

# “ASSESSMENT OF DETENTION TIME EFFECTS ON STP TREATMENT EFFICIENCY AND POLLUTANT REMOVAL”

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**Abstract:** As the urban population and urbanization and industrialization are growing at a very high rate the municipal wastewater generation is causing a high pressure on the existing sewage treatment infrastructure. Effective wastewater treatment is critical to safeguard people's health, maintain aquatic ecosystems and sustain water resource management. Hydraulic detention time (HDT) is one of the key operational parameters to consider in determining the amount of physical, chemical and biological pollutants that can be removed from a sewage treatment plant (STP). The contact time between wastewater and microorganisms in treatment units is determined by the hydraulic detention time which affects degradation efficiency, sedimentation

characteristics, nutrient removal and the stability of the plant. The present research is experimental study of the effects of hydraulic detention time of the sewage treatment plant on treatment efficiency and pollutant removal under different operating conditions. The study will emphasize the removal characteristics of the most important wastewater quality parameters, namely Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Nitrogen (TN), ammonia, and phosphorus at different detention times. The research is conducted on the field and in the lab employing standard research methods and procedures. Under varying detention times, wastewater samples are taken from the effluent and influent portions of the

treatment system at regular intervals to assess treatment efficiency and stability. The experimental observations are used to analyze the relationship between detention time and pollutant removal efficiency. Comparative analysis is carried out to determine the optimum detention time range that will give the best performance of the treatment plant without any change in the operational requirements. The study also assesses the pollutant removal as well as operational parameters like sludge settling behaviour, aeration efficiency and effluent quality uniformity under varying hydraulic conditions. The study also looks at the impact of under- or over-detention time on treatment reliability and process efficiency.

**Keywords:** Hydraulic detention time; Sewage treatment plant; Wastewater treatment; Pollutant removal efficiency; Treatment performance and Sustainable wastewater treatment etc.

## **I. INTRODUCTION**

Sewage Treatment Plant is the plant system that is used for the collection, treatment and removal of contaminants from domestic, municipal and industrial wastewater before its release to the environment or reuse for beneficial

purposes. The main purpose of an STP is to lower the concentration of the physical, chemical and biological pollutants found in sewage, to a level that allows the effluent to be discharged into the environment without causing damage to public health or aquatic ecosystems. Because of rapid urbanization, industrial growth, and population growth, the volume of wastewater has also expanded considerably, and effective sewage treatment is crucial for sustainable environmental management and conservation of water resources. Household, commercial, institutional and industrial operations produce wastewater that may contain organic matter, suspended solids, nutrients, pathogens, oils/greases and toxic materials. These pollutants may enter surface and ground water systems, lead to eutrophication, deplete water oxygen levels, and contribute to water borne diseases when discharged untreated. Sewage treatment facilities are designed to reduce the amount of pollution released and to help improve water quality, as a result of a series of physical, biological and chemical treatment processes.

A typical treatment system at an STP includes preliminary treatment, primary treatment, secondary treatment and

tertiary or advanced treatment. Preliminary treatment includes screening and grit removal to catch large, floating, or suspended debris like plastics, rags, sand, and grit in screens and grit chambers. This stage is used to safeguard downstream equipment from damage and operational blockage. Primary treatment primarily involves sedimentation in which heavier suspended solids are deposited at the bottom of sedimentation tanks as sludge and lighter particles float on the surface and are removed. The secondary treatment is regarded as the most significant phase of sewage treatment as it involves the removal of dissolved and biodegradable organic contaminants by biological processes. In this stage, the organic matter in wastewater is broken down by microorganisms under conditions of oxygen or no oxygen. The secondary treatment technologies are commonly Activated Sludge Process (ASP), Moving Bed Biofilm Reactor (MBBR), Sequential Batch Reactor (SBR), Membrane Bioreactor (MBR) and Trickling Filters. Pollutants like biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) are appreciably reduced during the process. Secondary treatment also helps to reduce

the nutrient load and stabilize the quality of wastewater.

When higher quality effluent is needed for other reuse or discharge purposes, a tertiary (advanced) treatment is required. This step can involve filtration, nitrogen and phosphorous removal, removal of trace contaminants, disinfection, adsorption using activated carbon, or membrane filtration to remove the remaining impurities, pathogens, nitrogen, phosphorus, and trace contaminants. The processed water can subsequently be safely released into the environment or recycled for irrigation, industrial use, landscaping and replenishment of groundwater. Some parameters of the operation of a sewage treatment plant that affect its efficiency are hydraulic detention time, flow rate, aeration, temperature, sludge age, microbial activity and organic loading. Hydraulic detention time is one of these factors and is important because it affects the amount of time spent in contact with wastewater before treatment processes. A longer detention time can enhance sedimentation, degradation by microorganisms and the removal of nutrients, while inadequate detention time might cause incomplete treatment and low effluent quality.

### **Hydraulic Detention Time**

The Hydraulic Detention Time (HDT) or Hydraulic Retention Time (HRT) is the average time water is held in the treatment process of a treatment unit or Sewage Treatment Plant. It is a critical operational parameter in wastewater engineering since it affects the efficiency of the physical, biological and chemical treatment processes. The time that the wastewater comes into contact with the microorganisms, treatment media, oxygen, and other mechanisms of pollutant removal in an oxidation pond is called the hydraulic detention time. In sewage treatment plants, wastewater passes through different treatment units such as sedimentation tanks, aeration tanks, clarifiers, wetlands, and reactors. Efficient removal of pollutants in each treatment unit can only be achieved through a minimum level of detention time. The detention time is influenced by various factors such as reactor size, wastewater flow rate, concentration of organics, treatment technology, and operating conditions. Adequate detention time is used to provide the necessary contact between pollutants and biological systems for effective degradation and stabilization of organic pollutants by microorganisms.

Hydraulic detention time is one of the most significant factors that govern the removal of pollutants including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), nitrogen, phosphorus, pathogens and other contaminants. In primary treatment, suspended particles are reduced in concentration by settling due to sedimentation, when the detention time is sufficient. Detention time is needed to allow microbial growth and biological oxidation of organic matter in biological systems like Activated Sludge Process (ASP), Sequential Batch Reactor (SBR), Moving Bed Biofilm Reactor (MBBR) and Membrane Bioreactor (MBR). The longer the detention time, the higher the degradation efficiency, as microorganisms have more time to degrade pollutants. Sometimes, however, too long a detention time is not advantageous. Increased detention time can lead to higher operating expenses, sludge generation, energy consumption and maintenance needs of the plant. Hydraulic efficiency may also be decreased and anaerobic conditions may occur in some treatment units if very high detention time occurs, causing odors and process instability. However, if detention time is too short, the non-completed

treatment results from the wastewater moving too rapidly through the system, thereby allowing fewer microorganisms and treatment media to contact the wastewater. This leads to bad effluent quality, low removal efficiency of pollutants and increased environmental pollution.

The impact of hydraulic detention time is dependent on treatment process and wastewater properties. The longer time spent in sedimentation tanks, the better the settling will be and the less suspended solids will be present. Detention Time influences oxygen transfer efficiency, microbial activity, sludge age and biodegradation rate in aeration tanks. In a constructed wetland or in a biofilm system, the longer the detention time, the better the adsorption, filtration, nutrient uptake, microbial decomposition processes. Thus, detention time optimisation is key to ensuring stable treatment performance and efficient wastewater management. Hydraulic detention times in sewage treatment plants are influenced by a number of factors. These include influent flow changes, peak loading conditions, infiltration of rainfall, tank size, sludge build-up, operational control and hydraulic short-circuiting. Under hydraulic overload

(excessive inflow) conditions, detention time can drop dramatically during periods of high rainfall, causing treatment effectiveness to deteriorate. Similarly, imbalanced flow distribution in treatment units, and dead zones, may lead to diminished effective detention time.

There is also a strong correlation between hydraulic detention time and treatment efficiency and operational stability. A properly maintained detention time will result in better microbial activity, nutrient removal, sludge settling and effluent quality. It also can alleviate the effects of shock loading and ensure process reliability in different operating conditions. Thus, it is crucial to monitor and control detention time continuously to enhance the overall performance of the sewage treatment plant. With increasing generation of wastewater, the limit of environmental regulations, and sustainable use of water, optimization of hydraulic detention time has gained importance in modern wastewater treatment systems. The effective management of detention time not only results in better pollutant removal but can also reduce energy, operating costs and environmental impact. Therefore hydraulic detention time becomes one of the

important parameters for the design, operation and performance evaluation of sewage treatment plants.

## **II. OBJECTIVES**

- To learn about the working of a sewage treatment plant and the significance of hydraulic detention time to wastewater treatment processes.
- To test the treatment efficiency of sewage treatment plant with change in hydraulic detention time.
- To study the efficiencies of major pollutants, like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), nitrogen, ammonia and phosphorus under various detention times.
- To study the effect of detention time on the performance of biological treatment such as microbial activity, effectiveness of aeration and settling behavior of sludge.
- To investigate the problem issues of inadequate detention time, including hydraulic overloading, sludge carryover and deterioration of effluent quality.

## **III. METHODOLOGY**

The approach taken for the current research work is the experimental evaluation of the effects of hydraulic detention time (HDT) on the efficiency of a sewage treatment plant (STP) and pollutant removal efficiency. The study uses field investigation, wastewater sampling, laboratory testing and comparative study of wastewater characteristics, both in and out of the system, under various operational conditions. The method aims to assess the performance of the major pollution removals and the overall plant efficiency as a consequence of the change of the hydraulic detention time. The major part of the research activity is related to the collection of wastewater samples at some treatment units of the sewage treatment plant and the standard laboratory analysis of the important physical, chemical, and biological parameters. The investigation focuses on real-world and experimental observations, rather than on numerical modelling or simulation. The effect of operational conditions including different flow rates and different detention times of the wastewater are studied to understand their influence on pollutant removal efficiency. The methodology is comprising selection of appropriate sewage treatment plant, identification of sampling points, calculation of hydraulic detention time, sampling and

preservation of wastewater samples, laboratory measurement of wastewater quality parameters and interpretation of the treatment performance. Wastewater samples are taken from the influent and effluent portions of the treatment system regularly to assess the changes in treatment efficiency. Pollutant removal characteristics such as the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, dissolved oxygen (DO), nitrogen, ammonia, and phosphorus are measured. Field observations of sludge settling behavior, aeration conditions, hydraulic loading, odor generation, and other operational aspects that can impact sewage treatment performance are also included in the study. Comparative analysis is done to compare the quality of both the influent and the treated effluent quality at different detention times to determine the optimum operation condition for reaching optimum treatment efficiency.

### **Experimental Details**

The laboratory testing program was carried out to determine the impact of the sewage treatment plant's operational performance and treatment efficiency when using the concept of Hydraulic Detention Time (HDT). The studies were conducted in

the experimental stage, where influent and effluent wastewater samples were analyzed from various treatment units under various hydraulic loading rates. The study was conducted to understand the quality of raw sewage and treated sewage effluent and to know the removal efficiency of major pollutants like BOD, COD, TSS. The investigation was also to find the best operating point of the STP so as to achieve efficient removal of pollutants and stable treatment performance. The treated effluent quality was also matched with CPCB issuing standards for discharge in the environment to ensure that environmental norms are met. Results obtained from the experiment were also analyzed to understand the effect of hydraulic loading on overall treatment efficiency of the sewage treatment plant and the performance under various hydraulic detention conditions. All tests were conducted in accordance with the Indian Standard (IS) codes, APHA standard methods and the guideline of CPCB.

### **Sampling Points at STP**

Wastewater samples will be collected from the major treatment units of the Delawas Sewage Treatment Plant for the present research work, to assess the effect of the Hydraulic Detention Time (HDT) on the

efficiency of wastewater treatment and pollutant removal. The sampling points are chosen as per recommendations of Indian Standards and CPHEEO Manual on Sewerage and Sewage Treatment Systems to

monitor performance of sewage treatment plants. The selected sampling points represent different stages of treatment and help in evaluating the variation in wastewater quality throughout the treatment process.



**Figure 1: Sample Collection**

#### **IV. RESULT AND DISCUSSION**

The experimental results from the study of sampling wastewater from various treatment units of Delawas Sewage Treatment Plant (STP) under different Hydraulic Detention Time (HDT) conditions are presented in this chapter. The influent and effluent appearance were tested for the STP treatment efficiency and pollutant removal performance. The standard laboratory procedures were used to test for important

parameters including pH, BOD, COD, TSS, DO, nitrogen, and phosphorus.

The performance of sewage treatment under different hydraulic flow rates (peak flow, normal flow and low flow) was compared to understand the effects of hydraulic detention time on sewage treatment performance. The experimental results showed that biological activity and sludge settling efficiency is significantly influenced by detention time, as are pollutant removals.

Efficiencies in treatment were better with higher detention times and better effluent quality, while lower detention times during peak flow conditions led to a decrease in treatment performance as a result of the hydraulic overloading of the treatment facility.

At the sewage plant during the field trip a number of significant observations were made at the influent section. The incoming wastewater was dark grey in colour, suggesting that there was a high level of organic and suspended pollutants. A strong sewage odour was noted as a result of the decomposition of organic waste and low dissolved oxygen in the raw sewage. The wastewater also had a high suspended solids concentration resulting in high turbidity and sludge production. Large hydraulic fluctuations were also noted during peak flow hours, particularly during morning and evening hours, leading to varying influent loadings and variations in hydraulic detention time in treatment units.

Continuous aeration and mixing during the treatment process was observed during the field investigation for the aeration tank in order to ensure adequate dissolved oxygen for microbial activity. Aeration basin water was a brownish mixed

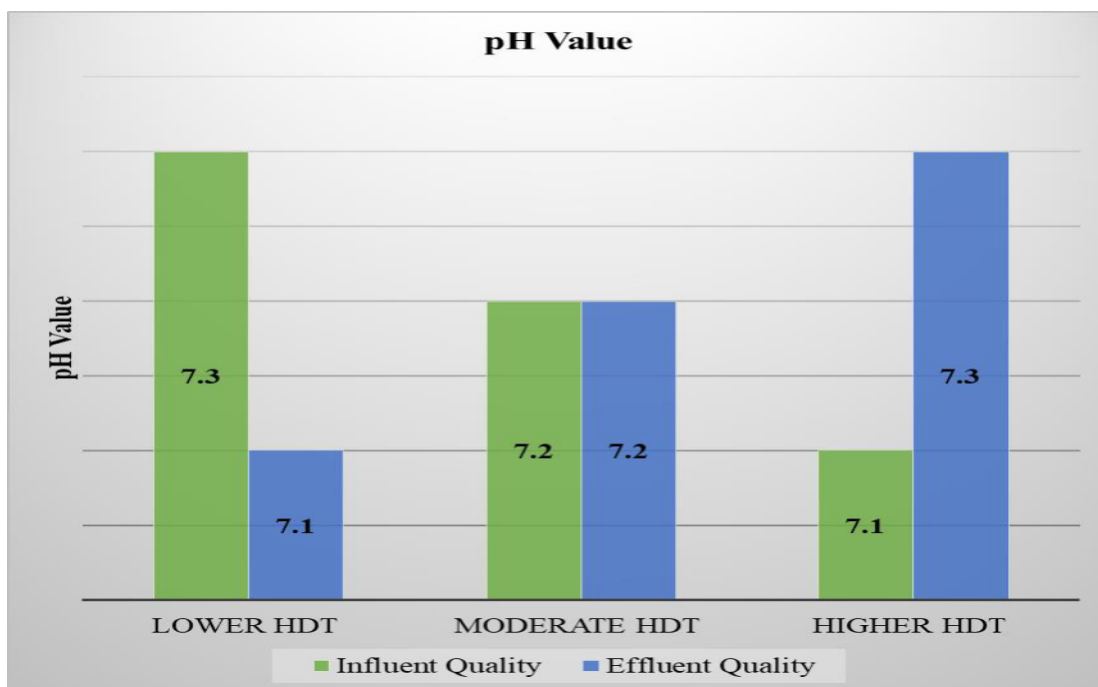
liquor with suspended biological solids and active biomass. Small amounts of foam rising in the aeration tank also were noticed, primarily caused by turbulence of aeration and biological reactions during treatment. The presence of active microbial flocs was clearly visible which showed effective biological degradation of the organic pollutants and proper function of activated sludge process in the treatment unit.

During the field investigation at the secondary clarifier, good sludge settling was observed at the bottom of the clarifier, suggesting the separation of biological solids from treated wastewater was adequate. Overflow of clear water was observed at the outlet section of the clarifier, indicating good clarifier performance during normal operation. The sludge recirculation system was in operation to recirculate activated sludge back to the aeration tank to provide activated sludge concentration and efficient treatment. But during high flow conditions, some sludge carryover was seen because of high hydraulic loading and low residence time in the clarifier unit.

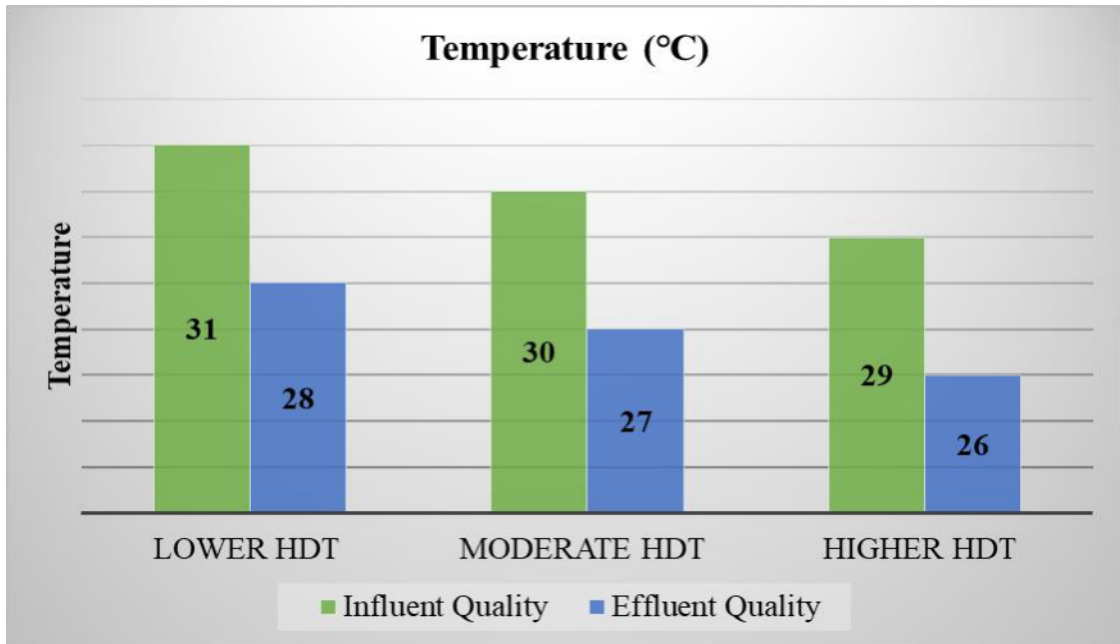
At the final effluent point during the field investigation, the treated effluent was clear and improvement in visual quality was noticed compared to the sewage which was

supplied to the treatment plant as the influent. The treatment process was successful in significantly reducing the levels of odor, thus demonstrating the effectiveness of organic pollutants removal and wastewater stabilization. Efficient sedimentation and biological treatment processes in the plant

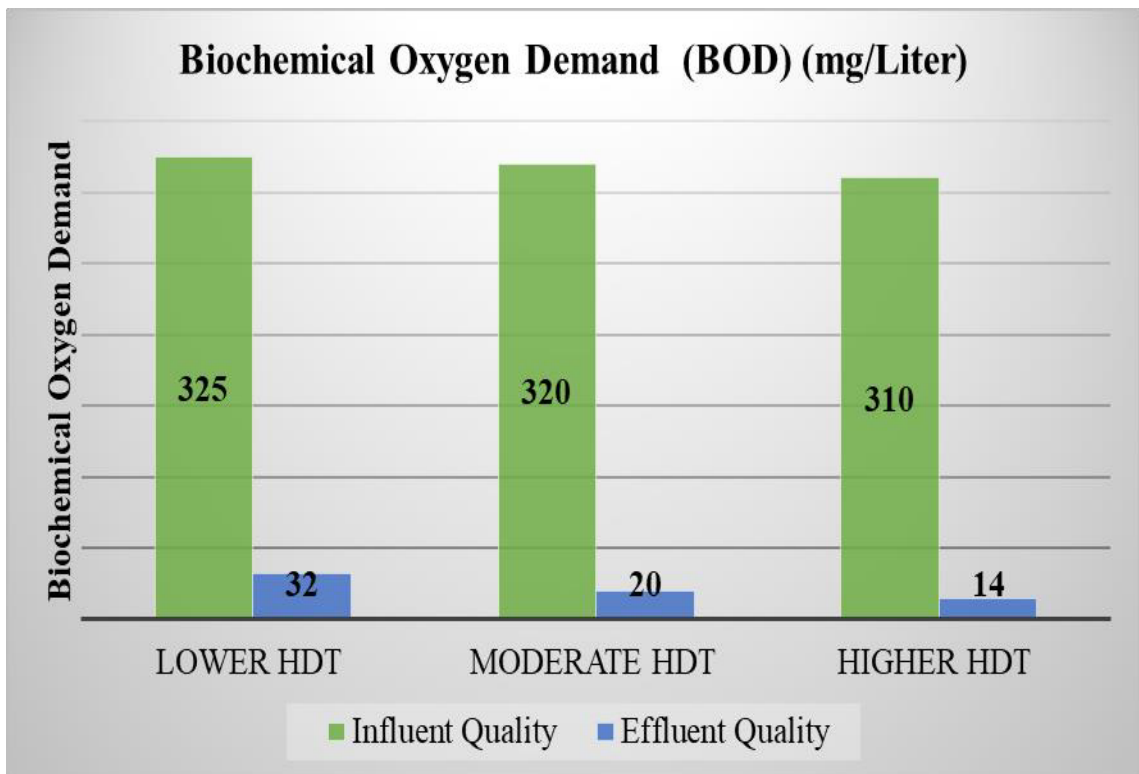
units greatly reduced the concentration of suspended solids. The quality of the effluent observed was suitable for reuse in irrigation as well as other non-potable applications following the wastewater reuse practices and discharge standards.



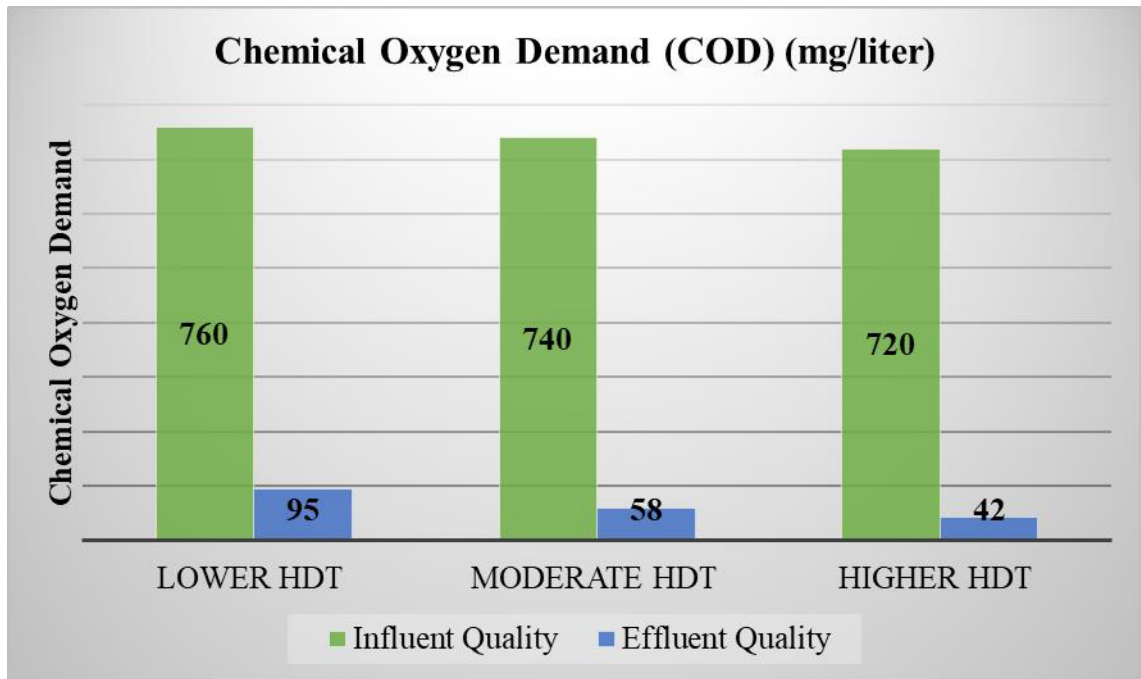
**Figure 2: pH Comparison of Influent and Effluent Quality**



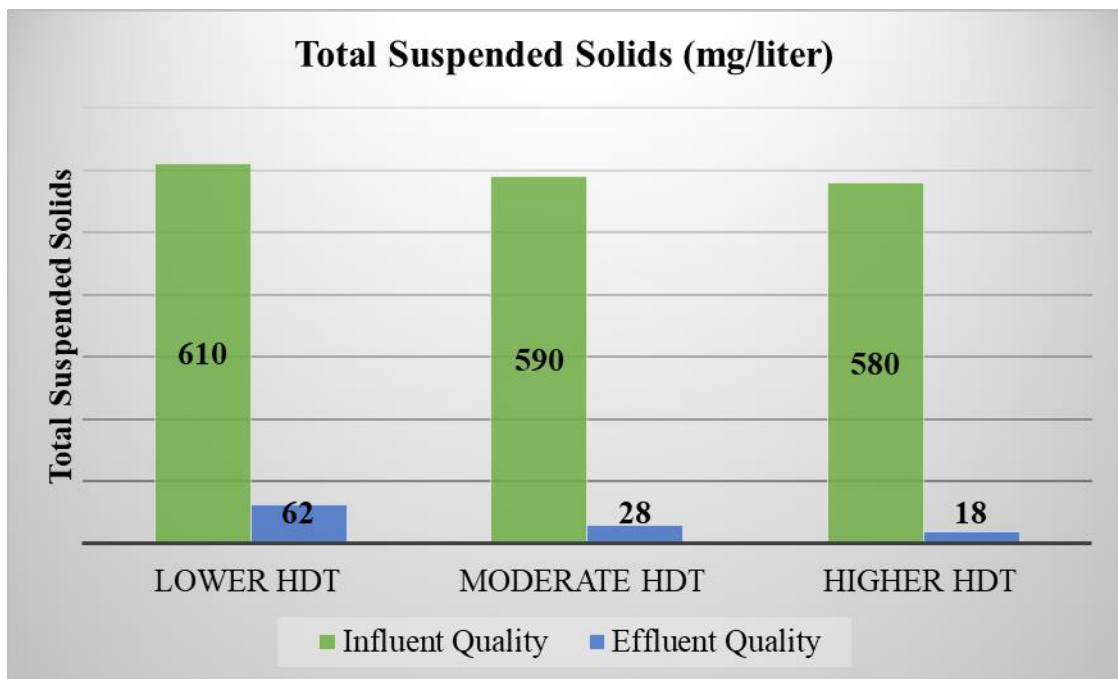
**Figure 3** Temperature Comparison of Influent and Effluent Quality



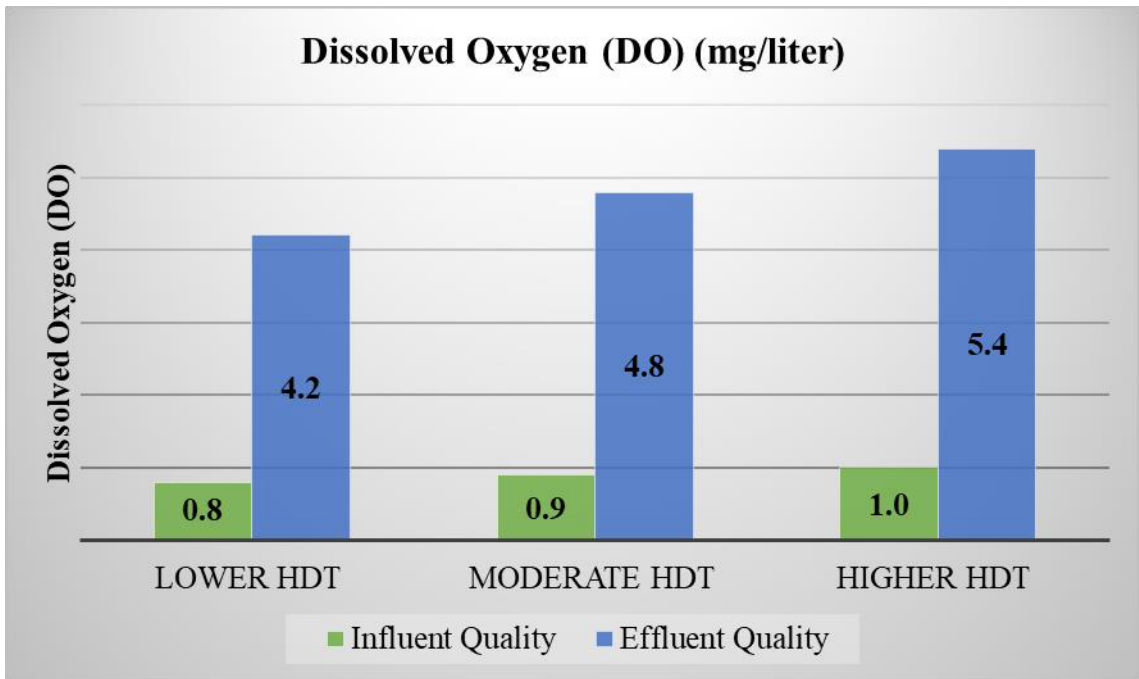
**Figure 4: Biochemical Oxygen Demand Comparison of Influent and Effluent Quality**



**Figure 5: Chemical Oxygen Demand Comparison of Influent and Effluent Quality**



**Figure 6: Total Suspended Solids Comparison of Influent and Effluent Quality**



**Figure 7: Dissolved Oxygen (DO) Comparison of Influent and Effluent Quality**

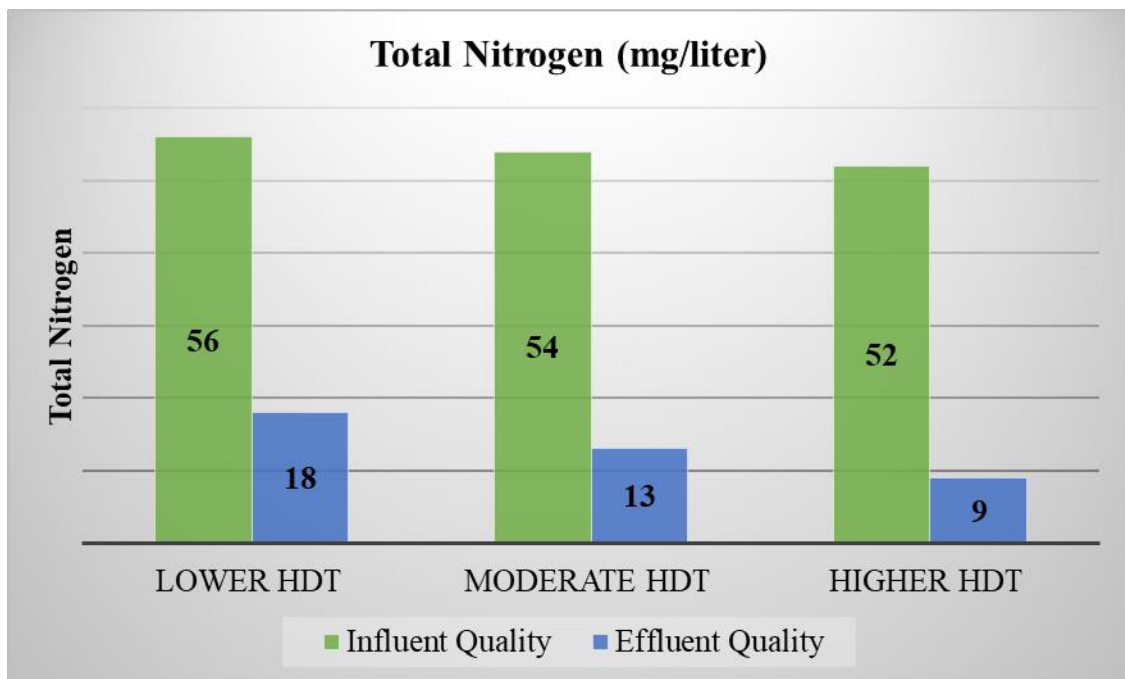


Figure 8: Total Nitrogen Comparison of Influent and Effluent Quality

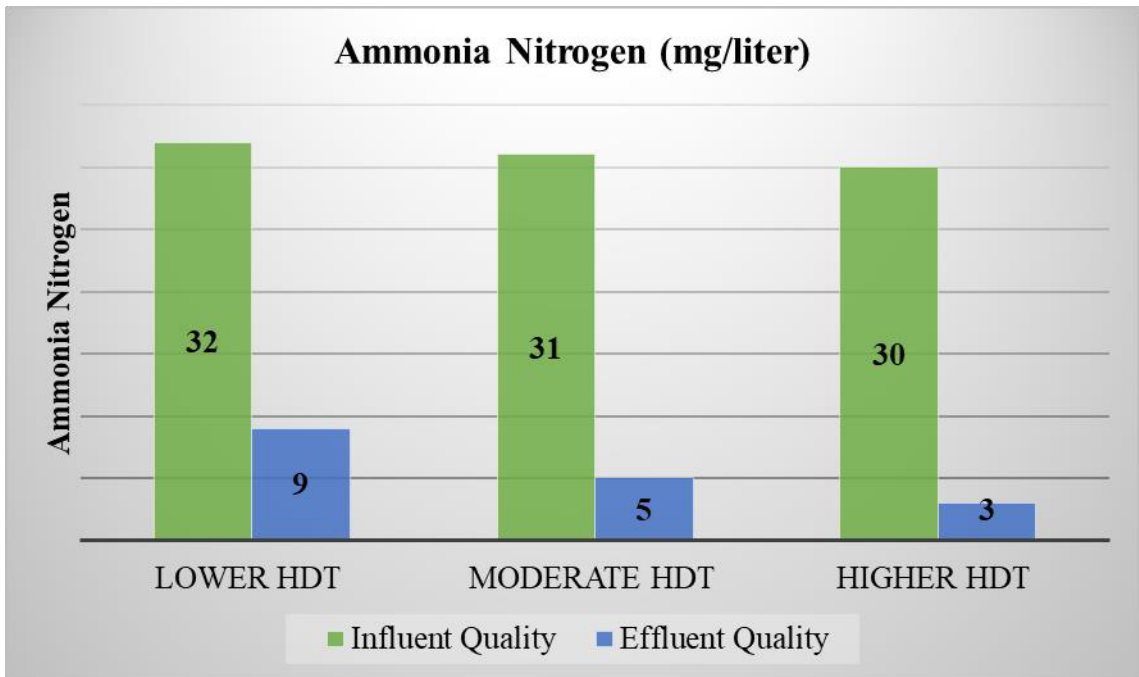


Figure 9: Ammonia Nitrogen Comparison of Influent and Effluent Quality

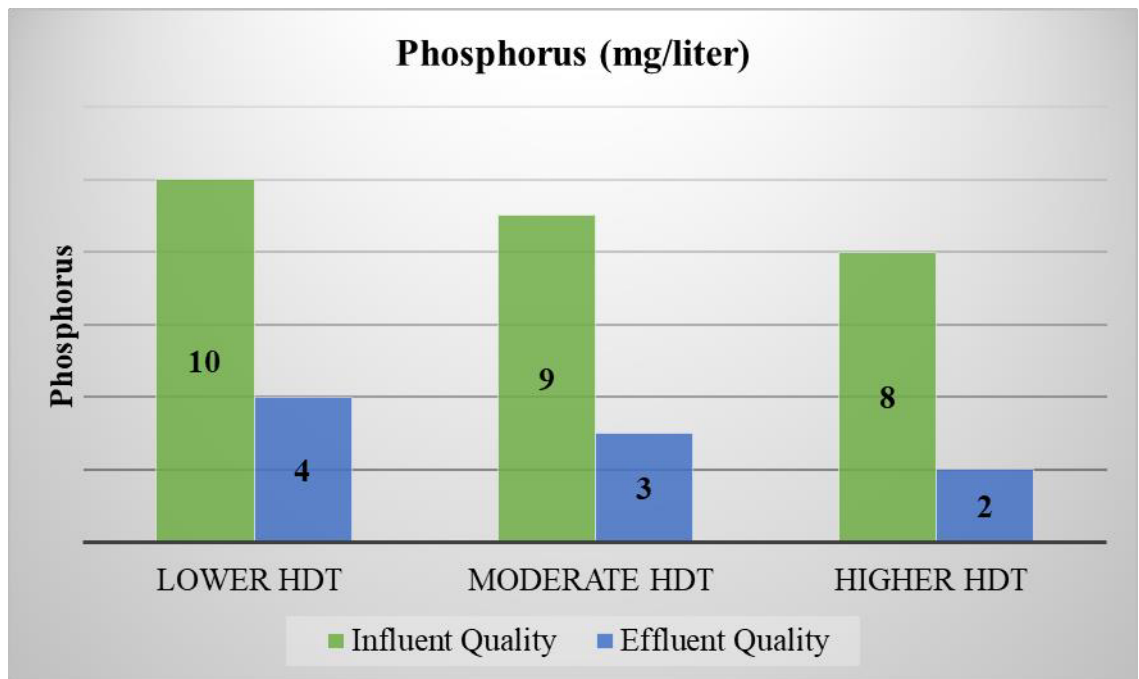


Figure 10: Phosphorus Comparison of Influent and Effluent Quality

## V. CONCLUSION

The present experimental study aimed to evaluate the treatment efficiency and pollutant removal characteristic of the sewage treatment plant under various hydraulic loading conditions by varying the Hydraulic Detention Time (HDT). Wastewater samples from influent and effluent were tested for various parameters such as pH, temp, BOD, COD, TSS, DO, Total Nitrogen, Ammonia Nitrogen, Phosphorus. The experimental results showed that the overall performance of the sewage treatment plant was greatly affected by the Hydraulic Detention Time. At lower HDT levels at the peak flow, treatment efficiency lowered because of hydraulic overload and insufficient contact time of microorganisms and wastewater. Though significant reduction in the pollutants was obtained, the effluent BOD (32mg/L) and TSS (62mg/L) were found to be more than the desirable limits as prescribed by CPCB. Removal efficiency of BOD, COD and TSS obtained under lower HDT were 90.15%, 87.50% and 89.83% respectively. Efficiencies for nutrient removal were also somewhat lower in this state.

When the HDT was moderate, stable biological treatment and efficient sludge settling was observed. The removal

efficiencies for BOD, COD and TSS in the treatment plant were satisfactory (93.75%, 92.16% and 95.25% respectively). The effluent quality met the effluent standards prescribed by the CPCB, suggesting that the detention time was adequate to favor good sewage treatment when operating under moderate conditions. Higher treatment efficiencies were found during low flows when higher HDT conditions were applied. With a higher detention time, the efficiency of biological oxidation, sludge settling and clarification were enhanced. The removal efficiency of BOD, COD and TSS was maximum at 95.48%, 94.16% and 96.89% respectively. Likewise, the nutrient removal efficiency had remarkably improved, with ammonia nitrogen and phosphorus removal efficiencies being 90.00% and 75.00% respectively. Under higher HDT conditions, the quality of the treated effluent was found to be well within the permissible CPCB limits.

The study found that the sewage treatment performance can be enhanced by increasing the Hydraulic Detention Time (HDT), which allows for a better treatment of the sewage due to increased microbial activity, degradation of organic matter, removal of nutrients and more efficient

settling of the sludge. Lower detention time, however, has a negative impact on treatment efficiency because of hydraulic overloading and because treatment time is too short. Thus, it is important to ensure the optimum hydraulic detention time in order to have a stable plant operation, better pollutant removal efficiency, and meet the environmental discharge requirements. In general, the research has confirmed that the relation between the operational parameter (Hydraulic Detention Time) and the efficiency and reliability of the sewage treatment plant is significant. Management of detention time can be used to greatly improve effluent quality and treatment efficiencies under the various hydraulic loading conditions.

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