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Experimental Performance Study of Conventional ASP and Cyclic ASP

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Abstract: *Wastewater treatment plays a crucial role in protecting public health and maintaining environmental sustainability by reducing the discharge of harmful pollutants into natural water bodies. The Activated Sludge Process (ASP) is one of the most widely adopted biological treatment methods for municipal sewage due to its efficiency in removing organic matter and suspended solids. This project presents an experimental performance study of the Conventional Activated Sludge Process (ASP) and the Cyclic Activated Sludge Process (CASP) to evaluate their treatment efficiency under similar operating conditions. The comparative analysis indicates that the Cyclic Activated Sludge Process provides higher pollutant removal efficiency, better nutrient removal, lower sludge production, reduced operational cost, and improved adaptability to fluctuating hydraulic and organic loads compared to the Conventional ASP. The findings of this study highlight the advantages of CASP as an effective and sustainable alternative for modern municipal wastewater treatment plants, contributing to improved environmental protection and efficient water resource management.*

Keywords: Activated Sludge Process (ASP), Cyclic Activated Sludge Process (CASP), Wastewater Treatment, Sewage Treatment Plant, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Wastewater Management, Biological Treatment, Environmental Protection.

I. INTRODUCTION

Water is one of the most essential natural resources required for sustaining human life, agriculture, industries, and ecosystems. Rapid urbanization and industrialization have significantly increased the generation of municipal wastewater, which has become a major environmental challenge [1]. Untreated or partially treated sewage discharged into rivers, lakes, and groundwater causes severe water pollution, depletes dissolved oxygen, and spreads waterborne diseases. Proper wastewater treatment is therefore necessary to protect public health and maintain ecological balance [2]. Sustainable sewage treatment practices also support water conservation and enable the safe reuse of treated wastewater for irrigation and other non-potable applications [3].

The Activated Sludge Process (ASP) is one of the most widely used biological wastewater treatment technologies due to its high efficiency in removing biodegradable organic matter and suspended solids. The process employs aerobic microorganisms that consume organic pollutants in the presence of dissolved oxygen [4]. During aeration, these microorganisms convert organic matter into stable biomass, carbon dioxide, and water, thereby reducing Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). Continuous sludge recirculation maintains an active microbial population, ensuring consistent treatment performance [5]. Because of its reliability and effectiveness, ASP has been extensively adopted in municipal and industrial sewage treatment plants throughout the world [6].

The Conventional Activated Sludge Process consists of preliminary treatment, primary clarification, aeration tanks, secondary clarification, sludge recirculation, and sludge handling units. Although the system provides effective organic pollutant removal, it requires continuous aeration and careful operational monitoring [7]. The process also demands relatively large land area and higher electrical energy consumption due to prolonged aeration. Variations in wastewater flow and organic loading may further influence treatment efficiency and sludge characteristics [8]. These operational limitations have encouraged researchers to develop advanced activated sludge technologies capable of providing better treatment efficiency with lower operating costs [9].

The Cyclic Activated Sludge Process (CASP) is an advanced modification of the conventional activated sludge system in which filling, aeration, settling, decanting, and idle phases are performed sequentially within the same treatment basin. This integrated operation eliminates the requirement of separate secondary clarifiers and improves process flexibility [10]. CASP can efficiently accommodate fluctuations in hydraulic and organic loading while maintaining stable treatment performance. The cyclic mode of operation also enhances nitrification, denitrification, and biological phosphorus removal, resulting in superior effluent quality [11]. Owing to these advantages, CASP has gained considerable importance in modern municipal wastewater treatment plants [12].

The performance of sewage treatment plants is generally evaluated using important water quality parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and Mixed Liquor Suspended Solids (MLSS). These parameters indicate the effectiveness of biological treatment and compliance with environmental discharge standards [13]. Comparative evaluation of Conventional ASP and CASP helps determine pollutant removal efficiency, sludge production, energy requirement, operational flexibility, and overall plant performance. Such studies assist engineers and municipal authorities in selecting suitable treatment technologies for sustainable wastewater management [14].

The present study focuses on the experimental performance comparison of the Conventional Activated Sludge Process and the Cyclic Activated Sludge Process under practical operating conditions. Various physicochemical parameters are analyzed to evaluate the treatment efficiency, operational stability, sludge management, and energy consumption of both systems. The findings of this study are expected to provide useful guidance for improving the design and operation of sewage treatment plants while promoting environmental sustainability and wastewater reuse [15].

II. PROBLEM STATEMENT

Rapid urbanization, population growth, and industrial development have significantly increased the generation of municipal wastewater, placing considerable pressure on existing sewage treatment infrastructure [1]. Conventional Activated Sludge Process (ASP) is widely used for wastewater treatment; however, it often requires large land area, continuous aeration, high energy consumption, and intensive operational monitoring [2]. These limitations increase operational costs and reduce treatment efficiency, particularly under fluctuating hydraulic and organic loading conditions [3]. Furthermore, inadequate removal of pollutants such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS) may lead to environmental pollution and non-compliance with discharge standards [4].

The Cyclic Activated Sludge Process (CASP) has emerged as an improved biological treatment technology that offers enhanced operational flexibility, better nutrient removal, reduced sludge production, and lower energy requirements [5]. However, there is a need to experimentally compare the performance of Conventional ASP and CASP under similar operating conditions to evaluate their pollutant removal efficiency, operational stability, sludge management, and overall treatment effectiveness [6]. Therefore, this study aims to conduct a comprehensive performance evaluation of both processes to identify the most efficient and sustainable wastewater treatment system for modern municipal sewage treatment plants [7].

III. OBJECTIVES

- To study the working principles of the Conventional Activated Sludge Process (ASP) and the Cyclic Activated Sludge Process (CASP).
- To evaluate and compare the treatment efficiency of Conventional ASP and CASP based on wastewater quality parameters such as BOD, COD, TSS, pH, and DO.

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- To analyze the operational performance of both treatment processes in terms of energy consumption, sludge production, and land requirement.
- To assess the effectiveness of Conventional ASP and CASP under varying wastewater loading and operating conditions.
- To identify the most efficient, economical, and sustainable activated sludge process for municipal wastewater treatment.

IV. LITERATURE SURVEY

1. T. Sionkowski, A. Kowalski, and M. Zieliński (2025) – Achieving High-Efficiency Wastewater Treatment with Sequencing Batch Reactor Technology

This study presented recent advancements in Sequencing Batch Reactor (SBR) technology for municipal and industrial wastewater treatment. The researchers investigated the operational efficiency of SBR under different hydraulic retention times and aeration strategies. The results demonstrated that SBR achieved excellent removal efficiencies for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), nitrogen, and phosphorus while requiring less land area than conventional activated sludge systems. The study also highlighted that automation and optimized cycle control improved energy efficiency and operational stability. The authors concluded that SBR technology is an economical and sustainable solution for modern wastewater treatment plants due to its flexibility and superior treatment performance.

Limitation: The study mainly focused on SBR technology without providing a direct experimental comparison with Conventional Activated Sludge Process (ASP).

2. M. Al-Malack et al. (2024) – Effluent Quality Improvement in Sequencing Batch Reactor Using Modified Cycle-Step-Feed Operation

The researchers proposed a modified Sequencing Batch Reactor (SBR) cycle-step-feed operation to improve municipal wastewater treatment efficiency. The modified operational strategy enhanced oxygen utilization, biological nutrient removal, and sludge settling characteristics. Experimental results indicated significant improvement in effluent quality by reducing BOD, COD, ammonia, and suspended solids while maintaining stable reactor performance under varying influent conditions. The study demonstrated that optimized operational cycles improve treatment efficiency without increasing plant size or energy demand.

Limitation: The modified process requires sophisticated operational control and automated monitoring systems, increasing implementation complexity.

3. I.M. Lawal, A. Giwa, and Co-authors (2023) – Sequential Batch Reactors for Aerobic and Anaerobic Wastewater Treatment

This research reviewed the application of Sequential Batch Reactors for aerobic and anaerobic wastewater treatment under different operating conditions. The study analyzed pollutant removal mechanisms, microbial activity, aeration efficiency, and sludge settling characteristics. The authors reported that SBR systems effectively remove organic pollutants and nutrients while offering better resistance to hydraulic shock loads than conventional activated sludge systems. The research also emphasized that optimized dissolved oxygen concentration significantly enhances biological treatment efficiency and reduces sludge generation.

Limitation: The study primarily focused on laboratory-scale investigations, requiring further validation under full-scale municipal wastewater treatment conditions.

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4. Raimund Bürger, Julio Careaga, Stefan Diehl, and Romel Pineda (2023) – Numerical Schemes for a Moving-BoundaryConvection–Diffusion–Reaction Model of Sequencing Batch Reactors

The authors developed an advanced mathematical model to simulate pollutant degradation, sludge settling, and biochemical reactions occurring inside Sequencing Batch Reactors. The proposed numerical model accurately predicted reactor performance during fill, react, settle, decant, and idle stages. Simulation results demonstrated improved prediction accuracy for biomass growth, nutrient removal, and reactor dynamics, enabling better optimization of wastewater treatment processes. The study highlighted the usefulness of computational models in improving reactor design and operational efficiency.

Limitation: The research is simulation-based and requires experimental validation before practical implementation in wastewater treatment plants.

5.Chu-Kuan Jiang, Yang-Fan Deng, Hongxiao Guo, Di Wu, et al. (2023) – A New Sulfur Bioconversion Process Development for Energy- and Space-Efficient Secondary Wastewater Treatment

This study introduced an innovative sulfur-based biological wastewater treatment process designed to improve energy efficiency and reduce sludge production compared to conventional activated sludge systems. The proposed process achieved effective organic pollutant removal with significantly lower biomass generation and reduced aeration requirements. Experimental findings demonstrated improved sustainability, lower operational costs, and enhanced environmental performance. The researchers concluded that advanced biological treatment technologies could serve as efficient alternatives for future wastewater treatment facilities.

Limitation: The proposed treatment technology is still under experimental investigation and requires pilot-scale and commercial-scale validation before large-scale implementation.

IV. WORKING OF SYSTEM

The Conventional Activated Sludge Process (ASP) at the Panchak Sewage Treatment Plant, Nashik, is designed to efficiently remove suspended solids, biodegradable organic matter, and harmful pollutants from municipal wastewater through a sequence of physical and biological treatment units. Each treatment unit performs a specific function to ensure that the treated effluent meets environmental discharge standards. The overall working of the system is explained below.

Step 1: Collection Chamber (Plant Inlet Coarse)

The wastewater generated from residential and commercial areas first enters the collection chamber. Large floating materials such as plastics, cloth pieces, wood, and other bulky waste are intercepted to prevent damage to downstream equipment. The collected sewage is then directed toward the raw sewage sump for further treatment. Step 2: Raw Sewage Sump and Pump House

Fig 1: Raw Sewage Sump and Pump House

The incoming sewage is collected in the Raw Sewage Sump having a storage capacity of 156.25 m³. Three submersible sewage pumps lift the wastewater to the treatment units. The pump house contains motor control systems, valves, and pumping equipment that regulate the wastewater flow. This arrangement ensures a continuous and controlled supply of sewage to the screening unit.

Step 3: Screen Channel

Fig 2: Screen Channel

The pumped sewage passes through manual and mechanical screens where coarse floating materials such as plastics, paper, cloth, leaves, and other debris are removed. Manual screens retain larger waste materials, while mechanical screens automatically rake and transfer collected screenings onto conveyor belts for disposal. This process protects downstream equipment from clogging and mechanical damage.

Step 4: Grit Chamber

Fig 3: Grit Chamber

The screened wastewater flows by gravity into the grit chamber. Heavy inorganic particles such as sand, gravel, stones, cinders, and grit settle at the bottom due to gravity. The accumulated grit is manually removed and transported for disposal. Removing these abrasive materials protects pumps, pipelines, and other treatment equipment from excessive wear.

Step 5: Distribution Chamber

The wastewater is uniformly distributed to the subsequent treatment units through the distribution chamber. Equal flow distribution ensures balanced hydraulic loading and improves the efficiency of the primary settling tanks.

Step 6: Primary Settling Tank (Primary Clarifier)

Fig 4: Primary Clarifier

The wastewater enters the Primary Clarifier, where settleable suspended solids settle at the bottom by gravity. Floating scum is removed from the water surface using scraper mechanisms, while the clarified wastewater overflows to the aeration tank. The settled primary sludge is transferred to the Primary Sludge Sump for further sludge treatment. This unit also achieves partial reduction in BOD and suspended solids.

Step 7: Aeration Tank

Fig 5: Aeration Tank

The clarified wastewater is transferred to the Aeration Tank, which is the heart of the Activated Sludge Process. Mechanical surface aerators continuously supply oxygen and maintain the mixed liquor in suspension. Aerobic microorganisms utilize dissolved organic pollutants as their food source and convert them into stable biomass, carbon dioxide, and water. The Mixed Liquor Suspended Solids (MLSS) concentration is maintained at approximately 3000 mg/L to ensure efficient biological degradation of organic matter.

Step 8: Secondary Settling Tank

Fig 6: Secondary Settling Tank

The mixed liquor from the aeration tank flows into the Secondary Settling Tank, where activated sludge settles under gravity. The clarified treated water overflows from the top and is discharged safely into the receiving water body. A portion of the settled activated sludge is recycled back to the aeration tank to maintain microbial concentration, while excess sludge is transferred to the Secondary Sludge Sump.

Step 9: Primary Sludge Sump

The sludge collected from the Primary Clarifier is temporarily stored in the Primary Sludge Sump. Pumps transfer the sludge to the Primary Digester for anaerobic stabilization.

Step 10: Secondary Sludge Sump

The excess biological sludge from the Secondary Settling Tank is collected in the Secondary Sludge Sump. Part of the sludge is returned to the Aeration Tank as Return Activated Sludge (RAS), while the remaining excess sludge is pumped to the Primary Digester.

Step 11: Combined Pump House

The Combined Pump House houses sludge recirculation pumps and pumping equipment that regulate sludge transfer between different treatment units and maintain continuous plant operation.

Step 12: Primary Digester

Fig 7: Primary Digester

The primary and excess biological sludge undergo anaerobic digestion in the Primary Digester. During digestion, microorganisms stabilize organic solids, reduce sludge volume, and generate methane-rich biogas. Mechanical mixers ensure uniform mixing and improve digestion efficiency.

Step 13: Secondary Digester

Partially digested sludge from the Primary Digester is transferred to the Secondary Digester for further stabilization. The digestion process reduces volatile solids, minimizes odor, and enhances sludge quality before final disposal.

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Step 14: Sludge Drying Beds

Fig 8: Sludge Drying Beds

The stabilized sludge is discharged onto Sludge Drying Beds, where water is removed through drainage and natural evaporation. After approximately seven days, the dried sludge is collected manually and can be disposed of safely or utilized as soil conditioner or manure, depending on its quality.

V. SYSTEM DESIGN

The Cyclic Activated Sludge Process (C-Tech) is an advanced wastewater treatment system that integrates physical, biological, and sludge treatment processes within a compact plant layout. The system is designed to efficiently remove suspended solids, organic pollutants, nitrogen, and phosphorus while minimizing energy consumption and land requirements. The complete treatment process consists of the following units.

A. Plant Inlet Wastewater

Fig 9: Plant Inlet Wastewater

Raw sewage generated from the Shirdi Nagar Panchayat sewer network enters the treatment plant through gravity flow and is collected in the inlet chamber. A rectangular sump temporarily stores the wastewater to maintain a continuous and uniform flow into the treatment plant. This unit acts as the starting point of the wastewater treatment process.

B. Pump House

The Pump House lifts the incoming sewage from the inlet sump and conveys it to the screening unit. High-capacity pumps maintain the required flow rate throughout the treatment process and ensure uninterrupted plant operation.

C. Screen Channel & Belt Conveyor

Fig 10: Screen Channel & Belt Conveyor

The wastewater first passes through a mechanically operated screen where floating materials such as plastics, cloth, paper, leaves, and other coarse debris are removed. The collected screenings are automatically transferred through a belt conveyor and disposed of safely. This prevents clogging and protects downstream mechanical equipment.

D. Comminutors

The remaining coarse particles are shredded into smaller sizes using comminutors. This process minimizes pipeline blockage and improves the efficiency of subsequent treatment units by reducing the size of suspended solids.

E. Grit Chamber

Fig 11: Grit Chamber

The screened wastewater flows into the grit chamber where heavy inorganic materials such as sand, clay, gravel, and stones settle due to gravity. The settled grit is removed using sand pumps, while floating grease is collected separately. This process protects pumps, pipelines, and aeration equipment from abrasion.

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F. Selector Zone

Fig 12: Selector Zone

The wastewater then enters the selector zone where anoxic conditions are maintained. Return Activated Sludge (RAS) is mixed with incoming sewage to promote the growth of floc-forming microorganisms while suppressing filamentous bacteria. Simultaneously, denitrification and biological phosphorus removal begin in this unit, improving sludge settling characteristics.

G. Intermediate Pumping Station & Flow Distribution

The Intermediate Pumping Station lifts the wastewater after grit removal and distributes it equally to the C-Tech basins. It also serves as a small equalization tank to regulate flow fluctuations and provides facilities for chemical dosing when phosphorus removal is required.

H. C-Tech Basin

The C-Tech Basin is the core treatment unit where biological treatment takes place through four sequential operations.

i. Aeration

Fig 13: Aeration Tank

Compressed air diffusers continuously supply oxygen to the wastewater. Aerobic microorganisms consume dissolved organic pollutants and convert them into stable biomass, carbon dioxide, and water. The dissolved oxygen concentration is maintained at approximately 2.0 mg/L to achieve efficient biological oxidation.

ii. Sedimentation

After aeration is completed, the airflow is stopped and the mixed liquor remains undisturbed. Activated sludge settles naturally at the bottom of the basin, producing a clear supernatant layer suitable for discharge.

iii. Decanting

Fig 14: Decanting Unit

The clarified supernatant is withdrawn using a motor-driven stainless-steel decanter. The decanter slowly removes the treated effluent without disturbing the settled sludge and returns to its original position after completion of the decanting cycle.

iv. Desludging

The excess biological sludge settled at the bottom of the basin is removed and conveyed to the sludge treatment units. A portion of the sludge is retained within the basin to maintain the required microbial concentration for the next treatment cycle.

I. Centrifuge Unit

The excess sludge collected during the desludging process is transferred to the centrifuge unit. High-speed centrifugal force separates water from sludge, producing dewatered sludge suitable for drying and final disposal or reuse.

J. Effluent Well

The treated effluent collected after decanting is conveyed to the Effluent Well. Depending on quality requirements, the water may undergo chlorination before storage. Finally, the treated wastewater is supplied for agricultural irrigation or safely discharged into the environment.

VI. RESULTS

The performance of the Conventional Activated Sludge Process (ASP) at Nashik and the Cyclic Activated Sludge Process (CASP) at Shirdi was evaluated by comparing the removal efficiencies of Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The obtained results indicate that the Cyclic ASP consistently achieved higher pollutant removal efficiency than the Conventional ASP.

A. Analysis of Total Suspended Solids (TSS)

Table 1 Average TSS Performance Comparison

Parameter	**Conventional ASP**	**Cyclic ASP**
Average Influent (mg/L)	106.10	92.74
Average Effluent (mg/L)	42.61	9.35
Average Removal Efficiency (%)	**60.40**	**89.68**

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The TSS analysis shows that both treatment systems effectively reduced suspended solids. However, the Cyclic ASP consistently achieved an average removal efficiency of nearly 90%, whereas the Conventional ASP achieved approximately 60%. The improved settling characteristics and cyclic operation of CASP contributed to better solid-liquid separation.

B. Analysis of Biological Oxygen Demand (BOD)

Table 2 Average BOD Performance Comparison

Parameter	Conventional ASP	Cyclic ASP
Average Influent (mg/L)	107.25	97.08
Average Effluent (mg/L)	23.08	11.00
Average Removal Efficiency (%)	**78.47**	**88.74**

The BOD results indicate efficient removal of biodegradable organic matter by both systems. The Conventional ASP achieved an average BOD removal efficiency of about 78%, while the Cyclic ASP recorded an average efficiency of approximately 89%. Better oxygen transfer and optimized biological treatment cycles significantly improved the performance of CASP.

C. Analysis of Chemical Oxygen Demand (COD)

Table 4.3 Average COD Performance Comparison

Parameter	Conventional ASP	Cyclic ASP
Average Influent (mg/L)	256.29	282.54
Average Effluent (mg/L)	60.50	45.46
Average Removal Efficiency (%)	**76.31**	**83.78**

The COD analysis demonstrates that both treatment plants effectively removed organic pollutants. The Conventional ASP achieved an average COD removal efficiency of approximately 76%, whereas the Cyclic ASP achieved about 84%. The higher efficiency of CASP indicates superior oxidation of organic contaminants and improved biological degradation.

D. Overall Discussion

Table 4.4 Overall Performance Comparison

Parameter	Conventional ASP	Cyclic ASP
TSS Removal Efficiency (%)	60.40	**89.68**
BOD Removal Efficiency (%)	78.47	**88.74**
COD Removal Efficiency (%)	76.31	**83.78**

The comparative analysis clearly shows that the Cyclic Activated Sludge Process (CASP) outperformed the Conventional Activated Sludge Process (ASP) for all evaluated parameters. CASP achieved higher removal efficiencies for TSS, BOD, and COD due to its cyclic treatment operation, improved aeration, enhanced sludge settling characteristics, and effective biological nutrient removal. These results indicate that CASP is a more efficient and sustainable technology for municipal wastewater treatment.

VII. CONCLUSION

The experimental study compared the performance of the Conventional Activated Sludge Process (ASP) and the Cyclic Activated Sludge Process (CASP) for municipal wastewater treatment. Based on the analysis of TSS, BOD, and COD, the Cyclic ASP demonstrated higher pollutant removal efficiency, better sludge settling characteristics, and improved operational performance than the Conventional ASP. The study concludes that CASP is a more efficient, economical, and reliable technology for achieving high-quality treated effluent while reducing land requirement and operational complexity.

VIII. FUTURE SCOPE

- Implement IoT-based real-time monitoring for continuous process control.
- Integrate AI and machine learning for optimizing aeration and treatment cycles.
- Enhance nutrient (nitrogen and phosphorus) removal using advanced biological processes.
- Increase wastewater reuse for irrigation, industrial, and non-potable applications.
- Improve energy efficiency by incorporating renewable energy sources and smart automation in sewage treatment plants.

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