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PERFORMANCE ANALYSIS OF DAIRY ETP: STUDY OF COAGULANT TREATMENTS AND SOFTWARE-BASED MODELING

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PERFORMANCE ANALYSIS OF DAIRY ETP: STUDY OF COAGULANT TREATMENTS AND SOFTWARE-BASED MODELING

This report has been submitted for partial fulfillment of the degree of Bachelor of Science in Civil and Environmental Engineering.

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The thesis titled "Performance Analysis of Dairy ETP: Study of Coagulant Treatments And Software-Based Modeling" was successfully submitted by Abdullah Al Jobair (180051250), Muid Mahmud Khan Kwoshik (180051216) and Md. Touhidul Haque Sajid (180051233) have been found satisfactory and accepted as partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering.

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ABSTRACT

This report presents a study on the performance of a dairy effluent treatment plant (ETP) with a focus on coagulant treatments and software-based modeling using BioWin software. The study evaluates the effectiveness of different coagulants in enhancing the removal of pollutants from dairy wastewater and optimizing the treatment process. The report includes laboratory-scale coagulant treatment experiments, data collection, and analysis, and the development and validation of a BioWin model for the dairy ETP.

The study found that Lime + Iron Polaroid in a ratio of 1:2 was the most effective coagulant for treating dairy effluent. By utilizing the BioWin simulation software, the following parameter values were obtained in accordance with the ECR 1997 standard: pH (6.35), TSS (24.19 mg/l), BOD5 (14.79 mg/l), and COD (145.31 mg/l). The study provides valuable insights into the operational dynamics of the ETP and suggests strategies for improving its efficiency.

Additionally, the research findings suggest that Tamarind seed is a promising natural alternative to chemical coagulants for dairy wastewater treatment. However, it is important to consider the limitations associated with the small-scale nature of laboratory tests and the accuracy of simulation software, which rely on precise input parameters and assumptions.

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CHAPTER 1
INTRODUCTION

1.1 Background of Dairy Effluent Treatment Plants (ETP):

The dairy industry, being a critical contributor to global dairy product supply, generates substantial volumes of wastewater containing high organic loads, nutrients, and contaminants. Inadequate treatment of this wastewater poses significant environmental and public health risks. Effluent Treatment Plants (ETPs) have been developed to address this issue by employing various treatment technologies to remove pollutants and ensure compliance with environmental regulations. However, the performance and efficiency of these treatment plants can vary due to factors such as coagulant treatments and overall plant design and operation (Ashita Rai et al., 2022).

Despite the abundance of freshwater resources on our planet, accessibility and quality remain significant concerns. According to the World Health Organization (WHO), approximately 785 million individuals lack access to potable water, and waterborne pathogens contribute to 485,000 deaths annually (WHO, drinking water, 2019). The availability and quality of water have profound implications for people's living conditions and standards. In India, the total utilizable water resource is estimated to be around 1123 BCM (690 BCM from surface water and 433 BCM from groundwater), representing only 28% of the water derived from precipitation. Furthermore, approximately 85% (688 BCM) of water usage is directed towards irrigation, a figure projected to rise to 1072 BCM by 2050 (Rakesh Singh Asiwal et al., 2016).

To address the challenges associated with dairy wastewater treatment, this research will utilize the BioWin software for modeling and simulating ETP performance. The study will involve laboratory-scale coagulant treatment experiments, data collection, analysis, and the development and validation of a BioWin model specific to dairy ETPs. The activated sludge model implemented in BioWin software will be validated using data from full-scale wastewater treatment plants (Oleyiblo et al., 2014).

The research findings are expected to provide valuable insights into optimizing the performance of dairy industry wastewater treatment, contributing to sustainable and efficient management practices in the dairy sector.

1.2 Importance of Performance Analysis in Dairy ETPs:

Performance analysis plays a crucial role in ensuring the effectiveness and efficiency of Dairy ETPs. By assessing and evaluating the performance of these treatment plants, several important objectives can be achieved:

Compliance with Environmental Regulations: Dairy ETPs must meet specific regulatory standards and discharge limits set by environmental authorities. Performance analysis helps determine whether the treatment plant is effectively removing contaminants and meeting the required effluent quality standards.

Environmental Protection: Effective treatment of dairy effluent is essential to protect the environment from pollution. Performance analysis helps identify any shortcomings or areas of improvement in the treatment process, enabling adjustments to be made to reduce the environmental impact of the effluent discharge.

Resource Conservation: Dairy ETPs consume significant amounts of energy, water, and chemicals. Performance analysis helps optimize the treatment process, leading to reduced resource consumption and improved overall efficiency. This contributes to cost savings and sustainability in dairy operations.

Process Optimization: Through performance analysis, the factors influencing the performance of the Dairy ETP can be identified and analyzed. This information can be used to optimize the treatment process, improve treatment efficiency, and enhance the overall operational performance of the plant.

1.3 Overview of Coagulant Treatments and Software-Based Modeling:

Coagulant treatments are an integral part of Dairy ETPs, particularly in the initial stages of wastewater treatment. Coagulants are chemicals that are added to the effluent to facilitate the aggregation of suspended solids, colloids, and other contaminants, making them easier to remove during subsequent treatment steps. Common coagulants used in dairy wastewater treatment include lime, alum, ferric chloride, and polymers.

Software-based modeling, such as the BioWin software, is a powerful tool used in the design, analysis, and simulation of wastewater treatment processes, including Dairy ETPs. BioWin is a widely used software that employs mathematical models to simulate and predict the performance of treatment processes based on input data, process parameters, and the characteristics of the wastewater. It enables engineers and researchers to assess the efficiency of treatment systems, optimize process design, and evaluate the impact of various operational and design parameters on the overall treatment performance.

By incorporating coagulant treatments and software-based modeling, the performance analysis of Dairy ETPs can be enhanced. Coagulant treatments aid in the removal of suspended solids and contaminants, while software-based modeling allows for a comprehensive evaluation of the treatment process, helping to optimize the system design and improve overall performance.

1.4 Research Objective and Scope

The primary objective of this research paper is to analyze the performance of a dairy effluent treatment plant (ETP) with a specific focus on coagulant treatments and software-based modeling using BioWin software. The research aims to investigate the effectiveness of different coagulants in enhancing the removal of pollutants from dairy wastewater and optimizing the treatment process. Additionally, the study will utilize BioWin software for modeling and simulating the ETP performance, allowing for the evaluation of various scenarios and prediction of treatment outcomes.

The scope of this research includes laboratory-scale coagulant treatment experiments, data collection and analysis, as well as the development and validation of a BioWin model for the dairy ETP. The findings of this research will provide valuable insights into the performance optimization of dairy industry wastewater treatment and contribute to sustainable and efficient management practices in the dairy industry.

CHAPTER 2
LITERATURE REVIEW

2.1 ETP Performance Analysis

2.1.1 Performance and Evaluation Study of Dairy Wastewater: A Review

There have been several studies on the removal of contaminants, the use of various treatment technologies, and the effects of various operating circumstances on the effectiveness of these technologies while treating dairy wastewater.

Utilizing biological treatment techniques is one of the keyways to handle dairy wastewater. These procedures reduce the chemical oxygen demand (COD) and total suspended solids (TSS) by using microbes to degrade the organic contaminants in the wastewater. Due to the high organic content of the waste stream, studies have revealed that the adoption of anaerobic treatment methods, such as anaerobic digestion, can be particularly efficient in treating dairy wastewater.

The study's findings by Patel et al. are expected to contribute to this field by providing new insights into the performance and evaluation of different treatment methods for dairy wastewater. One of the main methods for treating dairy waste water is through the use of biological treatment processes. These processes utilize microorganisms to break down the organic pollutants in the waste water, resulting in the reduction of chemical oxygen demand (COD) and total suspended solids (TSS). Studies have found that the use of anaerobic treatment processes, such as anaerobic digestion, can be particularly effective in treating dairy waste water, due to the high organic content of the waste stream.

In addition to biological treatment processes, physical and chemical treatments can also be used to remove pollutants from dairy waste water. For example, coagulation and flocculation are commonly used to remove suspended solids, while adsorption can be used to remove organic contaminants. The literature indicates that there is a need for continued research and development in the area of dairy wastewater treatment.

2.1.2 Performance Evaluation of Effluent Treatment Plants in the Dairy Industry: A Review

Wastewater generated in the dairy industry contains highly putrescible organic constituents, necessitating its prompt and adequate treatment before disposal to the environment. The organic constituents in dairy waste are easily biodegradable, making the wastewater amenable to biological treatment, either aerobic or anaerobic. However, the rapid growth of industries has resulted in the production and release of toxic substances into the environment, causing health hazards and disrupting the natural ecosystem.

In this study, the performance evaluation of an ETP implemented in a dairy industry was conducted. The wastewater samples were collected from various units of the treatment plant with a capacity to treat 400 m³/day of wastewater. The treatment process involved multiple steps, including equalization, neutralization, physical treatment, and biological treatment. The ETP consisted of collection tanks, a screening chamber, an oil and grease removal tank, an equalization tank, a neutralization tank, a primary clarifier, an aeration tank, and a secondary clarifier.

The results obtained during the five-month study period were analyzed and discussed. The pH of the influent wastewater ranged from 9.60 to 9.93, while after physical and biological treatment, the pH values decreased to 8.43 and 7.22, respectively, achieving a reduction of 27.25%. The TSS content in the influent wastewater varied from 1732 to 1766 mg/l, and after physical and biological treatment, the values decreased to 1200 and 98 mg/l, respectively, achieving a reduction of 94.45%. The TDS content in the influent wastewater ranged from 1837 to 1858 mg/l, and after treatment, the values decreased to 1459 and 1229 mg/l, respectively, achieving a reduction of 33%. The COD of the influent wastewater ranged from 2013 to 2049 mg/l, and after treatment, the values decreased to 1331 and 97 mg/l, achieving a reduction of 95.26%. The BOD of the influent wastewater ranged from 1362 to 1366 mg/l, and after treatment, the value decreased to 24 mg/l, achieving a reduction of 94%. The performance of the ETP was found to be satisfactory, with the removal efficiencies meeting the standards set by the GPCB for discharge into inland surface water. Based on the five-month data collected and analyzed, it can be concluded that the overall performance of the effluent treatment plant implemented in the dairy industry was satisfactory. The individual units of the ETP demonstrated efficient removal of total suspended solids (94.45%), COD (95.26%), and BOD (98.18%), indicating the plant's capability to withstand shock loads. The treated effluent met the GPCB standards for discharge into inland surface

2.2 Coagulant treatments in dairy ETPs:

2.2.1 The Effective Use of Ferrous Sulfate and Alum as Coagulants in the Treatment of Dairy Industry Wastewater: A Review

This study compares the efficiency of ferrous sulfate and alum as coagulants in the chemical treatment of raw wastewater collected from a dairy plant. The aim of the study is to evaluate the effectiveness of these coagulants in improving the selected characteristics of the wastewater.

The raw wastewater samples collected from the dairy plant exhibited high levels of organic pollutants, such as proteins and fats, as well as chemicals used for cleaning and sanitizing processing equipment. The treatment of such wastewater typically involves a combination of physical and chemical methods.

In the study, the researchers visually and physiochemically evaluated the wastewater samples before and after chemical treatment. The coagulation process using ferrous sulfate and alum resulted in significant improvement in the selected characteristics of the wastewater. However, the response to the coagulant treatment varied among the tested samples. Alum, which is based on aluminum sulfate (Al2(SO4)3), is a commonly used coagulant in wastewater treatment. It reacts with alkalinity in the water to form insoluble aluminum salts, which help in the precipitation of pollutants. Ferrous sulfate (FeSO4) is another coagulant that has been widely used in the treatment of various industrial wastewaters.

The coagulation study with alum determined the optimal dose to be 100 mg/l. The turbidity of the treated wastewater remained around 5.5 NTU (Nephelometric Turbidity Units) even at the optimal conditions. Increasing the alum concentration led to higher removal efficiencies of COD and turbidity. Similarly, the coagulation study with ferrous sulfate identified the optimal dose as 200 mg/l.

The removal efficiencies of individual parameters varied widely, ranging from 20.9% to 97.2%. The parameters analyzed included COD (chemical oxygen demand), BOD (biological oxygen demand), TDS (total dissolved solids), and pH value. The values of BOD and COD in the raw wastewater were found to be high, indicating a significant pollution potential that requires treatment before discharge into the environment.

both alum and ferrous sulfate demonstrated effective coagulation capabilities in reducing solids, organics, and nutrients in the dairy industry wastewater. However, certain parameters such as COD and BOD still exceeded the discharge limits even after coagulant treatment, indicating the need for additional corrective measures before discharge.

It is worth noting that the study refers to previous research that has reported similar findings, including the use of ferric sulfate as a coagulant in the treatment of wastewater from food industry plants. These previous studies have shown reductions in COD and BOD percentages ranging from 48.8% to 85.4% and 30.5% to 86.1%, respectively, depending on the wastewater source and the coagulant used.

2.2.2 The Effect of Tamarind Kernel Powder for Treating Dairy Industry Wastewater: A Review

Due to the high organic content of the waste stream, anaerobic treatment methods, such as anaerobic digestion, can be particularly successful in treating dairy wastewater. Biogas is created as a result of these processes, and it may be used as a renewable energy source. According to studies, anaerobic treatment can significantly enhance water quality by lowering the chemical oxygen demand (COD) and total suspended solids (TSS) in dairy wastewater.

Temperature, pH, and hydraulic retention time (HRT) are a few of the operational factors and parameters that have an impact on how well the anaerobic treatment procedure functions. Higher biogas yields and better treatment performance may result from optimizing these factors. In order to ensure efficient treatment, it is also crucial to choose the right bacteria for the anaerobic treatment procedure. The findings of the study by Demirel et al. are expected to make a valuable contribution to this field by providing a comprehensive review of the current state of knowledge on the anaerobic treatment of dairy wastewater. Further research is needed to continue to improve the treatment of dairy wastewater and to develop more sustainability.

The efficiency of tamarind kernel powder in treating wastewater generated by the dairy sector is investigated in the study by Durairaj et al. The study uses TKP, a natural coagulant made from tamarind seeds that have demonstrated promise in several water treatment applications because of its wide availability and eco-friendly structure.

The difficulties that come with effluent from the dairy sector, such as its high organic content, nutrients, and suspended particulates, are highlighted by the authors at the outset. Traditional treatment techniques can demand expensive chemicals or labor-intensive procedures, making them less suited for small-scale dairy enterprises or having limited financial resources. Investigating alternative therapy modalities like TKP becomes essential as a result.

2.3 BioWin software and its applications in ETP simulations

2.3.1 Evaluation and Improvement of Wastewater Treatment Plant Performance Using BioWin: A Review

The study focuses on optimizing an existing wastewater treatment plant (WWTP) by validating the activated sludge model implemented in the BioWin software against full-scale WWTP data. The model required calibration for two stoichiometric parameters: Yp/acetic and heterotrophic yield (YH). The calibrated value for Yp/acetic was 0.42, while the default value in BioWin is 0.49. Then they evaluated three scenarios for improving plant performance: wasting sludge from the aeration tank or the secondary clarifier, constructing a new oxidation ditch, and constructing an equalization tank.

Data collection and evaluation of historical data were performed to assess plant operations and treatment efficiency. The WWTP was intensively sampled for 5 and 7 days to characterize the influent wastewater and validate the model. The simulation was conducted using the BioWin software v.3.0, which employs the integrated activated sludge/anaerobic digestion model.

Model calibration and validation were carried out using steady-state and dynamic data. The calibration targets were set for effluent parameters such as TP, TN, COD, NO3-N, and NH3-N, with relative percent differences between model and plant data. The model's performance was assessed based on the Janus coefficient and the average relative difference between observed and simulated values.

The study demonstrated the predictive quality and stability of the model for the WWTP. The results of the dynamic simulations showed good agreement between the observed and simulated values for various parameters. The Janus coefficient and average relative difference indicated the model's ability to predict WWTP performance accurately.

Overall, the study emphasized the importance of mathematical models in WWTP design, optimization, and control. By using models like BioWin, existing facilities can be optimized in terms of capital and operational improvements, leading to cost-effective compliance with effluent regulations.

CHAPTER 3
METHODOLOGY

3.1 Description of the Sample Collection Site and Data Collection Process

Wastewater samples were collected from the ETP of a dairy industry named "New Zealand Dairy" located in Vulta, Rupganj, Narayanganj, Dhaka. The sample collection site was chosen at the influent point of the ETP, influent of Primary Clarifier, as well as at the final effluent. The site represented the initial stage of wastewater treatment and provided an opportunity to assess the effectiveness of coagulant treatments.

The samples were collected following standard protocols and transported to the laboratory for analysis in appropriate containers and labeled with relevant information such as sample location, date, and time of collection.

3.2 Coagulant Treatment Experiments

3.2.1 Selection of Coagulants

Several parameters were tested to assess the effectiveness of the coagulant treatments, which involved the use of five chemicals and a natural coagulant. The chemicals used were as follows:

1. **Cationic Polymer:** Cationic polymers are synthetic organic compounds that possess positive charges. They are commonly used as coagulants and flocculants in wastewater treatment processes. The cationic nature of these polymers helps destabilize and aggregate negatively charged particles in the wastewater, aiding in their removal.
2. **Iron Polaroid:** Iron polaroid, often in the form of ferric chloride (FeCl3), is an inorganic coagulant. It works by forming positively charged iron hydroxide precipitates that adsorb and neutralize negatively charged particles in the wastewater, facilitating their removal through sedimentation or flotation.
3. **Poly-Aluminium Chloride (PAC):** Poly-aluminium chloride is an inorganic coagulant commonly used in wastewater treatment. It functions by forming positively charged aluminum hydroxide flocs that effectively coagulate and settle suspended particles and colloidal matter in the wastewater.
4. **Ferrous Sulphate (FeSO4):** Ferrous sulphate, also known as iron(II) sulfate, is an iron-based coagulant. It undergoes hydrolysis to produce iron hydroxide flocs that aid in the coagulation and precipitation of suspended particles in the wastewater.
5. **Lime:** Lime, or calcium hydroxide (Ca(OH)2), is an alkali coagulant used in wastewater treatment processes. It raises the pH of the wastewater, promoting the precipitation of metals and phosphates and enhancing the coagulation and settling of suspended solids.

Tamarind Seed Powder (Natural Coagulant): Tamarind seed powder contains polysaccharides that exhibit coagulation properties. The natural coagulant aids in the aggregation of suspended particles and facilitates their removal from the wastewater.

3.2.2 Jar Test Experimental Setup and Procedure

The jar test is a laboratory procedure commonly used to determine the optimal dosage and conditions of coagulants for water and wastewater treatment. It involves a series of steps to simulate the coagulation, flocculation, and settling processes. The experimental setup included the following steps:

1. Six jars were selected for simultaneous testing. Each jar contained 500 ml of wastewater collected from the influent point of the ETP.
2. Various dosages of different coagulant combinations, including Cationic Polymer, Iron Polaroid, Poly-Aluminium Chloride (PAC), Ferrous Sulphate (FeSO4), Lime, and Tamarind Seed Powder (as a natural coagulant), were prepared and added to the jars according to the experimental design.
3. The jars were placed in a Flocculator (Model-Wr230-20) to facilitate the mixing of coagulants with wastewater. The mixing process was conducted in two steps: the first step involved rotating the jars at a speed of 100 rpm for 1 minute, followed by a second step of rotating the jars at a speed of 30 rpm for 10 minutes.
4. After the mixing and flocculation steps, the jars were left undisturbed for a settling period of 15 minutes. This allowed the flocs to settle down, separating them from the clarified water.
5. The transparency and quality of the treated water in each jar were observed and recorded. Different parameters were measured to evaluate the efficiency of different coagulant dosages.

3.2.3 Dosage Optimization

The following combinations and dosages of coagulants were selected based on their known effectiveness in wastewater treatment, as well as their compatibility with the specific characteristics of the wastewater being treated. The use of different coagulant combinations allows for the optimization of the coagulation process and the removal of various contaminants, such as suspended solids, organic matter, and heavy metals, from the wastewater.

Stock solutions of the coagulants were prepared to ensure accurate and consistent dosing throughout the experimental process. The stock solutions were prepared by dissolving the coagulants in a specific volume of distilled water.

- Lime (2gm) + Iron Polaroid (20ml) + Distilled water (200ml)
- Lime (2gm) + Ferrous Sulphate (2gm) + Distilled water (200ml)
- PAC (2 gm) + Cationic Polymer (2gm) + Distilled water (200ml)
- Lime (2 gm) + PAC (2gm)+Distilled water (200ml)
- Lime (1gm) + Distilled water (100ml)
- Iron Polaroid (1ml) + Distilled water (100ml)
- Cationic Polymer (1gm) + Distilled water (100ml)
- PAC (1 gm) + Distilled water (100ml)
- Ferrous Sulphate (1gm) + Distilled water (100ml)
- Lime (1gm) + Ferrous Sulphate (1gm) + PAC (1gm) + Distilled water (300ml)
- Tamarind seed powder (1gm) + Distilled water (100ml)

The dosages of the coagulants were adjusted accordingly to achieve the desired treatment objectives.

3.2.4 Parameters Tested

Several parameters were tested to assess the efficiency of the coagulant treatments. These parameters included:

pH: The acidity or basicity of an ingredient is determined by its pH. It will need a pH meter or pH paper to test the pH. While the pH meter gives a digital readout, pH paper changes color based on how basic or acidic a solution is.
In this study, a pH meter was used to measure the pH of the samples.

TDS: Total dissolved solid is referred to as TDS. It counts all of the solids that have been dissolved in a solution.To test TDS, you need a TDS meter, which measures the electrical conductivity of the solution.
The TDS of the samples was measured in this experiment using a multimeter from where TDS is counted.

TSS: Total suspended solids are referred to as TSS. It calculates the overall concentration of suspended solids in a solution. A filter that can remove the particles from the solution is required to test TSS. In this experiment, TSS is measured by using Spectrophotometer.

TS: Total solid is referred to as TS. It calculates the total quantity of dissolved and suspended solids in a solution. In order to assess TS, the TDS and TSS values must be combined.
TDS and TSS measurements were conducted in this investigation to ascertain the sample's TS.

Turbidity: Turbidity describes a liquid's cloudiness or haziness that is brought on by suspended particles. Turbidity is a crucial factor in measuring the quality of water because it sheds light on the amount of particulate matter that is present in a solution. High turbidity can degrade the appearance of water, have an influence on aquatic life, and signal possible pollution.
Formazin Nephelometric Units (FNU) or Nephelometric Turbidity Units (NTU) are often used to measure and report turbidity. Since these units are standardized, it is possible to make reliable comparisons between various measurements and places.

A turbidimeter, also known as a nephelometer, is used in this experiment to measure the quantity of light scattered by the suspended particles in the water. The fundamental idea underlying this measurement is that light flows straight through a clean solution, but scatters when it passes through a turbid solution because of the presence of particles.

Color: In order to evaluate the visual appearance and intensity of color in wastewater samples, the color test of wastewater is a crucial component of water quality analysis. This test aids in locating the presence of pollutants, other chemicals, and organic and inorganic components that affect the wastewater's color. Depending on the source and the presence of various pollutants, the color of wastewater can fluctuate dramatically.
In this experiment color test is conducted using a Spectrophotometer and the coloring unit is Pt. and Co. Also, dilution is done when the value crossed 500.

Electro Conductivity: The electrical conductivity (EC) test, commonly referred to as the electro-conductivity test, is a technique for determining how well a solution conducts electricity. It is often used in a variety of industries, including agriculture, soil science, environmental monitoring, and water quality studies.
An essential metric that tells you how much salt is in a solution and how many dissolved ions are present is electrical conductivity. It is beneficial to evaluate the water quality, soil fertility, and appropriateness of irrigation water for agricultural use.
In this experiment, an electro-conductivity meter or conductivity probe is used to measure the conductivity of a solution during the electro-conductivity test. Two electrodes are put into the solution to make up the meter, and an electrical current is then transmitted via the electrodes. The resistance that electrical current encounters while measuring conductivity is directly inversely related to the conductivity of the solution. The conductivity of the solution is reported in units of Micro Siemens per centimeter (µS/cm).

Salinity: A technique for determining the amount of dissolved salts and ions in wastewater samples is the salinity test. It offers useful details about salinity levels generally as well as the possible effects of salts on water quality, water treatment methods, and the environment.
The electrical conductivity (EC) of the wastewater sample is measured during the salinity test using an electro-conductivity meter or probe. Since dissolved salts enhance the water's conductivity, the EC measurement serves as a direct measure of salinity. The concentration of salt in the wastewater increases as the EC measurement rises. The unit is measured in percentile value.

BOD: To determine the degree of organic contamination in wastewater, the Biological Oxygen Demand (BOD) test is frequently employed. The quantity of oxygen that microorganisms need to break down organic material in the water sample is measured.
In the BOD test, a certain amount of wastewater is incubated in a sealed container for a predetermined amount of time, often five days, in a controlled laboratory environment. This enables the water's microbes to break down the organic material while also using oxygen. The residual dissolved oxygen in the sample is calculated following the incubation time.
Both the carbonaceous and nitrogenous organic components present in the wastewater are measured by the BOD test. The data are shown as the amount of oxygen used per liter of

wastewater (mg/L), which represents the quantity of oxygen necessary for the microbial breakdown of the organic matter.

COD: A common technique for estimating the concentration of organic and inorganic contaminants in wastewater is the Chemical Oxygen Demand (COD) test. It calculates how much oxygen is needed to chemically oxidize the organic content in a sample of water. The COD test offers insightful data on the total pollutant load and the level of organic matter in wastewater.
The COD test involves mixing a certain amount of wastewater with a potent oxidizer, usually potassium dichromate (K2Cr2O7), in the presence of a catalyst. In order to hasten the oxidation reaction, which breaks down the organic components and transforms them into carbon dioxide and water, the mixture is heated. The amount consumed is then calculated by titrating the residual oxidizing agent, which is decreased during the process.
The COD test quantifies the amount of organic compounds in wastewater that are both biodegradable and non-biodegradable. The results are expressed as the chemical oxygen demand of the sample in milligrams of oxygen used per liter of effluent (mg/L).

3.3 Software-Based Modeling Using BioWin

3.3.1 Existing Layout of the ETP

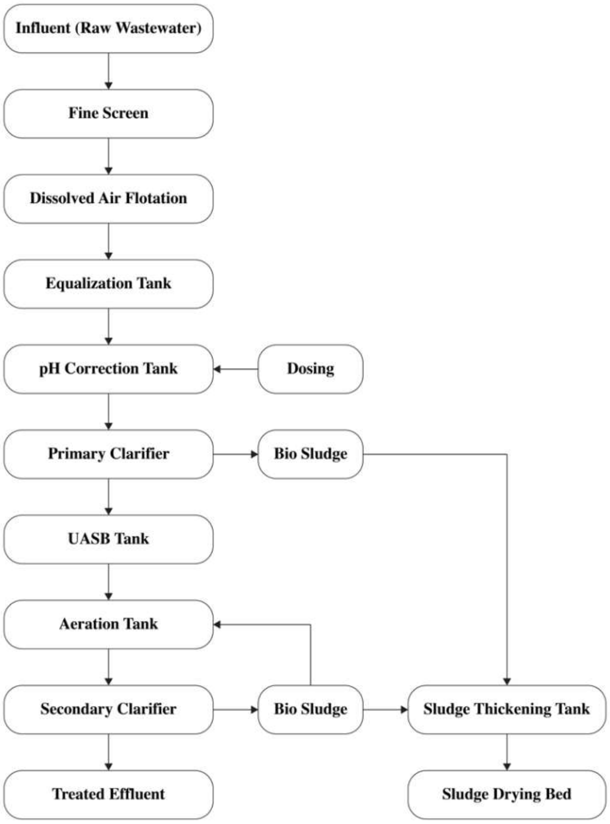

Figure 3. 1 Layout of ETP

The existing layout of the dairy effluent treatment plant (ETP) for treating dairy wastewater is depicted in Figure 1. This layout incorporates various unit processes designed to effectively treat and remove contaminants from the dairy wastewater, ensuring compliance with regulatory standards and environmental requirements.

Fine Screen: The screening unit serves as the initial unit process, where the dairy wastewater undergoes a screening process to remove larger solid objects such as debris, trash, and coarse particles. The wastewater is passed through a series of screens, which act as physical barriers, capturing and preventing these materials from entering downstream treatment units. This step helps protect the integrity of the ETP system, reducing the risk of blockages and damage to equipment.

Dissolved Air Flotation (DAF): The DAF unit is employed for the separation and removal of suspended solids, fats, oils, and greases (FOGs) from the dairy wastewater. In this process, fine bubbles of air are dissolved under pressure and then released in the flotation tank. The microbubbles attach to the suspended solids and FOGs, causing them to rise to the surface, where they form a layer that can be skimmed off. This step helps to significantly reduce the concentration of these contaminants in the wastewater.

Equalization Tank: The equalization tank, also known as a balance tank or buffer tank, plays a crucial role in the treatment of dairy wastewater. It receives and equalizes the flow of wastewater, allowing for the smooth and consistent distribution of influent to downstream treatment processes. By balancing hydraulic and organic loadings, the equalization tank ensures that the subsequent treatment units receive a stable and well-distributed wastewater flow, leading to enhanced treatment efficiency.

Primary Clarifier: The primary clarifier is designed to remove settleable solids and heavy organic particles from the dairy wastewater. It operates based on the principle of gravity sedimentation, where the wastewater is held in a tank under quiescent conditions. This allows the heavier particles to settle to the bottom, forming a layer of primary sludge, while clarified effluent is collected from the top. The primary clarifier significantly reduces the concentration of suspended solids and organic matter in the wastewater.

Upflow Anaerobic Sludge Blanket (UASB) Tank: The UASB tank is an anaerobic treatment process specifically designed for the removal of organic pollutants from dairy wastewater. It creates favorable conditions for the growth of anaerobic microorganisms that degrade organic matter. Wastewater flows upward through the tank, allowing the microorganisms to break down the organic pollutants and produce biogas, primarily methane. The UASB tank offers high treatment efficiency and biogas recovery potential.

Aeration Tank: The aeration tank, also known as the activated sludge tank or biological reactor, is a key component of the secondary treatment process for dairy wastewater. It provides an oxygen-rich environment to support the growth of aerobic microorganisms. These microorganisms utilize the dissolved organic matter and nutrients present in the wastewater as a food source, effectively degrading and removing them. The aeration tank promotes biological treatment, leading to the reduction of organic pollutants and nutrients.

Secondary Clarifier: The secondary clarifier functions to separate the biomass, known as activated sludge, from the treated wastewater. After the biological treatment in the aeration tank, the wastewater flows into the secondary clarifier. The settled activated sludge accumulates at the bottom of the clarifier, while the clarified effluent is collected from the top. The activated sludge can be recirculated back to the aeration tank to maintain the microbial population for continuous treatment.

3.3.2 Dimension Determination:

The HRT values for each unit operation were collected from the ETP along with the flow capacity of the plant. These HRT values represent the average time that wastewater spends in each unit and are crucial for evaluating treatment performance. To calculate the volume of each ETP unit, the HRT values and the plant's flow capacity were utilized. The volume (V) of each unit was determined using the formula:

$$\mathrm{HRT} = \mathrm{V}/\mathrm{Q}$$

The following are the HRT values (obtained from the plant) and Volume (calculated) for each unit operation:

Table 3. 1 HRT Values and Volume of Each Unit Operation

Flow capacity of the Plant, Q = 48 m^3/day (2 m^3/hour)		
Unit Operation	**HRT** (hours)	**Volume** (m^3)
Dissolved Air Flotation (DAF):	2.62	5.24
Equalization Tank:	7.14	14.28
Primary Clarifier	3.8	7.6
Upflow Anaerobic Sludge Blanket (UASB) Tank:	48	96
Aeration Tank:	35	70
Secondary Clarifier	6.15	12.3

Once the volume of each unit was calculated, other dimensions such as length, width, and depth were determined based on the existing layout of the ETP. These dimensions are crucial for proper design and operation of the treatment system.

3.3.3 Inputting Dimensions and Parameters into BioWin for Simulation:

BioWin by EnviroSim is a widely used simulation software specifically designed for modeling and analyzing wastewater treatment processes. It offers a comprehensive platform for evaluating and optimizing the performance of treatment systems.

The software utilizes advanced mathematical models to simulate the complex biological, chemical, and physical processes involved in wastewater treatment. By inputting the relevant design parameters and operating conditions, researchers can accurately predict effluent quality, assess system performance, and identify areas for improvement.

For simulation, the existing ETP layout was first modeled in the software to replicate the design and configuration of the actual treatment system. This step ensures an accurate representation of the ETP's unit processes and their interconnections. Then the determined dimensions of each unit and the wastewater characteristics of the influent along with the flow capacity of the plant were inputted into the software. This information serves as the basis for creating a virtual representation of the ETP.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Coagulant Treatment Analysis

4.1.1Test Results with Different Coagulants

The coagulation treatment process in this research aimed to assess the efficacy of various coagulants in treating wastewater samples. Prior to treatment, the initial characteristics of the samples were thoroughly examined through pre-treatment analysis, encompassing measurements of pH, turbidity, color, total suspended solids (TSS), total dissolved solids (TDS), salinity, electro-conductivity, chemical oxygen demand (COD), and biochemical oxygen demand (BOD). These analyses provided a baseline understanding of the wastewater samples' composition and quality.

To ensure precise dosing, stock solutions of coagulants including Lime, Iron Polaroid, Ferrous Sulphate, Poly-Aluminum Chloride (PAC), Cationic Polymer, and Tamarind seed powder were prepared. The dosages of these coagulants varied depending on the specific combinations employed for treatment. This meticulous approach aimed to accurately evaluate the impact of different coagulant dosages on the treatment process.

During the treatment process, it is noteworthy that the values of COD and BOD were specifically obtained from the clearest and most transparent samples of each combination at their respective dosages. This selection strategy ensured that the measured COD and BOD values represent the maximum achievable level of treatment effectiveness for each coagulant combination.

By establishing the initial treatment conditions and precisely documenting the dosages of the coagulants, the subsequent results obtained from this study will provide valuable insights into the effectiveness of the coagulation treatment process and its overall impact on the wastewater samples.

Table 4. 1 Testing result of ETP Output, ETP Input, Primary Influent

	Color (Pt.Co)	**TS (mg/L)**	**TDS (mg/L)**	**TSS (mg/L)**	**PH**	**Salinity (%)**	**EC (µS/cm)**	**BOD (mg/L)**	**COD (mg/L)**
ETP OUTPUT	333	939	34	905	7.45	0.91%	1803	28	66
ETP INPUT	442	580	512	68	6.07	0.06%	127.5	1298	2221
Primary Influent	93	3662	3640	22	9.29	3.73%	7220	8.7	152

Table 4. 2 Testing result of Lime + Iron Polaroid (1:1)

lime and Iron polaroid 1:1; 2mg and 20 ml and 200 ml water	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD
10 ml	458	149.76	13.76	136	5.99	1.38%	2826		
20 ml	461	2658	2538	120	5.79	2.56%	5080	99	292
30 ml	453	3776	3656	120	5.78	3.72%	7220		
40 ml	383 (1D)	4868	4740	128	5.83	4.82%	9260		
50 ml	345 (1D)	5928	5780	148	5.68	5.92%	11120		

Table 4. 3 Testing result of Lime + Iron Polaroid (1:2)

lime and Iron polaroid 1:2; 2mg and 40 ml and 200 ml water	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD
30 ml	658 (1D)	7072	6900	172	6.1	7.06%	13500		
40 ml		9828	9660	168	5.72	9.96%	18060		
50 ml		11836	11660	176	5.68	12.04%	21500		

Table 4. 4 Testing result of Lime + Iron Polaroid (2:1)

lime and Iron polaroid 2:1; 2mg and 40 ml and 200 ml water	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD
30 ml	568	3870	3748	122	6.1	3.82%	13500		
40 ml	599	5046	4920	126	6.14	5.02%	18060		
50 ml	541	6048	5940	108	6.13	6.08%	11280		

Table 4. 5 Testing result of Cationic polymer + PAC (1:1)

Cationic polymer + PAC (10% stock solution) 1:1	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD
5 ml	660	455.2	285.2	170	4.95	0.28%	596	139	306
10 ml	601	670	488	182	5.14	0.48%	992		
20 ml	689	1030	830	200	4.92	0.82%	1796		

30 ml	712	1354	1146	208	4.98	1.14%	2300		
40ml	765	1650	1448	202	4.96	1.46%	2904		
50 ml	893	1966	1750	216	4.99	1.76%	3454		

Table 4. 6 Testing result of FeSo4 + Lime (1:1)

FeSo4 + Lime (10% stock solution) 1:1	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD
5 ml	418	383	265	118	7.42	0.26%	560		
10 ml	393	493.2	361.2	132	7.28	0.36%	760		
20 ml	338	562	476	86	7.95	0.48%	992		
30 ml	292	590	518	72	8.24	0.52%	1078		
40 ml	269	872	786	86	8.87	0.78%	1614		
50 ml	258	1076	1028	48	8.93	1.02%	2100	84.3	322

Table 4. 7 Testing result of Iron Polaroid, Cationic Polymer, Lime, PAC, FeSO4

	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD	Turbidity (NTU)
Iron Polaroid (1gm) + 100ml diluted WW	293 (3D)	8304	8160	144	3.23	16.92%	29420		26	160.4
Cationic Polymer (1gm) + 100ml diluted WW	241 (2D)	6547	6380	167	5.11	13.20%	23280		117.8	274
Lime + 100ml diluted WW	254 (1D)	3324	3270	54	10.1	6.70%	12440		314	216
PAC + 100 ml diluted WW	495 (3D)	3529	3170	359	4.37	6.48%	12080		276	918
FeSO4 + 100 ml diluted WW	458 (2D)	2423	2290	133	4.28	4.66%	8880		166	324

Table 4. 8 Testing result of Lime + Iron Polaroid with 1:1, 1:2 and 2:1 ratio

	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD	Turbidity (NTU)
Lime + Iron Polaroid (10% stock Solution) (1:1)	140	624	608	16	10.67	0.60%	1294			60.2
Lime + Iron Polaroid (10% stock Solution) (1:2)	64	605	598	7	10.71	0.60%	1287	15	219	9.4
Lime + Iron Polaroid (10% stock Solution) (2:1)	418	673	628	45	10.95	0.60%	1330			79.5

Table 4. 9 Testing result of Lime + PAC with 1:1, 1:2 and 2:1 ratio

	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD	Turbidity (NTU)
Lime + PAC (10% stock Solution) (1:1)	424	486	440	46	7.84	0.44%	931			57
Lime + PAC (10% stock Solution) (1:2)	134	524	520	4	8.51	0.52%	1110	103	222	21.1
Lime + PAC (10% stock Solution) (2:1)	577	556	480	76	10.19	0.48%	1044			89.3

Table 4. 10 Testing result of Lime + PAC+ FeSO4 with 2:1:1, 1:2:2 and 1:1:1 ratio

	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD	Turbidity (NTU)
Lime + PAC+ FeSO4 (10% stock Solution) (2:1:1)	173	668	648	20	10.66	0.65%	1380	15	210	22.8
Lime + PAC + FeSO4 (10% stock Solution) (1:2:2)	412(2D)	692	652	44	9.06	0.65%	1381			81.3
Lime + PAC+ FeSO4 (10% stock Solution) (1:1:1)	473	560	514	46	8.55	0.51%	1097			66.9

Table 4. 11 Testing result of Tamarind Seed Powder

Tamarind Seed Powder (5mg) + 50 ml Distilled water	Color	TS	TDS	TSS	PH	Salinity	EC	BOD	COD	Turbidity (NTU)
2ml with 500 ml WW	420(2D)	550	334	216	6.98	0.33%	707			170
3ml with 500 ml WW	350(2D)	502	335	185	6.9	0.33%	712			152
4ml with 500 ml WW	319(2D)	477	337	140	6.81	0.33%	720	75	155	137

4.1.2 Test Result Comparison with Standards

Upon comparing the treatment results, it was observed that the combination of Lime + Iron Polaroid (10% stock solution) in a ratio of 1:2 demonstrated the most favorable outcomes across all tested parameters when compared to the ECR 1997 standard.

The following table presents a comprehensive comparison between the ETP input, ETP output, and Primary Clarifier Influent, showcasing the performance of the best coagulant combination. This combination comprised a stock solution of Lime (2 mg), Iron Polaroid (2 mg), and 200 ml of distilled water, with a Lime to Iron Polaroid ratio of 1:2.

Table 4. 12 Comparison of best coagulant combination with ECR 1997 standards

	PH	EC (µS/cm)	Color (Pt.Co)	Salinity (%)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	TS (mg/L)	BOD (mg/L)	COD (mg/L)
ECR 1997 Standard	8.5	1200	80	4%	10	10	1000	1010	150	200
ETP INPUT	6.07	127.5	442	0.06%	214	68	512	580	1298	2221
ETP OUTPUT	7.45	1803	333	0.91%	105	905	34	939	28	66
Primary Clarifier Influent	9.29	7220	93	3.73%	34	22	3640	3662	8.7	152
Lime (2mg) + Iron Polaroid (2mg) + 200ml (1:2)	10.71	1187	64	0.60%	9.4	7	598	605	15	219

Based on the comparison, it can be concluded that the Lime + Iron Polaroid coagulant combination, formulated as described above, exhibited superior performance in meeting the desired treatment objectives and surpassing the ECR 1997 standard for various wastewater parameters. This underscores the potential of this coagulant combination for effective treatment and the removal of contaminants in the dairy wastewater treatment process.

4.1.3 Graphical Comparison of Tested Parameters

The following figures illustrate the performance of the Lime + Iron Polaroid coagulant combination in relation to ETP input, ETP output, and Primary Clarifier Influent, and the ECR 1997 standard for each parameter.

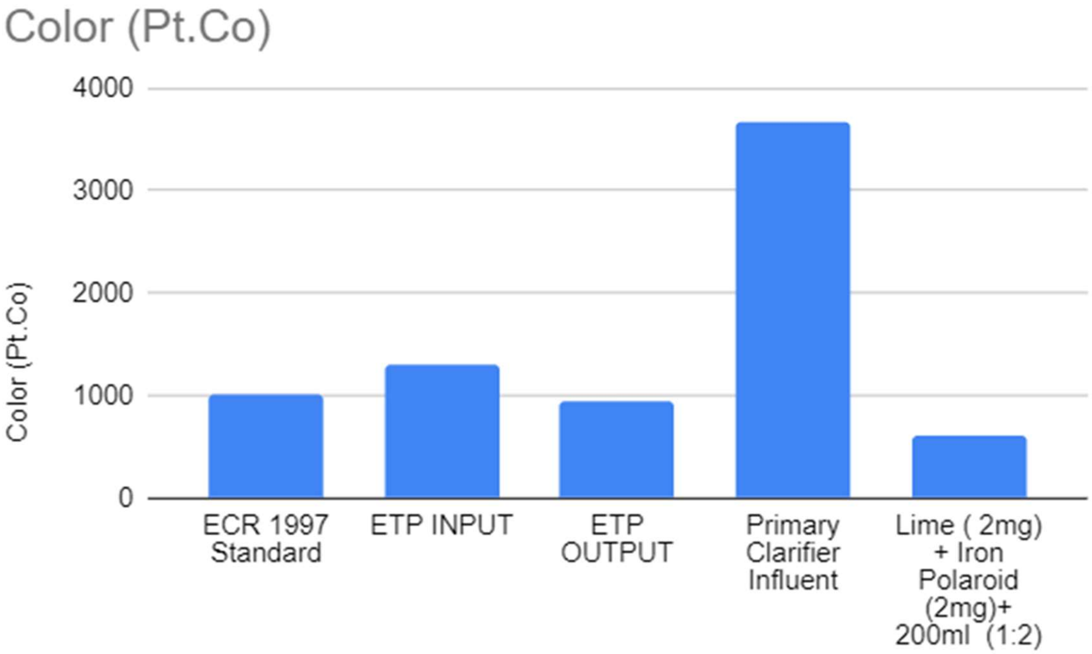

Figure 4. 1 Graphical Comparison of Color

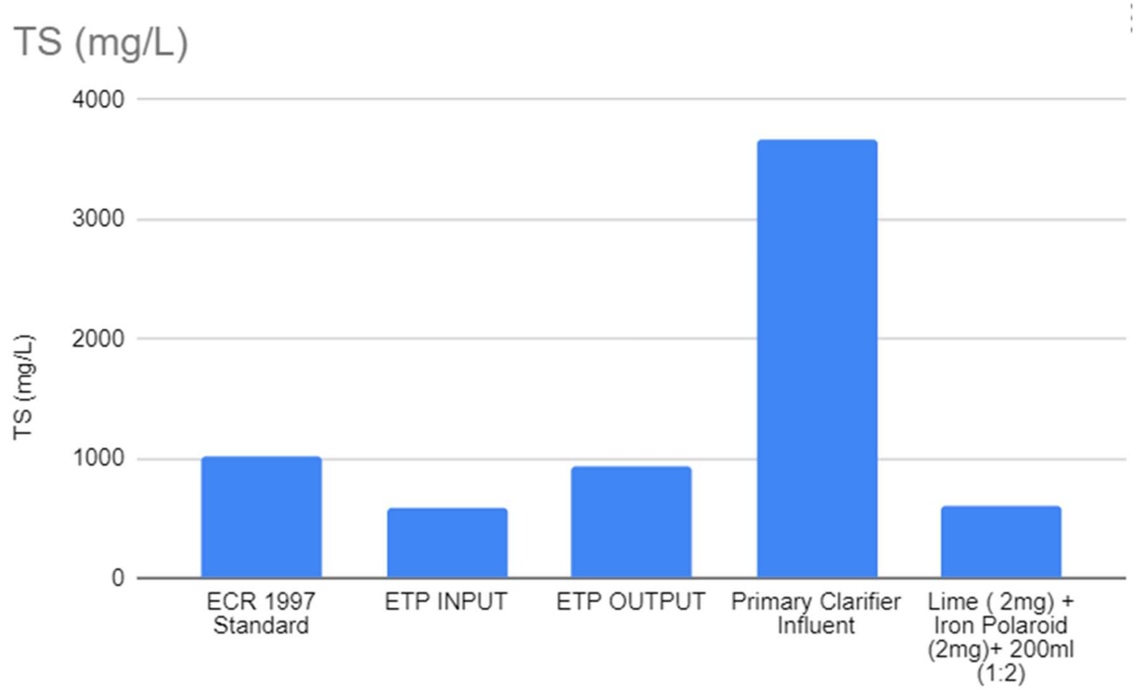

Figure 4. 2 Graphical Comparison of TS

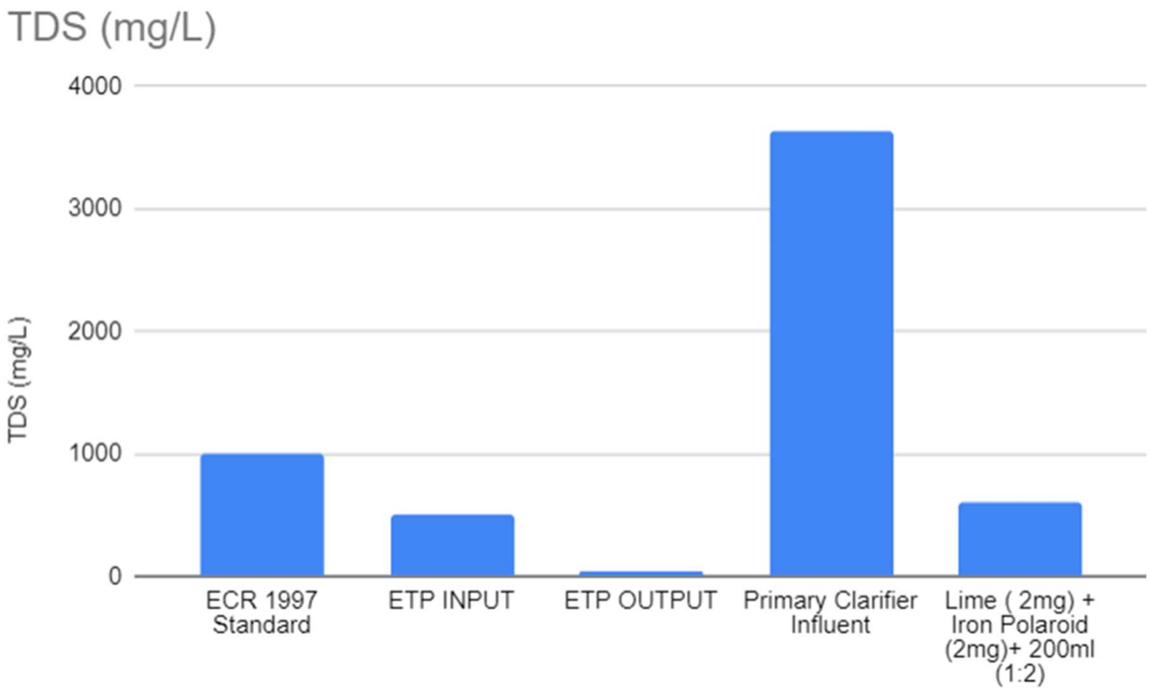

Figure 4. 3 Graphical Comparison of TDS

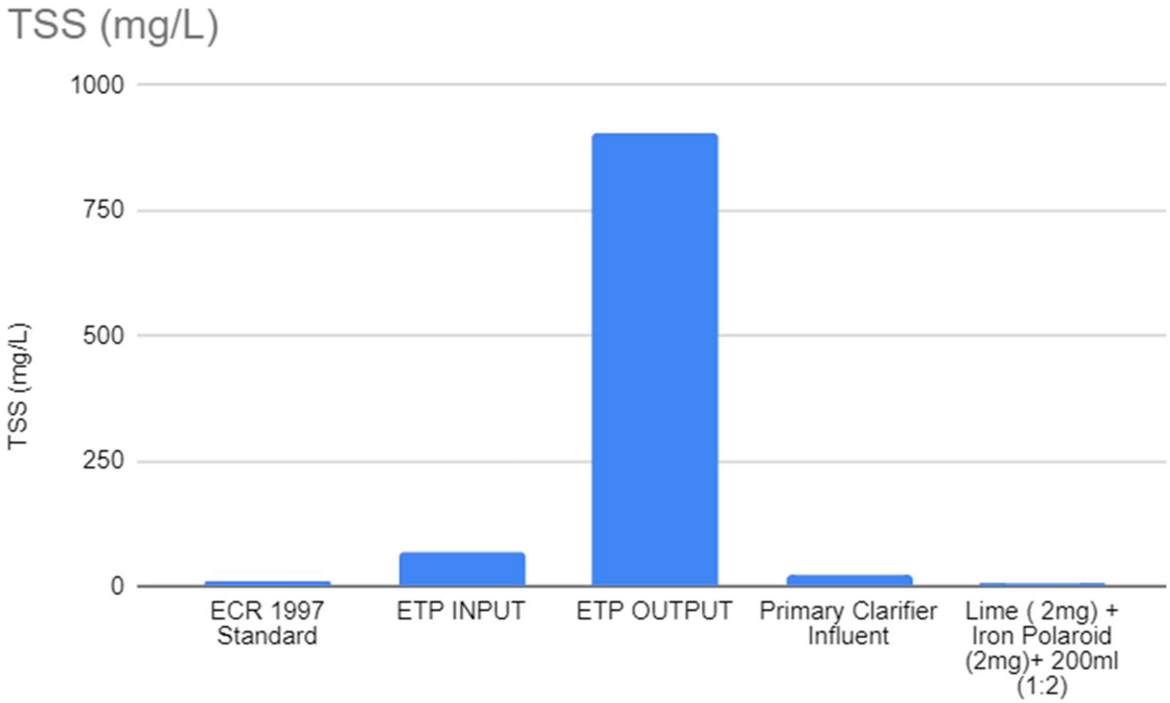

Figure 4. 4 Graphical Comparison of TSS

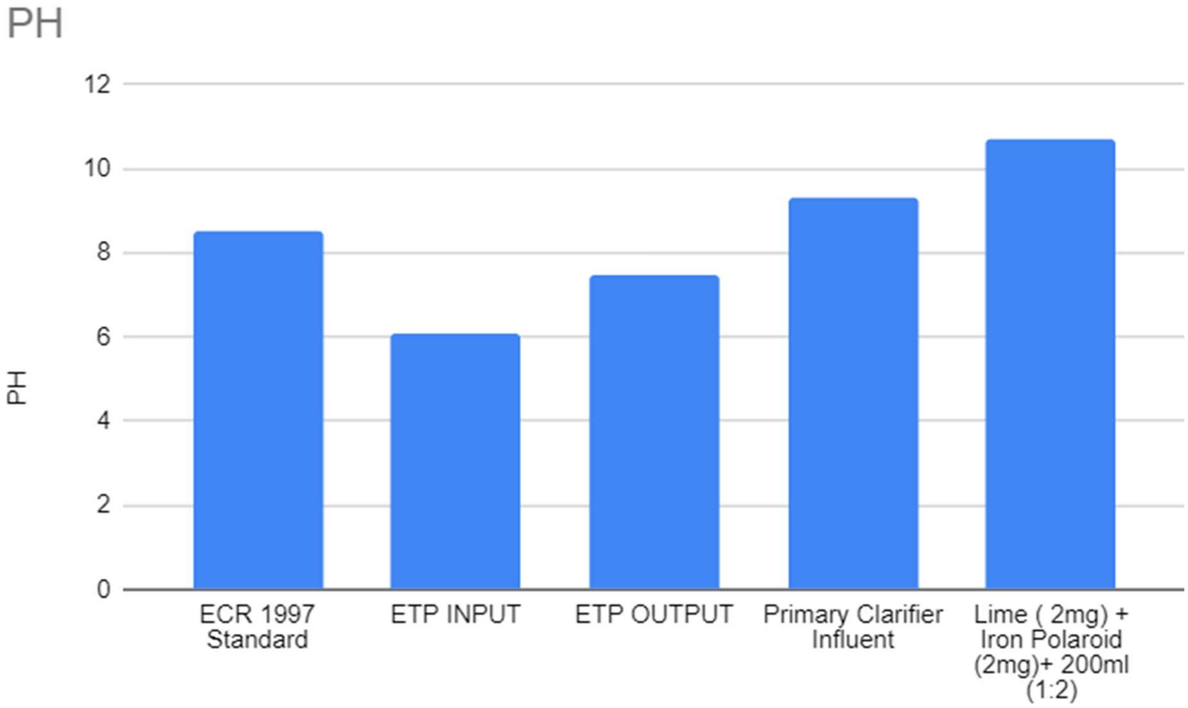

Figure 4. 5 Graphical Comparison of PH

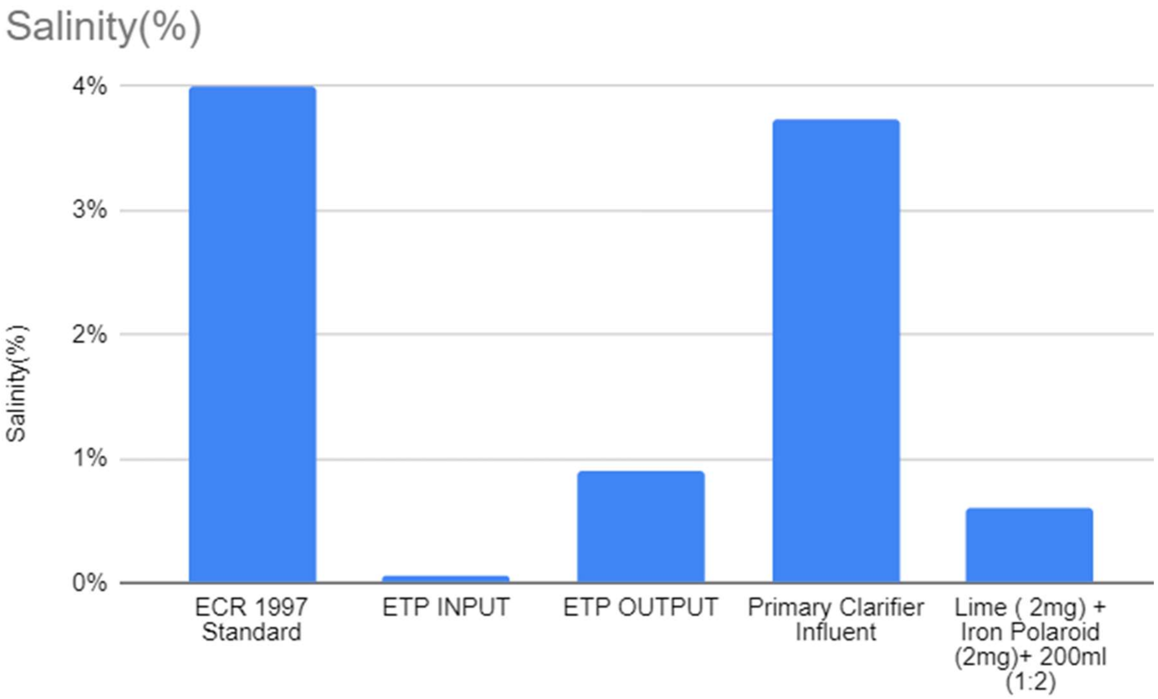

Figure 4. 6 Graphical Comparison of Salinity

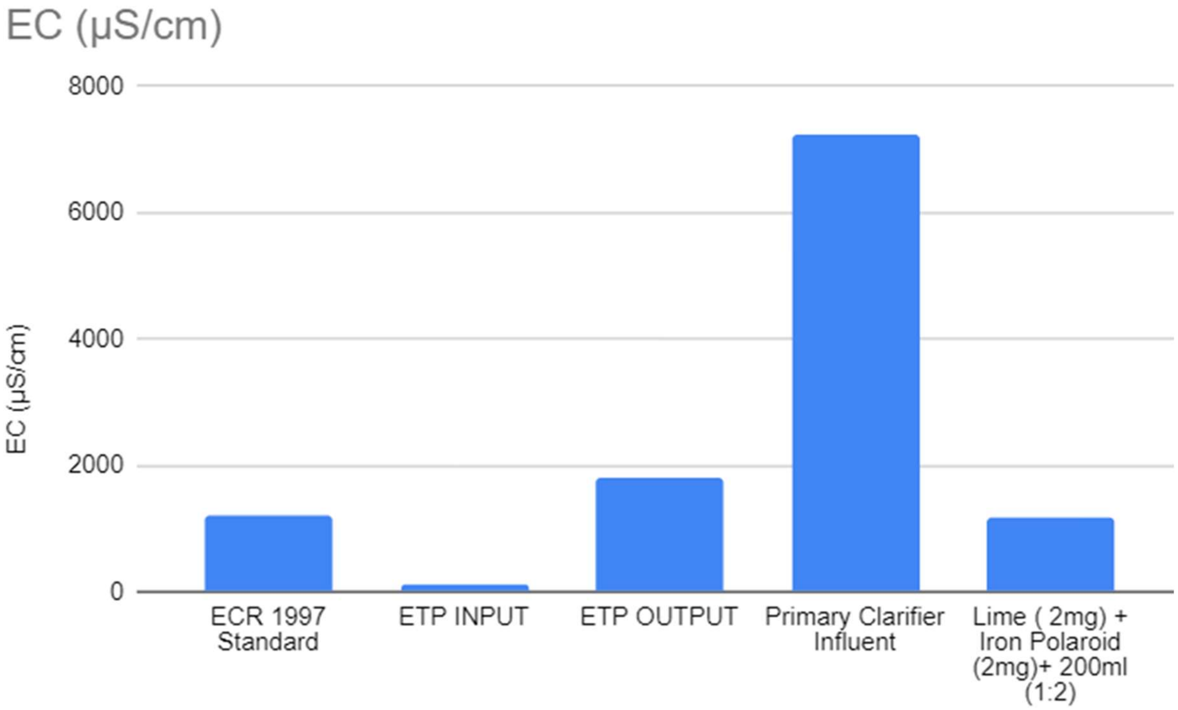

Figure 4. 7 Graphical Comparison of EC

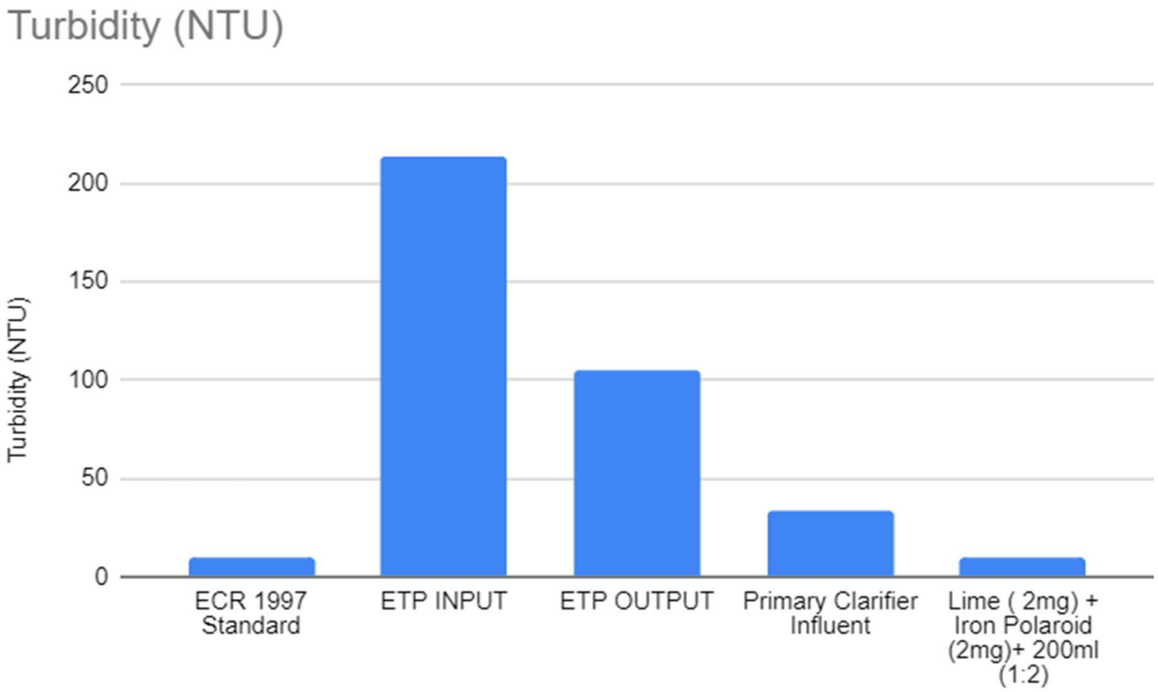

Figure 4. 8 Graphical Comparison of Turbidity

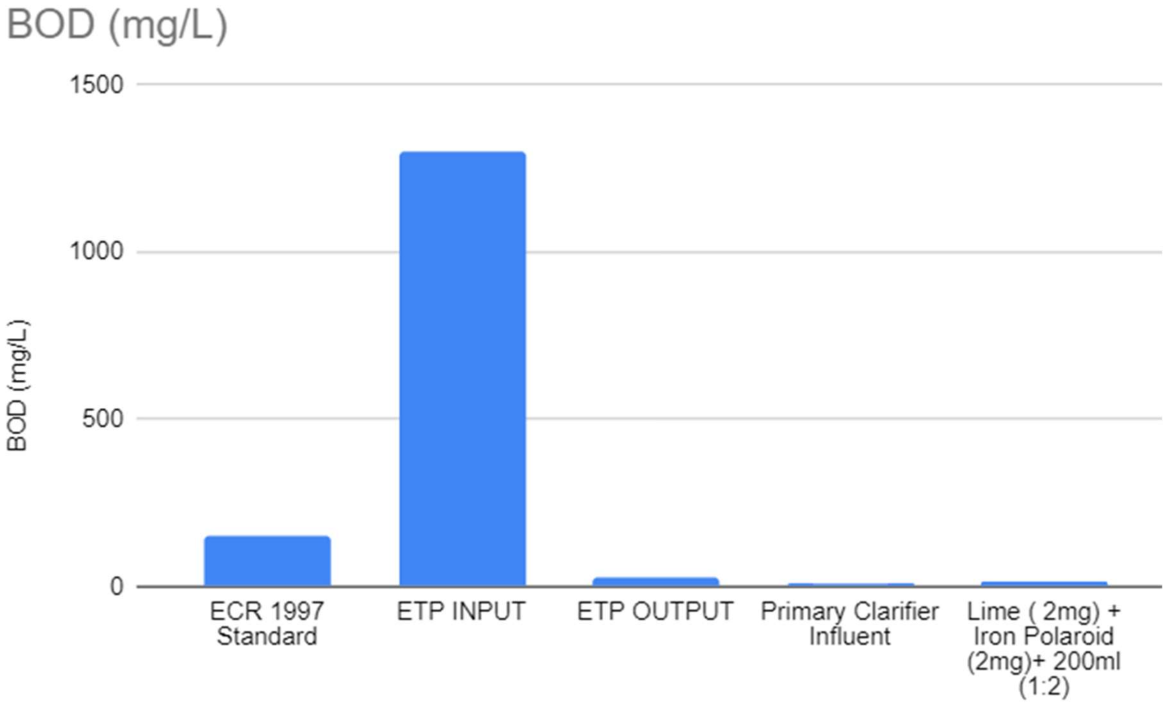

Figure 4. 9 Graphical Comparison of BOD

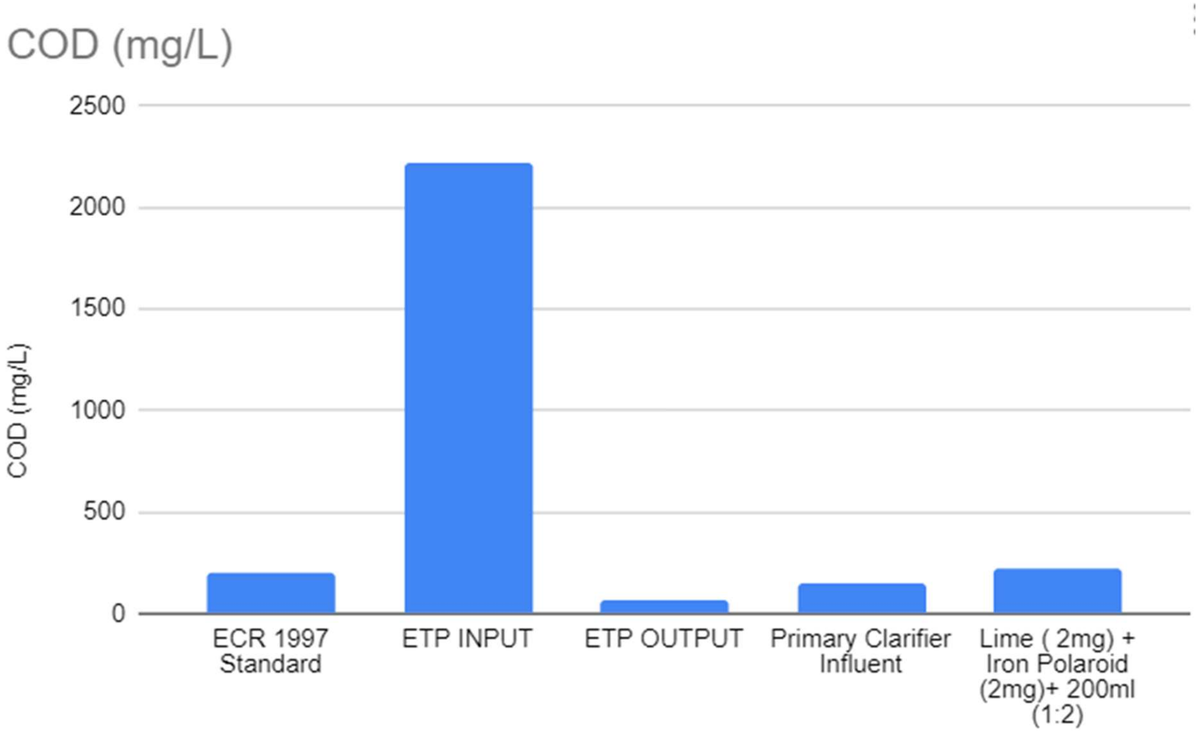

Figure 4. 10 Graphical Comparison of COD

The analysis of the coagulation treatment process conducted in this research paper revealed that the combination of Lime and Iron Polaroid consistently demonstrated superior performance in comparison to other tested parameters, including ETP Input, ETP Output, Primary Clarifier Influent, and the ECR 1997 Standard. This coagulant combination proved highly effective in reducing contaminants and enhancing the water quality of the wastewater samples.

The Lime and Iron Polaroid combination exhibited exceptional efficacy in reducing key parameters such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS), turbidity, pH, color, salinity, and Electro-Conductivity (EC). By effectively removing both organic and inorganic pollutants, it resulted in visibly clearer water with an improved visual appearance.

Furthermore, the Lime and Iron Polaroid combination successfully adjusted the pH levels and reduced the salinity of the wastewater samples. These adjustments significantly contributed to the overall enhancement of water quality and compliance with regulatory standards.

Based on the comprehensive evaluation of the tested parameters, it can be concluded that the Lime and Iron Polaroid combination emerged as the most effective treatment option for the dairy wastewater samples. Its consistent performance in pollutant removal and water quality improvement highlights its potential as an efficient and reliable solution for wastewater treatment in dairy industry settings.

4.2 BioWin Modeling Results

4.2.1 Simulation of Dairy ETP Performance Under Different Scenarios

The BioWin v6.0 simulation software was utilized to verify the performance of the dairy effluent treatment plant. By inputting the flow capacity, dimensions and wastewater characteristics into the software, various the simulation was conducted to evaluate the ETP's performance. It is also possible to explore different operational scenarios, such as variation in coagulant dosages, alternative treatment configurations etc.

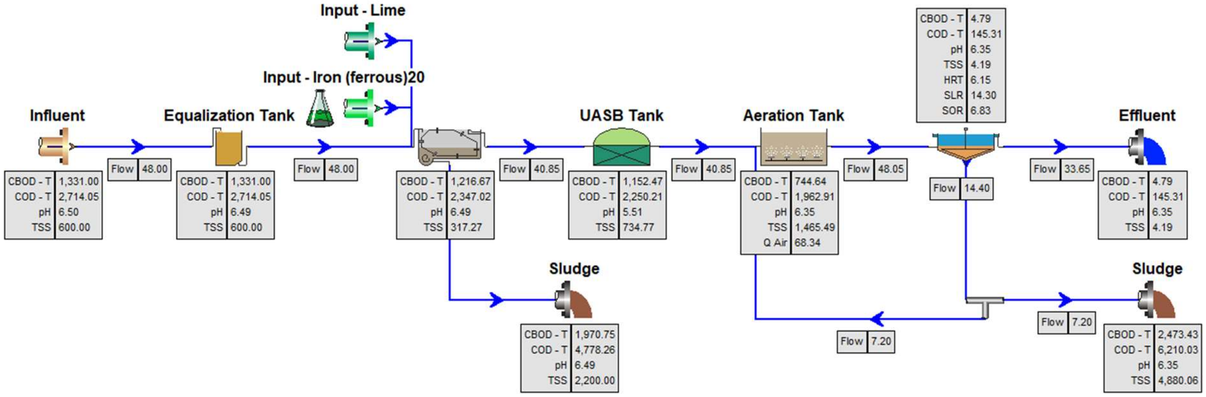

Figure 4. 11 Simulation Analysis with BioWin

4.2.2 Comparison of Simulated and Tested Data with Standard

A comprehensive comparison was made between the simulated results obtained from BioWin and the observed data collected during the experimental phase. Various key performance indicators, including parameters such as pH, turbidity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and other relevant metrics, were analyzed and compared. Additionally, the simulated results were compared against the ECR (Effluent and Discharge Regulations) standard to evaluate the ETP's compliance with regulatory requirements.

This comparative analysis allowed for an assessment of the accuracy and reliability of the BioWin model in predicting the performance of the dairy ETP. Discrepancies between the simulated and observed data, as well as deviations from the ECR standard, were carefully examined and analyzed. Any variations and deviations were thoroughly investigated to identify potential areas for improvement in the modeling approach, data inputs, or operational parameters.

By considering the ECR standard in the comparison of simulated and observed data, the study aimed to assess the ETP's compliance with regulatory guidelines. This analysis not only validated the BioWin model's predictive capability but also provided insights into the plant's performance in meeting the required effluent quality standards. The comparison with the ECR standard allowed for a comprehensive evaluation of the ETP's effectiveness in achieving regulatory compliance.

Table 4.13: Comparison of existing ETP, Simulation value with ECR1997 standard

Name of Parameters	**Effluent before treatment (Plant Value)**	**Effluent after treatment (Plant Value)**	**Simulation Value (BioWin)**	**ECR 1997 Standard**
pH	4.0 - 6.5	6.5 – 7.5	6.35	8.5
TSS	200-600 mg/l	<100 mg/l	4.19 mg/l	10 mg/l
BOD5	1331 mg/l	<50 mg/l	4.79 mg/l	150 mg/l
COD	2650 mg/l	<200 mg/l	145.31 mg/l	200 mg/l

The comparison between simulated and observed data, along with the assessment of compliance with the ECR standard, provided valuable information for the refinement and optimization of the dairy ETP's performance. These findings contribute to a deeper understanding of the ETP's operational dynamics, support informed decision-making, and facilitate the development of strategies to improve the overall efficiency and effectiveness of dairy wastewater treatment processes.

CHAPTER 5
CONCLUSION

5.1 Summary of the Research Findings

The research findings provide significant insights into the performance evaluation of dairy effluent treatment. After comparing the treatment results, it was observed that the combination of Lime + Iron Polaroid in a ratio of 1:2 demonstrated the most favorable outcomes across all tested parameters when compared to the ECR 1997 standard. This coagulant combination showed promising results in effectively treating the dairy effluent.

Additionally, the BioWin simulation results closely aligned with the tested values from the effluent, indicating the accuracy and reliability of the simulation software in predicting and modeling the treatment process. The simulation values not only matched the tested values but also met the ECR standard, further validating the suitability of BioWin as a predictive tool for assessing the performance of dairy effluent treatment plants.

These findings underscore the effectiveness of the Lime + Iron Polaroid coagulant combination in treating dairy effluent and highlight the potential of using BioWin simulation software for performance evaluation. The successful application of Lime + Iron Polaroid points to its suitability for practical implementation in real-world treatment systems. Moreover, the close alignment of simulation results with tested values and adherence to the ECR standard emphasizes the reliability and applicability of the BioWin software in simulating the complexities of the treatment process.

Furthermore, it is worth exploring the potential of tamarind seed as a natural coagulant for dairy wastewater treatment. Tamarind seed has been reported to contain active compounds that exhibit coagulation properties, making it a promising alternative to chemical coagulants. Further research can investigate the effectiveness of tamarind seed as a coagulant in combination with Lime or other additives, using both laboratory testing and simulation models, to determine its feasibility and potential benefits for dairy effluent treatment.

In conclusion, the research findings demonstrate the effectiveness of the Lime + Iron Polaroid coagulant combination in treating dairy effluent. The BioWin simulation software proves to be a valuable tool for predicting and modeling the treatment process. By advancing research in this field and exploring different coagulants, including natural alternatives like tamarind seed, through simulation and experimentation, the performance of dairy effluent treatment plants can be further improved, leading to more efficient and sustainable wastewater treatment practices in the BioWin sector.

5.2 Limitations and Potential Improvements

Limitations:

1. The laboratory jar test is limited by its small-scale nature, failing to capture the complexities and variations of full-scale ETP operations.
2. The jar test does not account for the dynamic nature of wastewater treatment processes, necessitating long-term monitoring for a comprehensive understanding of ETP performance.
3. The accuracy of BioWin simulation depends on precise input parameters and assumptions, which may deviate from real-world conditions.
4. The assumptions and algorithms in BioWin may not fully capture the intricacies of ETP processes, requiring validation and sensitivity analyses for reliable results.

Potential Improvements:

1. Conduct pilot-scale tests that closely mimic full-scale ETPs to gain realistic insights into coagulant treatments and scaling-up effects.
2. Incorporate real-time monitoring systems to validate laboratory test results and enhance the accuracy of BioWin simulation models.
3. Consider different operational scenarios, such as varying coagulant dosages and alternative treatment configurations, for a comprehensive understanding of ETP performance.
4. Invest in continuous research and development to advance simulation software capabilities, refining algorithms and incorporating advanced modeling techniques.

By addressing these limitations and exploring potential improvements, researchers and practitioners can enhance the reliability, accuracy, and applicability of the laboratory jar test and simulation software for assessing and optimizing dairy ETP performance.

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