Seasonal Variations in the Performance of the Amberpet Wastewater Treatment Plant: Assessing the Impact of Temperature and Dissolved Oxygen.

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CERTIFICATE

It is certified that the work contained in this thesis, titled "***Seasonal Variations in the Performance of the Amberpet Wastewater Treatment Plant: Assessing the Impact of Temperature and Dissolved Oxygen.***" by **VEERANNAPET SANTHOSH VISHAL**, has been carried out under our supervision and is not submitted elsewhere for a degree.

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To My Parents Dr. V Venkateshwarlu and N.T Kalyani

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Abstract

Water resources sources have deteriorated in recent years due to rapid population growth, chemical industry effluents, agricultural practices, and climate change. The primary cause of contamination of water-bodies is due to disposal of untreated sewage water pollution. Hence effective sewage treatment is necessary to safeguard water-bodies from contamination. Many cutting-edge techniques have been developed in recent years to increase the effectiveness of the removal of organic matter and nutrients by Waste Water Treatment Plants (WWTPs). To comprehend the effectiveness of wastewater treatment, the current study considered a Sewage Treatment Plant (STP) located in Amberpet, Hyderabad. The capacity of the STP at Amberpet is 339 MLD (Million Liters per Day) and is evaluated by collecting 156 samples for 12 months (January 2018 – December 2018). The data collected was based on grab and composite collection. In STPs, grab sampling and composite sampling are two frequently used techniques for gathering wastewater samples. Grab sampling is the process of taking one wastewater sample at a specific time. Contrarily, composite sampling involves collecting multiple effluent samples over a predetermined period. An STP aims to minimize or remove organic debris, sediments, disease-causing organisms, and other pollutants in sewage water before disposing into streams and other water bodies. The current study observed the removal efficiencies of the constituents such as Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and several other parameters. This investigation assesses whether the effluents emitted into the river body are within the National River Conservative Directorate (NRCD) set limitations as the treated sewage water is discharged into the Musi River (a tributary of Krishna Basin). This study investigated the seasonal variation of WWTP efficiencies for different water quality parameters for the year 2018. The study was conducted over four seasons: winter (December, January, February), pre-monsoon (March, April, May), monsoon (June, July, August, September), and post-monsoon (October, November). The study analyzed the influents and effluents of each available water quality parameter, using both grab and composite sampling and the performance efficiency of STP. For each water quality parameter, the findings revealed considerable seasonal fluctuations in treatment plant efficiencies.

For example, if Dissolved Oxygen (DO) level is too low, the microorganisms may become stressed or die, leading to reduced treatment efficiency. On the other hand, if DO level is too high, it can lead to the growth of aerobic bacteria that consume DO, reducing the available oxygen for the treatment process. Therefore, it is important to monitor the DO levels in the STP regularly and maintain them within the recommended range to ensure efficient and effective treatment of the wastewater. The type of treatment technique used in STP determines the DO saturation level necessary for a sewage treatment facility. For an activated sludge process, the DO saturation level should typically be kept between 2 and 3 mg/L, and between 1 and 2 mg/L for a trickling filter process. Water temperature is a prominent variable for water quality and aquatic habitat

affecting saturation dissolved oxygen concentrations, algal metabolism, fish growth, and production in aquatic systems. Water temperature also signifies the health of the river water body and regulates many physical and chemical parameters related to river water quality parameters, which speculatively depend on many factors. The study provided valuable insights into the influence of water temperature on saturation oxygen levels in the water, highlighting the importance of considering temperature as a crucial environmental factor in assessing water quality. So far, most River Water Temperature (RWT) models are either physical or data-driven models requiring large amounts of hydrological and meteorological observations. Many climate change studies have been conducted with increasing stream water temperatures, but how it affects saturated DO levels have not been addressed. To address these, the present work aims to work with a hybrid model - Air2Stream as a function of air temperature and discharge and also demonstrates how the Air2Stream method can be used to generate accurate RWT predictions and subsequent DO concentrations in river water quality modeling. RWT, which combines the ideas of the heat budget equation that generalizes physical processes and infers relationships between input and output data, can be predicted using the Air2Stream model. With two river gauging stations at Mantralayam, Shimoga in the Krishna River Basin, the efficiency of the suggested modeling framework is demonstrated. By comparing simulated RWT time series with matched observations and calculating the Nash Sutcliffe Efficiency (NSE), model performance was assessed. According to model results, NSE values for the calibration period for the study sites ranged from 0.76 to 0.97. Saturated DO levels are evaluated using the simulated RWT. The estimated saturated DO concentrations were ranging from 7.3% to 10.08% at the Mantralayam station, and from 6.78% to 9.27% at the Shimoga station. According to the study, wastewater treatment operations are affected by DO levels since DO saturation levels in wastewater were found to be much lower than those in river water. Additionally, the study discovered that downstream of wastewater discharge stations, DO saturation levels in river water were much lower than upstream, indicating that wastewater release may be a key factor in the decreased DO levels in rivers. The study's findings show how important effective wastewater treatment methods are for maintaining the water quality in river systems downstream. WWTPs must optimize their treatment processes in order to maintain appropriate DO levels and minimize their influence on downstream water quality.

The study concluded that the efficiency of the treatment plant varied significantly for each water quality parameter, with some parameters showing better efficiencies during some seasons than others. The results of this study emphasize the significance of considering seasonal fluctuations into account when designing and operating WWTPs. To ensure the efficient removal of pollutants and the preservation of downstream water quality, WWTPs must optimize their treatment procedures to maintain consistent and dependable treatment efficiency throughout the year. The efficient removal of these contaminants is crucial to ensure the safe reuse of treated wastewater for agricultural purposes. Therefore, continuous monitoring and analysis of the quality of treated wastewater is necessary to ensure that it meets the required standards for agricultural irrigation.

Additionally, effective management practices such as crop selection, irrigation methods, and soil amendments can help mitigate the potential risks associated with the use of treated wastewater for irrigation.

Contents

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List of Symbols

pH	Power of Hydrogen
DO	Dissolved Oxygen
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solids
TVSS	Total Volatile Suspended Solids
TN	Total Nitrogen
VFA	Volatile Fatty Acids
FC	Fecal Coliform
RWT	River Water Temperature
MLD	Million Liters per Day
RMSE	Root mean square error
MAE	Mean absolute error
NSE	Nash-Sutcliffe efficiency
MSE	Mean Square Error
R^2	Coefficient of Determination

List of Acronyms

STP	Sewage Treatment Plant
WWTP	Waste Water Treatment Plant
WW	Waste Water
DO Concentration	Dissolved Oxygen Concentration
DO Saturation	Dissolved Oxygen Saturation
MBR	Anaerobic Membrane Bioreactors
ASBR	Anaerobic Sequencing Batch Reactors
HMWSSB	Hyderabad Metropolitan Water Supply and Sewerage Board
CWC	Central Water Commission
NRCD	National River Conservative Directorate
UASB	Up-flow Anaerobic Sludge Blanket

Chapter 1

1. Introduction

1.1 Background

Wastewater treatment (WWT) is a crucial technology for the preservation and redistribution of water resources, as shown by the enormous success of its subsequent implementation in numerous nations throughout the world. Over the past two centuries, significant progress has been made in the understanding of the complex and diverse characteristics of the fundamental biological, metabolic, chemical, and mechanical processes for wastewater treatment. The global application of current knowledge and experience in wastewater treatment technologies will be a crucial aspect of future water management. At present, nearly half of the wastewater produced globally is being properly treated [1]. While the wastewater treatment process studies are vital for protecting the environment, promoting sustainability, and ensuring public health and safety. Through the advancement and optimization of treatment processes, the mitigation of water pollution, preservation of ecosystems, conservation of water resources, and prevention of waterborne disease transmission can be achieved, ultimately resulting in the promotion of healthier and more sustainable communities. In future, low and moderate-income countries will often struggle with limited resources and outdated infrastructure. They may lack proper wastewater treatment facilities or have insufficient capacity to handle the increasing volume of wastewater generated by growing urban populations. The largest challenge to achieving the objectives of sustainable water management may be the lack of educated, qualified individuals who can comprehend and apply the findings of scientific study. To address modern water management challenges, there is a need of flexible wastewater technologies. Innovations like anaerobic digestion and membrane filtration showed great potential for clean water. But high costs adoption, especially in resource-limited nations, requires cost-effective wastewater treatment systems to address this issue [2]. Additionally, including renewable energy sources like solar and wind power into wastewater treatment plants (WWTPs) can result in energy independence and a decrease in greenhouse gas emissions. Overall, the future of wastewater treatment lies in the development and deployment of innovative and sustainable technologies that can address the growing water crisis and promote a more sustainable and equitable water management system globally.

1.2 Motivation

All life on earth depends on water, thus having access to clean water is a fundamental human necessity [2]. However, the issue of water scarcity has become increasingly severe due to the rise of urbanization. In response to this, the concept of recycling and reusing wastewater has become more prevalent. By treating and purifying wastewater before it is released into water bodies, WWTPs are essential for preserving human health and the environment [2]. The motivation behind the research study on the seasonal variations in the performance of the WWTP is driven by the need to understand how temperature and dissolved oxygen impact the treatment processes. By assessing these factors and their seasonal variations, the study aims to optimize plant performance, enhance resource efficiency, and contribute to the scientific understanding of wastewater treatment processes. The temperature and dissolved oxygen was considering because of its significance in microbial activity, reaction rates, and treatment efficiency, their analysis provides valuable insights into the overall performance of wastewater treatment processes. By understanding the relationship between these parameters and treatment outcomes, operators can make informed decisions to optimize plant operations, ensure compliance with regulatory standards, and improve the effectiveness of wastewater treatment.

1.3 Introduction

An essential source of water for human activity is rivers. River water quality is impacted by human settlements near rivers due to many causes of pollution, including industrial and municipal waste. The quality of the water is impacted when residential sewage and wastewater, are discharged into rivers [1]. It may be efficient and inexpensive to treat pollution by utilizing the river's potential for self-purification. There are several instances of pollutants released into rivers that have endangered human health and created irreversible changes to plant and animal populations. Therefore, determining a river's ability to assimilate contaminants by adjusting its flow is a key technique for managing water quality. River pollution mitigation strategies have been the subject of research [1]. The decrease in precipitation causes a lack of water and soil moisture and the consequent impact on the crops, thereby reducing yield and resulting in agricultural losses. The decrease in productivity of rangeland due to lack of water results in losses to livestock production. Low streamflow damages the habitat for fish and other aquatic animals causing losses to fisheries production and the losses to power generation can be caused due to the unavailability of the required amount of water for the power generation due to the low streamflow [2]. Given that over 68% of the population in India depends on agriculture, monsoon climates like India see alternating dry and rainy seasons as a result of extensive atmospheric processes. Efficient management of river water quality is crucial for sustaining human activities and ecosystems that depend on rivers. In addition to self-purification techniques, river restoration, and conservation measures can also contribute to maintaining healthy river ecosystems. Many studies have highlighted the importance of balancing water demand with the maintenance of river flows and ecology. Several conservation and restoration techniques, such as dam removal, stream bank stabilization, and the establishment of riparian zones, can help to enhance river health and restore degraded ecosystems. Effective river water quality management requires a collaborative effort between various stakeholders, including policymakers, water managers, and local communities. It is necessary to develop sustainable river water management strategies that are adaptable to changing environmental conditions and meet the needs of all stakeholders, including human populations and ecosystems.

1.4 Sewage Treatment Plant Classification

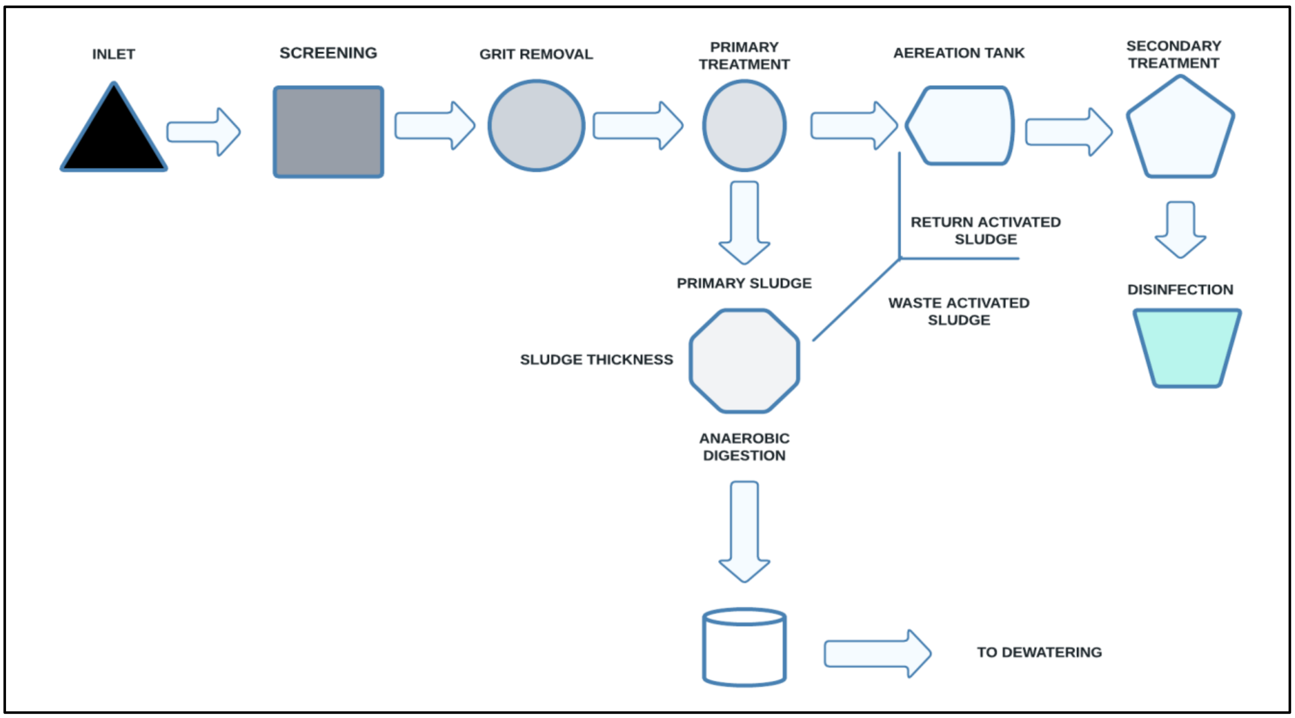

Figure 1.1: The processes which are involved in purifying the water.

The process of treatment includes Screening and Grit Removal, Primary Treatment, Secondary Treatment, Activated Sludge Process, UASB (Up-flow Anaerobic Sludge Blanket), and Disinfection as shown in Figure 1.1.

The initial stage of the wastewater treatment process involves screening and grit removal. In this step, large debris, such as plastics, sticks, and other solid objects, are removed from the wastewater through physical screening. This helps prevent damage to equipment and clogging of downstream treatment processes. Grit removal is then carried out to separate heavier inorganic particles, like sand and gravel, from the wastewater. Grit chambers or cyclone separators are used to settle and collect these particles, ensuring smoother operation and preventing abrasion in subsequent treatment units.

The primary treatment process focuses on the physical separation of suspended solids and the reduction of organic matter. Wastewater flows into large settling tanks or clarifiers, where gravity allows the heavier particles to settle at the bottom as primary sludge, while greases and lighter substances float to the surface as scum. The wastewater undergoes secondary treatment, which involves the removal of dissolved and colloidal organic matter. One commonly used method is the activated sludge process.

In addition to the activated sludge process, some wastewater treatment plants utilize the UASB process for anaerobic treatment. In this method, wastewater is introduced at the bottom of an up-flow reactor where anaerobic bacteria break down organic matter in the absence of oxygen. The bacteria form a sludge blanket, which serves as the active zone for the anaerobic digestion process. Biogas, primarily consisting of methane and carbon dioxide, is produced as a byproduct. The effluent from the UASB reactor is then further treated in subsequent stages to achieve desired treatment goals. After the secondary treatment process, disinfection is performed to remove or inactivate any remaining pathogens in the wastewater. Disinfection helps prevent the transmission of waterborne diseases. Common disinfection methods include chlorination, ultraviolet (UV) irradiation, and ozonation.

1.5 Problem definition

Water pollution is a widespread environmental challenge in India, with significant implications for resources. Wastewater treatment plants (WWTPs) play a crucial role in mitigating this issue, yet their effectiveness can be influenced by a number of factors, including seasonal variations in temperature, dissolved oxygen (DO) levels, and the composition of wastewater. The Amberpet WWTP, one of Hyderabad's largest facilities, serves a population exceeding 10 million residents, processing sewage from diverse sources. Notably, the efficiency of the Amberpet WWTP in removing pollutants displays substantial seasonal fluctuations, with the highest performance observed during the winter and reduced efficiency during the monsoon season.

These variations in WWTP performance can be attributed to a combination of factors, including shifts in temperature, DO concentrations, and wastewater composition. Temperature significantly influences the activity of microorganisms crucial for pollutant removal, while adequate DO levels are essential for their survival and activity. In addition to these factors, this study explores the broader regional context by examining the Effects of Dissolved Oxygen Saturation and Water Temperature using Air2stream over Krishna River Basin, India. By investigating this relationship in a different river basin, this study aims to advance understanding of the interconnected dynamics influencing wastewater treatment. The seasonal variability in WWTP performance raises concerns about the potential discharge of inadequately treated wastewater into the Musi River, posing risks to water quality, aquatic ecosystems, and public health. This study addresses these critical challenges by promoting sustainable and efficient urban wastewater management practices, emphasizing the significance of environmental factors in diverse geographical contexts. The main research gaps from this problem are framed like below.

- Limited exploration of seasonal variations in STP efficiency
- Lack of understanding into the influence of Dissolved Oxygen and temperature on STP efficiency
- Absence of comprehensive models for simulating river water temperature
- Limited research on the relationship between Dissolved Oxygen saturation and river health

1.6 Objectives of the Study

The objectives of the present study are:

- To study the efficiency of a Sewage Treatment Plant using grab and composite sampling methods using various water quality parameters
- To study the seasonal efficiency of Amberpet Sewage Treatment Plant using various water quality parameters
- Investigating the impact of saturated Dissolved Oxygen concentration and water temperature on efficiency of STP at Amberpet
- To simulate RWT of Krishna River using hybrid river water temperature modelAir2Stream
- To estimate Saturated Dissolved Oxygen of Krishna River using the simulated river water temperature from Air2Stream model

1.7 Thesis Organization

- Chapter 1 presents an introduction to Wastewater, STPs, and the Classification of STPs.
- Chapter 2 presents detailed literature on Wastewater impacts on STPs, Impacts on Water Quality, and impacts of climate change on water bodies.
- Chapter 3 presents an introduction to the case study and datasets used in this study.
- Chapter 4 presents a study on the different steps involved in the process of treating water, the impacts of parameters on STPs and efficiencies of each particular parameter, and the impacts of sewage water on agricultural use.
- Chapter 5 presents a study on the effects of DO saturation and water temperature using Air2stream at KRB.
- Chapter 6 presents a summary of the thesis findings, conclusions, and potential directions for additional research.

Chapter 2

2. Literature Review

2.1 Introduction

The health of communities that use the water downstream can be directly impacted by the discharge of wastewater into rivers. This is why it's crucial to treat wastewater before dumping it into bodies of water [9]. As urbanization expands and the demand for freshwater grows, recycling and repurposing wastewater for agricultural use is becoming essential. With 10.1 million inhabitants and a daily water consumption of 1800 MLD, Hyderabad is the fourth most populated city in India. The entire sewage is transported to the River Musi through 16 drains, and there are 18 wastewater treatment facilities in Hyderabad, with a combined capacity of 715 MLD. The Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) is responsible for maintaining all treatment facilities. In order to ensure proper utilization, the Ministry of Urban Development mandated that 28% of treated water be recycled. Urban wastewater is generally a combination of flows produced by diverse urban activities, including domestic and industrial effluent, stormwater, and other urban discharge. Consumers use only between 80 and 90 percent of the urban water supply for homes, businesses, and industries before it is released as wastewater back into the city [10]. Since it contains human excreta as well as potentially dangerous chemicals from industry, households, and other sources, urban wastewater is unhygienic and poses a serious health risk to the local population. A common method of health protection is to construct a sewage system to remove the wastewater from the neighborhood, which isolates the risk from the homes close [1]. Where sewerage can be accessed though, it concentrates the wastewater flow and moves the pollution and health concerns there, endangering the lives of people downstream and the water supplies. To minimize or control these risks, the WWTP's physical, chemical, and/or biological processes must be brought up to a certain standard. The effluent is regarded as at best partially treated if the standard is not met. Where sewerage is not available, residential on-site sanitation alternatives can be used to handle wastewater safely. However, all on-site options still have accumulated fecal sludge that must be periodically removed and properly disposed of [11]. Additionally, grey-water flows must be handled with the same caution in communities without sewage. There have been various attempts to offer a thorough typology of wastewater reclamation and usage in agriculture, but nomenclature still varies among professionals in the field. The practice of using recycled water that has been transported directly from the location of treatment or production to the site of use, without first being released into a surface water body or groundwater body, is known as direct use of treated (or reclaimed) wastewater. The deliberate and regulated use of wastewater, whether it is undiluted (direct) or diluted (indirect), is an essential practice that can benefit agriculture [9]. However, unplanned and indirect uses of untreated wastewater predominate. There are two significant subcategories of planned wastewater use for irrigation: restricted irrigation and unrestricted irrigation. The farmer is the controlled use of treated wastewater to produce foods that are normally eaten raw by people, whereas the latter is the controlled use of treated wastewater to grow crops that are not typically eaten raw by people [1]. The disposal of wastewater into rivers and oceans can have a detrimental impact on aquatic animal life and downstream communities that consume the water. Prior to being released into waterways, wastewater must be treated, especially as urbanization and the need for freshwater increase. Hyderabad, a densely populated city in India, is an example of a city with high water usage and a need for proper wastewater management.

Table 2.1 Limits of the parameters given by NRCD

Sl.No	Parameters	Limits
1.	pH	<8.0
2.	DO	3-5mg/L
3.	TSS	<50mg/L
4.	COD	<250mg/L
5.	BOD	<30mg/L
6.	Alkalinity	<460mg/L
7.	Sulphate	<75mg/L
8.	Sulphide	<2mg/L
9.	V.F.A	<30 mg/L
10.	F.C	<310,000 MPN/100 ml

2.2 Impacts on Water Quality

Freshwater systems water quality is influenced by hydrological, biogeochemical, and anthropogenic factors that work on a variety of temporal and spatial scales (such as the world, river basins, and local catchments) [12]. Numerous methods, such as empirical relationships between water quality and climatic trends, had been used to evaluate the possible changes in water quality owing to climate change [13]. Using deterministic or black-box modelling techniques to evaluate the possible impacts of climate change on surface water quality at the continental or local scale [14]. Agronomic issues in irrigated agriculture may result from water quality characteristics such as the rise in total dissolved solids and their constituent ions as well as the fall in DO.

Sukhnag stream in the Kashmir Himalayas, India, was subjected to an analysis of all sources of pollution [15] Using Cluster Analysis (CA) and Factor Analysis (FA), the parameters responsible for spatiotemporal variability in water quality were found, and it was demonstrated that hydrological runoff and wastewater discharge have the greatest impact on stream water quality. Additionally, it was demonstrated that soluble salts from natural sources, nonpoint nutrients, and anthropogenic organic contaminants account for the majority of differences in water quality. The results of the regression analysis clearly demonstrated that runoff increases the concentration of the majority of the inorganic and organic parameters during the peak flow season. The stream's pollution levels increased with time, from the head to the tail, indicating growing anthropogenic pressure on the areas below [15]. The river water quality may become critically low when there is a lengthy period of low flow combined with a high water temperature [16]. A small chemical water quality analysis was also conducted by [16] to assess whether the water was fit for human consumption using Bureau of Indian Standards (BIS) guidelines. According to the findings of a chemical water quality analysis, the analyzed drinking water samples had high levels of nitrate-nitrogen, ammonium-nitrogen, and chlorides indicating future research study required.

These studies have shown that climate-related mechanisms, such as rising air temperatures, changes in hydrological factors (such as the limited dilution of point source emissions during low river flows), terrestrial factors (such as changes in vegetation and soil structure), and resource-use factors (such as rising water use and rising cooling water demand), can all have an impact on water quality [17]. Due to the possibility of river water quality degradation during extended low-flow conditions combined with high water temperatures [18],

2.3 Impacts of Climate change on Water Bodies and Atmosphere.

India's water supplies are being severely impacted by climate change [19]. The effects of climate change have been observed in the nation, including longer droughts, extreme rainfall events, and increasing sea levels. The country will experience increased water stress as a result of these extreme weather events, which are likely to increase in frequency and severity over the next decades [17]. On India's water resources, climate change is anticipated to have a number of effects, including:

- Reduced river flows: River flows in India are anticipated to decrease due to climate change. This is because rising temperatures will cause glaciers to melt at a faster rate, and increased evaporation will lead to lower rainfall levels. Reduced river flows will have a major impact on agriculture, hydroelectric power generation, and drinking water supply.
- Increased groundwater depletion: Climate change is also expected to increase groundwater depletion in India. This is because rising temperatures will cause groundwater to evaporate at a faster rate, and decreased rainfall levels will lead to less recharge of groundwater aquifers. Increased groundwater depletion will have a major impact on agriculture and drinking water supply.
- Increased salinity of coastal aquifers: The salinity of coastal aquifers is anticipated to rise as a result of climate change. This is because seawater will intrude into coastal aquifers as sea levels rise. Increased salinity of coastal aquifers will make them unfit for human consumption or irrigation.

Increased water conflicts: Increased water disputes in India are anticipated as a result of climate change. This is because it is anticipated that as a result of population expansion, economic development, and climate change, water consumption will rise. A rise in water disputes may cause societal discontent and instability [2]. India needs to act rapidly to mitigate the danger that climate change poses to its water supplies. This includes:

- Investing in water conservation and efficiency: To lower water consumption, India must make investments in water efficiency and conservation methods. This covers strategies like water recycling, rainwater harvesting, and water-smart irrigation systems.
- Developing new water sources: To address the nation's expanding water demand, India must create new water sources. This includes measures such as building dams, desalination plants, and water transfer projects.
- Adapting to climate change: India has to adapt to how climate change may affect its water resources. This includes actions like creating seawalls to safeguard coastal regions from flooding,

breeding crops that can withstand drought and enhancing early warning systems for extreme weather occurrences.

- India's supply of water is being severely impacted by climate change [19]. India can, however, lessen the effects of climate change and guarantee that its water resources will be accessible to future generations by acting quickly.

2.4 Conclusions

As urbanization expands and the demand for freshwater grows, recycling and repurposing wastewater for agricultural use is becoming essential. The fundamental objective of effluent irrigation-related suggestions is to safeguard the safety of the public. After treatment, the treated water is released into the river [20]. Various nations adopt different approaches to develop regulations that achieve this goal. Developing countries typically use low-tech, low-cost water treatment strategies like lagoon systems or constructed wetlands, which are less complex and more affordable to implement and maintain than the high-tech, high-cost strategies used by industrialized nations, such as reverse osmosis and UV disinfection systems. These high-tech systems require significant financial resources and technical expertise to operate [20]. Globally, the quality of treated wastewater for irrigation is assessed using the microbiological parameters advised by the WHO. However, there are no universally accepted criteria for water quality in this context. Regional general water quality requirements dictate the acceptable levels of physical and chemical pollutants [2]. The amount of fecal coliform concentration in the treated effluent is a critical microbiological characteristic that the reuse criteria take into account when determining whether treated wastewater is suitable for agricultural irrigation [9]. The suggestions strike a compromise between the threats and the practical use of unconventional resources. Rather than prohibiting effluent reuse, they encourage the application of best management practices. The majority of countries have made the WHO's health recommendations for effluent reuse in agriculture and aquaculture their standard. The treatment level necessary to satisfy microbiological standards and the microbiological quality standard for intestinal nematodes and fecal coliforms are specified in these guidelines. But nothing is known about how wastewater irrigation affects people in general [21]. Recycling and repurposing wastewater for agricultural use can be an effective approach to address the increasing demand for freshwater in urban areas. The sustainable and safe application of treated wastewater for irrigation requires a robust regulatory framework that ensures the protection of public health, and the environment and regulatory framework should be based on the latest scientific knowledge and risk assessment tools and should be regularly updated to reflect emerging concerns and changing conditions.

One of the key challenges in regulating wastewater reuse is the lack of consensus on the acceptable levels of contaminants in treated wastewater for irrigation. While the WHO guidelines provide a useful reference point, they may not be applicable in all contexts due to regional variations in water quality, irrigation practices, and crop types. Therefore, it is important to develop context-specific regulations that take into account local conditions and stakeholder preferences. This can be achieved through stakeholder engagement and participatory decision-making processes that ensure the inclusiveness and transparency of the regulatory framework.

Another important aspect of wastewater reuse is the need for effective monitoring and enforcement mechanisms that ensure compliance with regulatory requirements. This requires the development of appropriate monitoring protocols and the deployment of qualified personnel and equipment to carry out the monitoring activities. Moreover, it is essential to establish penalties and incentives that encourage compliance and discourage non-compliance and to provide adequate training and capacity building to the stakeholders involved in the implementation and enforcement of the regulations.

Overall, a broad and multi-stakeholder method that takes into account the technical, economic, social, and environmental aspects of the problem is needed for the safe and sustainable reuse of wastewater for irrigation. By using such a strategy, nations can realize the potential advantages of wastewater reuse, such as improved agricultural output, higher water security, and decreased pollution, while lowering the hazards to the ecosystem and the general population.

Chapter 3

3. Study Area and Data

3.1 Introduction

The current investigation was carried out at Amberpet's STP having capacity of 339 MLD in Hyderabad, India. The plant is one of the largest STPs in India and is designed to treat wastewater from a population of 10.2 million people. The plant is surrounded by a mix of residential and commercial areas, including Osmania University, NTR Gardens, Hussain Sagar Lake, L.B. Nagar, Charminar and Secunderabad Railway Station. The study's objective is to assess the STP's performance under a variety of circumstances, taking into account the local environment and its potential influence on the plant's operations. Mainly to study the seasonal efficiency of Amberpet sewage treatment plant using grab and composite sampling methods using various water quality parameters. The study is likely to offer insightful information about the potential and difficulties involved in wastewater management in a densely populated urban area like Hyderabad. Managing wastewater in metropolitan cities presents a number of opportunities and challenges, some of which are listed below:

Challenges:

- Infrastructure for wastewater treatment is being strained by the fast rise of urban populations.
- WWTPs are often located close to residential and commercial areas, which can lead to complaints about noise, odor, and other nuisances.
- Emissions of greenhouse gases from WWTPs may be a factor in climate change.

Opportunities:

- Wastewater can be a valuable resource that can be reused for irrigation, industrial processes, and other purposes.
- It is possible to design WWTPs to produce electricity and lower greenhouse gas emissions.

- The utilization of WWTPs can enhance water quality and safeguard the health of society.

3.2 Study area

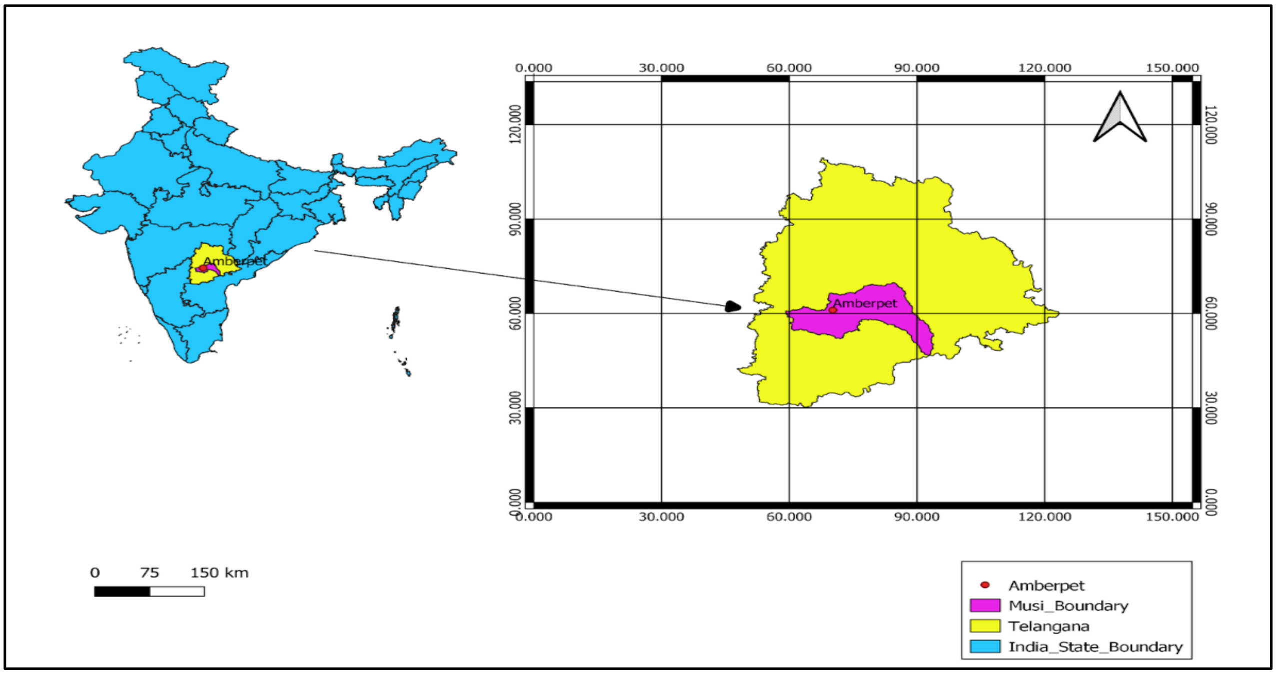

Figure 3.1: Map of the 339 MLD STP location in Amberpet, Hyderabad, India.

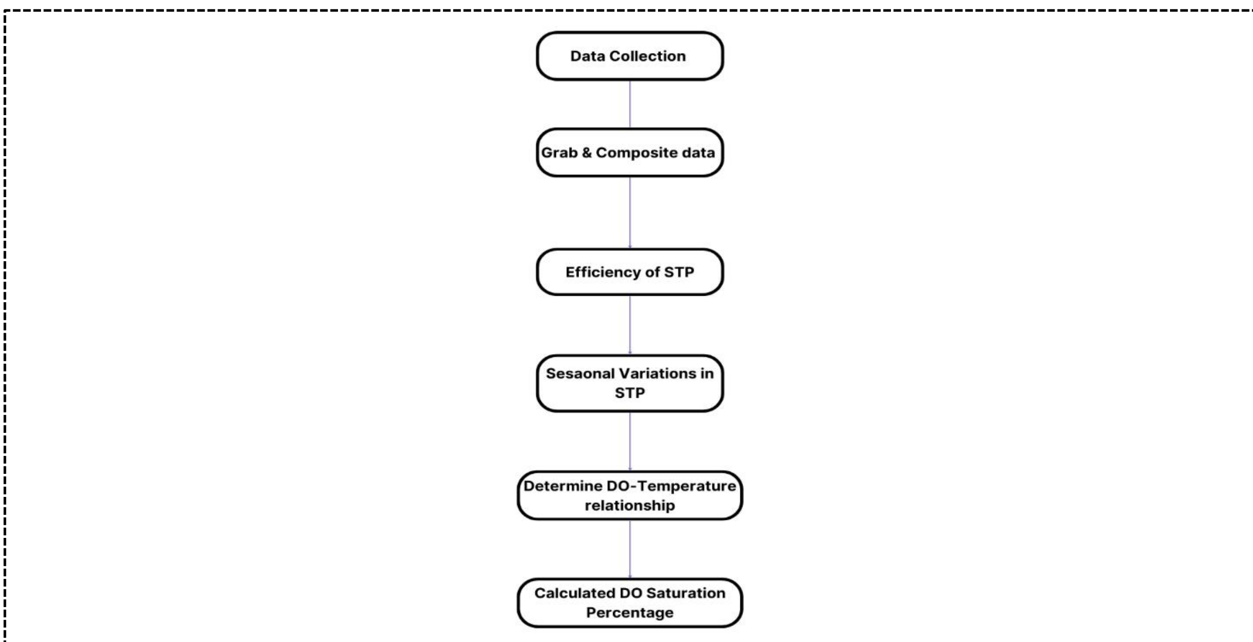

Figure 3.2: A flowchart designed for enhanced comprehension of the process for Amberpet Case Study.

3.3 Data Sets

STP Data Analysis

This study specifically examined data from the Amberpet STP in Hyderabad, India, for the year 2018, as it provided a comprehensive dataset for analysis. Data for this period was collected using both grab and composite sampling methods. Statistical techniques, including correlation analysis, regression analysis, and time series analysis, were used to analyze the data. Plant operators were also interviewed to understand the challenges they face while operating and maintaining the plant. In Table 3.1 and 3.2, the average values of each parameter for each month are shown for grab and composite data. The results of this investigation are essential for evaluating the plant's effectiveness and pinpointing its shortcomings. This will aid in ensuring that the plant functions optimally, reducing the environmental impact of untreated sewage on the surrounding areas [22].

Grab and Composite Sampling

In STPs, wastewater samples are collected using grab sampling and composite sampling techniques. Grab sampling is a straightforward method that involves taking one wastewater sample at a predetermined moment. The sample is often manually collected with the aid of a container or sampler. Grab sampling is frequently used to take fast readings of a variety of characteristics, such as pH, temperature, and turbidity. It is simple to carry out, requires little equipment, and offers a brief overview of effluent quality. However, grab sampling does have several drawbacks, such as the possibility of sample bias caused by changes in wastewater quality over time and the absence of representation of wastewater quality as a whole. In contrast, composite sampling involves collecting numerous effluent samples over a predetermined period. To create a composite sample, which represents the average quality of the wastewater over the sampling period, the samples are mixed. Composite sampling might be helpful when a representative sample is needed to evaluate the overall quality of wastewater. Composite sampling is frequently utilized to measure the amounts of contaminants in wastewater, such as fertilizers, metals, and organic substances. Composite sampling can record changes in wastewater quality over time, giving a more accurate picture of the effluent's overall quality. To ensure accurate sample collection and management, composite sampling needs more time and resources than grab sampling. It also needs specialized equipment.

BOD (Total) and BOD (Filter) are two different methods of measuring the amount of organic matter in sewage water. BOD (Total) quantifies how much oxygen is absorbed by micro-organisms over a five-day period. This method includes all of the organic matter in the water, including both dissolved and suspended solids. BOD (Filter), on the other hand, measures the amount of oxygen consumed by microorganisms in only the filtered portion of the water. The organic material in the suspended solids is not included in this procedure since it is filtered out prior to the test. In general, BOD (Filter) tends to give a lower result than BOD (Total) because it does not include the organic matter in the suspended solids. When measuring the amount of biodegradable organic matter in the water, or in situations when the test's accuracy may be affected by the suspended solids in the water, BOD (Filter) may be more appropriate.

Table 3.1: Monthly Averages of Different Parameter Data (Grab Samples) for the Year 2018 at STP Amberpet, Hyderabad.

Parameter	Unit	January		February		March	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.51	7.99	7.58	8.05	7.60	8.07
Dissolved Oxygen	**mg/l**	0.10	4.97	0.09	4.94	0.13	4.55
Total Suspended Solids (TSS)	**mg/l**	41.5	137.4	134	20.0	399	49.6
Chemical Oxygen Demand (Total)	**mg/l**	528.5	68.5	564.1	81.6	576.1	93
Chemical Oxygen Demand (Filter)	**mg/l**	234.2	26.4	241.6	33.3	240.7	33.8
BOD for 3 days at 27^{0}C (Total)	**mg/l**	244.2	14.5	257.5	15.6	263.8	15.9
BOD for 3 days at 27^{0}C (Filter)	**mg/l**	117.8	6.8	125	7.25	128.4	7.6
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	535071	4718.2	555500	5337.25	554307	5359.7

Parameter	Unit	April		May		June	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**

pH		7.61	8.11	7.62	8.10	7.50	8.05
Dissolved Oxygen	**mg/l**	0.12	4.51	0.07	4.14	0.09	4.43
Total Suspended Solids (TSS)	**mg/l**	369	81.3	378.6	132.3	393.4	17.6
Chemical Oxygen Demand (Total)	**mg/l**	530.7	90.7	554.6	56.9	551.5	50.7
Chemical Oxygen Demand (Filter)	**mg/l**	225.3	33	246.9	18.4	245.3	16.1
BOD for 3 days at 27^{0}C (Total)	**mg/l**	260	19	253.8	13	240	9
BOD for 3 days at 27^{0}C (Filter)	**mg/l**	126.9	9.1	127.6	6.3	120.7	4.2
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	543153	5421.6	545692	4125.7	532692.3	3610.5

Parameter	**Unit**	**July**		**August**		**September**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.44	8.04	7.47	8.09	7.50	8.14
Dissolved Oxygen	**mg/l**	0.07	4.55	0.08	4.67	0.10	4.76
Total Suspended Solids (TSS)	**mg/l**	378.1	5.0	374.1	4.9	359.1	10.75
Chemical Oxygen Demand (Total)	**mg/l**	490.7	35.3	496.4	45	118.4	4.0
Chemical Oxygen Demand (Filter)	**mg/l**	220	11.5	231.4	16.0	477.5	53.3
BOD for 3 days at 27^{0}C	**mg/l**	124.6	5.3	113	4.6	119.1	8.3

(Total)							
BOD for 3 days at 27^0C (Filter)	**mg/l**	108.4	2.2	96.4	5.9	120.6	4.9
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	497461.5	2969.9	486000	3167	514250	3686.1

Parameter	**Unit**	**October**		**November**		**December**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.39	8.08	7.45	8.12	7.33	8.02
Dissolved Oxygen	**mg/l**	0.12	4.64	0.12	4.78	0.08	4.75
Total Suspended Solids (TSS)	**mg/l**	362.2	7.5	403.5	10.7	418	10.2
Chemical Oxygen Demand (Total)	**mg/l**	457.8	52.1	676.9	40	720.9	40.9
Chemical Oxygen Demand (Filter)	**mg/l**	211.4	20	294.6	13.4	338.1	14.5
BOD for 3 days at 27^0C (Total)	**mg/l**	258.5	7.7	246.9	7.6	273.6	7.1
BOD for 3 days at 27^0C (Filter)	**mg/l**	125	3.2	118.4	3.07	135	3.0
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	481500	3715.6	582846.1	3781.9	597000	3728.2

Table 3.2: Monthly Averages of Different Parameter Data (Composite Samples) for the Year 2018 at STP Amberpet, Hyderabad.

Parameter	**Unit**	**January**		**February**		**March**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**

pH		7.59	8.11	7.63	8.11	7.61	8.07
Dissolved Oxygen	**mg/l**	0.15	5.18	0.15	5.20	0.13	7.32
Total Suspended Solids (TSS)	**mg/l**	388.08	42.69	396.67	49.67	399.08	49.62
Chemical Oxygen Demand (Total)	**mg/l**	506.92	91.54	555.00	99.17	576.15	93.08
Chemical Oxygen Demand (Filter)	**mg/l**	229.23	41.54	250.00	47.50	240.77	33.85
BOD for 3 days at 27^{0}C (Total)	**mg/l**	225.38	15.00	251.67	17.00	263.85	15.92
BOD for 3 days at 27^{0}C (Filter)	**mg/l**	106.15	7.23	125.83	8.58	128.46	7.62
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	486915.3	4816.846154	526000	5106.75	567898	5359.77

Parameter	**Unit**	**April**		**May**		**June**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.12	8.08	7.32	8.67	7.23	8.21
Dissolved Oxygen	**mg/l**	0.11	4.65	0.42	4.72	0.14	3.31
Total Suspended Solids (TSS)	**mg/l**	378.15	5.08	357.31	4.13	359.17	4.01
Chemical Oxygen Demand (Total)	**mg/l**	490.77	35.38	470.00	43.85	477.50	88.96
Chemical Oxygen Demand (Filter)	**mg/l**	220.00	11.54	214.62	14.65	219.17	35.76
BOD for 3 days at 27^{0}C (Total)	**mg/l**	224.62	5.58	176.15	7.33	184.17	22.85
BOD for 3 days at 27^{0}C	**mg/l**	108.46	2.17	88.46	3.08	85.83	10.32

(Filter)							
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	501234	2969.92	501234	2871.00	501000	3650.36

Parameter	**Unit**	**July**		**August**		**September**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.44	8.04	7.52	8.17	7.50	8.08
Dissolved Oxygen	**mg/l**	0.07	4.55	0.22	4.92	0.10	3.71
Total Suspended Solids (TSS)	**mg/l**	378.15	5.08	357.31	4.13	359.17	40.01
Chemical Oxygen Demand (Total)	**mg/l**	490.77	35.38	470.00	43.85	477.50	88.96
Chemical Oxygen Demand (Filter)	**mg/l**	220.00	11.54	214.62	14.62	219.17	35.76
BOD for 3 days at 27^0C (Total)	**mg/l**	224.62	5.58	176.15	7.33	184.17	22.85
BOD for 3 days at 27^0C (Filter)	**mg/l**	108.46	2.17	88.46	3.08	85.83	10.32
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	528000	2969.92	463333	2871.00	506000	3650.36

Parameter	**Unit**	**October**		**November**		**December**	
		Influent	**Effluent**	**Influent**	**Effluent**	**Influent**	**Effluent**
pH		7.40	8.05	7.35	8.07	7.35	8.03
Dissolved Oxygen	**mg/l**	0.19	4.82	0.26	4.92	0.09	4.72

Total Suspended Solids (TSS)	**mg/l**	361.62	7.38	392.54	10.38	420.78	9.78
Chemical Oxygen Demand (Total)	**mg/l**	444.62	55.38	625.38	47.69	704.44	42.22
Chemical Oxygen Demand (Filter)	**mg/l**	206.15	22.31	290.00	17.69	333.33	14.44
BOD for 3 days at 27^0C (Total)	**mg/l**	153.85	8.54	208.46	8.54	271.11	7.33
BOD for 3 days at 27^0C (Filter)	**mg/l**	72.31	3.92	100.77	3.73	130.00	4.00
Fecal coliforms (X10^5 for influent)	**MPN/100 ml**	475500	3540.50	635667	3385.00	635667	3713.22

Data interpolation

In this chapter, there was a need to utilize statistical techniques to estimate missing or incomplete data points in the dataset. In particular, applied data interpolation to the sewage influent and effluent data for various parameters such as FC, VFA, sulfide, sulfate alkalinity, and DO. Data interpolation techniques were used, even in circumstances of missing or incomplete data, to ensure the accuracy and dependability of results. Interpolating missing data points improved the overall quality of the dataset and ensured that conclusions are based on the best possible information. Data interpolation is a technique used to estimate missing values within a dataset. It involves determining the values of the missing data using the values of the existing data. Data interpolation techniques include linear interpolation, polynomial interpolation, and spline interpolation, among others. Due to its simplicity and convenience of use, linear interpolation is a frequently used approach for estimating missing data values. It's crucial to keep in consideration that linear interpolation relies on the assumption that the rate of change between the known data points will always be constant. In general, linear interpolation is a valuable method for filling in the gaps left by missing data points, but it should be used with caution and alongside other techniques to produce reliable and precise outcomes.

Study area for effects on DO Saturation and Water Temperature using Air2Stream over Krishna River Basin, India.

The Krishna River Basin (KRB), which is the 4th largest river in India after the Ganga, Godavari, and Brahmaputra, is one of the primary irrigation sources for Telangana, Karnataka, Andhra Pradesh, and Maharashtra. Some of Krishna River's standout characteristics are the catchment area of 1400 km long Krishna River is 258948 sq km, and its latitude and longitude coordinates are 13° 10' to 19° 22' N and 73° 17' to 81° 9' E, respectively. At KRB, there are 53 hydrological observation stations maintained by Central Water Commission (CWC) and 9 flood forecasting stations under CWC. Some of the river stations in the KRB are Bawapuram, Cholachagudda, Halia, Haralahalli, Madhira, Marol, Paleru Bridge, Pondugala, Shimoga, Takli, T Ramapuram, Vijayawada and Wadenapalli. Only a few of the stations are considered for this case study. Figure 3.2 is the map of the KRB with river stations generated with the tool "QGIS" in which locations are utilized to construct the Air2Stream model and apply quality control to the time series of observed water temperatures that are available. Numerous studies have used linear, nonlinear, or both models to simulate the relationship between RWT and Air Temperature. When data is combined over longer (> 6 months) periods including numerous seasons, it is often accepted that logistic functions are required to reflect the sigmoidal correlations between and that are seen. Although simpler linear models are frequently chosen, logistic methods do not always outperform linear models. The Air2stream model is utilized to anticipate the RWT, and the optimal data for this study is an average of 16 years' worth of monthly data spanning 9 to 15 years.

Table 3.3: Data of different kinds of parameters such as Air Temperature, Water Temperature, and Discharge for Shimoga Station from the year 1992 – 2005.

Sta-tion	Year	Air Temperature (°C)	Water Temperture(°C)	Discharge (m^3/s)
Shimoga	1992	29.1	27.2	208.9
Shimoga	1993	28.7	27.1	169.6
Shimoga	1994	28.5	26.9	268.9
Shimoga	1995	29.1	27.6	131.8
Shimoga	1996	29.1	27.5	130.6
Shimoga	1997	29.1	27.4	106.2

Shimoga	1998	29.8	28.4	175.8
Shimoga	1999	28.8	27.8	198.4
Shimoga	2000	31.1	27.9	178.8
Shimoga	2001	29.9	28.2	136.3
Shimoga	2002	30.6	28.6	114.8
Shimoga	2003	30.2	28.1	110.4
Shimoga	2004	29.8	26.6	146.9
Shimoga	2005	29.8	25.9	195.7

Table 3.4: Data of different kinds of parameters such as Air Temperature, Water Temperature, and Discharge for Manthralayam Station from the year 1992 – 2005.

Station	Year	Air Temperature(°C)	Water Temperature(°C)	Discharge (m^3/s)
Manthralayam	1992	27.3	25.1	411.3
Manthralayam	1993	27.2	24.8	312.4
Manthralayam	1994	27.4	24.9	330.4
Manthralayam	1995	27.4	24.8	86.1
Manthralayam	1996	27.4	24.8	86.1
Manthralayam	1997	27	24.3	309.7
Manthralayam	1998	27.5	24.8	143.7
Manthralayam	1999	28.2	25.6	346.3
Manthralayam	2000	27.2	24.6	223.5

Manthralayam	2001	27.2	27.6	152
Manthralayam	2002	28.3	28.5	41.2
Manthralayam	2003	27.6	28.6	25.9
Manthralayam	2004	26.3	28.3	87.7
Manthralayam	2005	25.9	24.4	138

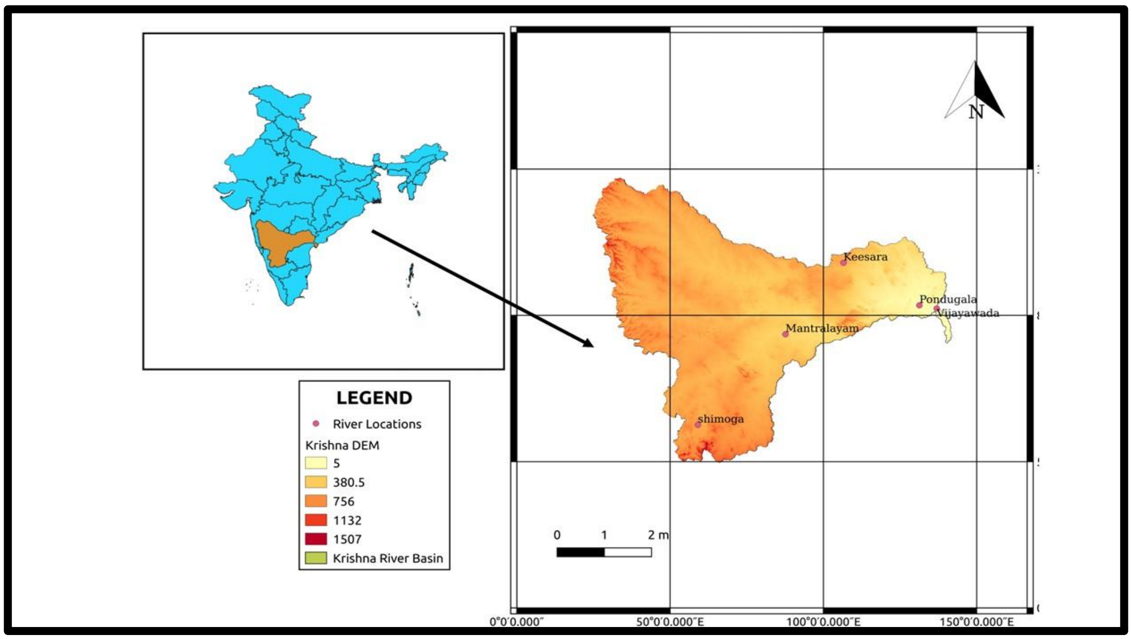

Figure 3.3.: Location map of Krishna River Basin with few stations, India.

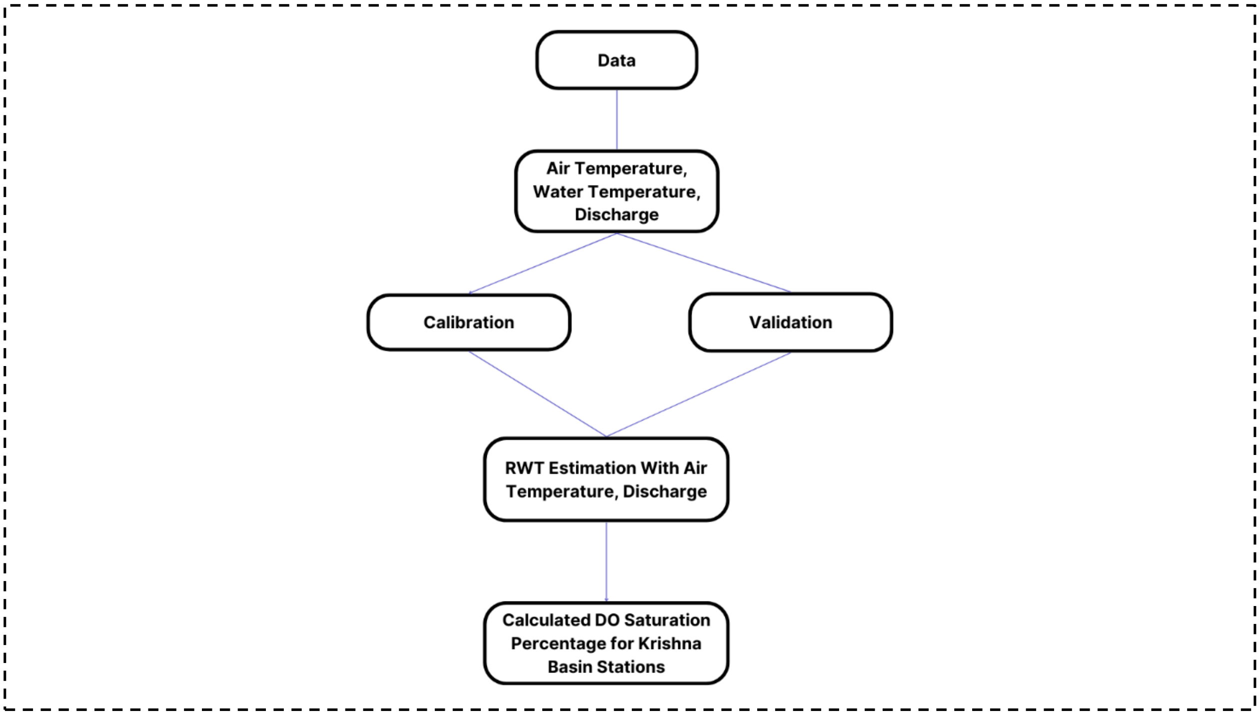

Figure 3.4: A flowchart designed for enhanced comprehension of the process for KRB Case Study.

3.4 Summary

The Amberpet STP is located in the Amberpet neighborhood of Hyderabad, India. A few major locations surrounding the STP are Osmania, LB Nagar, Charminar, Secundrabad, Hussain Sagar Lake and NTR Gardens, Rajeev Gandhi International Airport, and Hyderabad. Overall, the Amberpet STP is located in a densely populated area with easy access to major landmarks and transportation hubs in Hyderabad. HWMSSB has gathered information from the STP in Amberpet, Hyderabad and data is collected. Understanding how well the sewage treatment facility operates, data for the year 2018 has been gathered together with site inspections. While linear interpolation is a straightforward method for estimating missing data points, it's important to note that it may not always be the most accurate method. In some cases, the rate of change in the data may not be constant, which can result in inaccurate estimates. Additionally, linear interpolation may not work well if there are large gaps in the data or if the data contains outliers or other sources of noise. Overall, the choice of method for estimating missing data points depends on the characteristics of the data and the research question at hand. Researchers should carefully evaluate the strengths and weaknesses of different methods and choose the approach that is most appropriate for their specific needs.

Chapter 4

4. Performance Analysis of 339 MLD STP at Amberpet – Hyderabad.

4.1 Introduction

Due to public awareness of water pollution and scarcity, as well as the current water regulatory framework, there has been a growth in the number of wastewater treatment facilities during the last few decades [23]. WWTPs are currently a hot topic due to the significance of sustainable energy and water sources, as well as the accompanying carbon emissions, for urban growth [24]. These innovative processes are typically built on sophisticated biological treatment designs that combine reactors that are aerobic, anoxic, and anaerobic as well as internal recycling among the many unit-processes [25]. This demonstrates how the daily increase in water consumption coincides with population growth. In India, the average daily water consumption per person is from 90 to 100 gallons. There is a substantial amount of waste in addition to the use of water. The average waste generation per Indian inhabitant is 45 liters [26]. Water covers more than 75% of the Earth's surface, yet because the oceans and seas contain dangerously high quantities of salt, people cannot use the entire water supply for drinking or farming [27]. This pure water can be found in lakes, rivers, and other bodies of water. Hyderabad is one of the biggest cities in India. There were 10.2 million residents there in 2021, which is a definite sign of population growth. The 339 MLD STP in Amberpet is one of India's largest STPs. It purifies 339 million liters of water each day. To assess the plant's performance and develop cutting-edge control techniques, it is essential to have access to primary variables or effluent quality indicators such as COD, and TSS. Due to the high cost and time delay associated with real-time monitoring, it is typically difficult to measure these variables online. Several of these are typically determined offline in a laboratory with considerable uncertainty, creating an operational restriction [21]. The plant's mechanical wastewater treatment equipment includes an inlet channel, a coarse screen, a conveyor belt, a rake classifier, a distribution box, Detroit tanks, a division box, UASB Reactors, a compression system, a chlorine mixing tank, an effluent channel, and a biogas scrubber [27]. In recent years, India has been home to the development of many new technologies. UASB, anaerobic sludge blankets, membrane bioreactors, anaerobic filters, airbags (FAB), and other common procedures are a few examples. Each of these methods has benefits and drawbacks. The Amberpet STP develops UASB technology, which is the most economical of all the available systems.

4.2 Methodology

4.2.1 Primary Treatment

Coarse Screening: The mechanical gadget is positioned in the front. A screen is a device with uniform speed holes made up of parallel bars or rods and is the first unit operation used to remove large floating materials such as paper, fabric, wooden pieces, plastic, etc [3]. It is maintained in a screen channel at an angle of 30° to 60° to the horizontal and against the flow. Some of the screens and arms will rotate constantly, much like a plate moving in a parabolic system.

Skimming Tanks: Skimming tanks are used to remove oil and grease from wastewater flow [3]. It is a rectangular tank with an air application aperture at the bottom. If not completely eradicated, oil and grease contact will affect BOD removal at secondary treatment. Grease and oil cannot be used to dispose of wastewater effluents. Oil and grease are collected as byproducts. They cannot be separated by settling because the specific gravity of oil and grease is smaller than that of wastewater. As a result, the "flotation" method can be applied. When compressed air is applied at the bottom, oil and grease granules climb to the top and create a coating there. Water enters and since it is so heavy, it goes down [28]. It will be removed and dusted with very fine grit. It will be disturbed by a horn. To push along with water, the covered portion will be broken, and grit will be moved aside and picked up in the bin. An overflow device pumps the water that has overflowed using gravity [25]. This layer is manually or mechanically skimmed, and the byproduct is removed. The flotation process happens in the skimming tank.

Grit Removal: The purpose of the grit chamber is to remove grit from wastewater. Grit increases wear and tear and causes abrasion of mechanical equipment, including pipes and pumps at the treatment plant, if it is not removed [21]. Grit creates handling challenges since it settles quickly, and takes up the space that organic solids, a primary clarifier, should have. Two different types of particles make up grit.

(1) Inorganic grit [0.2 mm in size]

(2) Natural grit

The term "grit chamber" refers to a long, narrow rectangular channel with enhanced c/s dimensions that slows down the velocity and allows grit to settle. Slightly increasing water velocity causes settled grits to be scoured. Grit particles settle with a modest decrease in flow velocity, along with other substances. Therefore, regardless of flow rate, maintain a constant flow velocity of 0.3 m/sec during its operation. The exit of the grit chamber is equipped with a "Proportional weir," a velocity control mechanism. Water travels with the grit, and when rubber encounters the grit, water returns to the tank [21]. If the sand particles are larger than 40 mm, certain safety measures must be taken. 7 grit removals are scheduled in Amberpet station. If each of these seven grit removals is operating effectively, sewage water flows from them to the connected waterway. This procedure is called "pumping."

Figure 4.1: Coarse Screen at Amberpet STP.

(Photograph taken during a site visit by the author)

Figure 4.2: Conveyer Belt at Amberpet STP.

(Photograph taken during a site visit by the author)

Wastewater flows into the pumping station (Module 1 and Module 2). Both modules contain 9 functional motors. They often operate two motors from the modules depending on the volume. Pipes with a diameter of 1800 mm led to the secondary treatment. The name of this procedure is "Primary Treatment." The floating debris of various sizes can be dealt with using a coarse screen as part of the primary treatment, and the main screen will be followed by sand and fine grit before being removed by a broken mechanism [10]. In sedimentation tanks, scrapers are used to remove most of the solid particles in the sludge, which are subsequently pumped to a fine screen mechanism for sludge treatment [4]. Primary treatment is required, however, secondary treatment can be any of the available approaches. In this procedure, the number of modules is two. With the use of a 17-meter head, sewage water can be taken and then released through underground pipelines. The sewage water was up until this point pumped by gravity [29]. From this point forward, sewage water is released electrically. The hourly output volume of water for each pump is 2360 m^3. Cranes are set up to take care of these motors below the module's roof in a direction perpendicular to the motor, and they are secured with the aid of a belt or hook to keep them fixed to the foundation. If a repair is necessary, cranes are used to lift the motor and have it serviced [30]. The switches that control the motor's operation can be moved in all directions: up, down, and sideways. This motor typically experiences short-circuiting and burning issues.

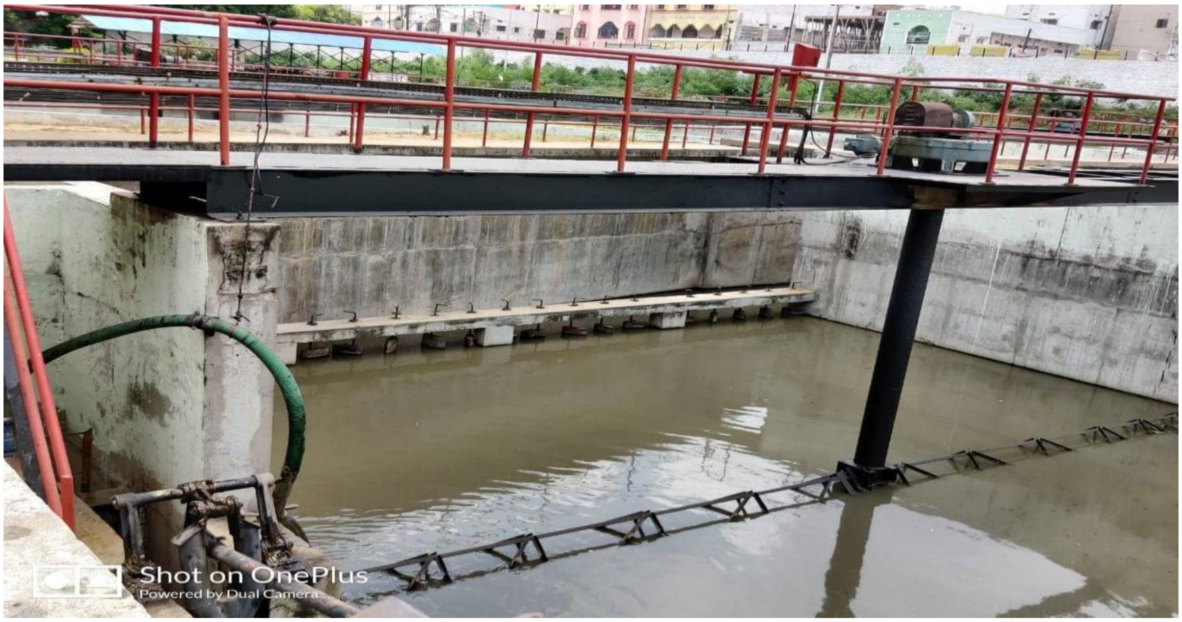

Figure 4.3: Process of treatment shown at Primary Treatment.

(Photograph taken during a site visit by the author)

4.2.2 Secondary Treatment

To get rid of soluble BOD, wastewater is subjected to secondary treatment. BOD is found in dissolved and colloidal forms. Physicochemical treatment and biological treatment eliminate soluble BOD from wastewater. Because they are expensive, physicochemical treatment technologies are typically the only ones used to treat wastewater that cannot be handled biologically [19]. For waste with a BOD/COD ratio under 0.6, this method works well. BOD/COD ratio more than 0.6 require biological waste management. This kind of treatment is pricey. There are two "primary division boxes" in the 339 MLD Amberpet STP, which are enormous tanks in this phase. Every module will be connected to the subsurface pumping that is used in the main treatment. The distribution box comes next, then the division boxes and subdivision boxes, and finally reactors. Here, sewage flows into reactors at a specific gravity [4]. Pumping will only be done up to this enormous tank. The Division Box is 900mm in diameter. Here, the volume drops while the velocity rises. Therefore, the relationship between velocity and volume is inverse. The pipeline connects "Module1" and "Module2" underground. A massive horizontal pipeline transports biogas from 24 reactors. Produce biogas, there are two units of one is always on while the other is on standby. It has a V-shaped form. There is a water connection termed a "valve" above the V-shaped pipe. The next step is to give water wash for the biogas, and all the acidic gasses—like carbon dioxide, H_2S, N_2, NO_2-, and ammonia—are dissolved and fall into the tank [27]. Biogas is treated with "Alkaline" [3] Salt and water are the byproducts of the reaction between acid and alkali. Salt contains water molecules as well as sodium hydroxide, sodium chloride, hydrogen Sulphide, and sodium sulfate. DO is not present in the water currently. The facultative Aerobic Lagoon (FAL) is maintained by water flowing into aerators. Methane gas leaves the system and ascends because it is lighter than air [31]. Using a compressor, it spreads the methane gas downward. The building blocks can be molecules, ions, or atoms. Volume is automatically reduced. The volume of solids and gas will vary significantly. Pressure has an inverse relationship with gas [32]. As a result, gas is transformed into heat energy and ignited using a spark plug. Heat energy is created by converting mechanical energy. The gas burns and releases heat energy after compression. Later, it is changed into mechanical energy. Different mechanical and screening procedures will be used to separate the coarse/floating material.

4.2.3 Aeration Tanks

Microorganisms are exposed to oxygen and food in a rectangular tank. Bacteria require oxygen to survive and it is useful for breaking down organic waste [28]. Since the water is pure, a covering is unnecessary. The polishing pond is filled with water that enters the tank through its exterior. The activated sludge that was created in the polishing pond can be used by farmers as a biofertilizer [33]. Following the disinfection process, the level of suspended particles is lowered to a level (60 mg/L) that is acceptable for the river to be reopened [3].

Figure 4.4: Process showing the treatment at Aeration tanks.

(Photograph taken during a site visit by the author)

Figure 4.5: Aeration Tanks.

(Photograph taken during a site visit by the author)

4.2.4 UASB Reactors

The UASB reactor's main objective is to treat wastewater. UASB reactors are only used for treatment forming high-rate anaerobic technology today. . It is an anaerobic digester used for treating or municipal wastewater. It is unique for its up-flow configuration where wastewater flows upward and sludge blanket allows anaerobic micro-organisms to efficiency treat organic pollutants the sludge bed and exits reactor. UASB reactors are effective for treating high-strength industrial waste. They are sensitive to temperature and their efficiency is influenced by moderate/high temperature conditions. Primarily removes organic matter only. It maybe not that effective for nutrient removal. As seen in the illustration, many boxes are present and divided into 90mm pipes that regulate the flow of water. The tanks are cleaned of heavy organic contaminants. Advance Membrane Bioreactors (MBR) that combines biological process with membrane filtration. In simple terms, it uses special membrane filtration along with microbes to clean and purify water more effectively.

4.2.5 Disinfection

The effluent water is given a 2-ppm chlorine addition. The process of encountering water and exiting through the contact basin takes 30 minutes. This will eliminate any leftover bacteria in the sewage water. Following the procedure that neutralizes the chlorine, sodium sulphide is added to eliminate it. Water is therefore suitable for irrigation.

Figure 4.6: Sewage Water after Treatment.

(Photograph taken during a site visit by the author)

4.3 Results & Analysis

4.3.1 Parameters Considered

The pH of wastewater is important to control. It should be between 6.5 and 8.5 to maximize the effectiveness of biological processes and prevent scaling, corrosion, and negative impacts on aquatic life.

pH can be monitored and controlled using automated sensors, manual titrations, or visual indicators. pH control agents can be added to adjust the pH to the desired range.

Wastewater temperature is an important factor in wastewater treatment. High temperatures can speed up biological reactions, which can be helpful or harmful depending on the treatment method. High temperatures can also affect the water's physical and chemical characteristics, such as DO content and pH level.

An essential parameter in wastewater treatment facilities (WWTPs) is dissolved oxygen (DO). The amount of oxygen that is dissolved in water and utilised by microbes to decompose organic matter is what is measured. The breakdown of organic material occurs during aerobic digestion, which takes place with oxygen present. For aerobic digestion to take place, sufficient DO levels are required. Low DO levels can make it difficult for microorganisms to function properly, which can result in insufficient treatment and potentially dangerous effluent. Numerous variables, such as temperature, salinity, pressure, the presence of other chemicals, and agitation, can have an impact on DO levels. For instance, high pressure can enhance DO levels while high temperatures can diminish them. Additionally, some compounds can absorb DO and lower its levels, such as chlorine. The right DO levels are maintained by WWTPs using a variety of methods, including agitation and aeration. Additionally, they frequently check DO levels to make sure they stay within the right range.

The quantity of organic material in wastewater is measured by COD. A helpful indicator for wastewater treatment and management, high levels of COD may point to the presence of contaminants that pose a risk to public health and the environment. Thus, one of the most important steps in the treatment of wastewater is to monitor and control COD levels.

The quantity of oxygen that bacteria use to break down organic materials in water is measured by a process known as biochemical oxygen demand, or BOD. It gauges how many organic contaminants are present in wastewater. Significant organic matter contamination, which can be bad for the environment and people's health, is indicated by high BOD levels. To make sure that treatment procedures are successful and that the water is safe to discharge into the environment, it is crucial to monitor BOD levels in wastewater.

Total suspended solids (TSS) are solids that can be filtered out of wastewater. High TSS levels can lead to blockages, reduced capacity, and altered water quality. TSS can come from home wastewater, stormwater runoff and industrial emissions. Sedimentation, filtration and biological treatment are the three most common methods for removing TSS. It is important to periodically evaluate TSS levels and implement the appropriate treatment procedures.

Alkalinity is the ability of water to neutralize acids. It is important for wastewater treatment because it helps to keep the water's pH level steady, which is essential for the efficient treatment of contaminants. Alkalinity can be calculated from the amount of bicarbonate, carbonate, and hydroxide ions present in the water. Alkaline chemicals can be added to change the alkalinity levels, such as soda ash or lime. It is essential to control and monitor alkalinity levels in wastewater in order to ensure effective treatment and avoid releasing untreated or insufficiently treated water into the environment.

Wastewater contains a contaminant called Sulphide. It can corrode infrastructure, emit a strong odour and destroy aquatic life and fish. If consumed or inhaled in excessive quantities, it can potentially be dangerous to people. Sulphide in wastewater can be controlled using treatment methods such chemical oxidation, biological treatment and physical removal. To avoid the production of Sulphide in the first place, it's crucial to handle and dispose of organic waste properly.

Sulphate is a naturally occurring substance that, at high amounts, is toxic to both the environment and people. Sewage, runoff, and industrial waste are few of the sources of wastewater that contain it. High sulphate concentrations can harm fish and other aquatic life, contribute to eutrophication, and result in digestive issues in people. Chemical precipitation, ion exchange, and biological therapy can all be used to remove sulphate from wastewater.

Volatile Fatty Acids (VFAs) are created when organic waste in wastewater is digested anaerobically. They are frequently discovered in municipal STPs, animal waste lagoons, and wastewater from food processing facilities. Some bacteria may receive energy from VFAs, which also act as a pH buffer for wastewater. High VFA concentrations, however, may have unfavourable outcomes, including less efficient wastewater treatment, decreased production of biogas, and the emergence of offensive odours. The harmful consequences of high VFA concentrations can be avoided by wastewater treatment plants using a variety of strategies.

Figure 4.7: Overview of the Primary and Secondary Treatments at Amberpet STP.

(Photograph taken during a site visit by the author)

Figure 4.8: Overview of the Sewage water at Amberpet STP.

(Photograph taken during a site visit by the author)

The effectiveness of treating sewage water

- The ability of a treatment plant to remove pollutants from wastewater is reflected in its ability to treat sewage. The kind of treatment procedure employed, the quality of the entering wastewater, and the operational circumstances of the treatment plant are some of the variables that determine how effective a treatment facility is.
- The effectiveness of sewage treatment can be evaluated in a number of ways. Measuring the difference between the concentration of contaminants in wastewater before and after treatment is one usual technique. For instance consider parameter BOD. By multiplying the difference between the BOD concentrations of the influent (raw wastewater) and the effluent (treated wastewater) by 100, it is possible to determine how effective a treatment facility is at removing BOD (biological oxygen demand).
- The rate of removal of nutrients like nitrogen and phosphorus, as well as TSS, BOD, and COD, are frequently used to assess an STP's overall effectiveness. A well-designed and properly operated treatment plant can achieve removal rates of up to 90% or more for these parameters.

- The effectiveness of sewage treatment, however, can be impacted by a number of variables, including changes in the entering wastewater's properties, variations in temperature, and the presence of harmful or inhibiting compounds. Therefore, it is important for treatment plant operators to constantly monitor the treatment process and make necessary adjustments to maintain efficient operation.
- The entire environmental impact of the treated wastewater should be calculated along with the efficiency of the treatment process. While a well-designed and operated treatment plant can significantly reduce the concentration of pollutants in the effluent, some pollutants may still be present at low concentrations. If these leftover contaminants are released into surface water bodies or are utilized for irrigation, they may harm the ecosystem and humans in general.
- In order to solve this problem, many treatment facilities include additional treatment procedures like disinfection or tertiary treatment to lower the amount of contaminants in the effluent even more. Disinfection techniques like chlorination or UV radiation can effectively get rid of dangerous bacteria in the effluent, whereas tertiary treatment methods like filtration or adsorption can get rid of residual impurities like nitrogen and phosphorus. Effective sewage treatment generally contributes significantly to protecting the environment and human health. By constantly monitoring

the treatment process and making the necessary adjustments, treatment plant operators can ensure that the effluent complies with legal criteria and is safe to release into the environment.

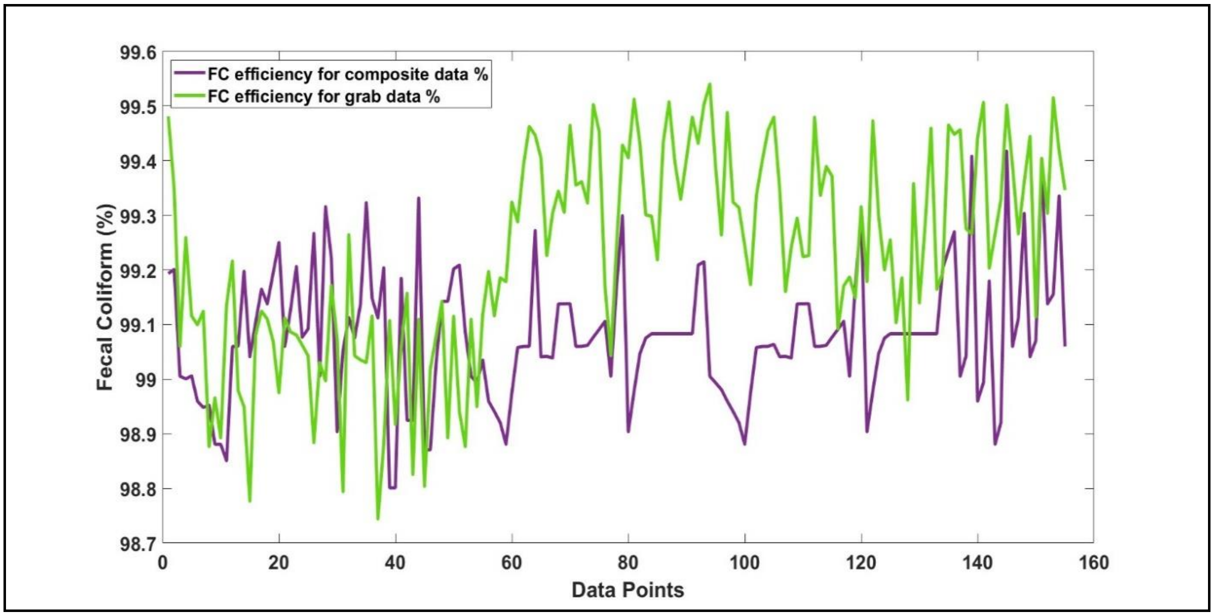

Figure 4.9: Graph to show the variation of Fecal Coliforms Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- The reduction of fecal coliforms in sewage water from 98.7% to 99.6% over one year is a significant improvement in water quality. Fecal coliforms are bacteria found in the intestines of mammals, including humans. Their presence in water can signal the presence of feces and possible pathogen contamination that could result in disease.
- The reduction in fecal coliforms suggests that the sewage treatment process is effectively removing or destroying these bacteria. This is important for protecting the environment and public health, as untreated sewage can contribute to the spread of diseases and harm aquatic life.
- Note that even with a high level of treatment efficiency, there may still be some residual fecal coliforms present in the treated water. To ensure that the water is safe for its intended use, it is crucial to adhere to the proper water quality standards and regulations.
- In summary, the reduction in fecal coliforms is a positive result that indicates effective treatment of the water. However, to ensure the safety and health of the environment and people in general, regular monitoring and adherence to water quality regulations are required.

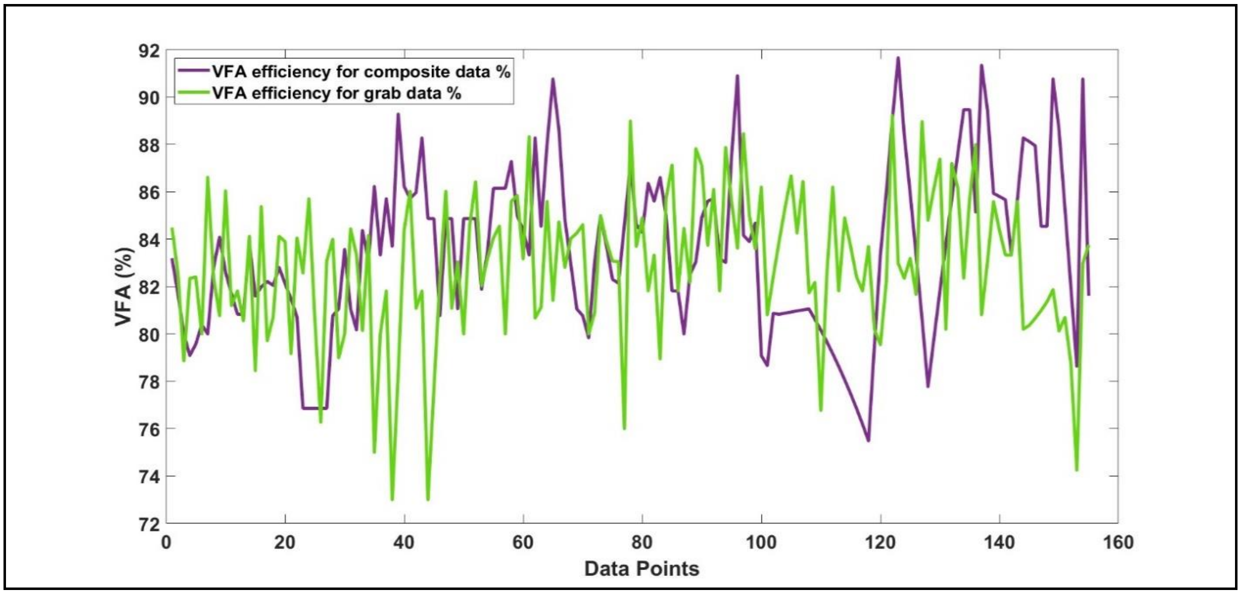

Figure 4.10: Graph to show the variation of Volatile Fatty Acids Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- The efficiency of VFA removal ranged from 72 to 92% over one year. This can be considered a good result, as it means that the treatment plant can remove a significant amount of VFAs from the incoming sewage. This is important for ensuring that the final effluent meets regulatory requirements and is safe for discharge into the environment.
- Anaerobic digestion techniques, which include the decomposition of organic materials by microorganisms without oxygen, are commonly used to remove VFAs. During this process, VFAs are produced as intermediate products, but they are typically further broken down into biogas and other byproducts.
- The adoption of modern treatment methods, such as MBRs or (ASBRs), can generally result in higher removal rates of VFAs. These processes can provide more efficient treatment of organic matter and produce higher-quality effluent.
- Overall, achieving a 72-92% removal rate of VFAs in sewage treatment is a positive result. However, it is important to continue monitoring and optimizing the treatment process to ensure that the highest level of efficiency is maintained over time.

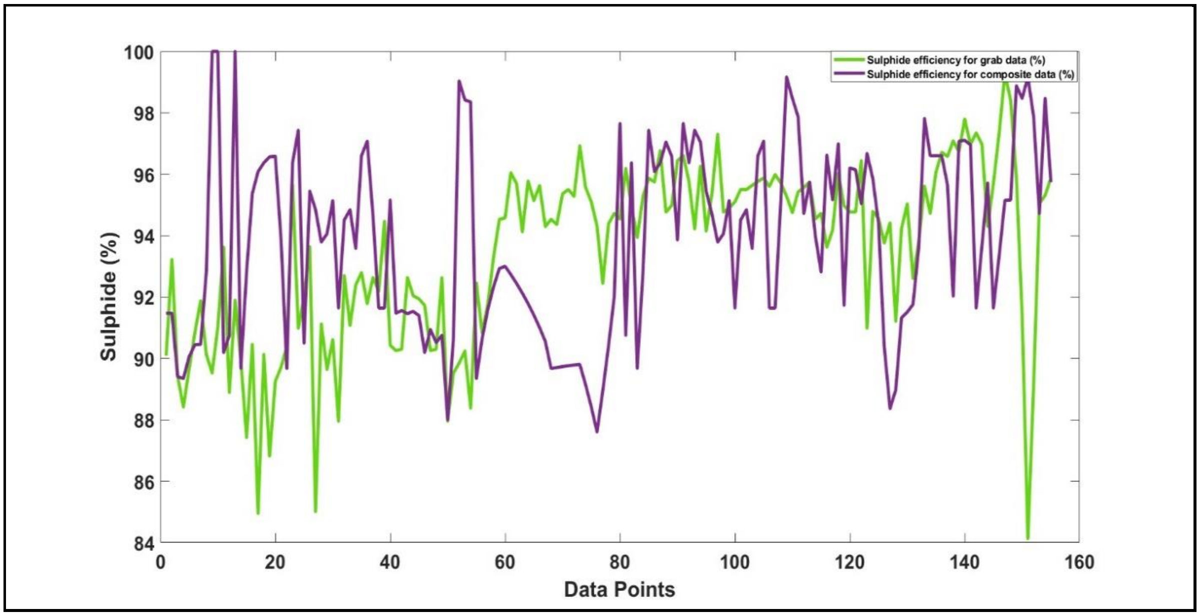

Figure 4.11: Graph to show the variation of Sulphide Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- For composite data, the efficiency of Sulphide removal in sewage water ranged from 87% to 100%, and for grab data, it ranged from 84% to 100%. This is a very effective level. However, on December 28th, 2018, the Sulphide removal effectiveness dropped to 84%. There could be several reasons for this temporary decrease in efficiency, such as equipment malfunction, changes in the quality or quantity of the incoming sewage, or changes in the operating conditions of the treatment plant.
- It's crucial to remember that a temporary decline in effectiveness does not always signify a serious issue with the course of treatment as a whole. However, it is essential to monitor and identify any trends or patterns in the efficiency of Sulphide removal to ensure that the treatment plant is operating efficiently and effectively.
- In conclusion, the overall efficiency of Sulphide removal in sewage water for the year 2018 was high. However, the temporary decrease in efficiency on December 28th, 2018, could be due to various factors, which need to be identified and addressed to ensure the continuous efficiency of the treatment process.

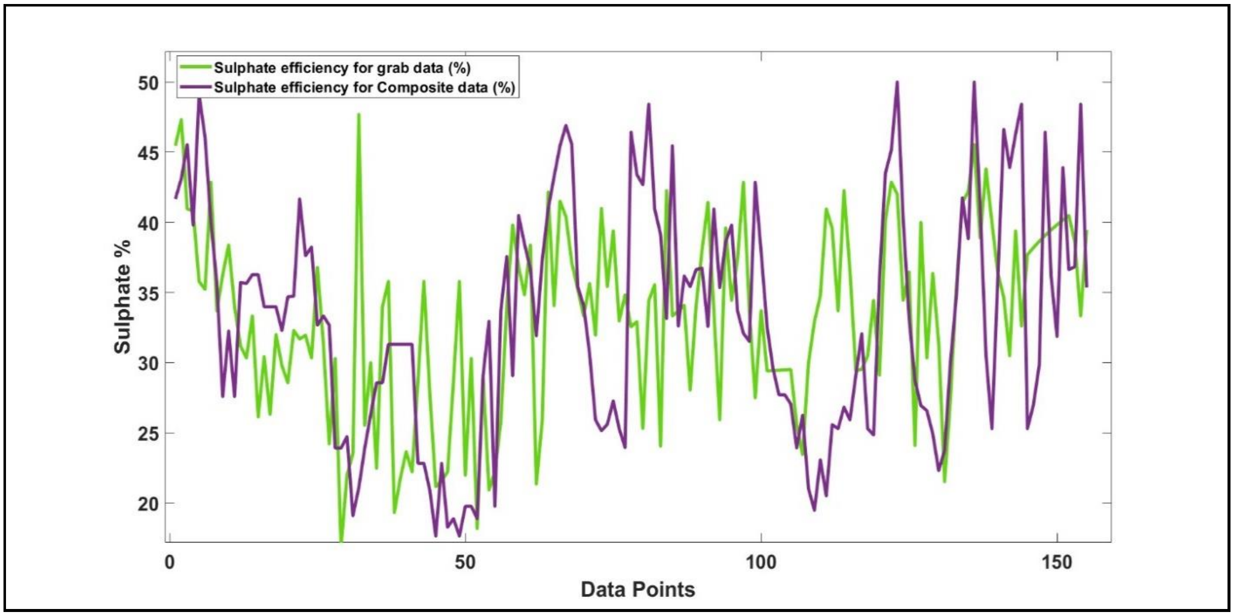

Figure 4.12: Graph to show the variation of Sulphate Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- In 2018, the sulphate removal efficiency of a particular STP ranged from 20% to 50%. This means that the treatment plant was only able to remove about half of the sulphate present in the incoming sewage water.
- Sulphate is a prominent pollutant present in sewage water that may be harmful to the environment. Sulphate concentrations above a certain threshold can cause the formation of toxic algae and the depletion of DO, both of which are bad for aquatic life.
- To improve the efficiency of sulphate removal in sewage treatment, it may be necessary to consider modifications to the treatment process. For example, the addition of chemical agents or the use of specialized membranes may help to improve the efficiency of sulphate removal. It is also important to monitor the quality of the incoming sewage water and make adjustments to the treatment process as needed to ensure that sulphate and other pollutants are effectively removed from the water before it is discharged into the environment.

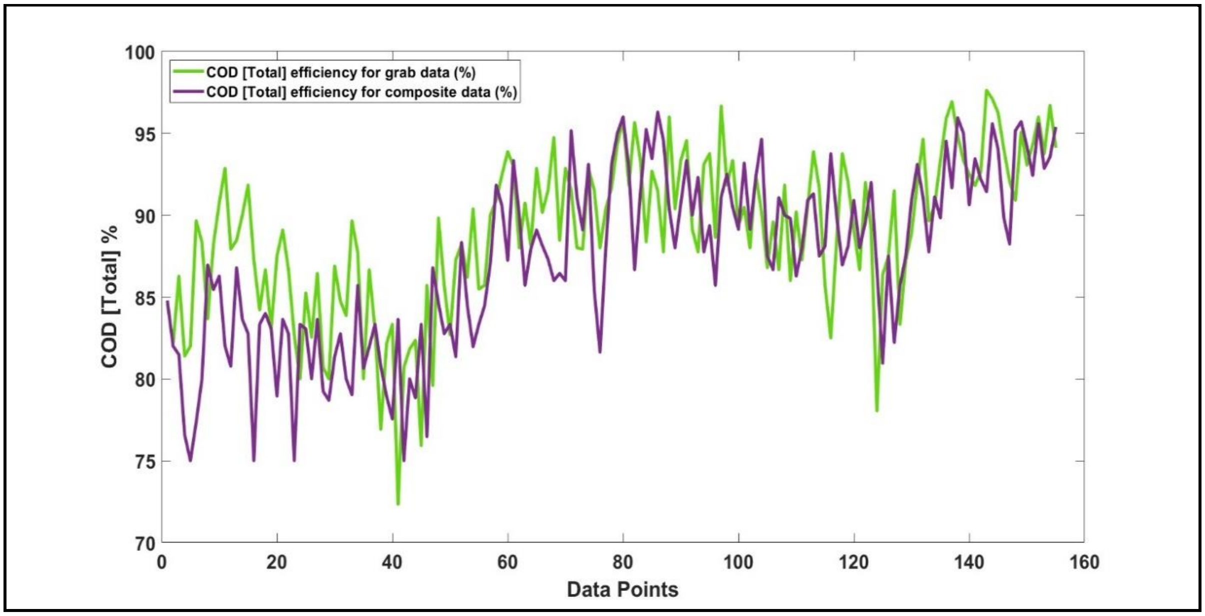

Figure 4.13: Graph to show the variation of COD (Total) Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- Over the course of a year in 2018, the effectiveness of COD (Total) removal in sewage water varied from 73 to 97 %. The amount of contaminants in the water increases with the COD (Total) value. The percentage of pollutants removed from the water during the treatment process is referred to as the COD (total) removal efficiency.
- A higher percentage indicates a more effective treatment process. A range of 73 to 97% efficiency suggests that the sewage treatment process is generally effective, but there may be some variations in the quality of the treatment over time. The effectiveness of the treatment procedure can be impacted by a variety of elements, including changes in the quality of the influent water, operational problems and operation of the treatment site.
- It's also crucial to keep in mind that COD (Total) is only one indicator of water quality; BOD, TSS, and pH may also be significant determinants.
- Overall, the data suggest that the sewage treatment process is generally effective at removing pollutants, but ongoing monitoring and analysis are necessary to ensure consistent performance and continued improvement of the treatment process.

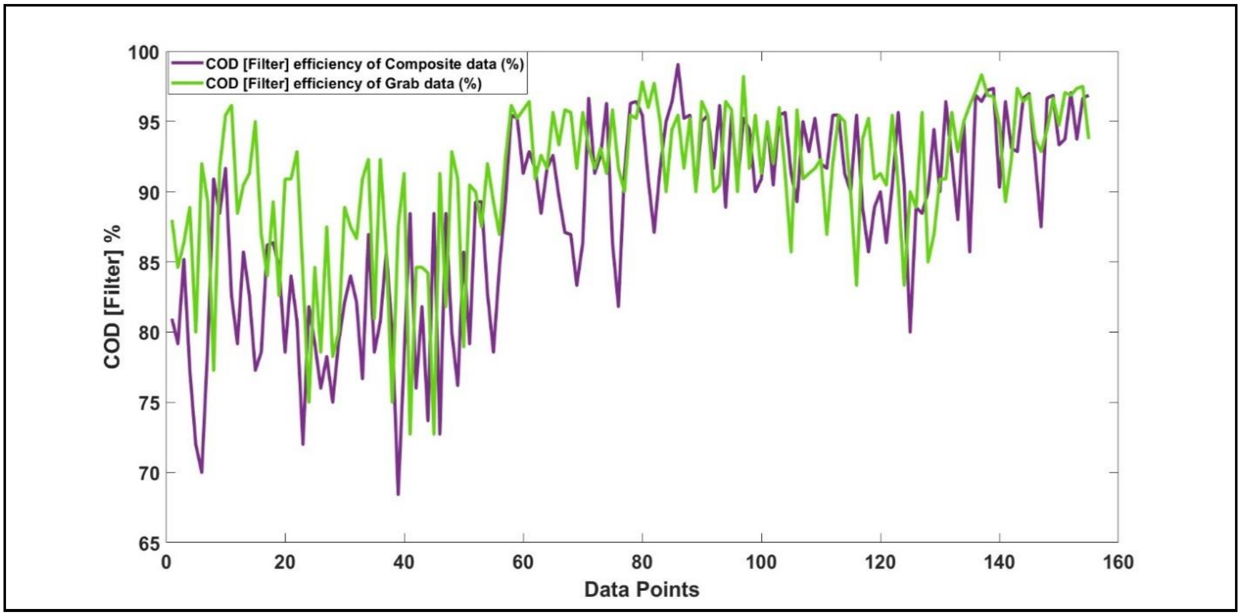

Figure 4.14: Graph to show the variation of COD (Filter) Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- The efficiency of COD removal in sewage water appears to be quite high, ranging from 68% to 100% over one year. This shows that the STP's treatment method for eliminating organic contaminants from water is effective.
- However, there was a sudden drop in efficiency to 50% on 28th April 2018. This is concerning and can point to a problem with the treatment procedure or a rise in the amount of pollutants in entering sewage water. To solve any potential difficulties and maintain the overall effectiveness of the sewage treatment process, it would be crucial to look into what caused this decline in efficiency.
- It is also important to keep in consideration that a number of variables, such as modifications in the properties of the incoming sewage water, variations in temperature, and modifications in the treatment plant's operational circumstances, may have an impact on the general effectiveness of the treatment process. Therefore, to ensure effective operation over time, ongoing monitoring and modification of the treatment process may be required.

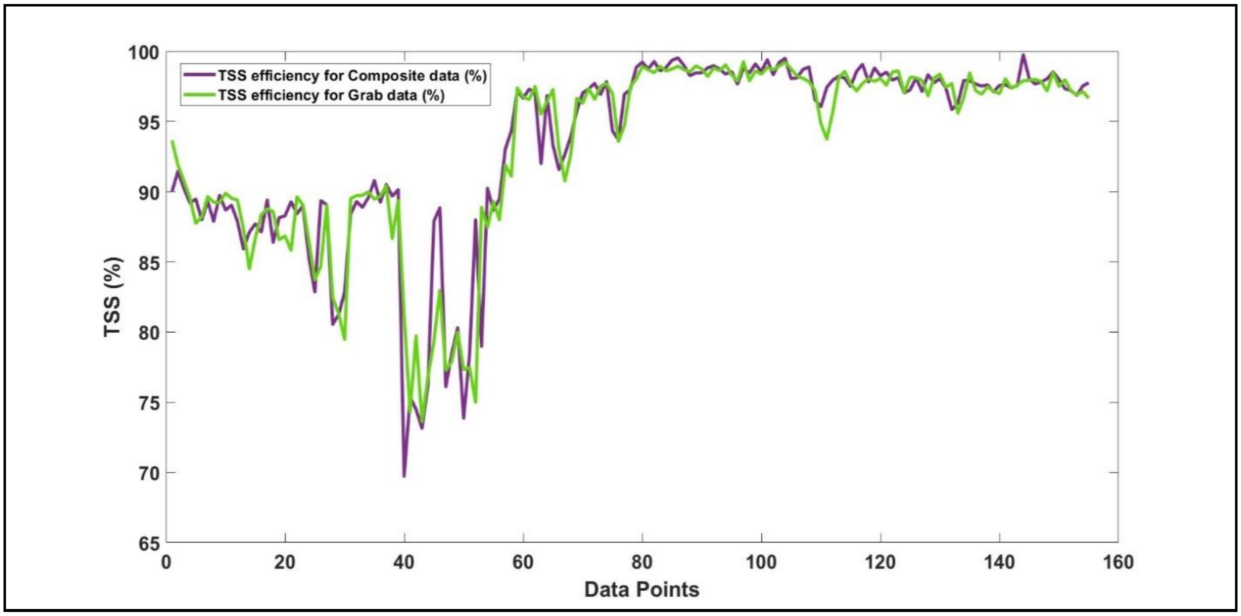

Figure 4.15: Graph to show the variation of TSS Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- Between 70% and 100%, TSS removal effectiveness in the STP was quite high in 2018. This means that the plant was effectively removing solid particles from the wastewater, resulting in a cleaner effluent that could be safely discharged into the environment.
- However, there was a decrease in the efficiency of TSS removal during April, followed by an increase in May. This could be caused by a number of changes, including modifications to the sewage's properties upon entry, adjustments to the treatment plant's operational circumstances, or adjustments to the weather or seasonal factors.
- In general, it's critical to keep a check on TSS removal effectiveness in the STP to make sure it's consistent and satisfies regulatory standards for discharge. If there are any significant changes in the efficiency of TSS removal, further investigation may be required to identify the root cause and take corrective action as needed.

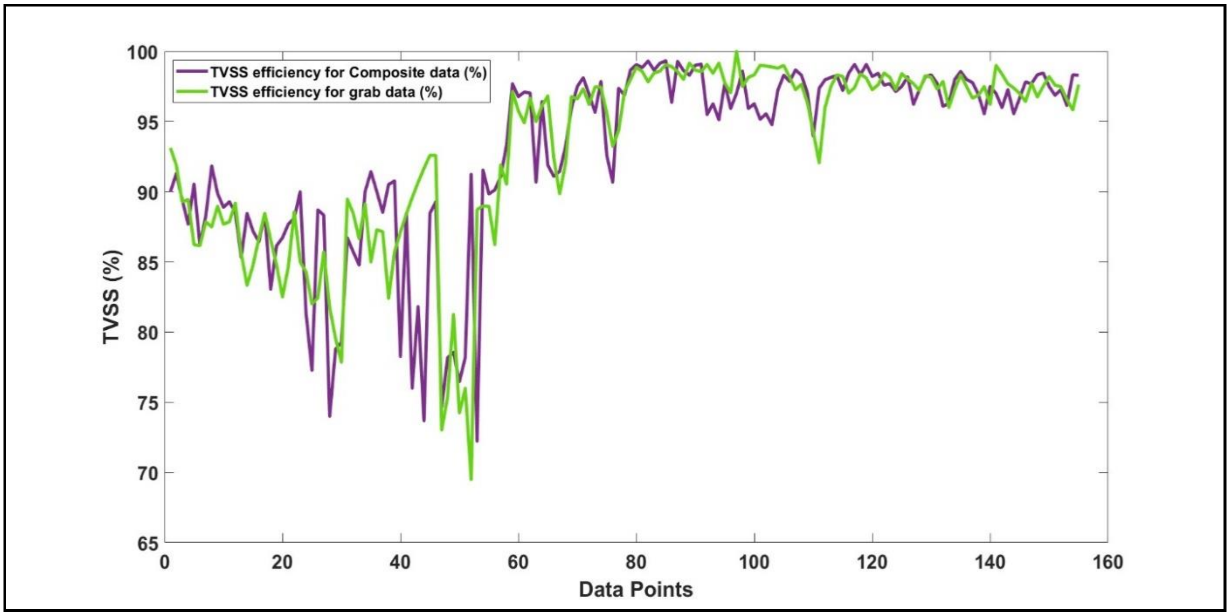

Figure 4.16: Graph to show the variation of TVSS Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- A study of WWTPs in 2018 found that the TVSS removal efficiency ranged from 70% to 100%. This is a relatively high level of efficiency, indicating that the anaerobic digestion process in the plants was operating effectively during that period.
- It's crucial to maintain in addition that TVSS removal effectiveness is only one aspect that affects how effectively sewage is treated overall. When assessing a WWTP's performance, additional factors including BOD, COD, and nutrient removal rates should also be taken into account.
- It is also critical to take into account any alterations in operating circumstances or maintenance procedures that can have an impact on the effectiveness of the treatment process, as well as any changes in the quality of incoming sewage over time. To maintain the best performance and effective operation of a WWTP, the treatment process must be continuously monitored and evaluated.

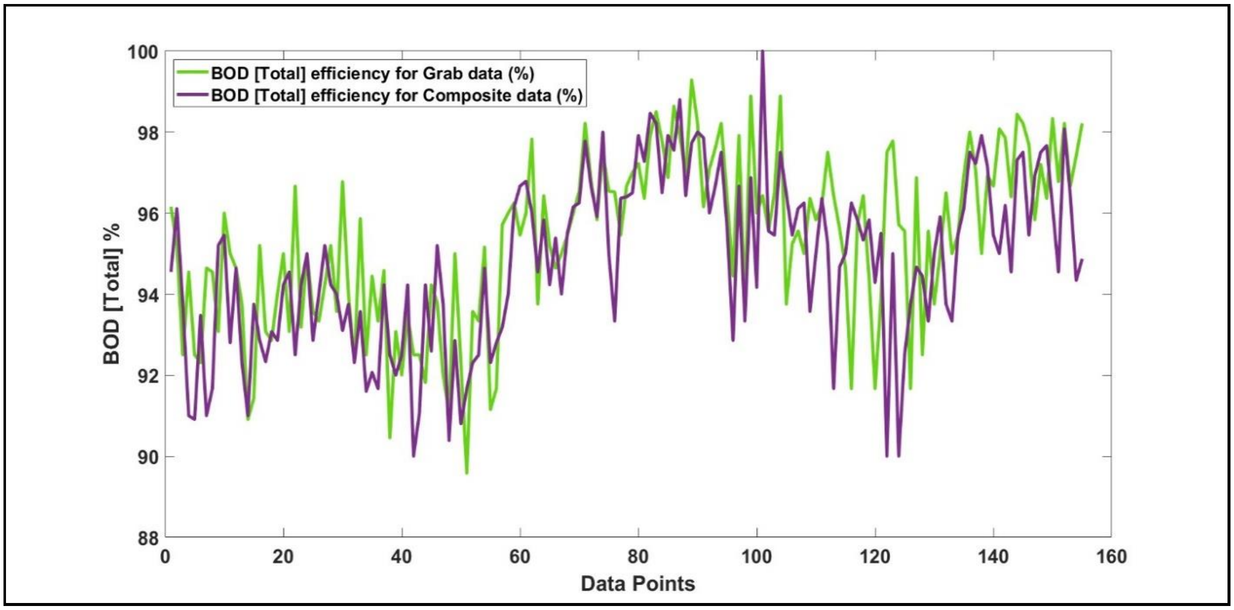

Figure 4.17: Graph to show the variation of BOD (Total) Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- A high BOD level in water indicates that it contains a significant amount of organic matter. This organic material can cause water bodies to become oxygen-depleted as bacteria break it down. This could result in the demise of aquatic life and have other detrimental effects on the environment.
- In 2018, the BOD levels in sewage water were reduced by 88 to 100% for both grab and composite data. This is a significant reduction and indicates that the sewage treatment process was efficient in removing organic matter from the water.
- The sewage treatment process was successful in eliminating the organic matter from the water as the BOD levels in the sewage water were reduced by 88 to 100%. To safeguard the ecosystem and the safety of everyone, sewage treatment must continue to operate at high levels of effectiveness.

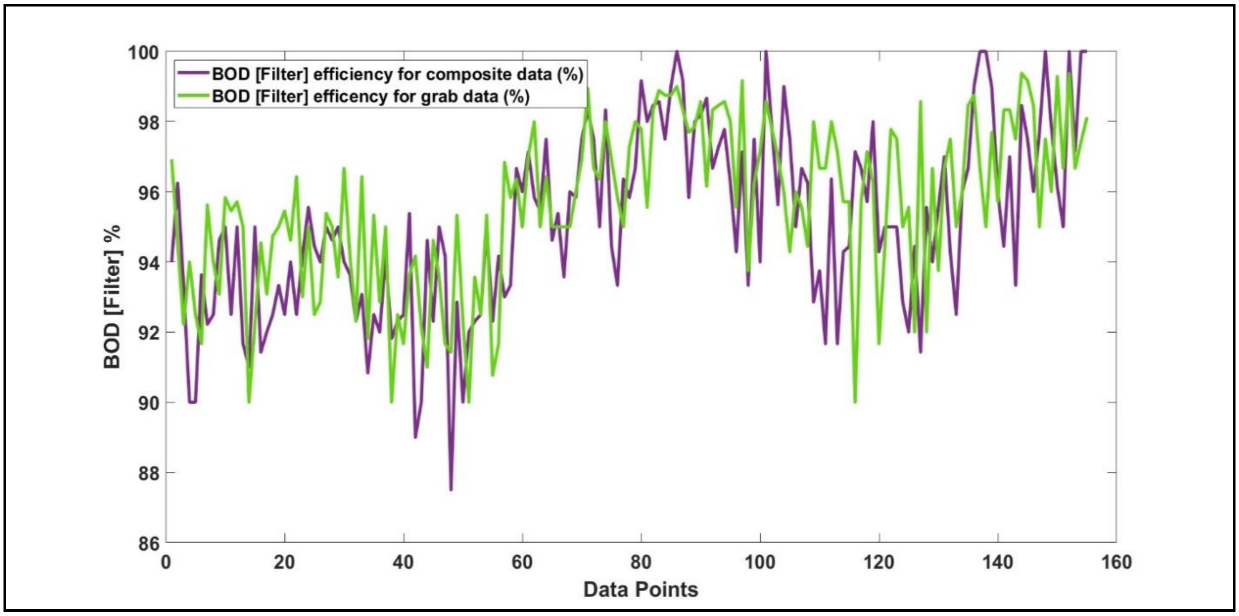

Figure 4.18: Graph to show the variation of BOD (Filter) Efficiency (%) for the year 2018 at Amberpet STP for Grab and Composite data.

- A study of a particular BOD filter found that the efficiency ranged from 88% to 100% over one year. However, on April 28th, 2018, the efficiency was only 87%. This lower efficiency suggests that something may have gone wrong on that day. It could be due to a variety of factors, such as a malfunction in the filter system or an unusually high load of organic matter in the sewage water.
- To better understand the cause of the lower efficiency on April 28th, 2018, there is a need to gather more information about the conditions on that day. For example, on examining the flow rate and temperature of the sewage water, as well as any maintenance or operational issues that may have occurred with the BOD filter. By analyzing these factors, one can able to identify the cause of the lower efficiency and take steps to prevent it from happening in the future.

Table 4.1: Comparative description of the efficiency of each parameter for each month:

Month	TSS	TVSS	COD (Total)	COD (Filter)	BOD (Total)	BOD (Filter)	Sulphate	Sulphide	Fatty Acids	Fecal Coliform
January	89.36%	89.01%	81.95%	81.69%	93.29%	93.13%	38.44%	91.82%	81.43%	99%
February	87.42%	85.90%	82.08%	80.99%	93.26%	93.20%	35.53%	95.48%	80.78%	99.13%
March	87.83%	86.25%	81.14%	79.56%	93.15%	93.23%	27.14%	94.24%	82.57%	99.11%
April	79.53%	80.16%	87.49%	68.41%	91.45%	95.96%	21.67%	90.20%	85.43%	99.10%
May	92.36%	91.92%	87.52%	89.50%	94.42%	94.70%	35.32%	93.29%	85.73%	99.01%
June	95.62%	95.02%	88.49%	89.69%	95.90%	95.95%	34.42%	89.58%	83.54%	99.08%
July	98.88%	98.74%	92.60%	94.09%	97.62%	98.24%	37.66%	93.74%	84.01%	99.07%
August	98.75%	96.23%	90.58%	93.07%	96.01%	96.66%	34.63%	95.01%	83.34%	99.01%
September	97.94%	97.74%	89.29%	92.60%	95.22%	92.63%	25.08%	95.39%	79.29%	99.08%
October	97.94%	97.86%	87.46%	89.18%	93.81%	94.52%	32.89%	93.35%	83.28%	99.07%
November	97.34%	97.13%	92.12%	93.69%	95.81%	96.55%	37.62%	95.16%	86.69%	99.07%
December	97.89%	97.33%	93.67%	95.01%	96.21%	98.13%	35.95%	96.09%	85.16%	99.08%

TSS: The efficiency ranges from a low of 79.53% in April to a high of 98.88% in July and August. Overall, the efficiency is generally high, with all months except April having an efficiency above 87%.

TVSS: The efficiency ranges from a low of 80.16% in April to a high of 98.74% in July. The efficiency is generally high, with all months having an efficiency above 85%.

COD (Total): The efficiency ranges from a low of 81.14% in March to a high of 93.67% in December. The efficiency is generally moderate to high, with all months except April and May having an efficiency above 87%.

COD (Filter): The efficiency ranges from a low of 68.41% in April to a high of 95.01% in December. The efficiency is generally moderate to high, with all months except April and March having an efficiency above 80%.

BOD (Total): The efficiency ranges from a low of 91.45% in April to a high of 97.62% in July. The efficiency is generally high, with all months except April having an efficiency above 93%.

BOD (Filter): The efficiency ranges from a low of 92.63% in September to a high of 98.13% in December. The efficiency is generally high, with all month except September having an efficiency above 94%.

Sulphate: The efficiency ranges from a low of 21.67% in April to a high of 37.66% in July. The efficiency is generally low, with all months except July and August having an efficiency below 35%.

Sulphide: The efficiency ranges from a low of 89.58% in October to a high of 96.09% in December. The efficiency is generally high, with all months except June having an efficiency above 80.78%.

Fatty Acids: The efficiency ranges from a low of 79.29% in September to a high of 86.69% in November. The efficiency is generally moderate, with all months except February having an efficiency below 87%.

Fecal Coliform: The efficiency is consistently high, with all months having an efficiency above 99%.

Overall, the results suggest that the wastewater treatment process is generally effective in removing the targeted parameters, but there may be scope for improvement in certain areas. It is crucial to keep a check on the treatment process's efficiency levels in order to spot any areas that might need improvement and to guarantee that all regulations are being met. The potential effects of treated wastewater on the environment must also be taken into account. Even though the efficiency levels of the treatment process appear to be generally high, there may still be residual contaminants present in the treated water that could have harmful impact on the ecosystem if discharged improperly. It is important to ensure that the treated water meets the regulatory requirements for discharge and to consider the potential environmental impact when designing and operating the treatment process. Additionally, constant research and development in the field of wastewater treatment may result in new and improved treatment techniques, which could enhance the effectiveness and environmental impact of the treatment procedure. This emphasizes how crucial it is to conduct continuing research and innovation in the field of wastewater treatment in order to maintain the preservation of both ecosystems and the health of the public.

4.3.2 Seasonal Variation in Efficiency

This study analyzed the seasonal performance of a STP in Amberpet, Hyderabad by examining the removal efficiencies of various parameters over a year by dividing it into four categories.

a Winter (December to February)

b Pre-monsoon (March to May)

c Monsoon (June to September)

d Post-monsoon (October to November).

STP seemed to have trouble sustaining constant removal efficiency during the winter, with certain metrics falling as low as 80%. This is likely due to the colder temperatures during this time, which may slow down the biological processes and negatively impact the STP performance. In contrast, during the pre-monsoon and monsoon months, the STP performed relatively well, with consistently high removal efficiencies of TSS, TVSS, COD, BOD, and Fecal Coliform. This may be due to the higher temperatures during these months, which may enhance the biological processes in the STP, leading to better performance. While some parameters, such as TSS and TVSS, remained consistently high, others, such as COD and BOD, showed a decline in efficiency. Changes in influent quality and quantity are among the possible cause for this. However, overall, the STP performance during this season was still better than during the winter months.

It is important to note that the performance of the STP in Hyderabad, India is seasonal and is affected by local temperature conditions. This result is in accordance with earlier research that examined the seasonal performance of STPs in different regions. By understanding the seasonal trends in STP performance, operators can optimize their processes and adjust their treatment strategies accordingly.

As a result, this study offers insightful information about the seasonal performance of STP in Hyderabad, India. Despite the fact that STP efficiency varies by season, results point to the pre-monsoon and monsoon months as having the highest removal efficiencies. The design and operation of STPs in Hyderabad and other areas with comparable climatic circumstances would be significantly impacted by these findings.

Moreover, in addition to the seasonal trends observed in the STP performance, it is also crucial to note that the removal efficiencies for different parameters varied significantly. For instance, while the removal efficiency for TSS and TVSS remained high throughout the year, the removal efficiency for COD and BOD was comparatively lower during the winter months. Similarly, the removal efficiency for Fecal Coliform was consistently high, indicating that the STP was effective in removing pathogenic microorganisms from the wastewater. On the other hand, the removal efficiency for other parameters such as Sulphate, Sulphide, and Fatty Acids varied significantly and showed a comparatively lower removal efficiency throughout the year. These variations in the performance of different parameters indicate that each parameter has a different removal mechanism and that their performance is affected differently by the local temperature conditions.

Understanding the seasonal trends in the STP performance is vital in developing effective strategies to improve its performance during the winter months. For instance, appropriate measures such as providing adequate insulation and heating systems could be implemented to maintain the optimal temperature for the biological processes in the STP during the winter months. Moreover, regular monitoring and maintenance of STP's equipment could also help in identifying any operational issues and addressing them promptly.

Furthermore, it is essential to analyze STP's performance over an extended period to identify any long-term trends and develop effective strategies to ensure its sustainable operation. Thus, future studies could focus on analyzing STP's performance over multiple years and consider other factors such as influent quality, quantity, and treatment processes to gain a comprehensive understanding of its performance. These investigations could contribute to the creation of STP management strategies that are efficient and provide safeguards for the public's health and the environment.

4.3.3 Efficiencies of each parameter of Grab and Composite data together with Seasonal Variation (winter, Pre-monsoon, Monsoon, Post-monsoon)

Seasonal Variation for TSS

The efficiency of TSS removal using grab and composite data fluctuated throughout the year. The lowest efficiency was 83.4% in early January, and the highest efficiency was 99.7% in early February. In general, monsoon season efficiency was higher than other seasons' efficiency. The fluctuation in efficiency can be attributed to various factors, including changes in influent water quality, variations in treatment process parameters, and operational issues at the plant.

- Winter: The efficiency of TSS removal using grab data fluctuated between 84% and 98% and the efficiency of TSS removal using composite data fluctuated between 90% and 99.7%.
- Pre-monsoon: The efficiency of TSS removal using grab data ranged from 70% to 96% and the efficiency of TSS removal using composite data was consistently above 95%.
- Monsoon: The efficiency of TSS removal using grab data mostly fluctuated between 91% and 99% and the efficiency of TSS removal using composite data was relatively stable in July and August, with values above 98.5%
- Post-monsoon: The efficiency of TSS removal using grab data ranged from 95.5% to 98.5% and the efficiency of TSS removal using composite data fluctuated between 97.5% and 98%.

Seasonal Variation of TVSS

With some variations throughout the pre-monsoon and monsoon seasons, the effectiveness of both grab and composite data was excellent overall throughout the year. The efficiency of composite data was generally higher than that of grab data.

- Winter: The efficiency of grab data ranged from 84.5% to 99% during the winter season, with a general trend of increasing efficiency and the efficiency of composite data started at 90% and dropped down to 78% by the end of January. It then picked up to 95% in early February and fluctuated between 95% and 99% after mid-February.

- Pre-Monsoon: The efficiency of grab data fluctuated between 70% and 95% during the pre-monsoon season, with no clear trend, and the efficiency of composite data gradually increased until the beginning of April, and it reached its highest point at the end of May, at 95%.
- Monsoon: The efficiency of grab data started at 90% in early June and increased steadily to a peak of 100% in early August. It then began to decline, reaching a low of 92% in mid-September before rising again to 98% at the end of the month the efficiency of composite data started at 90.2% in mid-June and fluctuated between 90.2% and 98.8% until reaching a low of 98.3% in mid-August. After mid-August, the efficiency of the composite data stabilized and remained between 96% and 98% for the rest of the period.
- Post-Monsoon: The efficiency of grab data fluctuated between 96% and 99% throughout the post-monsoon season and the efficiency of composite data showed an initial efficiency of 98.3%, which then increased to 99% at the beginning of October and maintained consistency until the end of October. However, the efficiency then dropped to 95.5% immediately and fluctuated between 95.5% and 97.5% at the end of November.

Seasonal Variation of COD [Total]

The efficiency of COD removal varied seasonally, with the highest efficiency during winter and the lowest efficiency during monsoon.

- Winter: The efficiency of COD removal fluctuated between 80% and 98%, with an average of 90%.
- Pre-monsoon: The efficiency of COD removal fluctuated between 72% and 94%, with an average of 83%.
- Monsoon: The efficiency of COD removal fluctuated between 83% and 97%, with an average of 90%.
- Post-monsoon: The efficiency of COD removal fluctuated between 78% and 96%, with an average of 87%.

The efficiency of COD removal was also affected by the type of data collected. Grab data, which is collected at a single point in time, showed a wider range of efficiency values than composite data, which is collected over some time. This is because grab data is more susceptible to fluctuations in the efficiency of COD removal. Overall, the efficiency of COD removal was high throughout the year, with an average of 88%. The highest efficiency was observed during winter when the weather is cold and there is less rainfall. The lowest efficiency was observed during monsoon when the weather is warm and there is a lot of rainfall.

Seasonal Variation of COD [Filter]

The effectiveness of removing COD varied seasonally, with the highest efficiency during winter and the lowest efficiency during monsoon.

- Winter: The effectiveness of removing COD using grab data fluctuated between 73% and 97%, with an average of 89%. The efficiency of COD removal using composite data fluctuated between 72% and 90%, with an average of 81%.
- Pre-monsoon: The effectiveness of removing COD using grab data fluctuated between 74% and 92%, with an average of 83%. The efficiency of COD removal using composite data fluctuated between 75% and 94%, with an average of 84%.
- Monsoon: The effectiveness of removing COD using grab data fluctuated between 83% and 97%, with an average of 90%.
- Post-monsoon: The effectiveness of removing COD using grab data fluctuated between 84% and 98%, with an average of 91%. The efficiency of COD removal using composite data fluctuated between 80% and 86%, with an average of 83%.

The efficiency of COD removal was also affected by the type of data collected. Grab data, which is collected at a single point in time, showed a wider range of efficiency values than composite data, which is collected over a while. This is due to the reason that grab data is more responsive to changes in the effectiveness of COD removal. Overall, COD removal efficiency was high throughout the year, with an average of 86%. The highest efficiency was observed during winter when the weather is cold and there is less rainfall. The lowest efficiency was observed during monsoon when the weather is warm and there is a lot of rainfall. Late in January, composite data efficiency suddenly dropped. This decline may have been caused by operational problems or changes in influent characteristics. The sudden increase in efficiency for composite data in early February could be due to changes in operational practices or adjustments made to the treatment process. The efficiency of COD removal using grab data was consistently higher than the efficiency of COD removal using composite data. This is likely since grab data is more susceptible to fluctuations in the efficiency of COD removal. However, the overall efficiency of COD removal was high for both grab data and composite data, indicating that the treatment plant is performing well and is effectively removing COD from the wastewater.

Seasonal Variation of BOD [Total]

The efficiency of BOD (Total) removal using both grab and composite data is generally high, except for a few periods during the pre-monsoon and monsoon seasons.

- During the winter season, the efficiency of BOD (Total) removal using grab data ranges between 91% and 98.5%, with the lowest point being 91% at the beginning of January, and the highest point being 98.5% in early February. Using composite data, the efficiency ranges between 91% and 98%, with the lowest value being at the start of winter and the highest value being in mid-February.
- During the pre-monsoon season, the efficiency of BOD (Total) removal using grab data ranges between 90% and 98%, with the lowest point being 90 at the end of March, while the highest was 97 in mid-May. Using composite data, the initial efficiency was at 94 and dropped slightly to 90 towards the end of March. It then gradually increased to 96 in mid-May, which was the highest efficiency of all. Towards the end of May, the efficiency dropped to 94 again.
- During the monsoon season, the efficiency of BOD (Total) removal using grab data fluctuates between 92% and 99% for most of the monsoon season. The lowest efficiency point was in late September at 92%, and the maximum efficiency point was in mid-July at 99%. The efficiency rate fluctuated in between but largely remained steady throughout the season. Using composite data, the efficiency fluctuates from 92% to 100%. The highest efficiency point was at the beginning of August at 100%, while the lowest efficiency point was in the middle of September at 92%.
- During the post-monsoon season, the efficiency of BOD (Total) removal using grab data fluctuated between 92% and 98% throughout the season. The lowest efficiency point for grab data occurred at the start of October and mid-October, and the highest efficiency point occurred at the end of November. Using composite data, composite data started at 95% and fell to its lowest point of 90% in mid-October. After that, it slightly increased to 94.5% at the start of November and maintained a consistent efficiency of 97.5%, which was the highest efficiency point recorded in the season, and later fell to 95% by the end of November.

Overall, the data shows that the efficiency of BOD (Total) removal is generally high, except for a few periods during the pre-monsoon and monsoon seasons. The following are some possible reasons for the observed fluctuations in efficiency.

Seasonal Variation of BOD [Filter]

The efficiency of BOD removal varied seasonally, with the highest efficiency during winter and the lowest efficiency during monsoon.

- Winter: The efficiency of BOD removal using grab data fluctuated between 92% and 98%, with an average of 95%. The efficiency of BOD removal using composite data fluctuated between 90% and 97.5%, with an average of 94.5%.
- Pre-monsoon: The efficiency of BOD removal using grab data fluctuated between 90% and 98%, with an average of 94%. The efficiency of BOD removal using composite data fluctuated between 94% and 97%, with an average of 95.5%.
- Monsoon: The efficiency of BOD removal using grab data was 100%. The efficiency of BOD removal using composite data fluctuated between 94% and 97%, with an average of 95.5%.
- Post-monsoon: The efficiency of BOD removal using grab data fluctuated between 88% and 97.4%, with an average of 93.2%. The efficiency of BOD removal using composite data fluctuated between 88% and 97.4%, with an average of 92.7%.

Overall, the efficiency of BOD removal was high throughout the year, with an average of 94.5%. The highest efficiency was observed during winter when the weather is cold and there is less rainfall. The lowest efficiency was observed during monsoon when the weather is warm and there is a lot of rainfall. The efficiency of BOD removal using grab data was consistently higher than the efficiency of BOD removal using composite data. This is likely since grab data is more susceptible to fluctuations in the efficiency of BOD removal. However, the overall efficiency of BOD removal was high for both grab data and composite data, indicating that the treatment plant is performing well and is effectively removing BOD from the wastewater.

Seasonal Variation of Sulphate

The efficiency of sulphate removal varied seasonally, with the highest efficiency during winter and the lowest efficiency during monsoon.

- Winter: The efficiency of sulphate removal using grab data fluctuated between 26% and 47%, with an average of 36.5%. The efficiency of sulphate removal using composite data fluctuated between 25% and 50%, with an average of 37.5%.

- Pre-monsoon: The efficiency of sulphate removal using grab data fluctuated between 17% and 47%, with an average of 32%. The efficiency of sulphate removal using composite data fluctuated between 17% and 40%, with an average of 28.5%.
- Monsoon: The efficiency of sulphate removal using grab data fluctuated between 24% and 43%, with an average of 33.5%. The efficiency of sulphate removal using composite data fluctuated between 21% and 32%, with an average of 26.5%.
- Post-monsoon: The efficiency of sulphate removal using grab data fluctuated between 23% and 45%, with an average of 34%. The efficiency of sulphate removal using composite data fluctuated between 25% and 47%, with an average of 36%.

Overall, the efficiency of sulphate removal was high throughout the year, with an average of 35.5%. The highest efficiency was observed during winter when the weather is cold and there is less rainfall. The lowest efficiency was observed during monsoon when the weather is warm and there is a lot of rainfall. The efficiency of sulphate removal using grab data was consistently higher than the efficiency of sulphate removal using composite data. This is likely since grab data is more susceptible to fluctuations in the efficiency of sulphate removal. However, the overall efficiency of sulphate removal was high for both grab data and composite data, indicating that the treatment plant is performing well and is effectively removing sulphate from the wastewater.

Seasonal Variation of Sulphide

- Both the grab data and the composite data show that the efficiency of sulfide removal was high overall, except for a few minor fluctuations.
- The effectiveness varied from 93% to 97% during the monsoon season, when it was at its peak. The efficiency ranged from 85.5% to 96% and 91% to 97.5%, respectively, during the pre-monsoon and post-monsoon seasons.
- There were a few minor fluctuations in the efficiency of sulfide removal during the study period. At the end of March and beginning of April, a minor decline in efficiency, however this could be attributable to modifications made to the water source or treatment processes.
- There was also a significant drop in the efficiency of sulfide removal towards the end of October, but this could be due to several factors, such as changes in weather conditions or increased levels of pollutants in the water. Overall, the data shows that the efficiency of sulfide removal was high overall and consistent throughout the study period. The only minor fluctuations in efficiency could be attributed to changes in water sources, treatment techniques, or weather conditions.

Seasonal Variation of Volatile Fatty Acids

The data shows that the efficiency of VFA removal using grab data and composite data was high overall, except for a few minor fluctuations. The efficiency was highest during the monsoon season when it ranged from 76 to 87 for grab data and 76 to 90 for composite data. The efficiency was slightly lower during the pre-monsoon and post-monsoon seasons, ranging from 73 to 88 and 76 to 81, respectively. There were a few minor fluctuations in the efficiency of VFA removal during the study period. The end of March and beginning of April saw a modest decline in efficiency, however this could be due to modifications made to the water source or treatment methods. There was also a significant drop in the efficiency of VFA removal towards the end of October, but this could be due to several factors, such as changes in weather conditions or increased levels of pollutants in the water. Overall, the data shows that the efficiency of VFA removal was high overall and consistent throughout the study period. The only minor fluctuations in efficiency could be attributed to changes in water sources, treatment techniques, or weather conditions.

- The efficiency of VFA removal was higher for composite data than for grab data. This could be because composite data is a more accurate representation of the overall efficiency of the treatment process, as it is based on a larger sample size.
- The efficiency of VFA removal was highest during the monsoon season. This could be because the monsoon season is a time of increased rainfall, which can dilute the concentration of VFA in the water.
- Pre-monsoon and post-monsoon seasons saw a small decline in the effectiveness of VFA elimination. This may be due to less rainfall during the pre- and post-monsoon seasons, which can raise the concentration of VFA in the water.

Overall, the data shows that the efficiency of VFA removal was high overall and consistent throughout the study period. The only minor fluctuations in efficiency could be attributed to changes in water sources, treatment techniques, or weather conditions.

Seasonal Variation of Fecal Coliform

Based on the data, the efficiency of fecal coliform removal is generally high, except for a few periods during the pre-monsoon and monsoon seasons. During the winter, the efficiency of fecal coliform removal is consistently high, fluctuating between 98.8% and 99.5%. During the pre-monsoon, the efficiency fluctuates between 73% and 88%, with the lowest point at 73% in mid-April and the highest point at 88% in late May. During the monsoon season, the efficiency fluctuates between 98.9% and 99.5%, with a low point of 98.9% at the end of June and mid-August, and a peak of 98.3% in early August. During the post-monsoon season, the efficiency remains consistently high, ranging between 99% and 99.5%. However, there are some times during the pre-monsoon and monsoon seasons when the effectiveness may be reduced, according to the data, which generally demonstrates that the efficiency of fecal coliform removal is good.

Table 4.2: Efficiencies of each parameter of grab data with seasonal variation (winter, pre-monsoon, monsoon and post-monsoon).

Parameter	Winter(%)	Pre-monsoon(%)	Monsoon(%)	Post-monsoon(%)
TSS	84-98	70-96	91-99	95.5-98.5
TVSS	84.5-99	70-95	90-100	96-99
COD (Filter)	73-97	75-94	83-97	80-86
COD (Filter)	80-98	72-94	83-97	78-96
BOD (Filter)	90-98	93-97	88-97.4	88-97.4
BOD (Total)	91-98	90-98	92-99	92-98
VFA	76-87	73-88	73-88	76-81
Fecal Coliform	98.8-99.5	73-88	98.9-99.5	99-99.5

Table 4.3: Efficiencies of each parameter of composite data with seasonal variation (winter, pre-monsoon, monsoon and post-monsoon).

Parameter	Winter(%)	Pre-monsoon(%)	Monsoon(%)	Post-monsoon(%)
TSS	90-99.7	>95	>98.5	97.5-98
TVSS	78-99	>95	90.2-98.8	98.3-99
COD (Filter)	72-90	75-94	83-97	80-86

COD (Filter)	80-98	72-94	83-97	78-96
BOD (Filter)	94-97	93-97	88-97.4	88-97.4
BOD (Total)	91-98.5	94-96	92-100	90-97.4
VFA	76-81	76-81	76-81	76-81
Fecal Coliform	98.8-99.5	73-88	98.9-99.5	99-99.5

4.3.4 Optimizing STP efficiency and the effects of DO concentration, saturation, and water temperature

Water temperature and DO concentration have an impact on STP efficiency. This chapter analyzes the data for the Amberpet STP in 2018 to explore this relationship. The data shows that DO concentration decreases as water temperature increases. This is because the solubility of oxygen decreases as temperature increases. The higher the temperature, the less oxygen can be dissolved in water. The efficiency of the STP also decreases as water temperature increases. This is because the biological processes that occur during treatment are slowed down at higher temperatures. The higher the temperature, the less active the microorganisms that break down organic matter and pollutants in the water. According to the data statistics, water temperatures between 15 and 25 degrees Celsius are optimal for treatment. At these temperatures, the DO concentration is high and the biological processes are active. The results of this study have effects on how STPs function. Plants should be designed to operate at temperatures between 15 and 25 degrees Celsius. If the water temperature is outside of this range, plants may need to be operated differently to maintain efficiency. The study also has implications for the management of STPs. Plants should monitor water temperature and DO concentration to ensure that they are operating efficiently. If water temperature or DO concentration is outside of the optimal range, plants may need to take corrective action. This study suggest that DO concentration and water temperature are crucial that can affect STP efficiency. By understanding these factors, plants can be operated more efficiently and effectively.

$$\ln DO_{sat} = -139.34411 + \frac{1.575701 * 10^5}{T_a} - \frac{6.642308 * 10^7}{T_a^2} + \frac{1.243800 * 10^{10}}{T_a^3} - \frac{8.621949 * 10^{11}}{T_a^4}$$

Where DO_{sat} is the saturation concentration of dissolved oxygen, $T_a = T + 273.15$ is an absolute temperature (K), and T is water temperature (°C).

Using the above equation, calculation of the DO saturation concentration for both the influent and effluent water samples and divided the measured DO concentration by the saturation concentration to obtain the DO saturation percentage. Evaluation of the efficiency of the treatment procedure in reducing the % saturation of DO in the effluent is done by comparing the findings for influent and effluent.

To provide a visual representation of the relationship between temperature and percent saturation, a graph is generated. The graph displayed a temperature range of 0 to 40 degrees Celsius on the x-axis and a saturation percentage range of 0 to 100 on the y-axis. The graph depicted a curve that illustrated the change in percent saturation of DO with temperature. Initially, as the temperature increased, the percent saturation decreased, reaching its minimum point in the middle-temperature range. Subsequently, as the temperature continued to rise, the percent saturation increased again, approaching 100 at the highest temperature. The solubility of oxygen in water, which declines with increasing temperature and decreases in percent saturation, can be used to determine this inverse relationship. By integrating the R.W. Doyle equation and the results, this research was able to comprehensively analyze the percent saturation of DO with temperature. This method revealed useful information on how temperature affects water oxygen levels, emphasizing the significance of taking temperature into account as a significant environmental factor when evaluating water quality.

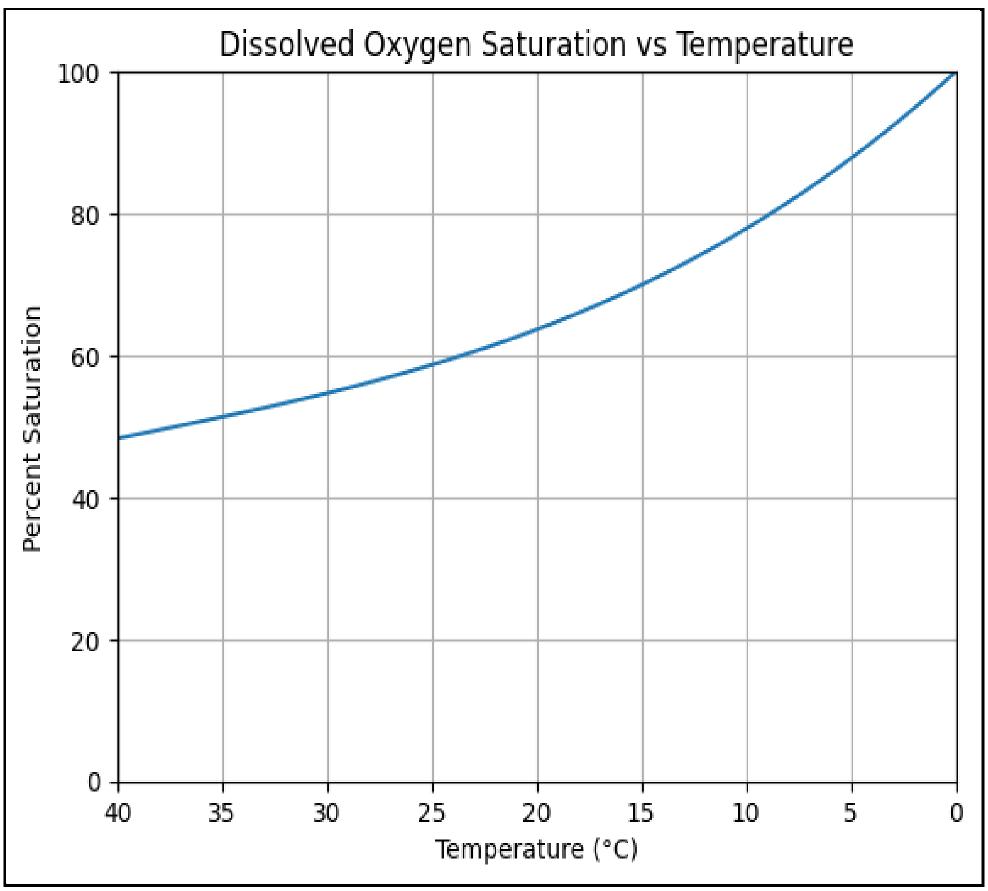

Figure 4.19: Graph illustrating percentage Saturation of Dissolved Oxygen in water.

4.4 Wastewater Use in Agriculture: Risks and Benefits

Using wastewater in agriculture poses a number of risks [34], including:

- Public health risks: Wastewater can contain harmful microorganisms, such as bacteria and viruses, which can cause diseases in humans and animals.
- Environmental risks: Wastewater can contaminate soil and groundwater, which can harm plants, animals, and people.
- Yield risks: Wastewater can contain high levels of salts, heavy metals, and other chemicals that can reduce crop yields.

4.4.1 Benefits of wastewater use in agriculture

There are also several benefits to using wastewater in agriculture [2], including:

- Water conservation: Wastewater can be used to irrigate crops, which can help to conserve freshwater resources.
- Fertilizer value: Wastewater can provide nutrients to crops, which can help to improve crop yields.
- Economic benefits: Wastewater irrigation can create jobs and generate income for farmers.
- Importance of proper planning and management

Through careful planning and management, the hazards and advantages of wastewater use in agriculture can be controlled [35]. This includes:

- Treating wastewater to remove harmful pathogens and chemicals.
- Irrigating crops with wastewater in a way that minimizes the risk of contamination.

Monitoring crop yields and soil quality to ensure that wastewater irrigation is not having a negative impact [36].

4.5 Conclusions

The study's objective was to assess the efficiency of Hyderabad's 339 MLD WWTP. Different phases and procedures have been observed, assessed, and connected with the data. Given that it is one of India's largest plants, a significant amount of sewage water is processed there every day. Many of the procedures are performed automatically by mechanical devices that are at various stages of development. According to the results obtained from the analysis, the concentration of TSS following treatment in the summer is significantly higher than during the winter and rainy seasons. This higher TSS concentration during the summer poses challenges for maintaining the health of aquatic animals when the water is released into the Musi River. In contrast, TSS levels are lower during the winter and rainy seasons, making it more suitable for aquatic life. Additionally, the levels of BOD and COD following treatment are within acceptable ranges. However, compared to the monsoon season, the COD level was higher in the pre-summer and summer months, indicating pollution from degradable organic waste sources.

Monitoring the efficiency of fecal coliform removal regularly is needed. This will help to identify periods when the efficiency is low and take steps to improve the efficiency. Investigating the causes of inadequate performance will enable to track the variables that contribute to it and take action to improve them. Improving the treatment process can be done by properly operating and maintaining the treatment process and by making improvements to the treatment process, such as adding new treatment units or upgrading existing treatment units. The following are some possible reasons for the observed fluctuations in efficiency:

- Seasonal variation: Seasonal fluctuations in temperature and rainfall may have an impact on how effectively fecal coliform is removed. For instance, the effectiveness of fecal coliform clearance may be higher in the winter, when temperatures are lower and rainfall is less frequent, than in the summer, when temperatures are higher and rainfall is more frequent.
- Variations in wastewater quality: The wastewater also have an impact on the effectiveness of fecal coliform removal. For instance, the effectiveness of fecal coliform removal may be poorer if the wastewater has a high concentration of organic matter than if it has a low concentration of organic matter.
- Variations in treatment: Efficiency of fecal coliform removal may also be affected by variations in the treatment process. For example, if the treatment process is not properly operated or maintained, the efficiency of fecal coliform removal may be lower than if the treatment process is properly operated and maintained.

The DO concentration in water should not be less than 5.0 mg/L for the survival of aquatic species. The study emphasizes the importance of maintaining the DO concentration above this threshold. The investigation additionally demonstrated that the link between water temperature and the DO saturation levels was inverse. The percent saturation of DO decreased with rising temperature. The solubility of oxygen in water can be used to explain this tendency; greater temperatures cause reduced solubility and, as a result, lower percent saturation.

Several byproducts are generated throughout the treatment process at the plant. Methane, extracted from biogas, is utilized to generate energy. The sludge, in the form of cake, is removed daily and used as bio-fertilizer by farmers after solar evaporation. These practices contribute to the overall adherence to the rules set by the NRCD and ensure that the water released into the Musi River is suitable for agricultural purposes. The risks and benefits of using wastewater in irrigation must be carefully evaluated and managed according to guidelines. The objectives include lowering hazards to both the community and the environment as well as enhancing urban farmers' means of subsistence. Continuous checks of the various stages of the treatment process is essential to preserving the efficient operation of the WWTP.

In conclusion, investigating the impact of DO concentration and water temperature on the performance of STPs is a crucial step toward optimizing their efficiency and ensuring their continued operation. The study's findings highlight the importance of continuous monitoring of TSS, BOD, and COD concentrations. Efforts should be focused on identifying and controlling sources of degradable organic waste to maintain acceptable COD levels. Adherence to guidelines is essential when utilizing wastewater in agriculture to prevent adverse impacts. In order to maintain the environment, safeguard public wellness, and reduce the consequences of climate change, STP performance must be optimized. Ongoing research & analysis are necessary to identify optimal treatment conditions and develop strategies to optimize the treatment process under different environmental conditions. By reducing the release of nutrients and improving treatment efficiency, STPs can help maintain a healthy balance in the aquatic ecosystem and prevent the degradation of water quality.

In summary, ongoing research into the effects of water temperature and DO levels on STPs provides valuable insights into their efficiency and performance. Implementing optimal treatment conditions based on data analysis can result in cost savings and reduced environmental impact. Strict adherence to regulations and continuous monitoring are essential to ensure the treated water's safety for agricultural use and its minimal impact on the environment. The effective operation of WWTPs, such as the one in Amberpet, Hyderabad, contributes to overall water resource conservation and promotes a sustainable and responsible approach to wastewater treatment.

Chapter 5

5. Effects of Dissolved Oxygen Saturation and Water Temperature using Air2stream over Krishna River Basin, India.

5.1 Introduction

In the preceding chapters, the connections between water quality, and the effectiveness of sewage treatment operations have been thoroughly discussed. Important variables such as temperature, dissolved oxygen concentration (DO) have gained prominence, each playing a crucial role in maintaining standard limits set by NRCD after treatment and also after merging into the river Musi (a tributary of Krishna River Basin) maintaining health of aquatic life. In Chapter 5, the scope broadens to the impacts of DO saturation and water temperature within the Krishna River Basin, India. While previous chapters delved into the mechanics of STP operations, this chapter extends its view to comprehend how these elements shape local water quality. In this section, the connection between STP study and the KRB is shown along with the interest on how DO and water temperature respond in both scenarios. In the previous chapter, STP investigation demonstrated that as water warms, DO levels decrease, impacting the efficiency of sewage treatment plants. Exploring the vast Krishna River Basin to determine whether this trend is consistent with the environment at large is explained in below sections. Instead than focusing only on similarities or differences, this investigation looks for practical considerations that may be applied to wastewater management in the context of climate change. Emphasizing the sustaining water quality and ecosystem balance generally depends on water temperature and DO levels.

Since climate change is the primary root cause, interest in stream water temperature modelling has increased over the past few decades [37]. DO and RWT, for instance, serve as crucial indicators of the ecosystem's health in a river water body [38]. RWT is a crucial physical characteristic that directly affects water quality (concentration of DO). The RWT has been a prominent variable over the last few years and has also been correlated with fluctuations in river flow. Climate change is possibly responsible for this, as it may impair organic biota and decrease the amount of water accessible for diverse human activities like consumption and industry. Water temperature has a significant impact on almost all ecological and biogeochemical processes in rivers, including chemical reaction rate, oxygen solubility, primary production, macro-benthos composition, and fish habitat. [39]. In regions lacking access to long-term observations, there is a bigger picture in short-term stream water temperature modelling or prediction for the current situation. Models can be broadly categorized into two groups which are actual models and physical models based on real facts. Physical models require a vast amount of data that is frequently unavailable. They are based on heat budget equations and attempt to generalize physical processes that occur between river water, atmospheric air and soil surface [40]. The focus of data-driven models is not on physical processes but tries to link the inputs of various hydro-meteorological variables and RWT [38]. In order to reduce the load of the enormous amounts of data required for physical models (due to the lack of physical representation of data-driven methodologies), the air2stream model hybrid model was recently utilized to model the temperature of the water [6]. The air2stream model, which was developed largely for simulating lake surface temperature, has been expanded. The performance of the air2stream model has lately been successful with a number of data-based models. The air2stream model, which is physically based on a lumped heat budget equation and can be solved with a small amount of data, parameterizes the processes that occur in air-river interactions. The only input data required are a stream flow data series and air temperature. The goal is to identify broadly applicable methods that have the potential to deliver the best outcomes for each run on each river. The results of the air2stream models are seen from a slightly wider perspective due to this comparison. RWT and DO concentrations in tropical rivers are known to be correlated, however, climate change has been shown to have an impact on this relationship [41]. Tropical rivers receive more solar radiation and have higher RWTs. For example, Indian tropical river systems experience the highest RWTs during low flow periods of non-monsoon and summer months [42]

5.2 Methodology

AIR2STREAM: Air2stream is a hybrid model for forecasting RWT that uses a physically-based framework and a stochastic calibration of parameters with little processing complexity [43]. The formulation and approach of this cutting-edge hybrid RWT model are comparable to those of a lake surface temperature model and it makes use of heat budgets [44]. The model implicitly considers both surface and subsurface water fluxes and uses a volume *V* river reach that is unknown shown in Equation 2 based on [45]. According to the Air2Stream model, the physical relationships are first condensed into a single ordinary differential equation that is linearly dependent on air temperature, water temperature, and discharge [46]. As a result, it is regarded as a physically based instrument that uses observable data to update its numerical integration [47]. The graph for observed RWT and simulated water temperature is displayed in the region using several linear regression models.

$$\text{Water Temperature} = c + a\,(\text{Air Temperature}) + b\,(\text{Discharge}) \tag{5.1}$$

Where *a*, *b*, *and c* are coefficients.

$$\rho c_p V \frac{dT_w}{dt} = AH + \rho c_p$$

(5.2)

Where ρ is the discharge from the water source, either tributary or groundwater, with water temperature T_w, Q is the discharge downstream of the insertion of tributaries, *t* is the passage of time, and *V* is an unknown volume of water of river reach with surface area *A* and water temperature, is water density with specific heat capacity at constant pressure, *H* is the net heat flux between air and water [46]. The performance of the Air2stream model has been studied based on the following performance measures.

Mean Square Error: During calibration, the MSE is utilized as an objective function.

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(T_w - T_m^w)^2 \quad (5.3)$$

Here, '*N*' represents the number of observations, T_w is the observed water temperature and T_m^w is the predicted water temperature.

Root Mean square Error (RMSE): The Square root of the MSE.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(T_w - T_m^w)^2} \quad (5.4)$$

Here, '*N*' represents the number of observations, T_w is the observed water temperature and T_m^w is the estimated water temperature.

.**Nash-Sutcliffe Coefficient**: Nash-Sutcliffe coefficient is used to evaluate the hydrological models' ability to predict. It's described as

$$NSE = 1 - \frac{\sum_{i=1}^{N}(T_w - T_m^w)^2}{\sum_{i=1}^{N}(T_w - \overline{T}_\omega)^2} \quad (5.5)$$

Where, '*N*' represents the number of observations, T_m is the observed water temperature and T_m^w is the estimated water temperature and $\overline{T_w}$ is the mean of the observed data.

Coefficient of Determination (R^2): It is a measurement of how well the regression model accounts for the variance in *y*. The coefficient of Determination is frequently high (0.85 to 0.9999) if a model tracks closely to the actual data; otherwise, the model needs to be modified.

$$R^2 = 1 - \frac{\Sigma(T_{wpred} - T_{wobs})^2}{\Sigma(T_{wpred} - T_{wmean})2} \quad (5.6)$$

Where, T_{wobs} is the observed water temperature and T_{wpred} is the predicted water temperature and T_{wmean} is the mean of the observed data.

5.3 Utilizing Air2stream & DO for Streamflow and Water Quality Modelling.

Stream temperature is calculated in this study using the well-known hydrologic model Air2stream, which incorporates climate simulation. It takes into account the combined effect of atmospheric variables like air temperature and hydrological inputs like streamflows on water temperature within a stream reach. The American Public Health Association developed the following equation to estimate DO, which is considered to be fully saturated for this study.

$$\ln DO_{sat} = -139.34411 + \frac{1.575701 * 10^5}{T_a} - \frac{6.642308 * 10^7}{T_a^2} + \frac{1.243800 * 10^{10}}{T_a^3} - \frac{8.621949 * 10^{11}}{T_a^4} \quad (5.7)$$

Where DO_{sat} is the saturation concentration of dissolved oxygen, $T_a = T + 273.15$ is an absolute temperature (K), and T is water temperature (°C).

Where the stream temperature model's simulation of the saturated water temperature in kelvin and the DO concentration (mg/L) are both present. The DO saturation assumption is the correct one for streams and rivers since it assumes that the water is moving swiftly and that there isn't much biological activity there. [48].

5.4 Results & Discussions

The study's data set comprises standard deviations for discharge, air temperature, and water temperature at two sites in the KRB from 1991 to 2005. Average air and water temperatures at the Mantralayam station are 27.63 °C and 36.3 °C, respectively, with a discharge rate of 87 (m^3/s). The Shimoga station's average air and water temperatures are 25.25°C and 25.1°C, respectively, with an average discharge of 70.14 (m^3/s). For a variety of stations, including Mantralayam, and Shimoga the estimated scores between observed and simulated RWT using Air2stream are 0.91, and 0.92 respectively. They varied from 0.40 and 0.74 on average. The projected NSE scores for two stations Mantralayam, and Shimoga using Air2stream are 0.96, and 0.98 respectively and RMSE values between the observed and simulated RWT using Air2stream are 0.62 and 0.58, respectively. They were, on average, between 0.6 and 1.2. The estimated MSE scores for stations Mantralayam and Shimoga between observed and simulated RWT using Air2stream are 0.38 and 0.33, respectively. The DO concentrations provided in this study are considered to be the maximum conceivable DO levels since the DO simulated by Eq. (7) is the saturated oxygen concentration, which is the total amount of DO that may be dissolved within the streamflow volume. Since the DO simulated by Eq. (2) is the saturated oxygen concentration, which is the total amount of DO that may be dissolved within the streamflow volume, the DO concentrations presented in this study are thought to reflect the upper limit of viable DO levels. Model predictions indicate that RWT will increase throughout the KRB, resulting in a decrease in DO concentration across the stream. DO concentrations are frequently below the saturation limit because of biological activity. [49]. It is anticipated that the DO concentrations observed during this investigation are at their highest. Only 10% to 20% below saturation levels may occur in headwater streams with low levels of organic matter in comparison to their DO content. [50]. In contrast, the amount of DO may drop by 90% in rivers that receive a lot of organic garbage. Since the DO and RWT have an inverse relationship, the DO decreases as the stream's temperature rises [49]. For the Mantralayam, the level of DO remained constant until 1996. From 1996 to 1997, there was a little uptick that persisted through 2004. For the Shimoga station, the DO level was constant until 1999, then it slightly increased from 1999 to 2003 before returning to being constant in 2004.

Table 5.1: Gauging station locations along with latitudes and longitudes with average Water Temperature, Air Temperature, and Discharge values within a time.

Gauging Station	Period	(Lat, Long)	T_w (ºC)	T_a (ºC)	Discharge (m^3/s)
Mantralayam	1991-2005	15.94, 77.42	25.40	27.30	242.01
Shimoga	1988-2006	13.92, 75.56	27.54	24.70	167.55

Table 5.2: Comparison of MSE, RMSE, R-square, & NSE for all river stations for Observed and Simulated data.

Station	MSE	RMSE	R-Square	NSE
Mantralayam	0.38	0.62	0.91	0.96
Shimoga	0.33	0.58	0.92	0.98

Table 5.3: Average percentage (%) of Saturated DO with Station names year-wise.

Year	Mantralayam	Shimoga
DO Saturation	**(%)**	**(%)**
1992	8.1	7.3
1993	8.1	7.3
1994	8.1	7.2
1995	8.0	7.2
1996	8.3	7.2
1997	8.8	7.3
1998	7.8	7.2
1999	7.8	7.3
2000	8.1	7.7
2001	8.2	7.9
2002	8.1	7.9
2003	7.8	7.8
2004	8.0	7.9
2005	8.1	7.9

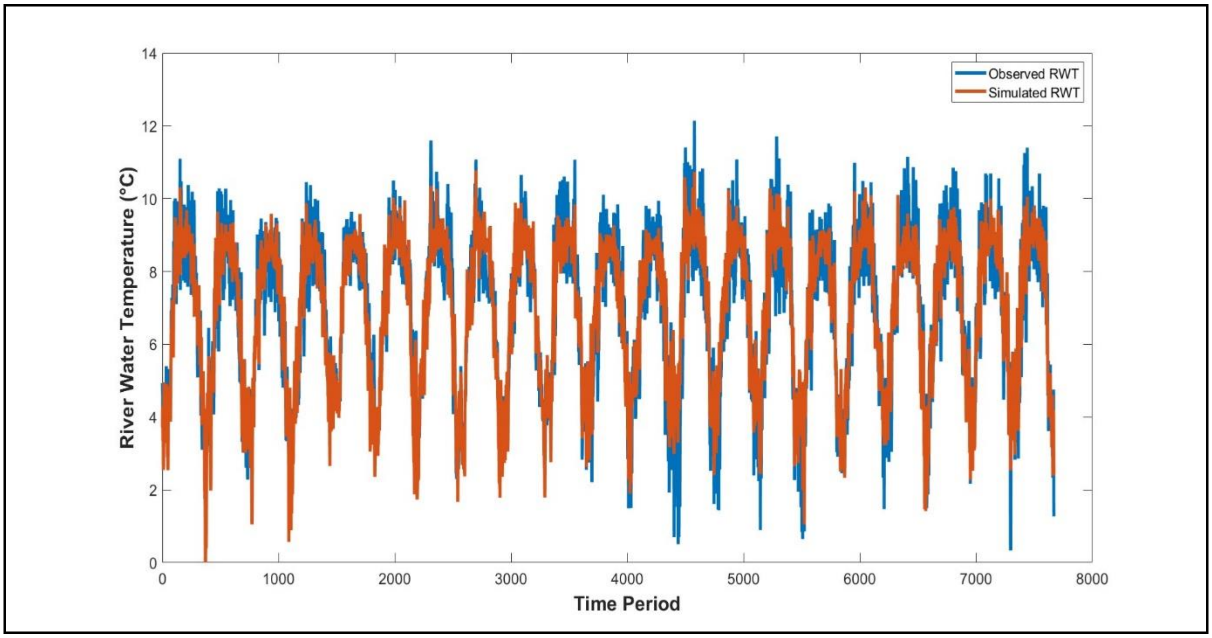

Figure 5.1: Observed vs Simulated RWT Using Air2Stream for Shimoga Station.

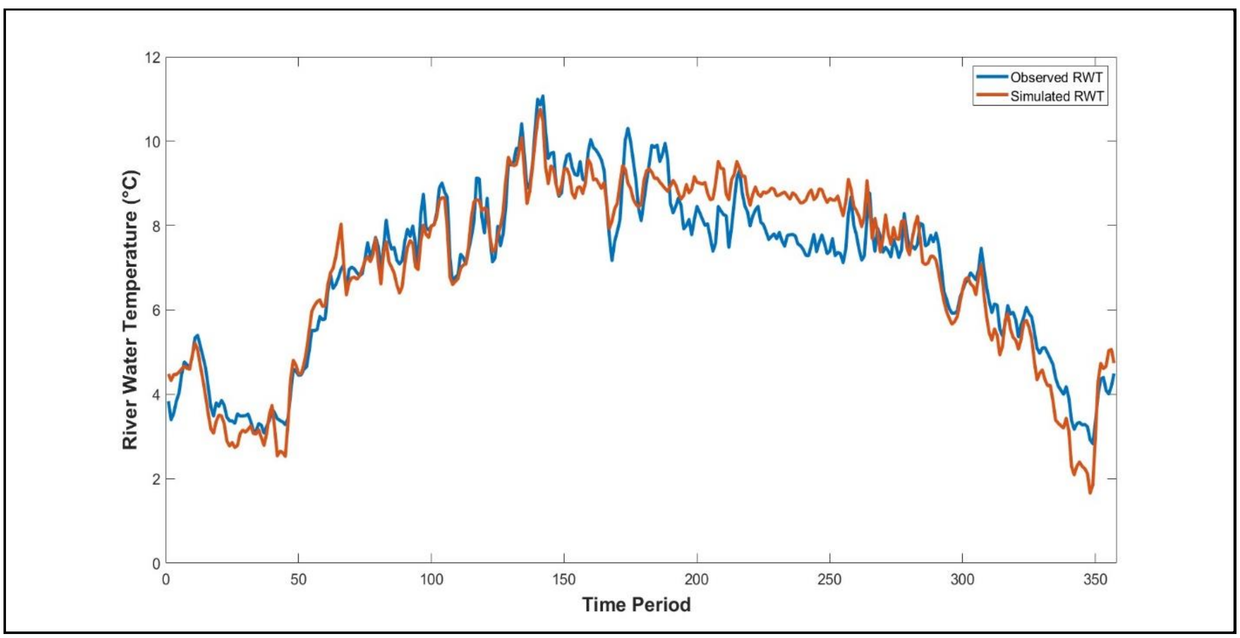

Figure 5.2: Observed vs Simulated RWT Using Air2Stream for Manthralayam Station.

5.4 Conclusions

The primary goal of the study is to evaluate the RWT using the Air2stream model together with Air Temperature and Discharge for the KRB. The suggested model, Air2water created for lentic waterways like lakes [46] is a potent tool that can assist in easily and effectively examining the thermal dynamics of diverse types of rivers. The model utilizes only the air temperature and flow discharge values, a pair of variables that can be observed in many rivers. With such a little quantity of input data, a model is a flexible tool with a wide range of potential uses. In this study, an important baseline for the temporal fluctuations in the simulated RWTs over the KRB is established using the Air2Stream model and observational data. Climate change may continue to have an effect on aquatic life in two ways mainly like increasing the number of aquatic fatalities in rivers and by making migration more challenging due to discharge changes. The simulated output from the Air2stream is displayed after comprehending and using the Air2stream at several sites in the KRB. The NSE values for all stations during the calibration period range from 0.76 to 0.97, according to model results. According to multivariate linear regression analysis, river discharge has secondary effects on simulated water temperatures in the KRB, but air temperature accounts for about 80% of its explained variance. The RWT is used to determine saturated DO levels. This study shows a negative relationship between saturated DO levels and RWT. Saturated DO levels from 7.3% to 10.08% at the Mantralayam station, Shimoga station had the best findings for the DO saturation out of all two gauging stations. Mantralayam also produced positive results. However, the Shimoga and Mantralayam stations produced the best results overall. According to the ongoing warming of thermal river conditions in the KRB, need to investigate projected changes in RWTs under climate change in future.

Chapter 6

6. Summary and Conclusions

The 339 MLD WWTP at Amberpet, Hyderabad, is one of India's largest plant and processes a significant volume of sewage water daily. The plant utilizes automated mechanical devices at various stages of development for effective treatment and filtration. The performance of sewage treatment plants (STPs) has been studied based on seasonal fluctuations and temperature conditions. Compared to the winter months (December to February), the STP in Hyderabad performs noticeably better in the summer (June to August).

- The STP typically achieves outstanding removal efficiencies of over 95% for criteria including TSS, TVSS, COD, BOD, and FC during the summer.
- During the winter months, the STP struggles to maintain consistent removal efficiencies, with some parameters dropping as low as 80%. This indicates the need for measures such as insulation and heating systems to maintain optimal temperature conditions for biological processes during the winter.
- TSS levels are significantly higher during the summer than in the winter and rainy seasons. This poses challenges for maintaining the health of aquatic animals when the water is released into the Musi River.
- It is essential to maintain DO levels above the critical level of 5.0 mg/L in order to ensure the survival of aquatic life. The fact that DO saturation and water temperature have an antagonistic relationship further emphasizes this requirement.
- The UASB reactor technology used at the Amberpet plant is a both economical and efficient anaerobic digester for treating wastewater and organic waste.
- Regular monitoring of DO saturation levels can help to evaluate the impact of STPs on the local environment. Implementation of strategies such as buffer zones or artificial wetlands can mitigate the potential impact of STP effluent on the local environment.
- The influence of air temperature and discharge on the river water temperature (RWT) in the KRB was assessed using the Air2stream model, a powerful tool for studying river thermal dynamics.

- In order to comprehend temporal fluctuations in simulated water temperatures over KRB, a critical baseline had to be established using the observation-based Air2Stream model.

- Two locations in the KRB were used to evaluate the performance of the Air2stream model, and the NSE values for each station during the calibration period ranged from 0.76 to 0.97.

- Multivariate linear regression analysis revealed that air temperature accounted for approximately 80% of the explained variance in simulated water temperatures in the KRB, while river discharge had secondary effects.

- A negative relationship was observed between RWT and saturated DO levels. The Mantralayam and Shimoga stations showed the best findings for DO saturation, with saturated DO levels ranging from 7.3% to 10.08%.

Overall, optimizing the performance of WWTPs is crucial for safeguarding public health, protecting the environment, and reducing the consequences of climate change. Ongoing research & analysis are necessary to identify optimal treatment conditions and develop strategies to optimize the treatment process under different environmental conditions. Strict adherence to regulations and continuous monitoring are essential to ensure the treated water's safety for agricultural use and its minimal impact on the environment. •

Efforts should be focused on maintaining acceptable levels of BOD and COD to prevent adverse impacts on aquatic life and the environment. Identifying and controlling sources of degradable organic waste is crucial for controlling COD levels. Due to urbanization and population expansion, wastewater management and treatment are becoming increasingly important internationally. The impact on the environment must be reduced while standards are met and treatment methods are optimized. The presence of pharmaceuticals in wastewater is a global issue that requires effective filtration to prevent potential health problems. Drip irrigation is considered the optimal strategy for utilizing wastewater in agriculture, with proper requirements and guidelines in place. By products generated from the treatment process, such as methane from biogas and sludge used as bio-fertilizer, contribute to the overall adherence to environmental regulations. To ensure safe disposal of wastewater in agriculture while minimizing challenges to the ecosystem and the general population, proper wastewater treatment, monitoring, and adherence to regulations are required. The effective operation of WWTPs, such as the one in Amberpet, Hyderabad, contributes to overall water resource conservation and promotes a sustainable and responsible approach to wastewater treatment. Regular monitoring, maintenance, and prompt addressing of operational issues are necessary for optimal functioning. Future studies should consider analyzing the STP's performance over multiple years, considering influent quality, quantity, and treatment processes to gain a comprehensive understanding.

Publications

Conference Papers

- Veerannapet Santhosh Vishal, Rajesh Maddu, Rehana Shaik, Effects of Dissolved Oxygen Saturation and Water Temperature using Air2Stream over Krishna River Basin, India. Hydro 2022, 27th International Conference, Hydraulics, Water Resources & Coastal Engineering, 22-24, December 2022. (Accepted and yet to publish)
- Veerannapet Santhosh Vishal, Rehana Shaik, N. Munilakshmi, L Partha Praveen, Performance Analysis of 339 MLD STP at AMBERPET – HYDERABAD. SVU 2022, International Conference, The International Society of Waste Management, Air and Water (ISWMAW), and the Organizing committee of 12th Icon SWM-CE & IPLA Global Forum 2022. (Attended conference and under review).

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