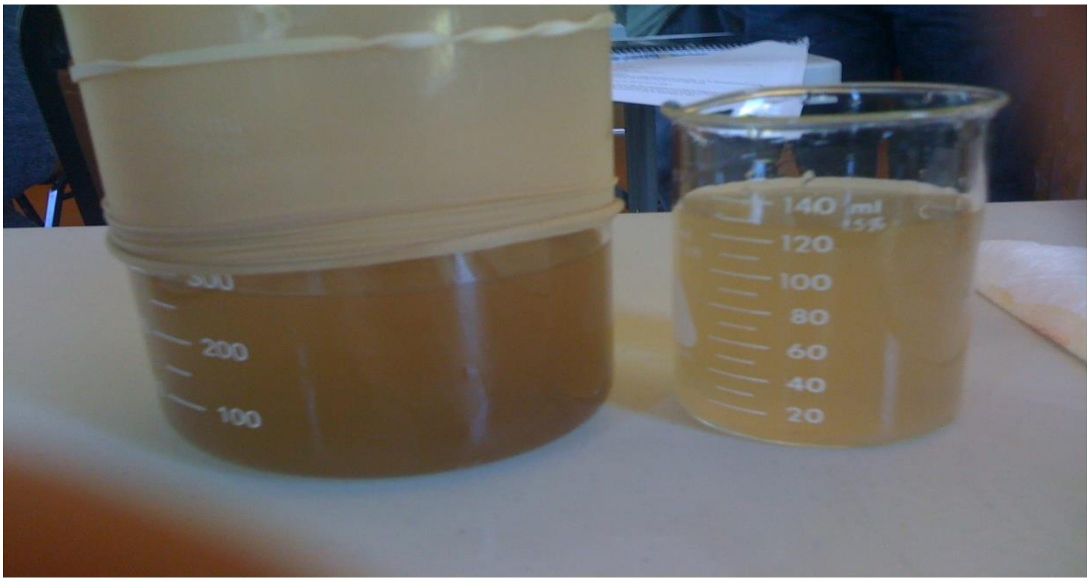

**Figure A. 5 Wastewater Sample Taken From Wastewater treatment plant**

# APPENDIX B

## TABLE OF RESULTS

Table B. 1 TSS Removal For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 211.95 | 98.31 | 53 |
| 2 | 311.25 | 142.21 | 54 |
| 3 | 294.89 | 138.94 | 53 |
| 4 | 313.55 | 143.21 | 54 |
| 5 | 217.2 | 97.21 | 55 |
| 6 | 313.22 | 145.21 | 54 |
| 7 | 287.23 | 120.35 | 58 |
| 8 | 223.33 | 92.12 | 59 |
| 9 | 317.6 | 128.78 | 60 |
| 10 | 317.3 | 123.56 | 61 |
| 11 | 285.76 | 106.23 | 63 |
| 12 | 358.79 | 130.72 | 63 |
| 13 | 257.76 | 93.88 | 64 |
| 14 | 202.83 | 72.23 | 64 |
| 15 | 207.22 | 73.12 | 65 |
| 16 | 215.34 | 72.14 | 66 |
| 17 | 267.33 | 87.12 | 67 |
| 18 | 259.32 | 82.56 | 67 |
| 19 | 279 | 92.33 | 69 |
| 20 | 398.67 | 108.21 | 73 |

Table B. 2 TS Removal For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1592 | 501.23 | 69 |
| 2 | 1489 | 465.3 | 69 |
| 3 | 1269 | 375.12 | 70 |
| 4 | 1629 | 478.12 | 71 |
| 5 | 1500 | 422 | 72 |
| 6 | 1758 | 486 | 72 |
| 7 | 1958 | 480 | 75 |
| 8 | 1929 | 485.77 | 75 |
| 9 | 1638 | 398.34 | 76 |
| 10 | 1356 | 323.56 | 76 |
| 11 | 1756 | 436 | 75 |
| 12 | 1508 | 345 | 77 |
| 13 | 1646 | 385.41 | 77 |
| 14 | 1200 | 268.12 | 78 |
| 15 | 1357 | 290 | 79 |
| 16 | 1229 | 261.29 | 79 |
| 17 | 1641 | 315.22 | 81 |
| 18 | 1592 | 301.55 | 81 |
| 19 | 1489 | 281.32 | 81 |
| 20 | 1765 | 274.21` | 84 |

Table B. 3 TDS Removal For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1380.05 | 402.92 | 70 |
| 2 | 1177.75 | 323.09 | 72 |
| 3 | 974.11 | 236.18 | 76 |
| 4 | 1315.45 | 334.91 | 74 |
| 5 | 1282.8 | 324.79 | 74 |
| 6 | 1444.78 | 340.79 | 76 |
| 7 | 1670.77 | 359.65 | 78 |
| 8 | 1705.67 | 393.65 | 77 |
| 9 | 1320.4 | 269.56 | 79 |
| 10 | 1038.7 | 200 | 80 |
| 11 | 1470.24 | 329.77 | 80 |
| 12 | 1149.21 | 214.28 | 78 |
| 13 | 1388.24 | 291.53 | 79 |
| 14 | 997.17 | 195.89 | 80 |
| 15 | 1149.78 | 216.88 | 81 |
| 16 | 1013.66 | 189.15 | 81 |
| 17 | 1373.67 | 228.1 | 83 |
| 18 | 1332.68 | 218.99 | 83 |
| 19 | 1210 | 188.99 | 84 |
| 20 | 1366.33 | 104.45 | 87 |

Table B. 4 DO Variation For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) |
|---|---|---|
| 1 | 3.97 | 0.27 |
| 2 | 3.82 | 0.26 |
| 3 | 3.85 | 0.28 |
| 4 | 3.84 | 0.25 |
| 5 | 3.95 | 0.26 |
| 6 | 3.88 | 0.25 |
| 7 | 3.85 | 0.25 |
| 8 | 3.85 | 0.25 |
| 9 | 3.64 | 0.24 |
| 10 | 3.88 | 0.2 |
| 11 | 3.97 | 0.21 |
| 12 | 4.12 | 0.21 |
| 13 | 3.86 | 0.2 |
| 14 | 3.81 | 0.18 |
| 15 | 3.88 | 0.17 |
| 16 | 3.85 | 0.18 |
| 17 | 3.87 | 0.16 |
| 18 | 3.9 | 0.17 |
| 19 | 3.88 | 0.16 |
| 20 | 3.91 | 0.16 |

.

Table B.5 COD Removal For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 525.02 | 188.24 | 64 |
| 2 | 462.12 | 168.54 | 64 |
| 3 | 533.5 | 187.21 | 65 |
| 4 | 483.04 | 171.21 | 65 |
| 5 | 426.65 | 140.56 | 67 |
| 6 | 572 | 195.24 | 66 |
| 7 | 457.09 | 128.24 | 72 |
| 8 | 536 | 137.21 | 74 |
| 9 | 576.65 | 139.41 | 76 |
| 10 | 526.35 | 111.32 | 79 |
| 11 | 586.98 | 118.98 | 80 |
| 12 | 476.67 | 86.87 | 81 |
| 13 | 554.19 | 103.25 | 81 |
| 14 | 570.12 | 101.24 | 82 |
| 15 | 406.89 | 70.24 | 83 |
| 16 | 574.776 | 88.56 | 84 |
| 17 | 479.91 | 79.21 | 84 |
| 18 | 472.1132 | 68.42 | 85 |
| 19 | 506.56 | 69.32 | 86 |
| 20 | 598.3 | 82.21 | 86 |

Table B. 6 BOD Removal For Domestic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 134.21 | 46.12 | 65 |
| 2 | 123.19 | 42.25 | 66 |
| 3 | 151.68 | 51.24 | 66 |
| 4 | 155.54 | 51.23 | 67 |
| 5 | 140.49 | 44.21 | 68 |
| 6 | 121.9 | 33.89 | 72 |
| 7 | 128.3 | 33.5 | 73 |
| 8 | 152.45 | 39.23 | 73 |
| 9 | 175.9 | 46.27 | 74 |
| 10 | 153.32 | 38.2 | 75 |
| 11 | 128.9 | 32.35 | 75 |
| 12 | 122.67 | 22.6 | 77 |
| 13 | 118.34 | 22.3 | 81 |
| 14 | 132.78 | 25.3 | 81 |
| 15 | 158.34 | 32.12 | 80 |
| 16 | 176.4 | 29.12 | 83 |
| 17 | 148.7 | 25.14 | 83 |
| 18 | 159.66 | 22.21 | 86 |
| 19 | 130.68 | 18.45 | 86 |
| 20 | 128.7 | 17.56 | 86 |

Table B. 7 TSS Removal For Domestic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 246 | 116 | 52 |
| 2 | 283 | 134 | 52 |
| 3 | 259.8 | 123 | 53 |
| 4 | 302.4 | 141 | 53 |
| 5 | 224.69 | 106.7 | 52 |
| 6 | 234.8 | 104 | 55 |
| 7 | 324 | 142 | 56 |
| 8 | 298 | 127 | 57 |
| 9 | 291.1 | 124 | 57 |
| 10 | 283.23 | 118.98 | 58 |
| 11 | 245 | 98 | 60 |
| 12 | 238 | 95 | 60 |
| 13 | 230.5 | 95 | 62 |
| 14 | 310 | 120 | 62 |
| 15 | 290.4 | 110 | 62 |
| 16 | 220.6 | 80 | 64 |
| 17 | 207.4 | 75.84 | 67 |
| 18 | 248.38 | 82.8 | 68 |
| 19 | 264.8 | 84.23 | 71 |
| 20 | 310.4 | 88.4 | 73 |
| 21 | 258 | 68.6 | 75 |
| 22 | 293.6 | 72.6 | 77 |
| 23 | 303.5 | 69 | 80 |
| 24 | 198.36 | 40.8 | 84 |
| 25 | 276 | 43 | 85 |
| 26 | 317.8 | 47 | 85 |
| 27 | 362.6 | 53 | 86 |
| 28 | 242 | 35 | 86 |
| 29 | 264 | 35.5 | 86 |
| 30 | 281 | 37 | 87 |

Table B. 8 TS Removal For Domestic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1843 | 682 | 62 |
| 2 | 1890 | 706 | 62 |
| 3 | 1778 | 662 | 63 |
| 4 | 1884 | 691 | 63 |
| 5 | 1682 | 627.4 | 62 |
| 6 | 1710 | 605 | 65 |
| 7 | 1856.6 | 652.8 | 65 |
| 8 | 1796.54 | 615 | 66 |
| 9 | 1751 | 589 | 66 |
| 10 | 1736.7 | 552 | 68 |
| 11 | 1680 | 513 | 69 |
| 12 | 1668 | 498 | 70 |
| 13 | 1923 | 545 | 71 |
| 14 | 1550 | 419.6 | 73 |
| 15 | 1785.9 | 473 | 74 |
| 16 | 1375 | 361 | 76 |
| 17 | 1398 | 338 | 79 |
| 18 | 1269 | 265 | 82 |
| 19 | 1657 | 296 | 82 |
| 20 | 1468 | 253 | 83 |
| 21 | 1795 | 280 | 84 |
| 22 | 1697 | 256 | 85 |
| 23 | 1895 | 288 | 85 |
| 24 | 1575.6 | 208 | 86 |
| 25 | 1288 | 157 | 88 |
| 26 | 1722 | 183 | 89 |
| 27 | 1836 | 175 | 90 |
| 28 | 1465 | 118 | 91 |
| 29 | 1518 | 135 | 91 |
| 30 | 1424 | 121 | 91 |

Table B. 9 TDS Removal For Domestic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1597 | 566 | 64 |
| 2 | 1607 | 572 | 64 |
| 3 | 1518.2 | 539 | 65 |
| 4 | 1581.6 | 530 | 64 |
| 5 | 1457.47 | 520.7 | 64 |
| 6 | 1475.2 | 501 | 66 |
| 7 | 1522.6 | 510.8 | 66 |
| 8 | 1498.54 | 488 | 67 |
| 9 | 1459.9 | 465 | 68 |
| 10 | 1453.47 | 433.02 | 70 |
| 11 | 1435 | 425 | 70 |
| 12 | 1430 | 403 | 71 |
| 13 | 1692.5 | 450 | 73 |
| 14 | 1240 | 299 | 75 |
| 15 | 1495.6 | 363 | 76 |
| 16 | 1154.4 | 281 | 76 |
| 17 | 1190.55 | 262.2 | 78 |
| 18 | 1020.62 | 182 | 82 |
| 19 | 1392.2 | 211.77 | 84 |
| 20 | 1157 | 104.6 | 86 |
| 21 | 1537 | 211.4 | 86 |
| 22 | 1403 | 183.4 | 87 |
| 23 | 1591 | 214 | 87 |
| 24 | 1377.24 | 167.2 | 87 |
| 25 | 1012 | 114 | 89 |
| 26 | 1404.2 | 136 | 90 |
| 27 | 1473.4 | 122 | 90 |
| 28 | 1223 | 83 | 91 |
| 29 | 1254 | 98.5 | 90 |
| 30 | 1143 | 84 | 91 |

Table B. 10 BOD Removal For Domestic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 186.8 | 65 | 65 |
| 2 | 148.3 | 52 | 64 |
| 3 | 121.8 | 43 | 64 |
| 4 | 175.6 | 61 | 65 |
| 5 | 159 | 57.3 | 65 |
| 6 | 183 | 59 | 67 |
| 7 | 148.4 | 47 | 67 |
| 8 | 155.7 | 48 | 68 |
| 9 | 132 | 41 | 68 |
| 10 | 191 | 62 | 67 |
| 11 | 142 | 43 | 69 |
| 12 | 155 | 45.2 | 70 |
| 13 | 153.4 | 45.6 | 70 |
| 14 | 132.8 | 36.8 | 72 |
| 15 | 124.6 | 32.4 | 73 |
| 16 | 169.3 | 41.5 | 75 |
| 17 | 119.9 | 27.6 | 76 |
| 18 | 126.1 | 28.3 | 77 |
| 19 | 147.36 | 29.56 | 79 |
| 20 | 164 | 27.8 | 82 |
| 21 | 138.48 | 21.58 | 84 |
| 22 | 167.36 | 24.42 | 85 |
| 23 | 117.58 | 16.65 | 85 |
| 24 | 131.67 | 15.76 | 86 |
| 25 | 193.38 | 19.28 | 87 |
| 26 | 155.9 | 14.84 | 87 |
| 27 | 128.6 | 9.46 | 88 |
| 28 | 148 | 15.2 | 89 |
| 29 | 132 | 13.8 | 89 |
| 30 | 165 | 15.87 | 90 |

Table B. 11 COD Removal For Domestic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 709.84 | 247 | 64 |
| 2 | 593.2 | 202.8 | 64 |
| 3 | 475.02 | 161 | 65 |
| 4 | 614.6 | 212 | 65 |
| 5 | 604.2 | 208.55 | 65 |
| 6 | 658.8 | 221.2 | 67 |
| 7 | 593.6 | 178.6 | 68 |
| 8 | 591.66 | 176 | 68 |
| 9 | 528 | 158.8 | 69 |
| 10 | 725.5 | 221 | 69 |
| 11 | 539.6 | 161.4 | 70 |
| 12 | 573.5 | 172 | 70 |
| 13 | 613.6 | 182 | 71 |
| 14 | 516 | 147.3 | 71 |
| 15 | 492.3 | 123.5 | 73 |
| 16 | 649.7 | 148.4 | 75 |
| 17 | 467.61 | 109.2 | 77 |
| 18 | 469.32 | 97.5 | 79 |
| 19 | 588.28 | 105.7 | 81 |
| 20 | 635.4 | 110.7 | 83 |
| 21 | 542.3 | 90.6 | 83 |
| 22 | 628.8 | 104.8 | 83 |
| 23 | 444.45 | 68.28 | 85 |
| 24 | 526.68 | 77.43 | 86 |
| 25 | 612.93 | 81.28 | 87 |
| 26 | 471.7 | 54.29 | 89 |
| 27 | 462.88 | 42.87 | 90 |
| 28 | 532.3 | 48 | 90 |
| 29 | 518.9 | 47.99 | 90 |
| 30 | 577.5 | 51.32 | 91 |

Table B. 12 DO variation For Domestic Wastewater having 6 hr cycle

| days | INFLUENT(mg/l) | EFFLUENT(mg/l) |
|---|---|---|
| 1 | 3.87 | 0.28 |
| 2 | 3.76 | 0.28 |
| 3 | 3.67 | 0.27 |
| 4 | 3.55 | 0.28 |
| 5 | 3.78 | 0.27 |
| 6 | 3.88 | 0.26 |
| 7 | 3.81 | 0.24 |
| 8 | 3.97 | 0.24 |
| 9 | 3.75 | 0.23 |
| 10 | 3.84 | 0.22 |
| 11 | 3.66 | 0.21 |
| 12 | 3.78 | 0.19 |
| 13 | 3.61 | 0.19 |
| 14 | 3.75 | 0.18 |
| 15 | 3.64 | 0.17 |
| 16 | 3.93 | 0.17 |
| 17 | 3.91 | 0.18 |
| 18 | 3.84 | 0.16 |
| 19 | 3.66 | 0.15 |
| 20 | 3.58 | 0.14 |
| 21 | 3.59 | 0.14 |
| 22 | 3.67 | 0.14 |
| 23 | 3.52 | 0.14 |
| 24 | 3.65 | 0.15 |
| 25 | 3.77 | 0.14 |
| 26 | 3.7 | 0.14 |
| 27 | 3.74 | 0.13 |
| 28 | 3.64 | 0.13 |
| 29 | 3.83 | 0.12 |
| 30 | 3.87 | 0.12 |

Table B. 13 TSS Removal For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 243.6 | 128.2 | 47 |
| 2 | 241.88 | 125.6 | 48 |
| 3 | 263.98 | 135.8 | 48 |
| 4 | 261.66 | 133.1 | 48 |
| 5 | 212.33 | 115.2 | 47 |
| 6 | 240 | 123 | 48 |
| 7 | 265.66 | 133 | 49 |
| 8 | 256 | 121 | 52 |
| 9 | 245 | 112 | 53 |
| 10 | 282 | 128 | 55 |
| 11 | 259.8 | 117 | 55 |
| 12 | 302.56 | 129.6 | 57 |
| 13 | 225 | 93 | 59 |
| 14 | 233.7 | 90 | 60 |
| 15 | 324 | 118 | 63 |
| 16 | 298 | 107 | 64 |
| 17 | 291.77 | 100.6 | 66 |
| 18 | 283.7 | 92.7 | 67 |
| 19 | 244 | 81 | 67 |
| 20 | 236.23 | 73.2 | 69 |
| 21 | 241 | 68 | 72 |
| 22 | 265.3 | 65.5 | 75 |
| 24 | 280.05 | 60.2 | 79 |
| 25 | 230.34 | 42 | 81 |
| 26 | 310.12 | 55.4 | 82 |
| 27 | 276 | 43 | 84 |
| 28 | 318 | 52.5 | 84 |
| 29 | 362.7 | 55.9 | 85 |
| 30 | 289.19 | 41 | 85 |

Table B. 14 TS Removal For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1664 | 836 | 49 |
| 2 | 1775 | 892 | 49 |
| 3 | 1342 | 673.53 | 49 |
| 4 | 1554 | 768.6 | 50 |
| 5 | 1489.9 | 723 | 49 |
| 6 | 1554.66 | 764 | 50 |
| 7 | 1478.9 | 719.4 | 51 |
| 8 | 1665 | 782 | 53 |
| 9 | 1752.2 | 765.67 | 56 |
| 10 | 1558.9 | 653.21 | 58 |
| 11 | 1467 | 587 | 59 |
| 12 | 1486 | 572.8 | 61 |
| 13 | 1365 | 489 | 64 |
| 14 | 1389 | 492 | 64 |
| 15 | 1924 | 628 | 67 |
| 16 | 1550 | 467.8 | 69 |
| 17 | 1784.8 | 541.45 | 69 |
| 18 | 1374 | 395 | 71 |
| 19 | 1399 | 373 | 73 |
| 20 | 1269.1 | 324 | 74 |
| 21 | 1654 | 388.6 | 76 |
| 22 | 1795.6 | 379.2 | 78 |
| 24 | 1678 | 312 | 82 |
| 25 | 1876 | 305 | 83 |
| 26 | 1668 | 252.41 | 84 |
| 27 | 1764.59 | 263.2 | 85 |
| 28 | 1743.87 | 247 | 85 |
| 29 | 1677 | 216 | 87 |
| 30 | 1658 | 209.34 | 87 |

Table B. 15 TDS Removal For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 1409.4 | 707.8 | 49 |
| 2 | 1533.12 | 766.4 | 50 |
| 3 | 1078.2 | 537.73 | 50 |
| 4 | 1292.34 | 635.5 | 50 |
| 5 | 1277.57 | 607.8 | 52 |
| 6 | 1314.66 | 641 | 51 |
| 7 | 1213.24 | 586.4 | 51 |
| 8 | 1409 | 661 | 53 |
| 9 | 1507.2 | 653.67 | 57 |
| 10 | 1276.9 | 525.21 | 58 |
| 11 | 1207.2 | 470 | 61 |
| 12 | 1183.44 | 443.2 | 62 |
| 13 | 1140 | 396 | 65 |
| 14 | 1155.3 | 402 | 65 |
| 15 | 1600 | 510 | 68 |
| 16 | 1252 | 360.8 | 71 |
| 17 | 1493.02 | 440.85 | 71 |
| 18 | 1090.3 | 302.3 | 72 |
| 19 | 1155 | 292 | 75 |
| 20 | 1032.87 | 250.8 | 75 |
| 21 | 1413 | 320.6 | 77 |
| 22 | 1530.4 | 313.7 | 79 |
| 24 | 1397.95 | 251.8 | 81 |
| 25 | 1645.66 | 263 | 84 |
| 26 | 1357.88 | 197.01 | 85 |
| 27 | 1488.59 | 220.2 | 85 |
| 28 | 1426.87 | 194.5 | 86 |
| 29 | 1314.3 | 160.1 | 87 |
| 30 | 1368.81 | 168.34 | 88 |

Table B. 16 BOD Removal For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 187.6 | 85.2 | 54 |
| 2 | 153.7 | 70.37 | 54 |
| 3 | 177.9 | 80.68 | 55 |
| 4 | 194 | 88.3 | 54 |
| 5 | 125.6 | 55.4 | 55 |
| 6 | 158 | 68.1 | 56 |
| 7 | 133 | 56.8 | 56 |
| 8 | 176 | 71 | 59 |
| 9 | 178.45 | 68.3 | 61 |
| 10 | 143 | 52 | 63 |
| 11 | 132.74 | 48.7 | 64 |
| 12 | 165.86 | 56 | 66 |
| 13 | 152.73 | 49.3 | 67 |
| 14 | 188 | 58 | 69 |
| 15 | 153.4 | 45.7 | 70 |
| 16 | 133 | 37.6 | 72 |
| 17 | 125 | 33.3 | 73 |
| 18 | 170.8 | 42.4 | 75 |
| 19 | 120 | 28.4 | 77 |
| 20 | 126.4 | 28.2 | 77 |
| 21 | 148.5 | 30.9 | 79 |
| 22 | 165.3 | 28.85 | 83 |
| 24 | 139 | 22.45 | 84 |
| 25 | 168 | 24.9 | 85 |
| 26 | 116 | 15.8 | 86 |
| 27 | 132.4 | 14.78 | 86 |
| 28 | 194.6 | 23.2 | 87 |
| 29 | 155.8 | 15.9 | 87 |
| 30 | 127 | 13.2 | 87 |

Table B. 17 COD Removal For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 712.88 | 318 | 56 |
| 2 | 568.69 | 243.5 | 57 |
| 3 | 693.81 | 293 | 57 |
| 4 | 737.2 | 323.87 | 56 |
| 5 | 477.28 | 208 | 57 |
| 6 | 632 | 265 | 58 |
| 7 | 535 | 224.52 | 58 |
| 8 | 668.8 | 256.17 | 61 |
| 9 | 677.92 | 254.51 | 62 |
| 10 | 557.7 | 199 | 65 |
| 11 | 530.96 | 174.8 | 67 |
| 12 | 630.26 | 193.31 | 69 |
| 13 | 610.92 | 167.6 | 72 |
| 14 | 695.6 | 184 | 73 |
| 15 | 623.6 | 158 | 74 |
| 16 | 533 | 124.4 | 76 |
| 17 | 471.2 | 104.6 | 77 |
| 18 | 577.8 | 121 | 79 |
| 19 | 480 | 92.2 | 80 |
| 20 | 480.32 | 91 | 80 |
| 21 | 564.3 | 112.2 | 81 |
| 22 | 628.14 | 96.43 | 84 |
| 24 | 528.2 | 71.3 | 86 |
| 25 | 638.4 | 77.3 | 87 |
| 26 | 452.4 | 57 | 87 |
| 27 | 529.6 | 63.21 | 88 |
| 28 | 778.4 | 88.3 | 88 |
| 29 | 592.4 | 61.53 | 89 |
| 30 | 495.3 | 51 | 89 |

Table B. 18 DO variation For Domestic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg/l) |
|---|---|---|
| 1 | 3.78 | 0.34 |
| 2 | 3.76 | 0.34 |
| 3 | 3.66 | 0.33 |
| 4 | 3.98 | 0.34 |
| 5 | 3.93 | 0.33 |
| 6 | 3.81 | 0.32 |
| 7 | 3.65 | 0.32 |
| 8 | 3.66 | 0.3 |
| 9 | 3.73 | 0.28 |
| 10 | 3.52 | 0.27 |
| 11 | 3.64 | 0.27 |
| 12 | 3.27 | 0.26 |
| 13 | 3.69 | 0.25 |
| 14 | 3.7 | 0.24 |
| 15 | 3.65 | 0.23 |
| 16 | 3.82 | 0.23 |
| 17 | 3.89 | 0.21 |
| 18 | 3.77 | 0.2 |
| 19 | 3.68 | 0.2 |
| 20 | 3.56 | 0.19 |
| 21 | 3.82 | 0.18 |
| 22 | 3.48 | 0.18 |
| 24 | 3.57 | 0.17 |
| 25 | 3.63 | 0.16 |
| 26 | 3.71 | 0.15 |
| 27 | 3.79 | 0.15 |
| 28 | 3.66 | 0.14 |
| 29 | 3.73 | 0.13 |
| 30 | 3.68 | 0.13 |

Table B. 19 TDS Removal For synthetic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 446 | 48 |
| 2 | 850 | 431 | 49 |
| 3 | 850 | 451 | 47 |
| 4 | 850 | 442.66 | 48 |
| 5 | 850 | 443.32 | 48 |
| 6 | 850 | 442 | 48 |
| 7 | 850 | 452 | 47 |
| 8 | 850 | 431.65 | 49 |
| 9 | 850 | 421.56 | 50 |
| 10 | 850 | 410.65 | 51 |
| 11 | 850 | 400.23 | 53 |
| 12 | 850 | 395.12 | 53 |
| 13 | 850 | 385.34 | 55 |
| 14 | 850 | 381.23 | 55 |
| 15 | 850 | 372.24 | 56 |
| 16 | 850 | 365.01 | 57 |
| 17 | 850 | 362.1 | 57 |
| 18 | 850 | 359.12 | 58 |
| 19 | 850 | 350.32 | 59 |
| 20 | 850 | 347.89 | 59 |
| 21 | 850 | 323.21 | 62 |
| 22 | 850 | 287.12 | 66 |
| 23 | 850 | 262.38 | 69 |
| 24 | 850 | 212.78 | 75 |
| 25 | 850 | 197.445 | 77 |
| 26 | 850 | 165.47 | 80 |
| 27 | 850 | 160.47 | 81 |
| 28 | 850 | 150.67 | 82 |
| 29 | 850 | 145.78 | 83 |
| 30 | 850 | 142.78 | 83 |

Table B. 20 TS Removal For Synthetic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 446 | 48 |
| 2 | 850 | 431 | 49 |
| 3 | 850 | 451 | 47 |
| 4 | 850 | 442.66 | 48 |
| 5 | 850 | 443.32 | 48 |
| 6 | 850 | 442 | 48 |
| 7 | 850 | 452 | 47 |
| 8 | 850 | 431.65 | 49 |
| 9 | 850 | 421.56 | 50 |
| 10 | 850 | 410.65 | 51 |
| 11 | 850 | 400.23 | 53 |
| 12 | 850 | 395.12 | 53 |
| 13 | 850 | 385.34 | 55 |
| 14 | 850 | 381.23 | 55 |
| 15 | 850 | 372.24 | 56 |
| 16 | 850 | 365.01 | 57 |
| 17 | 850 | 362.1 | 57 |
| 18 | 850 | 359.12 | 58 |
| 19 | 850 | 350.32 | 59 |
| 20 | 850 | 347.89 | 59 |
| 21 | 850 | 323.21 | 62 |
| 22 | 850 | 287.12 | 66 |
| 23 | 850 | 262.38 | 69 |
| 24 | 850 | 212.78 | 75 |
| 25 | 850 | 197.445 | 77 |
| 26 | 850 | 165.47 | 80 |
| 27 | 850 | 160.47 | 81 |
| 28 | 850 | 150.67 | 82 |
| 29 | 850 | 145.78 | 83 |
| 30 | 850 | 142.78 | 83 |

Table B. 21 COD Removal For Synthetic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 747 | 301.25 | 60 |
| 2 | 747 | 299.56 | 60 |
| 3 | 747 | 292.25 | 61 |
| 4 | 747 | 303.89 | 59 |
| 5 | 747 | 290.67 | 61 |
| 6 | 747 | 297.36 | 60 |
| 7 | 747 | 310 | 58 |
| 8 | 747 | 296.52 | 60 |
| 9 | 747 | 298.75 | 60 |
| 10 | 747 | 289.35 | 61 |
| 11 | 747 | 279.45 | 63 |
| 12 | 747 | 269.59 | 64 |
| 13 | 747 | 262.38 | 65 |
| 14 | 747 | 256.38 | 66 |
| 15 | 747 | 251.42 | 66 |
| 16 | 747 | 250.01 | 66 |
| 17 | 747 | 245.09 | 67 |
| 18 | 747 | 239.46 | 68 |
| 19 | 747 | 223.78 | 70 |
| 20 | 747 | 219.64 | 71 |
| 21 | 747 | 200.56 | 73 |
| 22 | 747 | 181.35 | 76 |
| 23 | 747 | 156.31 | 79 |
| 24 | 747 | 110.352 | 85 |
| 25 | 747 | 108.32 | 85 |
| 26 | 747 | 101.45 | 86 |
| 27 | 747 | 95.32 | 87 |
| 28 | 747 | 93.25 | 87 |
| 29 | 747 | 90.12 | 88 |
| 30 | 747 | 87.34 | 88 |

Table B. 22 DO Variation For Synthetic Wastewater having 4 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) |
|---|---|---|
| 1 | 7.94 | 0.96 |
| 2 | 7.88 | 0.93 |
| 3 | 7.85 | 0.95 |
| 4 | 7.87 | 0.89 |
| 5 | 7.78 | 0.91 |
| 6 | 7.99 | 0.89 |
| 7 | 8.01 | 0.93 |
| 8 | 7.95 | 0.91 |
| 9 | 7.92 | 0.95 |
| 10 | 8.12 | 0.92 |
| 11 | 7.92 | 0.89 |
| 12 | 7.78 | 0.88 |
| 13 | 7.87 | 0.91 |
| 14 | 7.94 | 0.92 |
| 15 | 7.84 | 0.89 |
| 16 | 7.98 | 0.92 |
| 17 | 7.85 | 0.87 |
| 18 | 7.78 | 0.88 |
| 19 | 7.96 | 0.87 |
| 20 | 7.89 | 0.86 |
| 21 | 7.99 | 0.83 |
| 22 | 7.86 | 0.84 |
| 23 | 7.78 | 0.77 |
| 24 | 7.89 | 0.8 |
| 25 | 8.02 | 0.81 |
| 26 | 7.99 | 0.79 |
| 27 | 7.92 | 0.81 |
| 28 | 7.89 | 0.79 |
| 29 | 7.95 | 0.78 |
| 30 | 8.01 | 0.81 |

Table B. 23 TDS Removal For synthetic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 422.34 | 50 |
| 2 | 850 | 431.87 | 49 |
| 3 | 850 | 420.56 | 51 |
| 4 | 850 | 422.78 | 50 |
| 5 | 850 | 425.98 | 50 |
| 6 | 850 | 442.67 | 48 |
| 7 | 850 | 429.38 | 49 |
| 8 | 850 | 417.32 | 51 |
| 9 | 850 | 400.56 | 50 |
| 10 | 850 | 380.56 | 55 |
| 11 | 850 | 370.92 | 56 |
| 12 | 850 | 360.01 | 58 |
| 13 | 850 | 321.25 | 62 |
| 14 | 850 | 317.32 | 63 |
| 15 | 850 | 310.25 | 63 |
| 16 | 850 | 302.12 | 64 |
| 17 | 850 | 300.54 | 65 |
| 18 | 850 | 295.42 | 65 |
| 19 | 850 | 284.51 | 67 |
| 20 | 850 | 281.56 | 67 |
| 21 | 850 | 272.45 | 68 |
| 22 | 850 | 210.14 | 75 |
| 23 | 850 | 200.57 | 76 |
| 24 | 850 | 199.87 | 76 |
| 25 | 850 | 195.67 | 77 |
| 26 | 850 | 191.75 | 77 |
| 27 | 850 | 180.15 | 79 |
| 28 | 850 | 171.78 | 80 |
| 29 | 850 | 150.11 | 82 |
| 30 | 850 | 139.65 | 84 |

Table B. 24 TS Removal For Synthetic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 422.34 | 50 |
| 2 | 850 | 431.87 | 49 |
| 3 | 850 | 420.56 | 51 |
| 4 | 850 | 422.78 | 50 |
| 5 | 850 | 425.98 | 50 |
| 6 | 850 | 442.67 | 48 |
| 7 | 850 | 429.38 | 49 |
| 8 | 850 | 417.32 | 51 |
| 9 | 850 | 400.56 | 50 |
| 10 | 850 | 380.56 | 55 |
| 11 | 850 | 370.92 | 56 |
| 12 | 850 | 360.01 | 58 |
| 13 | 850 | 321.25 | 62 |
| 14 | 850 | 317.32 | 63 |
| 15 | 850 | 310.25 | 63 |
| 16 | 850 | 302.12 | 64 |
| 17 | 850 | 300.54 | 65 |
| 18 | 850 | 295.42 | 65 |
| 19 | 850 | 284.51 | 67 |
| 20 | 850 | 281.56 | 67 |
| 21 | 850 | 272.45 | 68 |
| 22 | 850 | 210.14 | 75 |
| 23 | 850 | 200.57 | 76 |
| 24 | 850 | 199.87 | 76 |
| 25 | 850 | 195.67 | 77 |
| 26 | 850 | 191.75 | 77 |
| 27 | 850 | 180.15 | 79 |
| 28 | 850 | 171.78 | 80 |
| 29 | 850 | 150.11 | 82 |
| 30 | 850 | 139.65 | 84 |

Table B. 25 COD Removal For Synthetic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 747 | 277.32 | 63 |
| 2 | 747 | 275.36 | 63 |
| 3 | 747 | 290.56 | 61 |
| 4 | 747 | 301.67 | 60 |
| 5 | 747 | 281.32 | 62 |
| 6 | 747 | 277.98 | 63 |
| 7 | 747 | 267.57 | 64 |
| 8 | 747 | 268.32 | 64 |
| 9 | 747 | 275.56 | 63 |
| 10 | 747 | 261.32 | 65 |
| 11 | 747 | 251.26 | 66 |
| 12 | 747 | 241.26 | 68 |
| 13 | 747 | 232.77 | 69 |
| 14 | 747 | 219.45 | 70 |
| 15 | 747 | 215.15 | 71 |
| 16 | 747 | 202.54 | 73 |
| 17 | 747 | 196.32 | 74 |
| 18 | 747 | 181.54 | 76 |
| 19 | 747 | 162.12 | 78 |
| 20 | 747 | 159.98 | 78 |
| 21 | 747 | 156.31 | 79 |
| 22 | 747 | 111.98 | 85 |
| 23 | 747 | 101.63 | 86 |
| 24 | 747 | 98.31 | 87 |
| 25 | 747 | 95.61 | 87 |
| 26 | 747 | 92.12 | 88 |
| 27 | 747 | 91.89 | 88 |
| 28 | 747 | 88.31 | 88 |
| 29 | 747 | 81.29 | 89 |
| 30 | 747 | 79.25 | 89 |

Table B. 26 DO Variation For Synthetic Wastewater having 6 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) |
|---|---|---|
| 1 | 7.89 | 0.88 |
| 2 | 7.88 | 0.89 |
| 3 | 7.85 | 0.85 |
| 4 | 7.87 | 0.81 |
| 5 | 7.78 | 0.84 |
| 6 | 7.99 | 0.87 |
| 7 | 8.01 | 0.83 |
| 8 | 7.95 | 0.85 |
| 9 | 7.92 | 0.81 |
| 10 | 8.12 | 0.82 |
| 11 | 7.92 | 0.84 |
| 12 | 7.78 | 0.79 |
| 13 | 7.71 | 0.8 |
| 14 | 7.99 | 0.81 |
| 15 | 7.95 | 0.8 |
| 16 | 7.97 | 0.83 |
| 17 | 7.8 | 0.81 |
| 18 | 7.75 | 0.78 |
| 19 | 7.79 | 0.88 |
| 20 | 8.01 | 0.87 |
| 21 | 7.95 | 0.86 |
| 22 | 7.98 | 0.83 |
| 23 | 7.75 | 0.84 |
| 24 | 7.71 | 0.77 |
| 25 | 7.76 | 0.88 |
| 26 | 7.72 | 0.81 |
| 27 | 7.88 | 0.71 |
| 28 | 7.82 | 0.81 |
| 29 | 7.93 | 0.71 |
| 30 | 7.86 | 0.78 |

Table B. 27 TDS Removal For synthetic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 401.36 | 53 |
| 2 | 850 | 399.62 | 53 |
| 3 | 850 | 395.23 | 54 |
| 4 | 850 | 390.76 | 54 |
| 5 | 850 | 396.23 | 53 |
| 6 | 850 | 387.74 | 54 |
| 7 | 850 | 381.87 | 55 |
| 8 | 850 | 384.26 | 55 |
| 9 | 850 | 382.16 | 55 |
| 10 | 850 | 345.23 | 59 |
| 11 | 850 | 338.62 | 60 |
| 12 | 850 | 331.24 | 61 |
| 13 | 850 | 323.25 | 62 |
| 14 | 850 | 320.12 | 62 |
| 15 | 850 | 305.45 | 64 |
| 16 | 850 | 298.65 | 65 |
| 17 | 850 | 292.35 | 65 |
| 18 | 850 | 281.24 | 67 |
| 19 | 850 | 275.89 | 68 |
| 20 | 850 | 271.56 | 68 |
| 21 | 850 | 265.32 | 69 |
| 22 | 850 | 207.29 | 75 |
| 23 | 850 | 195.54 | 77 |
| 24 | 850 | 191.56 | 78 |
| 25 | 850 | 175.56 | 79 |
| 26 | 850 | 163.76 | 81 |
| 27 | 850 | 150.91 | 82 |
| 28 | 850 | 144.21 | 83 |
| 29 | 850 | 129.52 | 85 |
| 30 | 850 | 125.81 | 85 |

Table B. 28 TS Removal For Synthetic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 850 | 401.36 | 53 |
| 2 | 850 | 399.62 | 53 |
| 3 | 850 | 395.23 | 54 |
| 4 | 850 | 390.76 | 54 |
| 5 | 850 | 396.23 | 53 |
| 6 | 850 | 387.74 | 54 |
| 7 | 850 | 381.87 | 55 |
| 8 | 850 | 384.26 | 55 |
| 9 | 850 | 382.16 | 55 |
| 10 | 850 | 345.23 | 59 |
| 11 | 850 | 338.62 | 60 |
| 12 | 850 | 331.24 | 61 |
| 13 | 850 | 323.25 | 62 |
| 14 | 850 | 320.12 | 62 |
| 15 | 850 | 305.45 | 64 |
| 16 | 850 | 298.65 | 65 |
| 17 | 850 | 292.35 | 65 |
| 18 | 850 | 281.24 | 67 |
| 19 | 850 | 275.89 | 68 |
| 20 | 850 | 271.56 | 68 |
| 21 | 850 | 265.32 | 69 |
| 22 | 850 | 207.29 | 75 |
| 23 | 850 | 195.54 | 77 |
| 24 | 850 | 191.56 | 78 |
| 25 | 850 | 175.56 | 79 |
| 26 | 850 | 163.76 | 81 |
| 27 | 850 | 150.91 | 82 |
| 28 | 850 | 144.21 | 83 |
| 29 | 850 | 129.52 | 85 |
| 30 | 850 | 125.81 | 85 |

Table B. 29 COD Removal For Synthetic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) | REMOVAL EFFICIENCY (%) |
|---|---|---|---|
| 1 | 747 | 260.38 | 65 |
| 2 | 747 | 255.12 | 66 |
| 3 | 747 | 250.87 | 66 |
| 4 | 747 | 244.76 | 67 |
| 5 | 747 | 242.15 | 67 |
| 6 | 747 | 252.21 | 66 |
| 7 | 747 | 243.21 | 67 |
| 8 | 747 | 250.41 | 66 |
| 9 | 747 | 244.32 | 67 |
| 10 | 747 | 240.75 | 68 |
| 11 | 747 | 215.76 | 71 |
| 12 | 747 | 211.54 | 72 |
| 13 | 747 | 203.76 | 73 |
| 14 | 747 | 201.23 | 73 |
| 15 | 747 | 189.32 | 75 |
| 16 | 747 | 173.32 | 77 |
| 17 | 747 | 165.21 | 78 |
| 18 | 747 | 158.67 | 79 |
| 19 | 747 | 160.56 | 79 |
| 20 | 747 | 152.65 | 80 |
| 21 | 747 | 142.85 | 81 |
| 22 | 747 | 98.75 | 87 |
| 23 | 747 | 91.67 | 88 |
| 24 | 747 | 88.97 | 88 |
| 25 | 747 | 85.34 | 88 |
| 26 | 747 | 79.65 | 89 |
| 27 | 747 | 75.89 | 90 |
| 28 | 747 | 71.25 | 90 |
| 29 | 747 | 65.23 | 91 |
| 30 | 747 | 63.12 | 91 |

Table B. 30 DO Variation For Synthetic Wastewater having 8 hr cycle

| Days | INFLUENT(mg/l) | EFFLUENT(mg\l) |
|---|---|---|
| 1 | 7.91 | 0.95 |
| 2 | 7.85 | 0.92 |
| 3 | 7.89 | 0.88 |
| 4 | 7.87 | 0.87 |
| 5 | 7.76 | 0.85 |
| 6 | 8.01 | 0.87 |
| 7 | 8.04 | 0.88 |
| 8 | 7.92 | 0.89 |
| 9 | 7.88 | 0.87 |
| 10 | 7.99 | 0.89 |
| 11 | 7.95 | 0.87 |
| 12 | 7.81 | 0.84 |
| 13 | 7.85 | 0.85 |
| 14 | 8.01 | 0.88 |
| 15 | 7.96 | 0.87 |
| 16 | 7.82 | 0.81 |
| 17 | 7.78 | 0.85 |
| 18 | 7.74 | 0.86 |
| 19 | 7.76 | 0.91 |
| 20 | 7.78 | 0.89 |
| 21 | 7.91 | 0.88 |
| 22 | 7.95 | 0.85 |
| 23 | 8.01 | 0.87 |
| 24 | 7.97 | 0.79 |
| 25 | 7.87 | 0.84 |
| 26 | 7.86 | 0.83 |
| 27 | 7.98 | 0.82 |
| 28 | 7.96 | 0.81 |
| 29 | 8.01 | 0.77 |
| 30 | 8.05 | 0.8 |