SEWAGE WASTE WATERTREATMENT USING CHLOROBIO PROCESS: A REVIEW

[1]Abhay Mandavkar, [2]Dr. S. P. Shingare, [3]Purushottam Mishra, [4]Saurabh Marwadi

Department of Chemical Engineering,
Bharati Vidyapeeth College of Engineering, Navi Mumbai – 400 614, India

***ABSTRACT*: The sewage from colonies as well effluent from industrial units has been identified as main cause for water pollution across our country. The contaminants in wastewater are removed by physical, chemical, and biological means. The individual methods usually are classified as physical unit operations, chemical unit processes, and biological unit processes. The BOD, COD, TSS concentration of sewage ranges from 180-200 mg/l, 300- 440 mg/l and 150-200 mg/l respectively. Under this project report a suit treatment technology has been developed to treat sewage. Treatment technologies consist of filtration, chlorination and biological treatment. The results were very encouraging. The treatment system achieved 94% COD and 95% TSS removal respectively. The treated sewage can be reused for various purpose like cooling water make up, gardening, landscape development, toilet flushing, road washing etc. thus leading towards water conservation.**

***Keywords*: Biological treatment, Bio filter, BOD, COD, Sewage, TSS.**

Introduction:

Sewage is water-carried wastes, in either solution or suspension that is intended to flow away from a community. Waste water is liquid waste discharged by domestic residences, commercial properties, industry, agriculture, which often contains some contaminants that result from the mixing of wastewater from different sources (Shrirang Vrushali et.al, 2009). Based on its origin wastewater can be classed as sanitary, commercial, industrial, agricultural or surface runoff(Sanamdikar and K.R.Harne 2012). Term wastewater need to be separated from the term Sewage, The terms "sewage" and "Sewerage" are sometimes interchanged (Funk et al., 1960). Sewage is contaminated with feces or urine. The sewage generates from residence, hospitals, offices, industries etc. Domestic sewage contains a wide variety of dissolved and suspended impurities and is the primary source of pathogens (disease-causing microorganisms) and putrescible organic substances. Because pathogens are excreted in feces, all sewage from cities and towns is likely to contain pathogens of some type, potentially presenting a direct threat to public health. Putrescible organic matter presents a different sort of threat to water quality during recent years; there has been an increasing awareness and concern about water conservation all over the world. Hence, a new approach towards achieving sustainable development of water resources has been developed internationally.India is recognized as has having major problems with water Pollution, predominantly due to untreated Sewage. Rivers such as the Ganges, the Yamuna all flowing through highly populated areas, are polluted. 80 % of sewage in India is untreated and flows directly into the nation's rivers, polluting the main sources of drinking water. Indian cities produce nearly 40,000 million liters of sewage every day and barely 20 percent of it is treated (ShrirangVrushali and ChatterjeeKaustav, 2014). Hence treatment of sewage and its reuse is the need of the hour.The effects of the discharge of untreated waste-water into the environment are manifold and depend on the types and concentrations of pollutants. Important contaminants in sewage water and their potential effects are outlined in table below

Table: Important sewage Waste Water Contaminants :(Van der Heul et al, 2006)

Sr. no.	Contaminant	Effect	Sources
1	Solid matter	It can lead to development of sludge deposits and anaerobic conditions when untreated wastewater is discharged to the aquatic environment.	Domestic use, Industrial waste
2	Organic and inorganic matter	They are commonly measured in terms of BOD and COD. If discharged into inland rivers, streams or lakes, their biological stabilization can deplete natural oxygen resources and cause septic conditions that are detrimental to aquatic species.Dissolved inorganic constituents such as calcium, sodium and sulfate are often initially added to domestic water supplies, and may have to be removed for waste-water reuse.	Domestic use, Industrial waste
3	Mineral matter	Mineral matterusually added by commercial and industrial activities must be removed for reuse of the waste-water.	Industrial waste
4	Pathogens	Pathogens found in waste-water can cause infectious diseases.	Domestic water
5	Refractory organics	Refractory organics that tend to resist conventional waste-water treatment include surfactants, phenols and agricultural pesticides.	Domestic and Industrial waste

Source: Adapted from Metcalf and Eddy, Inc., Wastewater Engineering, 3rd edition.

Sewage treatment is the process of removing contaminants from wastewater and house hold sewage, both runoffs (effluents), domestic, commercial and institutional. Its objective is to produce an environmentally safe fluid waste stream (or Treated Effluent) and a solid waste (or treated sludge) suitable for disposal or reuse. Sewage treatment is the process of removing contaminants from wastewater and house hold sewage, both runoffs (effluents), domestic, commercial and institutional. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce an environmentally safe fluid waste stream (or Treated Effluent) and a solid waste (or treated sludge) suitable for disposal or reuse. The treatment of waste water is not only important for our own health but also to keep our environment clean and healthy.

2.1 Combined Activated Sludge – Ozonation process:

Marcia Regina et al. (2009) studied the combined activated sludge-O_3/pH 10 treatment was able to remove around 80% of COD, TOC and color from Kraft E_1 effluent. For the total phenols, the efficiency removal was around 70%. The ozonation post treatment carried out at pH 8.3 also showed better results than the single process. The difference in the concentrations of free radical produced by activated sludge-O_3/pH 10 and activated sludge-O_3/pH 8.3 affected mainly the TOC and total phenol removal values. These classical treatments have been successful in lowering the chemical and biological oxygen demands (COD, BOD), but their applicability is limited by a great number of problems. Given the limitations of the current biological wastewater treatment, there is an increasing interest to develop a more effective treatment approach to reduce the impacts of pulp mill effluents on the environment.

AntenehGetnet (2014) was observed that COD in the final effluent was reduced to total and soluble COD concentrations in the range of 548.2 mg/l and 379.2mg/l for control SBR and 537.581mg/l and 376.049 mg/l for SBR with ozonated sludge respectively at total cycling time of 24 h. In terms of overall sludge reduction, 35.1% reduction of the excess sludge could be achieved by ozone treatment at 0.168 g-O3/g-MLSS.

Pello Alfonso-Muniozguren et al. (2018) studied a combined lab scale activated sludge-filtration-ozonation system was used to treat a pre-treated abattoir wastewater. A hydraulic retention time of 24 hours and a solid retention time of 13 days were used for the activated sludge process, followed by a filtration step (4-7 μm) and using ozone as tertiary treatment. An average reduction of 93% and 98% was achieved for Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), respectively, obtaining final values of 128 mg/L COD and 12 mg/L BOD. For the Total Suspended Solids (TSS), the average reduction increased to 99% in the same system, reducing the final value down to 3 mg/L. Additionally, 98% reduction in Phosphorus (P) and a complete inactivation of Total Coliforms (TC) was obtained after 17 min ozonation time. For Total Viable Counts (TVC), a drastic reduction was observed with 30 min ozonation time (6 log inactivation) at an ozone dose of 71 mg O3/L. Overall, the combined process was sufficient to meet discharge requirements without further treatment for the measured parameters (COD, BOD, TSS, P, TC, and TVC).

Wesley et al. (1957), has experimented performance of activated sludge process on sewage. They have reported 90% reduction in BOD in case of sewage. In a similar study, Jungle et al. (2009), has studied the performance of activated sludge process in treating waste water from food industry. In their paper, "aerobic treatment of waste water generated from food industry by activated sludge process" they have reported BOD reduction of 82% and COD reduction of 72%. As a part of tertiary treatment, the biologically treated sewage has been further treated by chlorination. The pathogen removal achieved to the tune of 99%.The initial Coliform count was reported as 107 MPN/100 ml reduced to 104 MPN/100 ml. Chlorination also reported slight reduction in BOD from 18 to 8 mg/L and COD from 65 mg/L to 35 mg/L.

2.2 Combined Chlorination- Biofilm Process

Javed Iqbal Qazi et al. (2011) studied Biofilm support media including foam cubes, bamboo rings, fire bricks, PVC rings and gravels were employed to immobilize biomass for reduction in BOD, COD and VSS of dairy wastewater in batch and repeated batch cultivation systems. They considered main factors like efficiency of COD removal is associated with nature and properties of support material for effective results. Maximum percentage removal of COD, BOD and VSS turned out to be as 96 %, 93 % and 90 % respectively. Further they stated that dynamics of repeated batch evaluated in three cycles indicated that almost 89% reduction of volatile suspended solids (VSS) occurred after 12 days in each cycle and results evaluated under bio treatment process for high conversion of organic fraction to combustible methane gas for successful completion of experiment.

Berg et al. (1978), reported 99.9 % destroyed of indigenous fecal coliforms, total coliforms, and fecal streptococci in primary sewage effluent by combined chlorine in their unit. The treated sewage still was little turbid and was having a yellowish tinge. Hence, the treated sewage was finally passed through biomedia Filter. The Final TSS after passing through biomedia Filtration was reported as 10 mg/L. It achieved TSS removal to the tune of 95%. The final parameters achieved after treatment shows that the treated sewage can be reused for cooling tower water make up, gardening, toilet flushing, road washing, green belt/landscape development etc.

Chatterjee et al. (2003), reported TSS removal from 150 mg/l to 10 mg/l by bio media filtration. Along with TSS removal, COD and BOD removal was also reported .The BOD and COD reduction was achieved by bio media Filtration to the tune of 96.8 % & 92.5 %. This was mainly due to removal of TSS concentration which was otherwise contributing to total COD.

2.3 Biofilm Formation and its Mechanism

(Wuertz et al., 2003)studied thedetachment of biofilm is a common phenomenon, which always happens during the biofilm formation process. Biofilm detachment occurs through different processes. Detachment of biofilm by abrasion, erosion, sloughing, occurs when there is shear stresses, and lack of nutrient and oxygen in the biological filter. Abrasion and erosion leads to the removal of small groups of cells from biofilm while sloughing results in the detachment of a relatively large fraction of the biofilm. Porosity and roughness of the surface supporting the biofilm plays an important role in protecting the biofilm from hydrodynamic shear and abrasion.

Biological filtration or biofiltration is one water treatment process that can effectively remove organic matter that is not able to be removed from water and biologically treated sewage effluent in conventional sewage treatment (Carlson and Amy, 1998).The biological filter mainly relies on the activities of the community of microorganisms that are attached onto the filter media. The activities of microbes determine the performance of biological filtration. Microbes oxidize organic matters in water to produce energy and therefore available nutrients sources in feed water are essential for their development. In addition, the parameters such as hydraulic loading rate, back washing techniques, temperature and pH etc. can affect the growth of biomass onto GAC in the Biofilter. Moreover, biological filtration is economical and safe for environment. Biofiltration is more suitable than other treatment methods in terms of removing organic matter.

(Van Loosdrechtet al.1990) shown thatthere are three main biological processes that can occur in a biofilter, (i) attachment of microorganism, (ii) growth of microorganism and (iii) decay and detachment of microorganisms. As the success of a biofilter depends on the growth and maintenance of microorganisms (biomass) on the surface of filter media, it is necessary to understand the mechanisms of attachment, growth and detachment on the surface of the filter media.

Review Paper	Authors	Method used	Remark
Combined System of Activated Sludge and Ozonation for the Treatment of Kraft E1 Effluent	Marcia Regina et al. (2009)	Combined activated sludge-ozonation processes	The combined activated sludge-O_3/pH 10 treatment was able to remove around 80% of COD, TOC and color from Kraft E_1 effluent. For the total phenols, the efficiency removal was around 70%. The difference in the concentrations of free radical produced by activated sludge-O_3/pH 10 and activated sludge-O_3/pH 8.3 affected mainly the TOC and total phenol removal values.
A Combined Activated Sludge-Filtration-Ozonation Process for Abattoir Wastewater Treatment	Pello Alfonso-Muniozguren et al. (2018)	Combined lab scale activated sludge-filtration-ozonation system	A hydraulic retention time of 24 hours and a solid retention time of 13 days were used for the activated sludge process, followed by a filtration step (4-7 µm) and using ozone as tertiary treatment. An average reduction of 93% and 98% was achieved for Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), respectively, obtaining final values of 128 mg/L COD and 12 mg/L BOD.

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Validity of Fecal Coliforms, total Coliforms and Fecal Streptococci as indicators of viruses in chlorinated primary sewage effluent	Berg G., Dahling D. R., Brown G. A. and Berman D	Combined Chlorination Process	The Final TSS after passing through biomedia Filtration was reported as 10 mg/L. It achieved TSS removal to the tune of 95%.
Water Conservation and Reuse of Waste Water	Chatterjee K.M and Bhagwat R.C	Combined chlorine and Biological process	TSS removal from 150 mg/l to 10 mg/l by bio media filtration. The BOD and COD reduction was achieved by bio media Filtration to the tune of 96.8 % & 92.5 %.
Sewage treatment and reuse - a step towards water conservation	Shrirang Vrushali et al. (2014)	Activated sludge process, chlorination & filtration.	The BOD, COD, TSS concentration of Sewage ranges from 180 -200 mg/L, 280 -340 mg/L & 150 to 200 mg/L respectively. The treatment system achieved 96.8% BOD, 92.5% COD and 95% TSS & 99% total coliform removal respectively.
Anaerobic Fixed Film Biotreatment of Dairy Wastewater.	Javed Iqbal Qazi et al. (2011)	Anaerobic Fixed Film Biotreatment	Maximum percentage removal of COD, BOD and VSS turned out to be as 96 %, 93 % and 90 % respectively. Further they stated that dynamics of repeated batch evaluated in three cycles indicated that almost 89% reduction of volatile suspended solids (VSS) occurred after 12 days in each cycle.
Aerobic treatment of waste water generated from food industry by activated sludge process”	Wesley et al. (1957), Jungle et al. (2009).	activated sludge process	Wesley have reported 90% reduction in BOD in case of sewage. Jungle reported BOD reduction of 82% and COD reduction of 72%. The pathogen removal achieved to the tune of 99%.The initial Coliform count was reported as 107 MPN/100 ml reduced to 104 MPN/100 ml. Chlorination also reported slight reduction in BOD from 18 to 8 mg/L and COD from 65 mg/L to 35 mg/L.

After throughout evaluation of related literature, it can be revealed that most of treatment technologies are need to be combined withconventional treatment technologies. Certain experiments are done with treatment of activated carbon, packed bed filter, Chlorine Coagulation, Biofilms techniques. The review empowers researchers to choose available technologies will not only improve thetreatment efficiency but new treatment techniques can be used to design an economical and efficient wastewater treatment plant especially for sewage waste water.

Artificial Sewage Composition: Vegetable extract (200 mg/l) and meat extract (110 mg/l) serves as the basis of the artificial sewage as it incorporates the protein, Carbohydrate, and fat content. The rest of the components includes sodium chloride (7 mg/l), ammonium/ calcium chloride (4 mg/l), Glucose/cellulose powder (100 mg/l), banana starch (200 mg/l), urea (30 mg/l) and small amount of domestic sewage (4-5 L) (www.researchgate.net / www.nature.com/NatureISSN 1476-4687).

Development of Bio Filter Media:

It Consist of three layer of Gravel, sand and charcoal respectively. We have added each layer of 25 cm size in random manner with gravel size of (100 mm-200 mm), Sand size of (10 mm-20 mm) and Charcoal of Unequal size. Also we have maintained void space 30 cm-50 cm from the top and 15 cm -20 cm from bottom.

Normal Water with flow rate of 20 l/h has been passed over media till effluent water same as inlet water will be coming out. Now the media is ready to prepare Bio Film which will act as bio Filter with continuously addition of raw sewage. After Continuously addition of raw sewage for 10-15 days with flow rate of 10 l/h, bio film will develop over media of layer and media then will be ready to treat sewage water. (https://en.wikipedia.org/wiki/Biofilter).

Design of sewage treatment unit:

The compact design of the process is especially attractive where space is limited. It is particularly suitable for treating low pollution loadings (SS < 200 mg/L and soluble chemical oxygen demand (COD) < 400 mg/L). Energy consumption is low and having attached biomass in an immersed fixed bed. The bed features a single support media (bio filter) of a specific grain size. The filter looks like a conventional sand filter, but because of the introduction of oxygen is also a biological reactor. The process is designed to favor important biomass activity and solids retention during the filtration cycle.

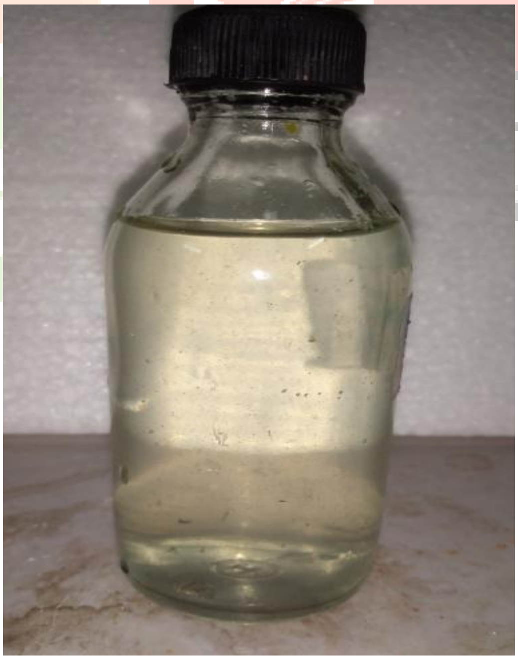
A typical unit installation incorporates a minimum of four-five sections. Raw water enters the first tank and falls over screen thereafter process wasmixed with chlorine. Introducing chorine in the primary treatment has given better results. Oxygen requirement was done by introducing air from the atmosphere. This satisfies the oxygen requirements of the fixed biomass population and maintains biological activity and growth. A Bio filtration effect by bio filter media has created and it retains the suspended solids introduced by the feed water as well as those generated by the biomass biological degradation and removes small particulate matter, bacteria and some chemicals. Biological filtration thus combines both biological degradation and mechanical filtration. Treated water was collected at the bottom of the second tank. After 72 to 96 hours of operation treated water properties have checked.

Why do we need to measure Inlet Flow rate?

As Different Flow rate has different impact on effluent quality and on the process. As the flow is high its measurement as well as effect on the media becomes difficult to handle but its fast and accurate process as compared to process in which flow is low and its slow process. So by doing experiments with different flow rate conditions we will come to a conclusion of need of measuring inlet flow rate.

1st Experimental Run with Artificial Sewage: The first run with artificial sewage has been done and the results are satisfactory. Below the results are shown

Artificial Sewage



Primary Filtration

Chlorination

Treated Sewage

Sample Observations:

Initial inlet flow rate: 40 liter/hour

COD value of raw sewage: 450 mg/liter

PH value of raw sewage: 7.8

TSS value of raw sewage: 400 mg/l

Experimental Result:

Sr. No.	Pollutants	Unit	Raw sewage	After Primary Filtration	Chlorination	Treated sewage	Percentage Removal
1	pH	pH	Sample 1 : 7.9 Sample 2 : 7.8	Sample 1 : 7.9 Sample 2 : 7.8	Sample 1 : 7.5 Sample 2 : 7.5	Sample 1 : 7.3 Sample 2 : 7.3	-
3	COD	mg/l	Sample1 : 440 Sample2 : 460	Sample 1 : 280 Sample 2 : 300	Sample 1 : 120 Sample 2 : 140	Sample 1 : 30 Sample 2 : 30	94-95
4	TSS	mg/l	Sample1 : 400 Sample2 : 390	Sample 1 : 210 Sample 2 : 210	Sample 1 : 130 Sample 2 : 130	Sample 1 : 30 Sample 2 : 20	95-97

Experimental result shows that set up has achieved COD reduction of 94-95 % and TSS removal of 95-97% of removal. Its result in the form of table as well as in the form of picture as shown above which shows how there is effluent quality has been changed after each stage. Treated effluent has met all the required parameter value to be used for secondary purpose. Also there analysis has been done and shown in the form of graph in stage wise reduction.

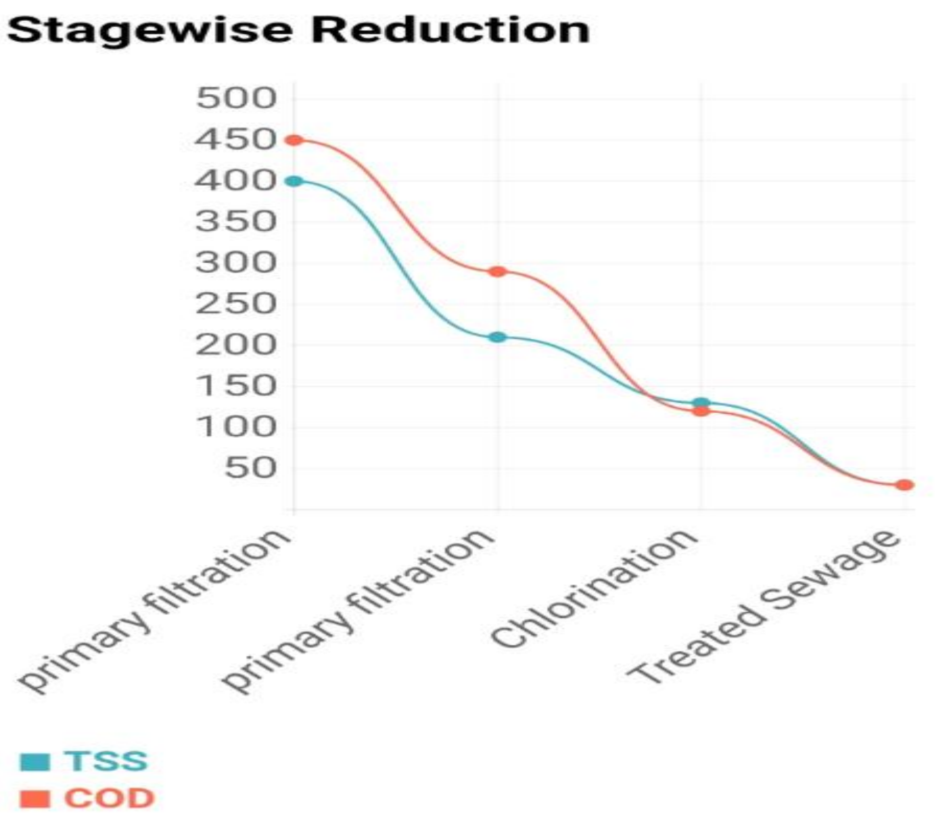
After first Experimental work done results show that after each of the operation pH, COD, TSS of the sewage decreases as below in the table:

Table: Stage wise reduction in COD

Operation	Decrease in percentage parameter
Primary filtration	35 - 37
Chlorination	72-74
Bio filter media	94 -95

A Stage wise reduction by operation such as Primary Filtration, Chlorination and BIO Filtration were estimated. It has shown below in graph

Graph: Showing Stage wise Reduction in COD, TSS Concentration by various Operation



The result shows that after primary filtration TSS, COD, pH of Artificial Raw sewage decreases up to 30 % then chlorination up to 70% and remaining is done by biological oxidation process. Without tertiary treatment the process is giving an extraordinary result which cannot be achieved with simple primary and biological methods.

Process runs with different flow condition:

Now Second run with different flow rate and loading condition has done. Its observation as well as comparison between the two is as given below.

Sample Observations:

Initial inlet flow rate: 5 liter/hour

COD value of raw sewage: 335 mg/l

pH value of raw sewage: 7.8

TSS value of raw sewage: 335 mg/l

Experimental Result:

Sr. No.	Pollutants	Unit	Raw sewage	After Primary Filtration	Chlorination	Treated sewage	Percentage Removal
1	pH	pH	Sample 1 : 7.9 Sample 2 : 7.8	Sample 1 : 7.9 Sample 2 : 7.8	Sample 1 : 7.5 Sample 2 : 7.5	Sample 1 : 7.3 Sample 2 : 7.3	-
3	COD	mg/l	Sample1 : 350 Sample2 : 320	Sample 1 : 240 Sample 2 : 250	Sample 1 : 120 Sample 2 : 130	Sample 1 : 30 Sample 2 : 30	93-95
4	TSS	mg/l	Sample1 : 333 Sample2 : 335	Sample 1 : 150 Sample 2 : 155	Sample 1 : 65 Sample 2 : 65	Sample 1 : 20 Sample 2 : 20	95-97

Experimental result shows that set up has achieved somewhat same result as appear in the first run. Here also treated effluent has met all the required parameter value to be use for secondary purpose. Now both of its comparison and effects has done and shown below.

Comparison of Runs:

Sr. No.	Parameter	Unit	First Run	Second Run
1	Initial Flow rate	Liter/hour	40	5
2	COD of Inlet	mg/l	450	335
3	TSS of Inlet	mg/l	400	335
4	Loading	-	High Compared to second process	Low compared to first process
5	Percentage removal of COD	-		
6	a) Primary Filtration	%	35-37	26-28
7	b) Chlorination	%	72-74	64-66
8	c) Treated Effluent	%	93-94	93-94
9	Overall percentage removal	%	93-95	93-95

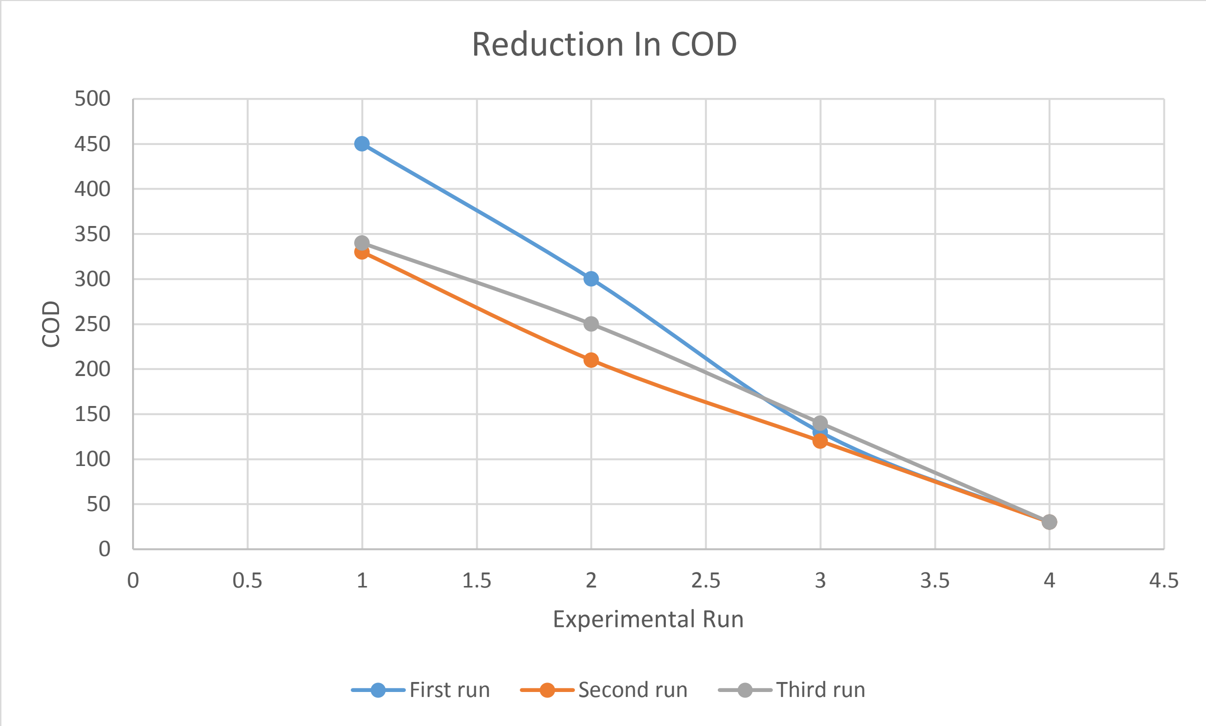


Figure: Reduction in COD of three runs

According to the theory, both the concentration and mass flow will be affected by the magnitude of the flow. As the inlet flow increases, the concentration of pollutants in the effluent will decrease or remain the same depending on pollutant or loading.

For first Run - loading as well as inlet flow rate was high while for second Run - loading as well as inlet flow rate was low as compared to the first. Comparison shows that percentage removal of COD after each stage was high in first Run as compared to second Run. It can also be seen that process is adjustable as for high loading with high flow rate and low loading with low flow rate. Even high loading with high flow rate was giving maximum percentage removal of COD than second it has been seen that condition like overflow, measurement of effluent was better handle in second run as compared to first. Comparison between runs shows that overall percentage removal for both the run is same.

Discussion:

The sewage has been treated by Chlorobioprocess and the results have been very encouraging. In 96 Hours, TSS and COD reduction achieved were 97% & 95% respectively. The Final TSS has been reported as 25 mg/L and COD as 30 mg/L.

Berg et al. (1978) reported in primary sewage effluent by combined chlorine in their paper "Validity of fecal coliforms, total coliforms, and fecal streptococci as indicators of viruses in chlorinated primary sewage effluents. The treated sewage still was little turbid and was having a yellowish tinge. Hence, the treated sewage was finally passed through Media Filter. The Final TSS after passing through Media Filtration was reported as 10 mg/L. It achieved TSS removal to the tune of 95%. The final parameters achieved after treatment shows that treated sewage can be reused for cooling tower water make up, gardening, toilet flushing, road washing, green belt /landscape development etc.

Table: Comparison with another Process (1)

Sr. No.	Parameter	Unit	There Run	Our Run
1	Method Used	-	Combined Chlorine and biological process	Chloro-bio process
2	TSS of Inlet	mg/l	150	350
3	TSS of Outlet	mg/l	10	25
4	Reduction in TSS and COD	%	98	95

Chatterjeeet al. (2003) - A Case Study has reported TSS removal from 150 mg/l to 10 mg/l by Media filtration. Along with TSS removal, COD and BOD removal was also reported .The BOD and COD reduction was achieved by Media Filtration to the tune of 96.8 % & 92.5 %. This was mainly due to removal of TSS concentration which was otherwise contributing to total COD.

Table: Comparison with another Process (2)

Sr. No.	Parameter	Unit	There Run	Our Run
1	Method Used	-	Combined Chlorine and biological process	Chloro-bio process
2	TSS of Inlet	mg/l	150	350
3	TSS of Outlet	mg/l	10	25
4	Reduction in TSS and COD	%	94	95

Both the comparison has shown that process has achieved almost same result as they got in their study and overall reduction of COD and TSS up to 94-95 % with treated effluent has met all the requirements to be used for the secondary purpose. The Process is also economical and effective which has completed the objective and aim of the process.

Conclusion:

In this study the application of chlorine in the primary treatment with the biological process has been studied and determined the characteristic of sewage. The result of this study indicates that biological process with chlorine effect in primary effluent gave satisfactory results. Initially the COD, TSS and pH values of sewage water were ranging from 300-450 mg/l, 300-400 and 7.8-7.9 respectively, after treatment the results were encouraging. The system had achieved about 90-95 % efficiency, and gave value as 20-30 mg/l, 20-30 and 7.8 of COD, TSS and pH respectively. Thus, we conclude that biofilm treatment with chlorine effect is the efficient way to treat sewage water.

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Abbreviations:

BOD – Biological oxygen demand

COD – Chemical oxygen demand

TSS – Total suspended solid

TDS – Total dissolved solid

GAC – Granular activated carbon

BF – Bio filter

VSS – Volatile suspended solid

SS – suspended solid

PVC – Polyvinyl chloride

pH – Hydrogen potential