

UTILIZATION OF TREATED WATER FROM SEWAGE TREATMENT PLANTS IN CONCRETE MIX REPLACING POTABLE WATER

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

**in
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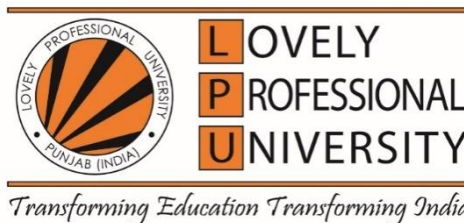
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CANDIDATE'S DECLARATION

I, hereby declare that the presented work in the thesis entitled “**Utilization of Treated Water from Sewage Treatment Plants in Concrete Mix Replacing Potable Water**” in fulfillment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Mrunmayee M Sahoo**, working as **Assistant Professor** and **Dr. Jaspreet Singh**, working as **Associate Professor** in the **School of Civil Engineering** of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



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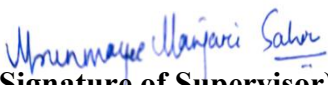
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CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled “**Utilization of Treated Water from Sewage Treatment Plants in Concrete Mix Replacing Potable Water**” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the School of Civil Engineering, is a research work carried out by **Jitin Vasudeva, 41800375**, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.


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At the very onset, I surrender myself before the Almighty Lord for blessing me with the best of what I could have had. Be it this thesis, the personal associated with it or the outcome of this research pursuit, all of it is HIS GRACE, MERCY and BLESSINGS. He has made this possible, and I thank to Almighty Lord with all humility and surrender.

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This thesis is dedicated to my loving and caring son & daughter, **Ruhan Vasudeva** and **Rehmat Vasudeva**.

(Jitin Vasudeva)

Abstract

This study examines the usage of purified sewage water from a 10 MLD sewage treatment plant at Bambianwali based on Sequential Batch Reactor technology to replace potable water in concrete mixing. An extensive analysis was conducted over a three-year period (2021-2023) to evaluate the suitability of treated sewage water for concrete production. Several water quality parameters, such as pH, temperature, total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), faecal coliform (F. Coli), and Total Kjeldahl Nitrogen (TKN), were examined. The pH value of the treated wastewater from the 10 MLD STP at Bambianwali was monitored on a monthly basis, and showed consistent results throughout the year and was found to be in the range of 7.02-7.18. Overall, the data for Temperature shows a seasonal variation with maximum temperatures in the summer months and minimum temperatures in the winter, indicating a typical climate and ranging between 20-30 °C. The data of monthly averages and medians of total suspended solids (TSS) for the year, and details variations in water quality parameters. The average values range from 16.42 to 17.14, with the lowest average in November and the highest in December. The median values are constantly hovering around 17, except in August where it drops to 16.5, indicating a slight decline in the TDS distribution in that month. In other months—April, May, June, July, September, and October—the median TDS remains stable at 17, indicating a constant central tendency despite fluctuating average prices. These measurements are important for monitoring water quality, guiding environmental decisions and ensuring that regulatory standards are met throughout the year. The data of monthly mean and median of chemical oxygen demand (COD) concentrations of wastewater used in concrete production, with respect to water transport standards. The mean COD values always ranged from 36 to 41, indicating a distinct central tendency in most months, except for September, which dropped slightly to 40. This measurement is important for the assessment of the suitability of pollutants for cement do about it, ensuring compliance with quality standards Prevent environmental damage. The data reveal monthly variations in COD levels, and guide management decisions to maintain water quality integrity throughout the year.

The data of monthly mean and median of biological oxygen demand (BOD) of a year, which may vary widely from a low of 7 in December to a high of 7.54 in October for water analyzed quality to be environmental or technical. The median BOD values are consistently around 7 or 8, reflecting the main trend in BOD levels in different months. July stands out with a BOD of 8, indicating a typical value for that month. These measurements are important indicators of contamination in water, affecting regulatory compliance and environmental management. The data highlight monthly variations in BOD, providing insight into seasonal variations and water quality trends throughout the year. The data summarizes monthly fecal coliform (F.Coli) counts which are likely to be used to assess water quality standards, especially for drinking water or environmental health around. The average F. coli count ranged from 542.5 in December to 642.5 in June, indicating a fluctuation in bacterial load throughout the year. F.Coli counts ranged from 540 in December to 645 in June, fluctuating widely from month to month. July stands out with a median F.Coli count of 595, indicating that infection predominantly occurred during that period. These measurements are important for monitoring water quality, as water coliform levels are indicators of potential health risks associated with waterborne disease. The data highlight monthly variations in F.Coli levels is emphasized, which is valuable for regulatory compliance and public health interventions aimed at protecting water resources and maintaining drinking water quality standards for year-round. The data gives monthly concentrations of total Kjeldahl nitrogen (TKN) during one year, which may be used in water quality assessment or environmental monitoring. Average and median TKN the value ranges from 2.25 in May to 3.5 in December throughout the year. It shows variation in nitrogen concentration. The median number of TKN ranged from 2 in May to 3.5 in June and September, showing significant monthly trends. TKN concentrations in July and November were 2.5, providing constant nitrogen concentrations in those months. These measurements are important for the assessment of nitrogen pollution in water bodies, identifying environmental policies and actions to maintain water quality standards. The data highlight the monthly variations in TKN, and provide insight into seasonal variation and nitrogen pollution throughout the year.

In addition, concrete cubes were formed and subjected to strength testing using several water mixtures: 100% potable water, a 60:40 ratio of primary treated wastewater to

potable water, and a 60:40 ratio of secondary treated wastewater to potable water. Apart from above, the concrete cubes were found mixed with various water proportions mainly 10%, 15% & 20% replacement of potable water with secondary treated wastewater from the outlet of 10 MLD Sewage Treatment Plant and 7 days & 28 days strength of cubes were tested and found to be complying as per IS standards. As per mix design, volume of water for 1 cum of concrete grade M-20 comes out of be 142 litres approximately. Hence the main rationale behind introduction of this and for replacement of potable water with treated sewage is to save potable water. Therefore in approximately every 1 cum of concrete, 142 litres of water is used. Replacing 60% means 85 litres potable water can be saved for every 1 cum of concrete work. The findings further indicate that treated sewage water can serve as a feasible substitute for drinking water in the process of mixing concrete, but the strength of the concrete may vary depending on the extent of treatment applied to the water. This strategy not only preserves drinkable water but also encourages the recycling of treated wastewater, in line with objectives for environmental sustainability. This practice ensures potential saving of potable water to the tune of 85 litres per 1 cum of concrete and also saves approximately Rs. 1700 per 1000 cum of concrete. Introduction of replacement of potable water in concrete mix with treated sewage shall ensure potable water available for future generations considering high cost of treatment and distribution.

Key words: sewage water, concrete production, pH, temperature, total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), faecal coliform (F. Coli), and Total Kjeldahl Nitrogen

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Dedicated to
Almighty God and my family members...

Chapter 1 : Introduction

1.1 General

The phrase "elixir of life" fits water perfectly. Only 3% water present on earth which is tagged as fresh water, also responsible for formation of 71% of hydrosphere. In addition, much of this freshwater—roughly 80% of it—is frozen in the polar caps and inaccessible to people. Thus, around 0.5% of the water on Earth is potable and drinkable^[1] (A. Micheal and H. A. El Salam 2024). Global water scarcity has occurred from overcrowding, urbanisation, pollution, climate change, inadequate management of freshwater resources, and environmental issues over the last 100 years^[2] (Hamada et al. 2023).

Water has prime importance in the production of cement-based materials (CBMs), such as paste, mortar, and concrete^[13] (Maroušek et al. 2022). Concrete is made by combining water with inert ingredients (coarse and fine particles) and binding elements (Portland cement or asphalt). Every year, almost 1 trillion gallons of water are used to produce concrete worldwide^[11] (Gokulanathan et al. 2021). Although concrete requires a sufficient quantity of water to generate a workable mixture that can be mixed, put, consolidated, and finished without difficulty, less water results in superior concrete (Mangi et al. 2021). Concrete manufacture and processing, concrete aggregate washing, concrete batching plant washing, and concrete truck mixer washing all need water^[13] (Maroušek et al. 2021). The creation of CBMs may be done with any drinkable water. There should be no harmful levels of acids, salts, alkalis, oils, sugar, or organic compounds in the water (Akbari et al. 2021). Water that is very alkaline or acidic, combined with algae, or that has a high concentration of chlorides (Pavolova et al. 2021) should be avoided as they may negatively impact the setting, hardening, and development of concrete's strength. The quest for potential substitutes has arisen from the scarcity of drinkable water (Varshney et al. 2021). Higher concentrations of dissolved chemicals and suspended particulates may be found in other water sources, including saltwater, treated industrial wastewater, treated sewage wastewater, wastewater from carwash service stations, wastewater from ready-mix concrete factories, and wastewater from the stone-cutting industry (Hassani et al. 2020). However, all of these water resources can be used in concrete production with

acceptable strength and durability (Maroušek et al. 2021). Concrete usage in the building sector is nearly exactly equal to water consumption (Akbari et al. 2021). As a result, different kinds of wastewaters, both completely and partly treated, may aid in the manufacture of concrete and save the expensive treatment expenses (Govindarajan et al. 2020). Wastewater is used in concrete building despite the negative effects it has on the environment and public health. Domestic, municipal, and some industrial wastewater that has had all pollutants and suspended particles removed before being disposed of in the environment is known as treated sewage wastewater (Liu et al. 2020). In order to produce treated effluent that is safe to discharge into the environment, a number of physical, chemical, and biological procedures are needed to remove the pollutants (Ghrai et al. 2020). Sewage sludge, a semi-solid waste that requires further treatment to be appropriate for land disposal, is a by-product of sewage treatment^[12]. Reclaimed water, often referred to as recycled water, is used to clean wastewater by removing all suspended and solid particles. Reclaimed water has several uses such as irrigation, concrete manufacture, ground water replenishment, and landscaping applications (Roychand et al. 2020). Sludge, a by-product of water reclamation, is combined with biowaste to create compost, which farmers utilise extensively (He et al. 2020). Spirulina, for example, may be grown directly on wastewater (Asadollahfardi et al. 2019). The use of recycled water in the production and curing of concrete is the main subject of this study. There may be further financial benefit to using treated wastewater in the production of concrete. The addition of a new client sector, such as the construction industry, which is a constantly expanding economic activity in any society, would promote investment in the field of treated wastewater for any investor (Crini et al. 2019) (Al-Joulani 2019).

India has the largest population in the world and the biggest concern is that India may lack the quantity and quality of water in the long term (Abdul 2015). Since, India is a country with large agricultural output and being a developing country, the various construction activities are going on at full swing, the overall water table is going down at a rapid pace. Concrete is the material responsible for strengthening of building that's why it is used worldwide in infrastructural development.

Concrete is a widely used building material in the world. The population growth

and rapid development have led to the massive use of concrete as construction industry's key material^[60] (Chetan 2015). The primary challenges of building industry are environmental damage which includes air and water pollution along with highly use of raw materials. The deficit of resources which provide drinking water is crucial in recent time and the problem is faced by world.

Therefore, the reuse of treated water becomes the main option to be considered as a new source of water in region where water is scarce. This will be achieved by establishing a balance between the amount of treated water to be used along with groundwater for various areas/ regions and thereby reducing the groundwater extraction (Sanjay, 2015). In case of construction activities, the replacement of water to be used in concrete mix by treated water from Sewage Treatment Plant will ensure reduction of use of potable water. The addition of treated water in concrete mix in different proportions will be done to check the various characteristics of concrete. The consumption of treated wastewater in mixing of concrete structures may reduce the environmental effects due to the disposal of waste water and will also minimize the cost of construction (Pritam, 2015). The use of treated sewage water would be a groundbreaking idea in concrete mix proportions which can decrease water shortage up to some extent.

Thus, the future possibilities are bright for treated water from Sewage Treatment Plants and its actual applications in real life. Hence, the proposed research work is chosen to be done in the field related to Sewage Treatment by utilizing Treated Water from the outlet of Sewage Treatment Plant and replacing the potable water in the concrete mix.

1.2 Sewage Treatment Plant (STP)

Sewage Treatment Plants (STP) is used for processing of wastewater in urban areas. A lot of cost is involved in treatment of wastewater received at the inlet of Sewage Treatment plant. There is a strong need of finding an effective method to reuse treated water at the outlet of Sewage Treatment Plant. The rapid increase in population makes the places denser and add extra pressure on Environment (Kumar and Dutta 2019). India's population is rising, thus the country must find ways to reduce, reuse, and recycle water to meet its future

freshwater needs. The application of treated water can be proved beneficial in concrete mix to replace potable water. Natural way of treating the wastewater is used to take benefits of purifying the water through physical, chemical and biological processes (Liu et al. 2016). Water has prime importance in the production of cement-based materials (CBMs), such as paste, mortar, and concrete (Maroušek et al. 2022). Concrete is made by combining water with inert ingredients (coarse and fine particles) and binding elements (Portland cement or asphalt). Every year, almost 1 trillion gallons of water are used to produce concrete worldwide (Gokulanathan et al. 2021).

1.3 Research Objectives

The objectives of the present study are:-

- To Analyse the quality of Treated Waste Water from Sewage Treatment Plant as per standards.
- To find optimum amount of treated water to be used in Plain & Reinforced Concrete Mix partially replacing potable water.
- To check various parameters of plain cement concrete and reinforced cement concrete mix with Treated Waste Water from Sewage Treatment Plant.
- To check effect of treated waste water on reinforcement particularly corrosion.

1.4 Outlines of the thesis

Chapter-1: Introduction- It describes about the sewage treatment plant and concrete mix and objectives the work etc.

Chapter-2: Review of literature- This section includes in-depth review of literature for the overall work.

Chapter-3: Materials and Methodology- The chapter details about materials used for the study and how experimental work has been done.

Chapter-4: Results and discussion- Experimental investigation is carried out and data is collected from each experiment, graphical and tabular representation is done for better understanding.

Chapter-5: Summary and Conclusion- Overall summary of the thesis is detailed in this section.

Chapter 2: Review of Literature

2.1 Overview

There is a growing body of research on the use of treated sewage water in concrete mixing. Studies have shown that treated sewage water can be used to produce concrete with similar or even better properties than concrete made with fresh water.

One study, conducted by researchers at the Indian Institute of Technology Roorkee, found that concrete made with treated sewage water had similar compressive strength and durability to concrete made with fresh water. The study also found that the use of treated sewage water did not affect the workability of the concrete.

Another study, conducted by researchers at the University of Cape Town, found that concrete made with treated sewage water had slightly higher compressive strength than concrete made with fresh water. The study also found that the use of treated sewage water did not affect the durability of the concrete.

In another study the use of treated sewage water in development, aiming to improve water resource management in a public area with a significant water shortage, comparing the quality of plain cement concrete. This study explores the use of tertiary treated wastewater from the Nablus Wastewater Treatment Plant (NWWTP) in concrete properties, focusing on environmental and economic aspects. Another study on concrete properties like compressive strength, natural absorption and workability. Results show an increase in maximum compressive stress with different water ratios and curing ages. This research evaluates the reliability of recycled wastewater for concrete manufacturing. Two treatment regimens, secondary and tertiary, are used, with the latter replacing potable water. Results show treated wastewater may delay setting, but compressive strength remains safe. The XRD test shows higher expansion under sulphate attack. In this study, the use of drinking water treatment sludge (DWTS) as sand replacement in Concrete Paving Blocks (CPB), revealing that above 10% replacement can negatively impact properties like compressive strength, water absorption, and abrasion resistance. In one more study,

the use of treated industrial wastewater in concrete production, comparing it to drinking water. Results show a 6.9% decrease in compressive strength but meet ASTM standards. However, the final setting time and electrical resistivity increase. The study analyses that the pozzolanic activity of water treatment plant sludge ash (WTPSA) as a potential alternative to Portland cement. The Response Surface Method (RSM) found optimal conditions for calcination and grinding, resulting in higher concrete compressive strength and reduced Portland cement consumption.

In another study, Sewage treatment plant treated effluent enhances cement paste setting time and compressive strength compared to potable water. Reclaimed wastewater can be used in concrete production without harmful effects, increasing 28-day compressive strength to 8%-17% with 25%-100% reclaimed water use. The research demonstrates that the use of treated effluent (TE) in concrete enhances the setting time and compressive strength of the cement paste more effectively than drinking water. Similarly, wastewater (WW) produced by concrete factories may be used in concrete curing and manufacture without adversely affecting concrete qualities. The research indicates that treated sewage water is suitable for use in concrete, since chemical tests provide good findings and the pollutants and suspended debris are below allowed limits. Furthermore, when this water is used to create concrete cubes under standard conditions, the resulting cubes exhibit good compressive strength findings. The compressive strength of cubes produced with treated sewage water exceeds that of cubes created with standard tap water.

The study evaluates the potential of recycling waste wash-water (WWW) in ready-mix concrete plants in Jordan. A 400 L sample was collected from a concrete company basin and used for replacement of mixing water. The results showed that raw WWW was not acceptable as mixing water, leading to reduced strength and low workability. However, settling pond, filtered, and filtered-neutralized WWW were found to be potential alternatives. The study suggests revising current guidelines for mixing water quality.

The another study uses steel slag from the steel industry to remove phosphorus from municipal wastewater, achieving a 90% phosphate removal efficiency. The

wastewater contains iron and manganese, and after treatment, it can be used as a replacement for conventional coarse aggregates in concrete. This study uses Concrete slurry waste, a dewatered residue from concrete production, is a significant issue due to high disposal costs. A study suggests using wet-milling to refine concrete slurry waste, partially replacing cement use. The process densifies paste microstructure, reducing initial and final setting time. Results show that wet-milling concrete slurry waste can improve compressive strength and harden cement paste. However, it also increases energy intensity, carbon emissions, and costs compared to Portland cement. In this study, the use of incinerated sewage sludge ash (ISSA) as a soil stabilizing agent for managing municipal solid waste. The ash contains silicon oxide, aluminium oxide, and iron oxide in high proportions. The soil with low to medium plasticity was replaced with varying amounts of ISSA. The soil showed the lowest OMC and highest MDD values at 7% ash content, and the PI reduced dramatically at short curing age. ISSA effectively increased the California Bearing Ratio (CBR) values of the soil.

This study analyses that the Concrete bio-corrosion in wastewater pipes is caused by aggressive solutions and sulfuric acid production by microorganisms. Preventing this requires altering the concrete mix or applying corrosion-resistant coatings. However, these coatings have a short bio-resistant lifespan and poor acid-resistant properties. This work examines three coated materials: Portland cement-based, geopolymer-based, and geopolymer magnesium phosphate-based, including zinc particles and zinc-doped clay particles. The coatings' chemical stability and resistance to biogenic corrosion were tested in an accelerated bio-corrosion chamber. The study states that the Concrete's hardening properties are crucial for its strength and durability. STP treated water, a recycled water from municipal wastewater treatment plants, has been extensively studied for its positive impact on concrete production. This water removes contaminants and impurities, reducing environmental impact and conserving water resources. It improves the concrete's hardening properties by containing dissolved minerals and organic matter, enhancing its strength and durability. Future studies is required to optimize water source and study the impact of long term effects.

The Literature Survey done till date has been summarized as per table 2.1 below:-

Table 2.1: Brief Literature review on use of treated water in concrete mix

Detail of the journal/ Book/Book chapter/ website link	Year of Publication	Main findings or conclusion relevant to proposed research work
A. Micheal and H. A. El Salam	2024	It basically focus on consistency of concrete and strength, the testing of various results prove that the treated water can be used effectively and safely. This further substantiates that the setting time is prolonged when using Treated Wastewater in comparison to concrete mixed with potable water.
H. M. Hamada, J. Shi, F. Abed, M. S. Al Jawahery, A. Majdi, and S.T. Yousif	2023	It studies a comprehensive analysis of UHPC in accordance with embedded CO ₂ , compressive strength and replacement level different waste materials.
J. Maroušek, A. Maroušková, T. Zoubek, and P. Bartoš	2022	Operators at water treatment plants and legislators often perceive that technological changes would result in increased costs for delivering drinking water to residents, benefiting primarily farmers. Nonetheless, the first results suggests that residues of Fe not only decompose pre-existing PE in the soil but also the PE introduced by later added P fertilisers.
Journal of Cleaner Production	2022	It has been observed that while using treated effluent (TE) in concrete not only improved the cement paste's setting time but also increased the compressive strength, it showed more strength than drinking water. Also, waste water (WW) generated from concrete mix plants can be further used in curing of concrete and production due to the reason that there is no critical influence on concrete properties.
Construction and Building Materials, vol. 309, p. 125089	2021	A comprehensive review was done on fresh and hardened properties of five non-potable water mixed and cured concrete.

Journal of Building Engineering, Volume-41	2021	The effluent from sewage treatment facilities is released adequately for designated industrial purposes. The use of treated water from sewage treatment plants enhances the setting time of cement paste and exhibits superior compressive strength relative to potable water. The use of recovered wastewater indicated that it may be employed in concrete production without adverse impacts. The 28-day compressive strength of specimens using recycled waste water enhanced by 8%–17% with 25%–100% incorporation of reclaimed water.
Silicon, Vol. 13, pages 4519-4526	2021	A comprehensive review on effects of sea water on engineering properties of concrete
International Journal of Engineering Research & Technology (IJERT) Vol. 9 Issue 02	2020	The concrete cubes were created using a mixture of sewage in varying quantities and possess strength within the specified limits. Critical strength values were documented in concrete mixtures with a water-to-cement ratio of 0.45. The concrete mixture including 50% secondary processed water and 50% ordinary water exhibits the highest compressive strength during the 28-day evaluation. Maximal effort and environmentally sustainable concrete may be achieved by the use of treated wastewater in concrete production. Consequently, purified sewage water serves as an excellent alternative for drinking water in concrete applications.
International Journal of Research in Engineering, Science and Management Volume-2, Issue-6	2019	The effluent from the sewage treatment plant may be used in concrete production, since chemical analyses provide favourable findings, and the contaminants and suspended particle matter are below acceptable limits. When treated water is used to make concrete cubes under standard laboratory conditions, the resulting cubes exhibit adequate and commendable compressive strength findings. The compressive strength of cubes constructed with treated water exceeds that of cubes created with conventional tap water.
IOSR Journal of Mechanical and Civil Engineering, Volume 13 Issue 4 Version II	2016	The examination of wastewater utilisation in concrete revealed that, when compared to drinking water, both cement concrete and treated water cement concrete provide approximately identical compressive strength findings.

Int. J. Adv. Research4(11)	2016	Research indicates that treated wastewater influences the compressive strength and permeability of M25 grade concrete, revealing that permeability values are lowest when using 100% treated wastewater. The compressive strength values for M25 grade using 100% treated wastewater exceed its target strength according to the design mix. The test findings indicate that the use of treated high-quality water is advisable for Plain cement concrete applications.
International Journal of Science and Research (IJSR)	2016	Secondary treated wastewater has a compelling use in concrete mixtures. The load-carrying capability and compressive strength of secondary treated wastewater concrete surpass those of potable water concrete. The compressive strength values show an increase of 9.62% for concrete cubes contained with secondary treated wastewater. Concrete produced with secondary treated wastewater has an excellent aesthetic quality. The compressive and tensile strength values of concrete made with potable water.
International Research Journal of Engineering and Technology (IRJET) Volume 02 Issue08	2015	There is a trend of decrease in the workability of concrete using primary treated water whereas use of secondary treated water gave better workability to concrete. In terms of compressive strength, no major difference was found in the values of compressive strength.
International Journal of Engineering Research-Online, Volume 3 Issue3	2015	Secondary treated wastewater has a compelling use in concrete mixtures. The load-carrying capacity and compressive strength of secondary treated wastewater concrete are superior to those of potable water concrete. The compressive strength values show an increase of 9.62% for concrete cubes contained with secondary treated wastewater. Concrete produced with secondary treated wastewater has an excellent aesthetic quality. The compressive and tensile strength values of concrete made using secondary treated wastewater are higher than those of concrete made with potable water.

International journal of Technology Enhancements and Emerging Engineering Research Volume 3 Issue5	2015	The types of grey water used met the standards of mixing water as mentioned in various IS codes. The Grey water should be disinfected and treated before use to avoid the health risks to people who are present at STP. As Compared with tap water lesser amount of the grey water is required to attain similar level of consistency of cement. The initial setting time is reduced with grey water and final setting time is also reduced but that reduction levels are marginal but still within the prescribed limits. Cement mixed with Grey water has shown more compressive strength values than the cement mixed with tap water.
International Research Journal of Engineering and Technology (IRJET) Volume 02 Issue07	2015	Study of the effect of untreated algae, kitchen and garage wastewater on characteristics of concrete as curing water and it has been found out that from test results we came to know that kitchen waste water can be used for curing of concrete structures and it has shown considerable increase in a compressive strength compared to algae, garage and potable curing water's for a period of 28 and 60 days.
International Journal of Scientific and Research Publications Volume 05 Issue01	2015	Rate of corrosion of steel increases as pH value of water decreases. It was found that, the rate of corrosion is more below 3.0 pH value of water. Chlorine ions present in water form hydrochloric acid (HCl), can act as a catalyst for oxidation of steel in concrete. This results formation of $\text{Fe}(\text{OH})_2$ which allows to easier penetration of chloride ions and hence formation of corrosion. There is reduction of compressive strength and tensile strength of concrete with reduction in pH value of water.
International Journal Of Science and Technology Volume04 Number03	2015	Effects of sugar factory waste water as mixing water on the properties of normal strength concrete” and concluded that there is a delay in the setting time of the cement mix using waste water, the delay increase with an increase in the percentage of mixing waste water.
International Journal of Applied Engineering Research ISSN 0973-4562 Volume10 Number19	2015	Effect of waste water on concrete properties” and concluded that Based on the experimental results in this study for concrete and mortar samples, it can be said that using slurry waste water in concrete mixtures improved the workability, compressive strength, splitting tensile strength and natural absorption. Compressive strength and splitting tensile strength were increased by 20% and 11% respectively.

International Journal for Scientific Research &Development Volume 2 Issue10	2014	Treated domestic waste water can be used in the preparation of concrete both for casting and curing purposes, without affecting target mean compressive strength at the age of 28 days curing for M20 grade concrete. Increase in compressive strength from 7 days to 14days for all the mixes is marginal for both the grades of concrete i.e. M 20 and M 40.
Assessment of replacing wastewater and treated water with tap water in making concrete mix	2014	The usage of Treated Waste Water will decrease the strength of the concrete, because the high amount of COD, BOD, TDS, and TSS in water affect cement compounds, which are responsible for the strength. After using waste water; the strength decreases more than using treated water in making concrete.
International journal of Engineering and Advanced Technology, Volume 4, Issue 7	2014	The effect of chemical impurities in mixing water on different properties of concrete using a mix for Grade M20 using potable, groundwater and sewage water". They reported an increase of 33.34% in compressive strength of potable water concrete when compared with concrete made using sewage water. They also reported a pH value for sewage water of 10.2 compared to 8.2 and 6.6 for portable water and groundwater respectively. If the pH value of water increases, the strength of concrete reduces substantially. On Comparison with specimens at higher concentrations of lead in mixing water, test samples had shown considerable loss of strength, and also their setting times had significantly increased.
International Journal of Mining, Metallurgy & Mechanical Engineering (IJMMME) Volume1	2013	The initial and final setting times either retarded or accelerated depending upon the type of alkalinity imparted by Sodium carbonate or Sodium bi-carbonate. Sodium carbonate when present in water accelerated both the initial and final setting time when its content is equal to
Issue2		6gm/L and 4gm/L respectively. Sodium bi-carbonate when present in water retarded both the initial and final setting time when its content is equal to 4gm/L and 6gm/L respectively.

Sustainable Use of Resources – Recycling of Sewage Treatment Plant Water in Concrete” in 2010 in international journal	2010	Studied the effect of usage of sewage treated water in preparing mortar. The study revealed that significant difference do not exist between mortar cube made of potable water versus sewage treatment plant water.
Journal - The Institution of Engineers, Malaysia (Vol. 68, No.4)	2008	They used a waste water product from the RMC plant for the purpose of curing of concrete for the period of 14 and 28 days after this curing period they did the test on the strength of concrete and they got an desirable values on the compressive, split tensile and flexural strength of concrete compared to the curing with portable water for the same period.
	2003	Concrete cubes were casted using Tap water (TW), Preliminary Treated Wastewater (PTWW), Secondary Treated Wastewater (STWW) and Tertiary Treated Wastewater (TTWW). They reported that the type of water used did not affect concrete slump and density. However, setting times were found to increase with deteriorating water quality. PTWW and STWW were found to have the most effect on retarding setting time and concrete made with them showed lower strength development for upto 1 year. At early ages (3 and 7 days), the strength of concrete made with TTWW was higher than that of concrete made with TW. They also observed that the possibility of steel corrosion increased with the use of STWW and PTWW, especially when at hinner covert other in forcing steel was used.
	2002	“Effect of copper slag waste water on the mechanical properties of concrete” studied the effect of copper slag waste water used for curing of concrete by 40% replacement with wastewater. She reported that there is a increase in the compressive and flexural strength but there is decrease in the tensile strength and also the setting time was beyond the limit. The workability and durability of the concrete gives the better result.

	2001	Use of Domestic waste water as curing waters” has concluded that they used a Domestic waste water as curing water’s for M20 grade concrete for a period of 7, 14 and 28 days. After curing for 14 and 28 days, they got a minimum increase in the Compressive strength, Split tensile strength and Flexural strength. But for 7 days of curing period they got an 1.12% decrease in the Compressive strength, 5.32% decrease in Split tensile strength and 6.52% decrease in Flexural strength.
	2001	Analysis of alternative water sources for the manufacture of concrete”. The report concluded that even a simplest purifying process provides water suitable for manufacture of concrete from wash out water. These results were compared to a series of alternative water sources. The water sources included treated effluent, sea water and dam water and were subjected to same testing parameters as the reference. Analysis of these results found that despite having higher levels of organic and inorganic properties, the water from these sources was found suitable for manufacture of plain concrete.
	1996	Two criteria should be considered in evaluating the suitability of Ready Mixed Concrete (RMC) waste water for producing fresh concrete: i. Whether the impurities in the waste water will affect the properties and quality of concrete. ii. The degree of impurity which can be tolerated.
	1989	Use of both treated and raw wastewater in concrete mixing” Treated wastewater was not shown to have an adverse effect on concrete. However, raw sewage reduced the 3 and 28 day compressive strength by 9%. Thus, the average raw domestic sewage was shown to increase the initial setting time, entrain air and reduce the strength of mortar and concrete.
	1987	Use of Waste Water in Concrete Mix”. They made an attempt to use waste water in concrete mix instead of portable water and they mixed the waste water in various proportions such as 0%, 25%, 50% and 100% to cast the cubes of mix proportion 1:2:4 and after this they studied on long and short term effect of concrete. But after 28 days they got an compressive strength of 1.5% increase then by using with portable water.

2.2 Research Gap

From the literature review it has been observed that there is huge requirement to find out sustainable method to replace potable water in concrete mix. First of all there is a need to control waste water parameters, then to check the effect of replacement of potable water by treated water on the properties of concrete. The replacement shall have an effect on reinforcement in RCC. By replacement of potable water there is a need to check long term durability of concrete. Replacement of potable water shall have social and economic implications which needs to be communicated to citizens as the resistance to change is always there and it takes some time to understand the treated wastewater in concrete will not impact its strength. This shall further have an environmental effect and will have help in achieving long term sustainable goals and shall be environment friendly. Further this study will help in framing policy at government level to save potable water for future generations.

Chapter 3: Study Area and Methodology

3.1 General

India has the largest population in the world and the biggest concern is that India may lack the quantity and quality of water in the long term. Since, India is a country with large agricultural output and being a developing country, the various construction activities are going on at full swing, the overall water table is going down at a rapid pace. Concrete is a widely used building material in the world. The population growth and rapid development have led to the massive use of concrete as construction industry's key material. The biggest negative effects of this industry are environmental contaminants, such as Air and Water pollution and the shortage of preliminary sources. The deficiency of sources of drinking water is deliberated today to be one of the world's biggest complications. Therefore, the reuse of treated water becomes the main option to be considered as a new source of water in region where water is scarce. This will be achieved by establishing a balance between the amount of treated water to be used along with groundwater for various areas/ regions and thereby reducing the groundwater extraction. In case of construction activities, the replacement of water to be used in concrete mix by treated water from Sewage Treatment Plant will ensure reduction of use of potable water. The addition of treated water in concrete mix in different proportions will be done to check the various characteristics of concrete. The consumption of treated wastewater in mixing of concrete structures may reduce the environmental effects due to the disposal of waste water and will also minimize the cost of construction. The use of treated sewage water would be a revolutionary concept in concrete mixing which may reduce water scarcity up to a certain limit.

3.2 Study Area

The samples of household domestic wastewater are collected from the Sewage treatment plant in the town of Bambianwali, Jalandhar, which is run by the Government of Punjab and has a capacity of 10 MLD. The area is located 16 kilometers away from Phagwara and 14 kilometers away from Jalandhar. The “Bambianwali” sewage treatment plant mostly received the domestic wastewater from houses which belongs to civil area. Surrounding land belongs to agriculture hence there is not much industry in said area. The testing has been done in Government approved lab near treatment and fulfills the norms (permissible limits) of Central Pollution Control Board (CPCB).

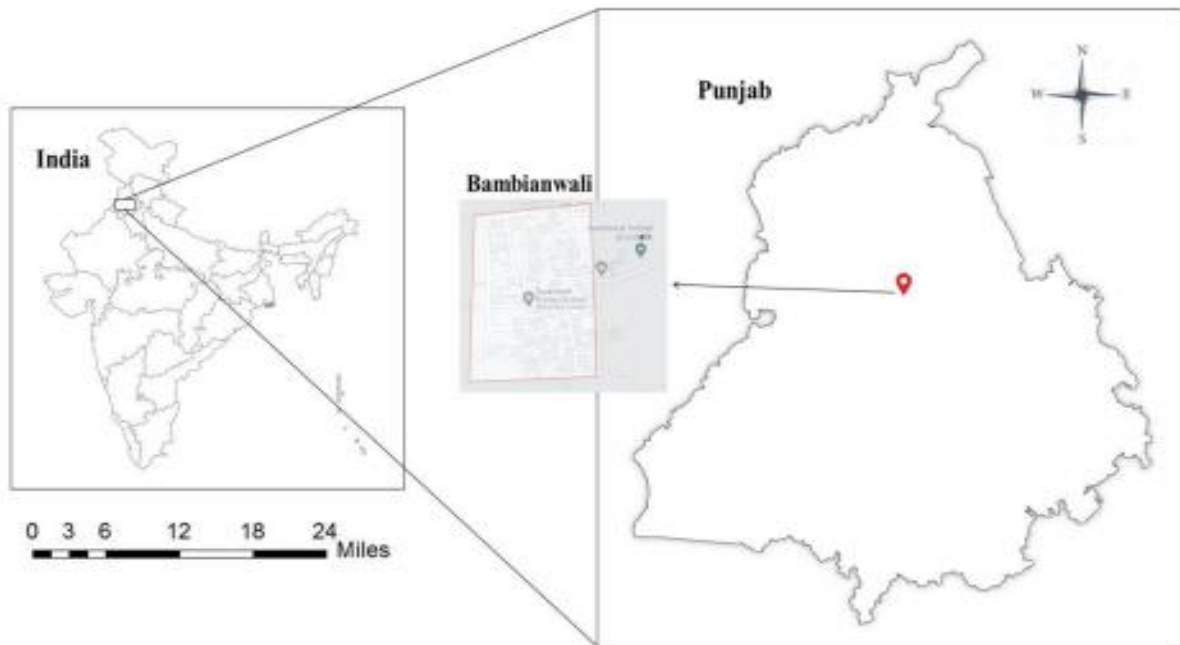


Figure 3.2: Location of Bambianwali sewage treatment plant

The “Bambianwali” Sewage Treatment Plant consist of the following steps of treatment. Initially the wastewater collected in “Inlet Chamber” so that flocculation in flow can be managed. Further, the screens are provided in order to remove floating matters and coarse particles. Then the wastewater goes through the mechanical chamber followed by “SBR basins” which is a type of activated sludge process. MEP/Blower room is utilized for processing the wastewater. The wastewater further goes into the chlorine contact tank for disinfection after which it goes through the process of tonner shed and sludge sump/sludge pump house.

3.3 Data collection

During the study total 1948 samples are collected in which nine different parameters i.e., pH, TSS, Temp, COD, BOD, TKN, F. Coli. are taken and analyzed. In order to understand the variation in the quality of treated wastewater flow, samples are taken for each of the day of the calendar month from 01.04.2021 to 30.11.2023.

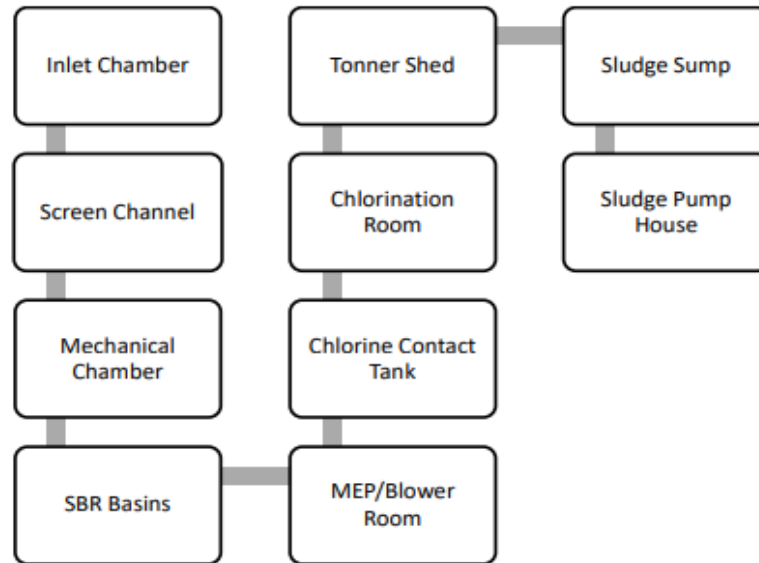


Figure 3.3: Flow chart of process of sewage treatment plant

3.4 Domestic Wastewater Analysis

During the testing in the lab, samples were taken throughout the month for better accuracy. The various parameters like pH, Temperature, BOD, COD, TSS, F. Coli. and TKN were taken under consideration which helps to examine the effectiveness of sewage treatment plant and regulate the water quality at outlet of Sewage Treatment Plant.

pH indicates the free hydrogen ions present in the wastewater. The addition of acidic/basic chemicals are important steps of sewage treatment plant since it separates the dissolved waste from the raw water. These dissolved solids keep moving inside the wastewater due to which settlement of the contaminates are very less. The contaminants can be settle down by increase the pH value due to which positive charged ions of metal makes bond with negatively hydroxide ions. In results of positive and negative charged ions, it erects heavy and unfathomable metal ions which could settle down easily in the wastewater.

During the experimentation, Labline pH meter (Model: HI96107) has been utilized.

Presence of TSS in higher amount creates the critical environment for the aquatic life. The presence of TSS blocks the sun light to enter into the water body due to which it lowers the potential of algae to process the food as well as oxygen. The TSS content has been found by using IS 3025 (Part 15 & 17) – 2003 in which glass fiber filter contain Pore Size 1.5 μm , Diameter 47 mm has been used. Prior to the weight of the filter paper, the filter paper has been dried in over at 105°C.

COD content indicates the organic content presence in the wastewater. The higher value of COD indicates higher content of the organics waste. The domestic waste largely consists of the organic wastes. While calculating the COD content, 2.5 Ml of sample, 1.5 ML of Potassium dichromate and 3.5 ml sulfate-sulfuric acid has been used. The closed reflux method in which Hach DRB 200 has been used for the determination of COD content in the waste water.

BOD is basically bio-chemical oxygen demand. The organic matter should be decomposed for the treatment of the wastewater under the aerobic conditions. The aerobic condition i.e., presence of oxygen content in the wastewater can be calculated by biochemical oxygen demand. The BOD test samples has been put under 5 days' incubation period at the temperature of 20°C. BOD digital incubator (Model: BOD171) has been used for BOD testing.

Faecal coliform test is a laboratory method used to detect the presence of faecal coliform bacteria in water, which are indicators of potential fecal contamination and the presence of pathogens. These bacteria are commonly found in the intestines of warm-blooded animals and their feces. Samples are incubated at a specific temperature (usually 44.5°C) for a certain period (e.g., 24 hours) to allow the fecal coliform bacteria to grow and produce visible colonies. Colonies are then identified based on their color, appearance, and ability to grow at the elevated temperature.

TKN content is found to know the Ammonia and Nitrogen content in the wastewater. The access amount of the ammonia can lead to eutrophication i.e.; increase plant growth eventually kills fishes. The TKN has been found using Hach TNT 880.

3.5 Methodology:

The Analysis of treated water from Sewage Treatment Plant is done according to the standard method for examination of wastewater. Table 3.1 shows the methods of analysis of different parameters.

Sr.No.	Parameters	Instruments used for parameters
1.	pH	pH meter
2.	Conductivity	Conductivity meter
3.	TDS	TDS meter
4.	COD	Open reflux method
5.	BOD	Winklers method
6.	Sulphate, chloride	Titration
7.	Sodium	Flame photo meter method
8.	Nitrate	Spectro photo meter Method
9.	Faecal Coliform	Laminar air flow

Table 3.1: Instruments used for testing of Various parameters



Figure 3.4 : LCD digital pen pH meter



Figure 3.5:-Electric Conductivity Meter

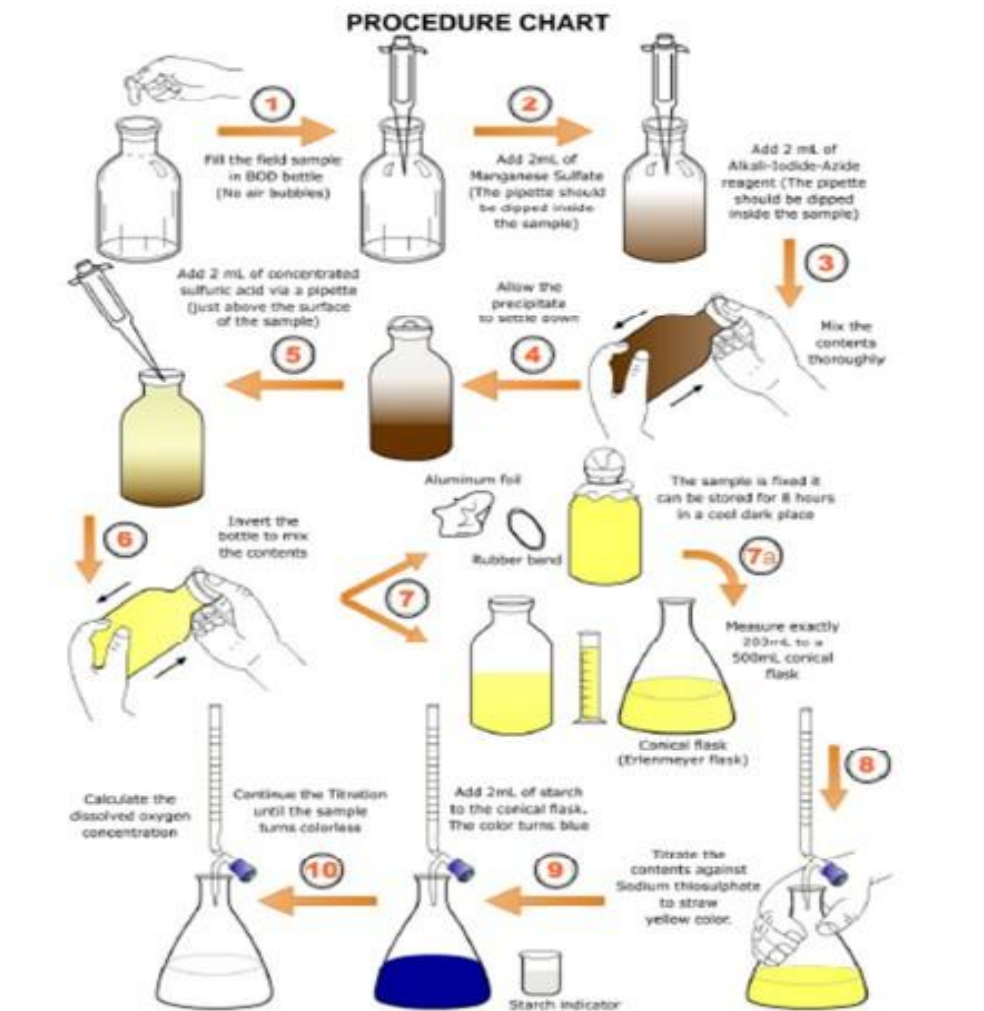


Figure 3.6:-flow chart diagram for measurement of D.O

- **Concrete cube sampling and its curing**

Concrete mix was made with fresh water and with treated sewage water in various proportions. After mixing, the cement concrete was placed in moulds.

- **Analysis of Concrete Cubes**

The properties of the concrete will be tested to determine the effects of the treated sewage water. Some of the tests with their procedures are listed below.

Sr. No.	Parameter	Test Performed
1.	Workability	Slump Test
2.	Compressive Strength	Load Test



Figure 3.7: 10 MLD Sewage treatment plant, a) STP capacity, b) Automatic screens, c) Fine screens, d) Processed wastewater chamber, e) Aeration chamber, f) Lab set-up, g) STP lab, h) Testing equipments

Chapter 4 :Results and Discussions

4.1 Introduction

The Treated Sewage Water has been collected from the outlet of 10 MLD Sewage Treatment Plant at Bambianwali, Jalandhar daily and laboratory analysis have been performed for various parameters and the results have been compiled. The treated water samples from 225 MLD at Jamalpur, Ludhiana based on SBR technology and 95 MLD STP at Ghausabad, Amritsar based on ASP technology have also been collected and laboratory analysis have been performed for various parameters and the results have been compiled.

The results of last 3 years data of various parameters of Treated Sewage at the outlet of 10 MLD Sewage Treatment Plant at Bambianwali have been compiled and tabulated below:-

4.2 Various parameters of Treated Sewage water from 2021-22

a) pH

The pH value of the treated wastewater from the 10 MLD STP at Bambianwali was monitored on a monthly basis, and showed consistent results throughout the year. The average of pH in April was 7.15, which is in good agreement with the mean value of 7.16, indicating slight alkalinity. The average pH in May was 7.18, and the mean was 7.18, indicating a stable pH level. June average pH 7.16, median 7.17, maintaining the same trend. It fell slightly in July with an average of 7.13 and a 7.13. The average volume for August is 7.15 and the median is 7.16, while the values for September are 7.14 and 7.14, respectively. The pH in October is 7.13, and the mean is 7.14. In November, the average pH increased slightly to 7.17 with a mean of 7.13. Finally, the average December pH is 7.13, with a mean of 7.14. Overall, the pH values remained within a narrow range, demonstrating effective treatment and stable water quality.

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-04-21	7.11	24.51	12	40	6		
02-04-21	7.12	24.49	17	39	5		
03-04-21	7.14	24.22	15	42	9	640	3
05-04-21	7.15	24.74	14	40	6		
06-04-21	7.11	24.72	16	41	5		
07-04-21	7.22	24.52	20	36	8		
08-04-21	7.18	24.75	16	40	9		
09-04-21	7.2	25.28	18	35	6		
10-04-21	7.23	25.34	15	38	8		
12-04-21	7.16	25.52	17	42	7	690	4
13-04-21	7.08	25.76	15	38	10		
14-04-21	7.05	25.81	19	39	6		
15-04-21	7.18	30	16	40	8		
16-04-21	7.1	31.2	18	44	7		
17-04-21	7.2	27.52	15	40	9		
19-04-21	7.16	27.32	19	38	7		
20-04-21	7.19	27.39	17	37	9	570	2
21-04-21	7.21	27.44	18	41	6		
22-04-21	7.16	27.62	16	43	8		
23-04-21	7.14	28	18	40	8		
24-04-21	7.17	28	17	40	5		
26-04-21	7.13	28.4	19	44	7		
27-04-21	7.15	28.57	18	39	6		
28-04-21	7.18	28.64	16	42	9	600	3
29-04-21	7.16	28.82	19	38	8		
30-04-21	7.12	28.73	16	40	7		
Mean	7.1538462	26.819615	16.769231	39.846154	7.2692308	625	3
Median	7.16	27.355	17	40	7	620	3
Standard Deviation	0.0436419	1.9485615	1.8397324	2.2215726	1.4299005	51.961524	0.8164966

Table 4.2.1: Various parameters of Treated Sewage water for the month 04/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-05-21	7.1	28.51	17	37	6		
03-05-21	7.14	28.56	15	39	9		
04-05-21	7.19	28.4	19	36	7		
05-05-21	7.15	28.37	18	40	6		
06-05-21	7.18	28.32	14	38	9	650	3
07-05-21	7.16	28.24	18	43	8		
08-05-21	7.21	28.13	16	41	5		
10-05-21	7.14	28.21	19	38	7		
11-05-21	7.19	27.93	17	39	9		
12-05-21	7.2	27.35	15	42	6		
13-05-21	7.2	26.8	19	44	8		
14-05-21	7.15	26.97	16	40	9	680	2
15-05-21	7.19	27.84	18	42	5		
17-05-21	7.21	27.94	16	36	7		
18-05-21	7.18	28.21	19	38	6		
19-05-21	7.19	28.24	17	41	9		
20-05-21	7.2	28.31	14	40	7		
21-05-21	7.14	28.12	18	39	6		
22-05-21	7.18	28.25	16	36	9	600	2
24-05-21	7.15	28.39	15	40	7		
25-05-21	7.17	28.08	19	37	9		
26-05-21	7.21	28.12	14	39	6		
27-05-21	7.2	28.19	17	36	8		
28-05-21	7.17	28.28	18	40	9		
29-05-21	7.21	28.23	15	38	5	570	2
31-05-21	7.22	28.32	19	36	7		
Mean	7.1780769	28.088846	16.846154	39.038462	7.2692308	625	2.25
Median	7.185	28.22	17	39	7	625	2
Standard Deviation	0.0293965	0.4271424	1.7364863	2.2712247	1.4299005	49.328829	0.5

Table 4.2.2: Various parameters of Treated Sewage water for the month 05/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-06-21	7.17	28.19	17	41	8		
02-06-21	7.15	28.11	18	39	6		
03-06-21	7.14	27.96	15	42	9		
04-06-21	7.11	27.93	14	44	8		
05-06-21	7.08	27.99	15	42	7		
07-06-21	7.11	28	14	39	9	690	4
08-06-21	7.13	28.16	19	43	6		
09-06-21	7.16	28.31	16	41	7		
10-06-21	7.16	28.51	19	36	8		
11-06-21	7.19	28.66	17	38	5		
12-06-21	7.15	28.81	15	41	9		
14-06-21	7.18	28.87	18	39	6		
15-06-21	7.19	28.89	17	36	8	600	4
16-06-21	7.21	28.74	14	36	7		
17-06-21	7.2	28.8	16	38	8		
18-06-21	7.16	28.81	13	36	6		
19-06-21	7.17	28.87	18	39	9		
21-06-21	7.17	28.83	17	38	5	700	3
22-06-21	7.2	28.92	15	41	8		
23-06-21	7.19	28.94	19	42	6		
24-06-21	7.14	28.97	18	40	5		
25-06-21	7.21	28.99	18	42	6		
26-06-21	7.18	29.07	15	43	9		
28-06-21	7.19	28.9	17	40	7		
29-06-21	7.16	29.95	18	41	6	580	2
30-06-21	7.18	28.97	19	37	9		
Mean	7.1646154	28.659615	16.576923	39.769231	7.1923077	642.5	3.25
Median	7.17	28.81	17	40	7	645	3.5
Standard Deviation	0.0322776	0.464917	1.8148956	2.3884337	1.3861957	61.305247	0.9574271

Table 4.2.3: Various parameters of Treated Sewage water for the month 06/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-07-21	7.16	29.07	15	38	7		
02-07-21	7.2	28.98	18	42	9		
03-07-21	7.17	28.93	16	40	6		
05-07-21	7.21	28.9	15	43	8		
06-07-21	7.16	28.65	17	43	9	630	2
07-07-21	7.14	28.67	18	40	5		
08-07-21	7.18	29.19	15	39	7		
09-07-21	7.1	29.13	16	37	9		
10-07-21	7.08	28.78	19	44	8		
12-07-21	7.13	28.72	18	42	9		
13-07-21	7.1	28.91	14	39	6	590	3
14-07-21	7.15	29.61	19	37	8		
15-07-21	7.12	29.47	17	42	9		
16-07-21	7.1	29.3	18	40	5		
17-07-21	7.14	29.41	16	43	7		
19-07-21	7.18	28.91	15	44	8		
20-07-21	7.13	28.56	18	42	6	600	2
21-07-21	7.09	28.7	16	37	7		
22-07-21	7.11	28.87	15	40	9		
23-07-21	7.14	28.98	18	42	6		
24-07-21	7.18	28.92	19	38	8		
26-07-21	7.08	28.3	17	41	8		
27-07-21	7.11	28.15	15	43	9	500	4
28-07-21	7.15	28.06	18	40	6		
29-07-21	7.13	28.26	16	42	7		
30-07-21	7.11	28.42	17	39	8		
31-07-21	7.12	28.31	19	41	7		
Mean	7.1359259	28.820741	16.814815	40.666667	7.4444444	580	2.75
Median	7.13	28.9	17	41	8	595	2.5
Standard Deviation	0.0356542	0.4016593	1.5200465	2.1483446	1.2810252	55.976185	0.9574271

Table 4.2.4: Various parameters of Treated Sewage water for the month 07/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
02-08-21	7.15	28.88	16	40	9		
03-08-21	7.22	29.11	18	38	6		
04-08-21	7.18	29.16	15	36	5	650	3
05-08-21	7.16	29.22	17	48	7		
06-08-21	7.19	29.19	16	37	9		
07-08-21	7.17	29	19	41	6		
09-08-21	7.19	29.11	14	43	9		
10-08-21	7.17	29.08	17	42	8		
11-08-21	7.15	29.1	16	43	7		
12-08-21	7.19	29.13	19	40	9	500	2
13-08-21	7.17	29.2	14	42	8		
14-08-21	6.96	29.39	16	38	5		
16-08-21	7.16	29.7	18	39	7		
17-08-21	7.15	29.81	19	40	6		
18-08-21	7.18	29.9	14	37	9		
19-08-21	7.21	29.78	13	39	8	600	3
20-08-21	7.19	30.4	19	43	5		
21-08-21	7.16	29.84	18	41	8		
23-08-21	7.13	29.66	19	40	5		
24-08-21	7.1	29.6	16	40	7		
25-08-21	6.98	29.57	19	37	6		
26-08-21	7.13	29.54	18	39	9	630	2
27-08-21	7.16	29.5	15	44	8		
28-08-21	7.15	29.52	17	42	8		
30-08-21	7.16	29.24	16	39	6		
31-08-21	7.19	29.3	14	37	9		
Mean	7.1519231	29.420385	16.615385	40.192308	7.2692308	595	2.5
Median	7.16	29.345	16.5	40	7.5	615	2.5
Standard Deviation	0.0593983	0.3515393	1.8989876	2.7132155	1.457606	66.583281	0.5773503

Table 4.2.5: Various parameters of Treated Sewage water for the month 08/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-09-21	7.18	29.32	19	41	7		
02-09-21	7.14	29.12	16	40	6	650	4
03-09-21	7.12	29.11	18	43	9		
04-09-21	7.13	29.04	13	42	8		
06-09-21	7.12	28.65	19	37	5		
07-09-21	7.19	28.58	15	9	7		
08-09-21	7.13	28.5	18	38	6		
09-09-21	7.1	28.47	14	42	5	550	3
10-09-21	7.16	28.9	16	40	8		
11-09-21	7.19	29.46	15	43	6		
13-09-21	7.17	29.24	18	40	9		
14-09-21	7.18	29.2	15	42	8		
15-09-21	7.06	29.19	17	40	9		
16-09-21	7.15	29.13	19	43	9		
17-09-21	7.17	28.93	17	38	8	620	4
18-09-21	7.13	28.7	19	39	7		
20-09-21	7.18	28.57	16	41	8		
21-09-21	7.12	28.31	17	37	7		
22-09-21	7.14	26.91	19	39	5		
23-09-21	7.16	27.18	17	42	7		
24-09-21	7.07	27.24	18	36	9		
25-09-21	7.1	27.43	18	39	8	470	2
27-09-21	7.12	27.63	15	38	9		
28-09-21	7.18	27.88	19	42	5		
29-09-21	7.14	27.7	17	40	7		
30-09-21	7.19	27.67	16	40	6		
Mean	7.1430769	28.463846	16.923077	38.884615	7.2307692	572.5	3.25
Median	7.14	28.615	17	40	7	585	3.5
Standard Deviation	0.036196	0.7602004	1.7186757	6.4082879	1.3944947	80.156098	0.9574271

Table 4.2.6: Various parameters of Treated Sewage water for the month 09/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-10-21	7.17	27.5	19	37	7		
02-10-21	7.18	27	14	39	9		
04-10-21	7.14	27.25	16	36	5	620	3
05-10-21	7.12	27.04	18	43	8		
06-10-21	7.16	27.6	17	40	7		
07-10-21	7.18	27.3	19	41	9		
08-10-21	7.14	27.35	16	43	6		
09-10-21	7.13	27.3	18	40	9		
11-10-21	7.18	27	14	42	7		
12-10-21	7.1	27.18	17	36	5	600	3
13-10-21	7.14	27.1	19	39	8		
14-10-21	7.17	27	15	40	9		
15-10-21	7.11	26.9	17	37	7		
16-10-21	7.13	27	15	39	8		
18-10-21	7.07	27.08	19	41	6		
19-10-21	7	27	16	40	9	680	2
20-10-21	7.02	26.98	18	37	7		
21-10-21	7.05	27.02	14	36	9		
22-10-21	7.11	26.9	17	39	9		
23-10-21	7.16	26.84	15	43	8		
25-10-21	7.13	26.63	14	41	9		
26-10-21	7.15	26.7	17	40	6		
27-10-21	7.2	26.65	16	44	8	450	2
28-10-21	7.11	26.57	18	40	7		
29-10-21	7.19	26.59	15	42	9		
30-10-21	7.15	26.5	19	38	5		
Mean	7.1303846	26.999231	16.615385	39.730769	7.5384615	587.5	2.5
Median	7.14	27	17	40	8	610	2.5
Standard Deviation	0.0503175	0.2845477	1.7453234	2.3247829	1.3922864	97.766729	0.5773503

Table 4.2.7: Various parameters of Treated Sewage water for the month 10/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-11-21	7.13	26.54	17	41	8		
02-11-21	7.18	26.49	14	36	6		
03-11-21	7.2	26.56	16	39	9		
04-11-21	7.15	26.49	14	37	7		
05-11-21	7.14	26.53	15	40	6		
06-11-21	7.16	26.47	19	42	8	500	4
08-11-21	7.12	26.39	20	43	5		
09-11-21	7.16	26.35	13	40	9		
10-11-21	7.18	26.35	16	40	6		
11-11-21	7.1	26.1	14	43	9		
12-11-21	7.8	26.11	18	38	7		
13-11-21	7.12	26.16	16	41	7		
15-11-21	7.09	26.09	19	42	5	540	3
16-11-21	7.11	26.13	15	37	8		
17-11-21	7.08	25.92	17	40	7		
18-11-21	7.12	25.8	15	38	6		
19-11-21	7.11	25.83	18	41	8		
20-11-21	7.16	25.85	19	39	9		
22-11-21	7.13	25.79	18	37	5	630	2
23-11-21	7.12	25.67	16	43	9		
24-11-21	7.17	25.65	15	40	7		
25-11-21	7.12	25.47	17	38	6		
26-11-21	7.11	25.4	15	36	8		
27-11-21	7.16	25.08	19	42	6		
29-11-21	7.19	24.6	18	40	9	680	2
30-11-21	7.21	24.45	14	39	7		
Mean	7.1661538	25.933462	16.423077	39.692308	7.1923077	587.5	2.75
Median	7.135	26.095	16	40	7	585	2.5
Standard Deviation	0.1337483	0.5714889	1.9631215	2.1310886	1.357033	82.209083	0.9574271

Table 4.2.8: Various parameters of Treated Sewage water for the month 11/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-12-21	7.2	24.63	19	43	8		
02-12-21	7.17	24.51	16	41	4		
03-12-21	7.13	24.31	17	42	7		
04-12-21	7.17	24.25	15	37	9	550	3
06-12-21	7.14	24.2	17	39	6		
07-12-21	7.14	23.14	16	38	6		
08-12-21	7.17	20.23	16	39	9		
09-12-22	7.16	21	18	36	6		
10-12-21	7.15	20.36	17	36	8		
11-12-21	7.1	21.2	16	36	7		
13-12-21	7.12	20.91	18	39	6	490	2
14-12-21	7.11	19.12	17	39	7		
15-12-21	7.09	19.23	16	38	6		
16-12-21	7.14	19.15	18	38	9		
17-12-21	7.15	20.23	18	35	8		
18-12-21	7.1	18.23	18	35	7		
20-12-21	7.13	18.25	16	36	6	530	3
21-12-21	7.1	18.52	17	39	7		
22-12-21	7.13	18.45	18	35	8		
23-12-21	7.14	19.23	18	35	8		
24-12-21	7.2	19.54	17	37	7		
25-12-21	7.18	20.25	17	34	7		
27-12-21	7.14	20.85	19	37	6		
28-12-21	7.08	20.79	16	38	6	600	6
29-12-21	7.06	19.21	18	35	8		
30-12-21	7.1	19.25	17	39	7		
31-12-21	7.08	19.25	18	39	6		
Mean	7.1325926	20.677407	17.148148	37.592593	7	542.5	3.5
Median	7.14	20.23	17	38	7	540	3
Standard Deviation	0.0365421	2.0927505	1.0267088	2.257624	1.1766968	45.734742	1.7320508

Table 4.2.9: Various parameters of Treated Sewage water for the month 12/2021

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-01-22	7.09	21.8	18	37	6		
03-01-22	7.14	21.59	16	41	8		
04-01-22	7.1	22.06	19	39	7		
05-01-22	7.12	21.42	16	43	8	560	4
06-01-22	7.08	21.18	15	42	6		
07-01-22	7.1	21.2	14	38	7		
08-01-22	7	20.02	15	36	7		
10-01-22	7.02	21.1	16	38	9		
11-01-22	7.23	21	18	40	5		
12-01-22	7.19	21.23	16	39	8		
13-01-22	7.12	21.8	19	43	6	650	3
15-01-22	7.09	21.42	14	41	9		
16-01-22	7.14	21.54	17	44	9		
17-01-22	7.1	21.48	19	40	8		
18-01-22	7.21	22	15	38	6		
19-01-22	7.18	21.77	18	41	7		
20-01-22	7.14	21.33	16	39	9		
21-01-22	7.19	20.76	18	43	6	600	2
23-01-22	7.13	20.29	15	38	8		
24-01-22	7.17	20.5	17	38	6		
25-01-22	7.1	20.64	14	42	9		
26-01-22	7.13	20.48	18	44	9		
27-01-22	7.09	20.56	15	39	5		
28-01-22	7.15	20.73	18	37	9		
29-01-22	7.04	20.81	16	40	7	600	3
31-01-22	7.15	20.98	14	40	6		
Mean	7.1230769	21.141923	16.384615	40	7.3076923	602.5	3
Median	7.125	21.19	16	40	7	600	3
Standard Deviation	0.0550468	0.5446101	1.6751579	2.2627417	1.3496438	36.855574	0.8164966

Table 4.2.10: Various parameters of Treated Sewage water for the month 1/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-02-22	7.07	20	18	36	7		
02-02-22	7.06	21	16	34	7		
03-02-22	7.1	19.1	19	36	6		
04-02-22	7.11	18.1	18	32	7		
05-02-22	7.13	19.3	17	34	8		
07-02-22	7.1	23.14	16	36	7		
08-02-22	7.19	19.98	18	37	6	490	3
09-02-22	7.18	24	19	36	6		
10-02-22	7.08	23.24	18	36	7		
11-02-22	7	19.82	17	37	7		
12-02-22	7.1	19.6	16	34	8		
14-02-22	7.08	20.71	14	32	7		
15-02-22	7.06	24	17	34	7		
16-02-22	7.09	20.88	18	36	6		
17-02-22	7.1	24.09	19	38	8	560	4
18-02-22	6.9	24	18	39	5		
19-02-22	6.93	23.91	17	36	9		
21-02-22	7.04	22	15	41	7		
22-02-22	7.08	21.7	18	43	6		
23-02-22	7.14	21.52	16	40	9		
24-02-22	7.12	21.4	15	37	8		
25-02-22	7.11	20.87	19	39	7	430	3
26-02-22	7.08	20.42	17	41	9		
28-02-22	7.12	20.6	15	43	6		
Mean	7.0820833	21.390833	17.083333	36.958333	7.0833333	493.33333	3.3333333
Median	7.095	20.94	17	36	7	490	3
Standard Deviation	0.0654735	1.7910694	1.44212	3.0571252	1.0598058	65.064071	0.5773503

Table 4.2.11: Various parameters of Treated Sewage water for the month 2/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-03-22	7.08	21.51	18	40	8		
02-03-22	7.13	21.8	16	37	5		
03-03-22	7.04	22	19	36	7		
04-03-22	7.1	22.2	17	42	5	550	4
05-03-22	7.09	22.41	16	40	9		
07-03-22	7.01	22.41	17	38	6		
08-03-22	7	22.45	19	42	9		
09-03-22	7.04	22.52	18	40	5		
10-03-22	7.05	22.6	15	43	8		
11-03-22	7.02	23.02	18	40	6		
12-03-22	7.07	23.09	16	41	8	500	3
14-03-22	7.11	23.11	19	36	7		
15-03-22	7.08	23.08	17	39	9		
16-03-22	7.13	23.1	16	38	6		
17-03-22	7.08	23.19	18	37	8		
18-03-22	7.11	23.25	16	40	6		
19-03-22	7.14	23.92	19	38	9		
21-03-22	7.13	24.04	16	36	8	470	2
22-03-22	7.16	24.15	17	40	9		
23-03-22	7.12	23.98	15	42	7		
24-03-22	7.11	24.31	18	41	6		
25-03-22	7.1	24.36	19	43	6		
26-03-22	7.04	24.45	16	40	8		
28-03-22	7	24.44	17	38	7		
29-03-22	7.04	24.39	17	43	9	530	3
30-03-22	7.09	24.47	19	42	5		
31-03-22	7.11	24.52	16	41	8		
Mean	7.0807407	23.287778	17.185185	39.740741	7.1851852	512.5	3
Median	7.09	23.11	17	40	7	515	3
Standard Deviation	0.0448867	0.939412	1.3019818	2.2117274	1.4152205	35	0.8164966

Table 4.2.12: Various parameters of Treated Sewage water for the month 3/2022

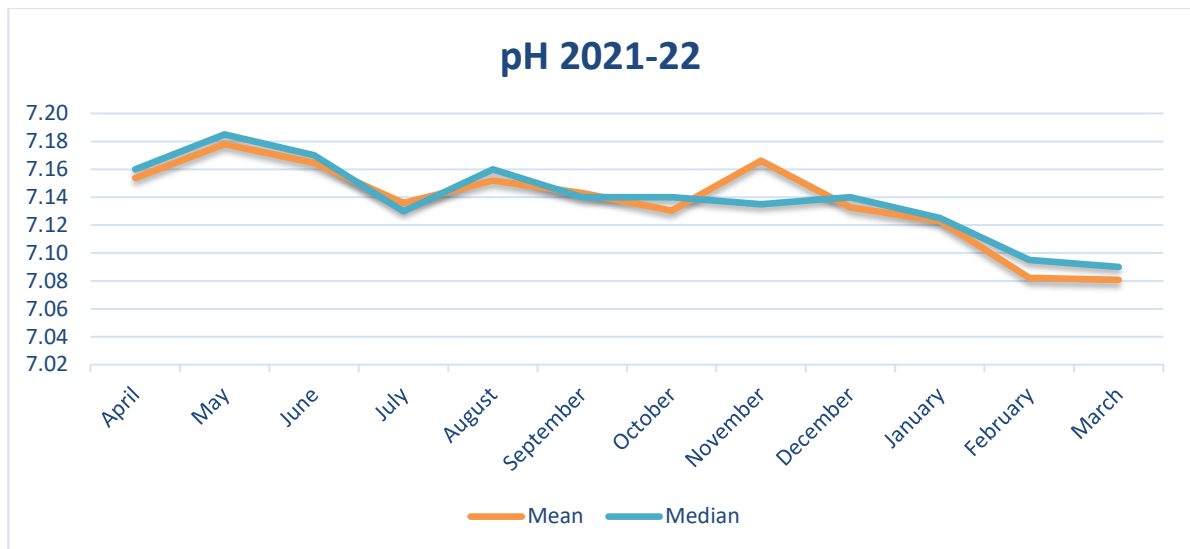


Figure 4.1 : pH value of 10 MLD Sewage Treatment Plant

b) Temperature

The graph shows monthly mean and median temperatures from April 2021 to March 2022. The mean temperature in April is 26.82°C, with a slightly higher temperature at 27.355°C. Temperature increased in May, where the average was 28.09°C and was 28.22°C. This increase continued until June, when the temperature reached 28.66°C and the humidity reached 28.81°C. There was also an increase in July, with an average of 28.80 degrees Celsius and a high of 28.90 °C. The highest temperature was recorded in August, with an average of 29.42°C and a mean of 29.345°C. In September, the average temperature dropped slightly to 28.46°C, and the average humidity was 28.615°C. A more notable decline occurred in October, with an average temperature of 27.00°C and a mean of 27.00°C. This cooling trend continued in November, with an average decrease to 25.93°C and a decrease to 26.095°C. December saw a significant drop in the minimum temperature for the year, at 20.68 °C, from 20.29 °C. January saw a dip in temperatures, with an average of 21.14 °C and a low of 21.19 °C. There was a slight increase in February, with an average of 21.39 °C and an average of 20.94 °C. The temperature finally peaked in March, with an average of 23.29°C and a low of 23.11 °C. Overall, the data show a seasonal variation with maximum temperatures in the summer months and minimum temperatures in the winter, indicating a typical climate.

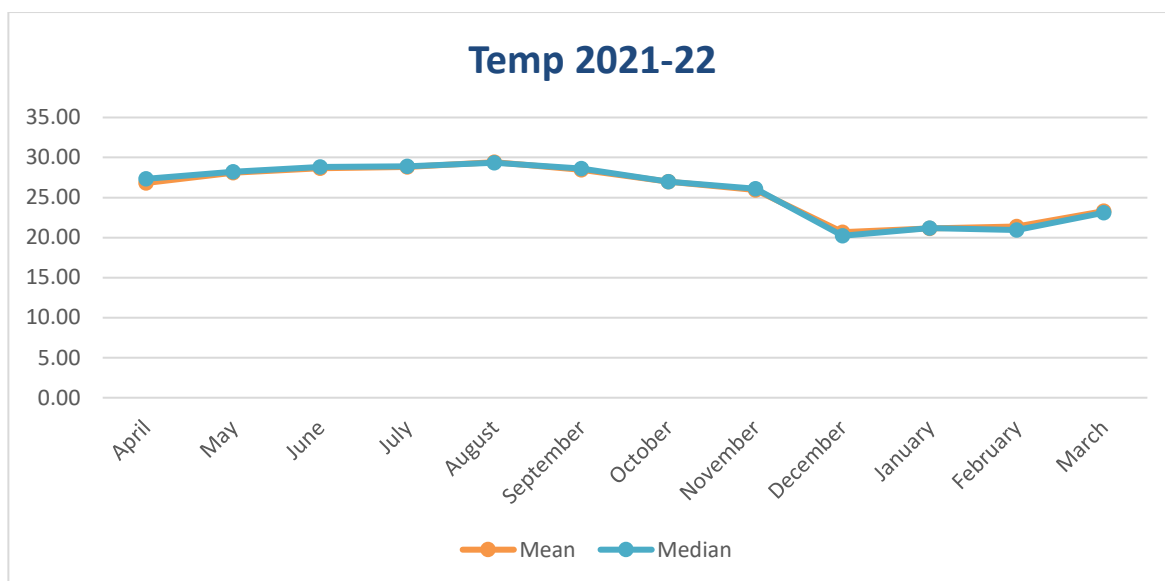


Figure 4.2 : Temp value of 10 MLD Sewage Treatment Plant

c) Total Suspended Solids

The graph presents monthly averages and medians of total suspended solids (TSS) for the year, and details variations in water quality parameters. The average values range from 16.42 to 17.14, with the lowest average in November and the highest in December. The median values are constantly hovering around 17, except in August where it drops to 16.5, indicating a slight decline in the TDS distribution in that month. In other months—April, May, June, July, September, and October—the median TDS remains stable at 17, indicating a constant central tendency despite fluctuating average prices. These measurements are important for monitoring water quality, guiding environmental decisions and ensuring that regulatory standards are met throughout the year.

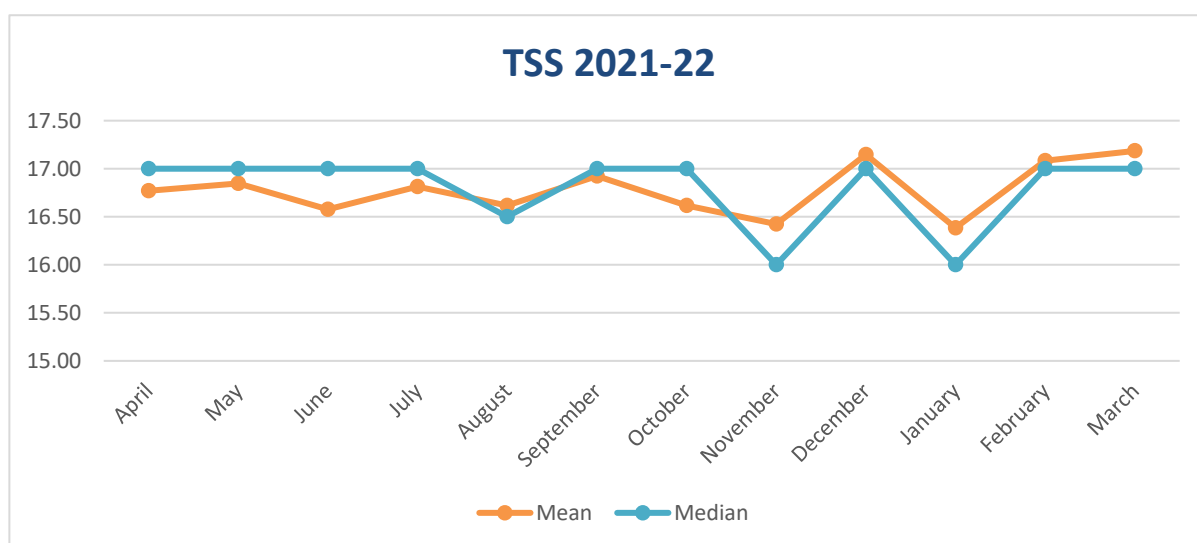


Figure 4.3 : TSS value of 10 MLD Sewage Treatment Plant

d) COD

The graph provides the monthly mean and median chemical oxygen demand (COD) concentrations of wastewater used in cement production, with respect to water transport standards. The mean COD values always ranged from 38 to 41, indicating a distinct central tendency in most months, except for September, which dropped slightly to 40. This measurement is important for the assessment of the suitability of pollutants for cement do about it, ensuring compliance with quality standards Prevent environmental damage. The data reveal monthly variations in COD levels, and guide management decisions to maintain water quality integrity throughout the year.

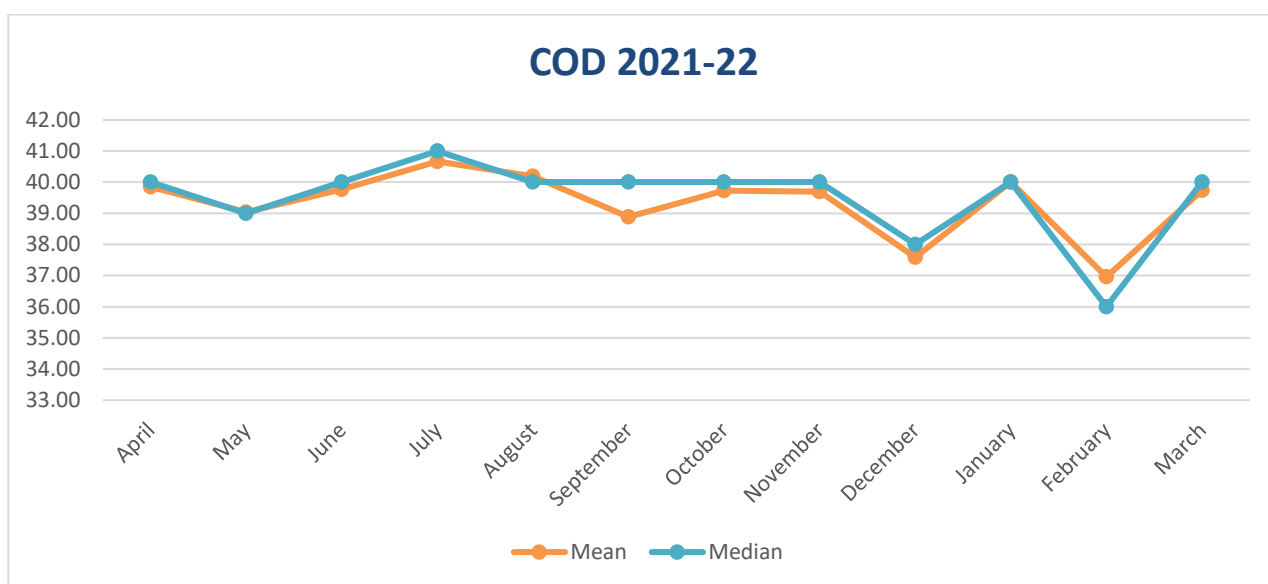


Figure 4.4 : COD value of 10 MLD Sewage Treatment Plant

e) BOD

The graph details the monthly mean and median of biological oxygen demand (BOD) of a year, which may vary widely from a low of 7 in December to a high of 7.54 in October for water analyzed quality to be environmental or technical. The median BOD values are consistently around 7 or 8, reflecting the main trend in BOD levels in different months. July stands out with a BOD of 8, indicating a typical value for that month. These measurements are important indicators of contamination in water, affecting regulatory compliance and environmental management. The data highlight monthly variations in BOD, providing insight into seasonal variations and water quality trends throughout the year.

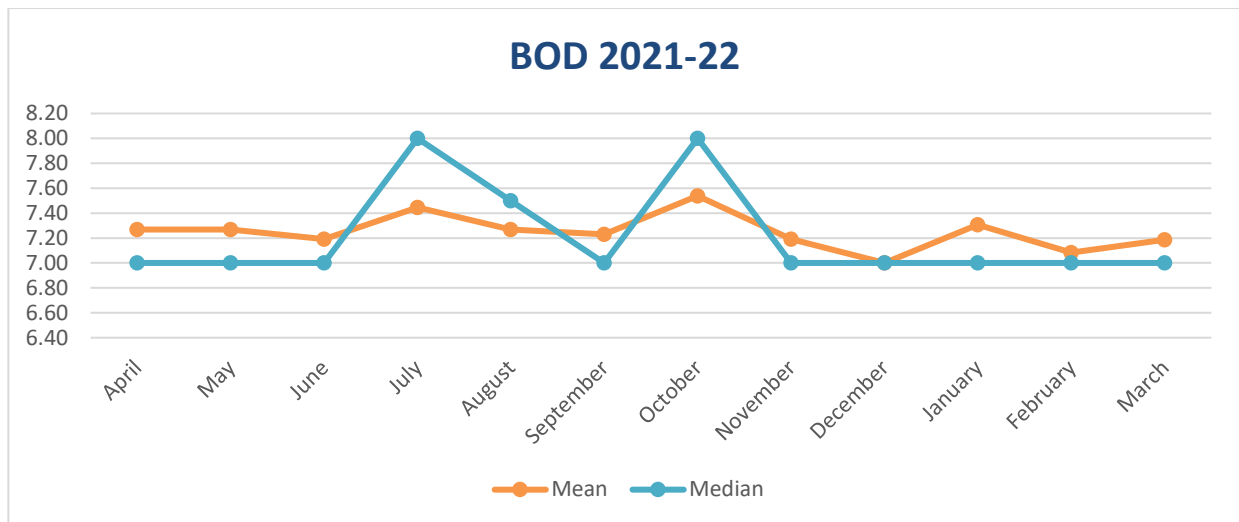


Figure 4.5 : BOD value of 10 MLD Sewage Treatment Plant

f) Faecal Coliform

The graph summarizes monthly fecal coliform (F.Coli) counts over a year, which are likely to be used to assess water quality standards, especially for drinking water or environmental health around. The average F. coli count ranged from 542.5 in December to 642.5 in June, indicating a fluctuation in bacterial load throughout the year. F.Coli counts ranged from 540 in December to 645 in June, fluctuating widely from month to month. July stands out with a median F.Coli count of 595, indicating that infection predominantly occurred during that period. These measurements are important for monitoring and monitoring water quality, as water coliform levels are indicators of potential health risks associated with waterborne disease. The data highlight monthly variations in F.Coli levels is emphasized, which is valuable for regulatory compliance and public health interventions aimed at protecting water resources and maintaining drinking water quality standards for year-round s ma insight.

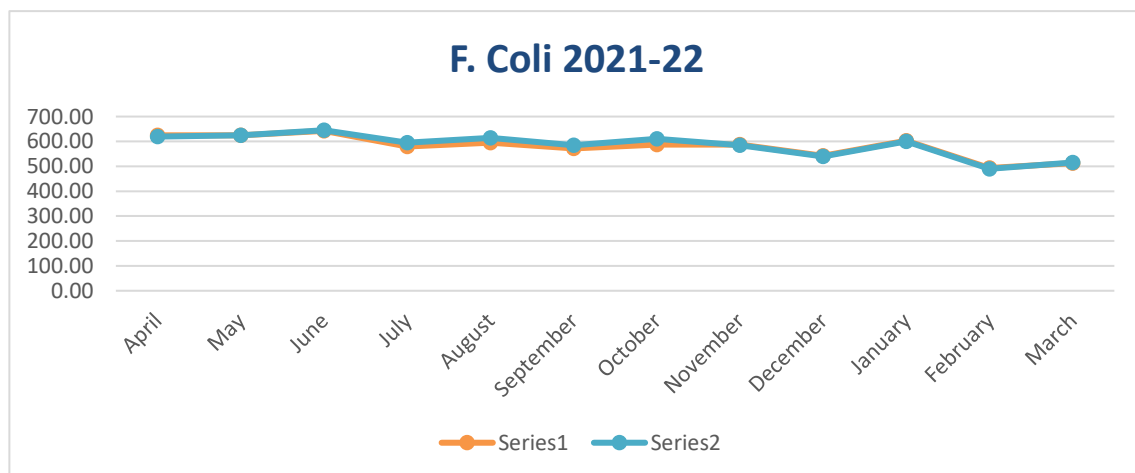


Figure 4.6 : F. Coli value of 10 MLD Sewage Treatment Plant

g) Total Kjeldahl Nitrogen (TKN)

The graph gives monthly concentrations of total Kjeldahl nitrogen (TKN) during one year, which may be used in water quality assessment or environmental monitoring. Average and median TKN values range from 2.25 in May to 3.5 in December throughout the year. It shows variation in nitrogen concentration. The median number of TKN ranged from 2 in May to 3.5 in June and September, showing significant monthly trends. TKN concentrations in July and November were 2.5, providing constant nitrogen concentrations in those months. These measurements are important for the assessment of nitrogen pollution in water bodies, identifying environmental policies and actions to maintain water quality standards. The data highlight the monthly variations in TKN ranging from 2.5 to 3.5 and average being 2.75 and hence variation of nearly 27% across seasons and provide insight into seasonal variation and nitrogen pollution throughout the year.

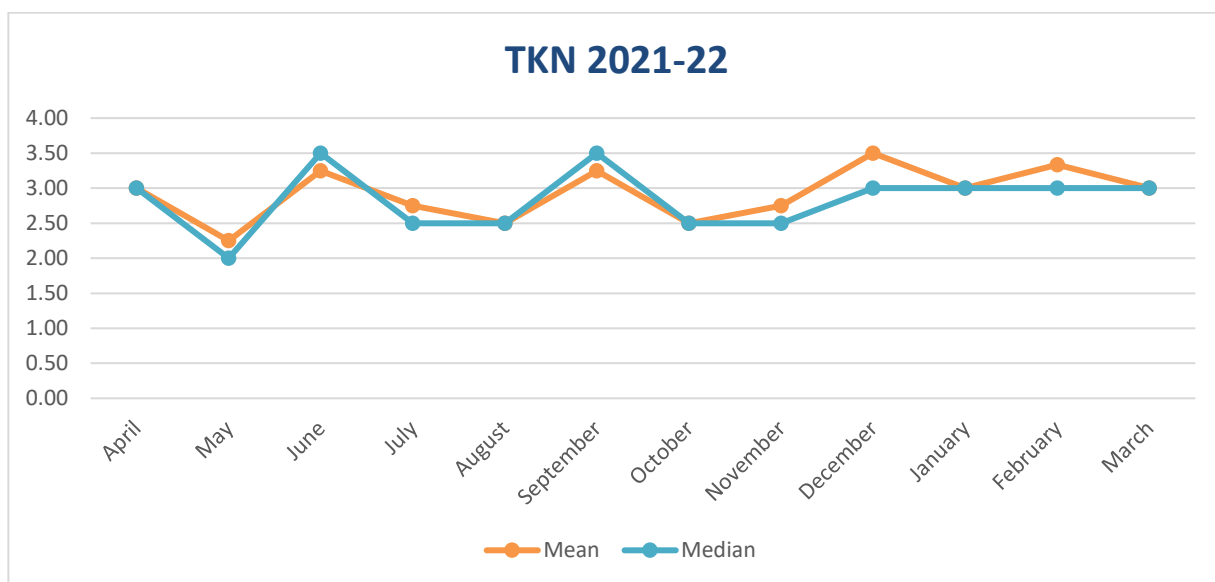


Figure 4.7 : TKN value of 10 MLD Sewage Treatment Plant

4.3 Various parameters of Treated Sewage water from 2022-23

a) pH

The graph shows the monthly temperature for 2022-23. These temperature readings may reflect environmental factors, perhaps region-specific or ecosystem-specific. Temperatures vary from a minimum of 20.75 °C in February to a maximum of 29.67 °C in August, showing seasonal variations in temperature throughout the year with temperatures ranging from 20.71 °C in February to 29.80 °C in August, showing similar variability among the months.

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-04-22	7.13	24.49	17	37	5		
02-04-22	7.17	24.47	19	39	7		
04-04-22	7.07	24.54	17	42	6		
05-04-22	7.06	24.52	18	40	8	490	4
06-04-22	7.03	24.83	16	42	9		
07-04-22	7.06	24.86	18	40	7		
08-04-22	7.03	24.94	18	41	9		
09-04-22	7.01	25.03	16	36	8		
11-04-22	7.04	25.07	19	39	5		
12-04-22	7.08	25.01	17	37	7	520	3
13-04-22	7.11	25.11	16	40	6		
14-04-22	7.1	25.16	18	42	9		
15-04-22	7.07	25.19	18	37	7		
16-04-22	7.13	25.27	17	40	8		
18-04-22	7.1	25.31	19	43	6		
19-04-22	7.12	25.35	15	41	9	590	2
20-04-22	7.14	25.51	17	42	7		
21-04-22	7.14	25.49	18	38	5		
22-04-22	7.11	25.44	15	40	7		
23-04-22	7.09	25.58	16	37	6		
25-04-22	7.13	25.66	18	36	9		
26-04-22	7.11	25.71	20	41	8		
27-04-22	6.94	25.73	18	37	6		
28-04-22	7.04	25.78	15	39	9	500	3
29-04-22	6.91	25.8	19	42	5		
30-04-22	7.08	25.86	17	40	8		
Mean	7.0769231	25.219615	17.346154	39.538462	7.1538462	525	3
Median	7.085	25.23	17.5	40	7	510	3
Standard Deviation	0.0601178	0.4309569	1.3547637	2.1020137	1.4054838	45.092498	0.8164966

Table 4.3.1: Various parameters of Treated Sewage water for the month 4/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
02-05-22	7.06	26.02	16	37	7		
03-05-22	7.09	26	19	41	9		
04-05-22	7.05	26.12	21	36	8		
05-05-22	7.11	26.15	18	39	6		
06-05-22	7.01	26.47	15	36	8	470	2
07-05-22	6.92	26.72	22	39	9		
09-05-22	9.97	26.86	20	43	5		
10-05-22	6.94	27.15	21	40	7		
11-05-22	7.08	27.12	18	42	9		
12-05-22	7.13	27.1	15	37	7		
13-05-22	7.11	27.21	20	40	5		
14-05-22	7.1	27.33	21	42	8	450	3
16-05-22	7.01	27.4	17	37	9		
17-05-22	7.07	27.28	20	39	7		
18-05-22	7.08	27.52	19	43	9		
19-05-22	7	27.6	16	40	6		
20-05-22	7.02	27.49	21	41	5		
21-05-22	6.97	27.7	15	44	8	520	3
23-05-22	6.93	27.29	18	40	9		
24-05-22	7.04	27.15	19	38	8		
25-05-22	7.11	27.24	17	36	6		
26-05-22	7.13	27.31	20	40	6		
27-05-22	7.15	27.4	15	39	8		
28-05-22	7.1	27.44	17	41	9	600	4
30-05-22	7.14	27.54	18	40	7		
31-05-22	7.19	27.51	20	37	9		
Mean	7.1734615	27.081538	18.384615	39.5	7.4615385	510	3
Median	7.08	27.26	18.5	40	8	495	3
Standard Deviation	0.5746926	0.5148879	2.1739719	2.2847319	1.3922864	66.833126	0.8164966

Table 4.3.2: Various parameters of Treated Sewage water for the month 5/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-06-22	7.19	27.65	16	39	8		
02-06-22	7.14	27.6	19	37	6		
03-06-22	7.15	27.59	17	42	7		
04-06-22	7.14	27.65	16	43	7		
06-06-22	7.19	27.68	19	40	9	480	3
07-06-22	7.16	27.73	15	42	6		
08-06-22	7.19	27.76	18	39	8		
09-06-22	7.17	27.74	16	40	7		
10-06-22	7.17	27.77	15	43	7		
11-06-22	7.1	27.75	16	36	9		
13-06-22	7.12	27.8	19	39	6	520	3
14-06-22	7.15	27.84	17	36	8		
15-06-22	7.09	27.83	17	40	7		
16-06-22	7.11	27.09	16	38	8		
17-06-22	7.14	26.84	18	42	5		
18-06-22	7.14	26.67	15	40	7		
20-06-22	7.1	26.72	19	43	9	470	2
21-06-22	7.18	26.64	18	39	8		
22-06-22	7.13	26.6	19	38	9		
23-06-22	7.11	26.75	16	41	6		
24-06-22	7.19	27.39	17	37	9		
25-06-22	7.21	27.44	18	41	8		
27-06-22	7.17	27.58	15	39	6		
28-06-22	7.14	27.69	18	43	9	430	3
29-06-22	7.18	27.74	16	40	8		
30-06-22	7.16	27.8	15	38	7		
Mean	7.1507692	27.436154	16.923077	39.807692	7.4615385	475	2.75
Median	7.15	27.65	17	40	7.5	475	3
Standard Deviation	0.032732	0.439837	1.4400855	2.154423	1.174079	36.968455	0.5

Table 4.3.3: Various parameters of Treated Sewage water for the month 6/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-07-22	7.11	27.07	18	42	8		
02-07-22	7.14	27.16	17	40	8		
04-07-22	7.13	27.43	19	39	6		
05-07-22	7.13	28.08	18	37	9	550	2
06-07-22	7.16	27.96	19	37	5		
07-07-22	7.18	28.04	15	41	7		
08-07-22	7.13	28.12	17	36	5		
09-07-22	7.11	28.16	16	39	8		
11-07-22	7	28.21	16	42	7		
12-07-22	7.02	28.39	18	41	8	510	4
13-07-22	7.08	28.42	17	40	9		
14-07-22	7.13	28.59	19	37	6		
15-07-22	7.16	28.62	17	40	9		
16-07-22	7.14	28.66	14	36	8		
18-07-22	7.19	28.71	18	39	6		
19-07-22	7.18	28.69	18	42	5	570	2
20-07-22	7.11	28.78	16	40	9		
21-07-22	7.16	28.91	19	43	7		
22-07-22	7.09	28.97	16	41	5		
23-07-22	7.17	29.02	15	38	9		
25-07-22	7.14	29.11	20	38	8		
26-07-22	7.19	29.15	18	36	8		
27-07-22	7.17	29.17	16	39	6	450	3
28-07-22	7.11	29.15	15	42	9		
29-07-22	7.1	29.22	17	40	6		
30-07-22	7.13	29.34	19	37	7		
Mean	7.1292308	28.505	17.192308	39.307692	7.2307692	520	2.75
Median	7.13	28.64	17	39.5	7.5	530	2.5
Standard Deviation	0.0464692	0.6255574	1.5496898	2.1122354	1.4228898	52.915026	0.9574271

Table 4.3.4: Various parameters of Treated Sewage water for the month 7/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-08-22	7.14	29.37	14	38	5		
02-08-22	7.16	29.42	18	42	9		
03-08-22	7.07	29.32	16	42	9		
04-08-22	7.12	29.39	18	39	7	520	4
05-08-22	7.16	29.33	16	36	9		
06-08-22	7.11	29.4	19	38	5		
08-08-22	7.14	29.38	15	37	7		
09-08-22	7.13	29.44	17	41	8		
10-08-22	6.97	29.49	19	40	8		
11-08-22	7.04	29.55	18	43	6		
12-08-22	7.09	29.58	18	40	9	600	2
13-08-22	7.1	29.67	16	37	7		
15-08-22	7.12	29.81	15	39	5		
16-08-22	7.16	29.78	19	36	5		
17-08-22	7.08	29.81	17	40	9		
18-08-22	7.03	29.86	18	38	7		
19-08-22	7	29.82	19	42	8		
20-08-22	7.11	29.89	15	40	9	500	2
22-08-22	7.13	29.84	18	43	6		
23-08-22	7.14	29.8	16	40	6		
24-08-22	7.11	29.86	19	36	8		
25-08-22	7.08	29.92	18	39	5		
26-08-22	7.1	29.85	15	42	7		
27-08-22	7.16	29.83	19	40	9		
29-08-22	7.14	29.94	16	41	5	460	3
30-08-22	7.12	29.81	18	39	6		
31-08-22	7.08	29.9	17	37	8		
Mean	7.1033333	29.668889	17.148148	39.444444	7.1111111	520	2.75
Median	7.11	29.8	18	40	7	510	2.5
Standard Deviation	0.0485957	0.2183739	1.5368225	2.136376	1.5275252	58.878406	0.9574271

Table 4.3.5: Various parameters of Treated Sewage water for the month 8/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-09-22	7.13	29.92	17	37	7		
02-09-22	7.16	29.88	15	39	5		
03-09-22	7.11	29.83	19	36	8		
05-09-22	7.07	29.76	18	42	9	530	2
06-09-22	7	29.7	18	40	6		
07-09-22	7.1	29.66	15	40	8		
08-09-22	7.12	29.72	17	43	5		
09-09-22	7.14	29.61	19	39	7		
10-09-22	7.13	29.64	16	40	9		
12-09-22	7.14	29.44	18	37	7		
13-09-22	7.09	29.4	16	40	6	600	4
14-09-22	7.15	29.43	19	38	9		
15-09-22	7.17	29.37	15	42	7		
16-09-22	7.13	29.35	18	39	8		
17-09-22	7.11	29.3	15	43	6		
19-09-22	7.15	29.29	17	40	5		
20-09-22	7.09	29.05	17	40	8		
21-09-22	7.11	29	19	43	7	490	3
22-09-22	7.06	28.98	15	38	6		
23-09-22	7.13	28.92	19	36	9		
24-09-22	7.16	28.8	16	40	7		
26-09-22	7.12	28.84	18	41	8		
27-09-22	7.13	28.78	18	37	6		
28-09-22	7.08	28.71	16	39	8	450	2
29-09-22	7.16	28.76	15	36	5		
30-09-22	7.13	28.67	19	42	9		
Mean	7.1180769	29.300385	17.076923	39.5	7.1153846	517.5	2.75
Median	7.13	29.36	17	40	7	510	2.5
Standard Deviation	0.0374186	0.4056055	1.5211332	2.1954498	1.3660724	63.966137	0.9574271

Table 4.3.6: Various parameters of Treated Sewage water for the month 9/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-10-22	7.13	28.57	16	42	7		
03-10-22	7.18	28.54	19	40	9		
04-10-22	7.15	28.47	17	43	8		
05-10-22	7.12	28.43	15	38	5	580	3
06-10-22	7.09	28.4	19	36	7		
07-10-22	7.11	28.43	16	40	8		
08-10-22	7.06	28.38	18	42	6		
10-10-22	7.13	28.41	16	38	9		
11-10-22	7.16	28.33	19	40	7		
12-10-22	7.18	28.37	17	39	9		
13-10-22	7.14	28.29	18	42	8	500	4
14-10-22	7.18	28.3	15	42	9		
15-10-22	7.11	28.24	16	40	6		
17-10-22	7.08	28.21	14	43	8		
18-10-22	7.12	28.26	18	39	5		
19-10-22	7.09	28.2	15	37	7		
20-10-22	7.09	28.11	17	40	6	450	2
21-10-22	7.12	27.94	16	42	8		
22-10-22	7.14	27.89	19	36	5		
24-10-22	7.08	27.9	15	39	9		
25-10-22	7.18	27.84	18	37	7		
26-10-22	7.13	27.8	16	41	8		
27-10-22	7.15	27.81	16	40	6		
28-10-22	7.11	27.59	18	36	9	430	3
29-10-22	7.16	27.52	14	42	5		
31-10-22	7.08	27.48	18	40	8		
Mean	7.1257692	28.142692	16.730769	39.769231	7.2692308	490	3
Median	7.125	28.25	16.5	40	7.5	475	3
Standard Deviation	0.0352333	0.3217397	1.5635266	2.1782138	1.4016474	66.833126	0.8164966

Table 4.3.7: Various parameters of Treated Sewage water for the month 10/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-11-22	7.12	27.65	16	41	9		
02-11-22	7.15	27.6	15	37	6		
03-11-22	7.09	27.62	19	39	8		
04-11-22	7.11	27.55	17	36	9		
05-11-22	7.13	27.53	19	42	5	500	2
07-11-22	7.16	27.6	16	43	8		
08-11-22	7.12	27.51	18	38	6		
09-11-22	7.1	27.5	14	41	9		
10-11-22	7.16	27.48	15	37	7		
11-11-22	7.11	27.21	19	39	9		
12-11-22	7.12	27.19	19	36	5		
14-11-22	7.1	26.69	17	41	8	490	3
15-11-22	7.08	26.92	15	40	9		
16-11-22	7.09	26.9	18	43	6		
17-11-22	7.11	26.93	16	40	6		
18-11-22	7.14	26.88	18	44	7		
19-11-22	7.11	26.84	14	40	9		
21-11-22	7.12	26.8	16	38	5	540	4
22-11-22	7.05	26.75	17	41	7		
23-11-22	7.09	26.81	15	40	8		
24-11-22	7.06	26.71	17	44	9		
25-11-22	7.14	26.73	19	42	6		
26-11-22	7.13	26.63	16	39	9		
28-11-22	7.15	26.65	18	36	7	500	3
29-11-22	7.12	26.59	15	40	5		
30-11-22	7.04	26.46	17	38	8		
Mean	7.1115385	27.066538	16.730769	39.807692	7.3076923	507.5	3
Median	7.115	26.91	17	40	7.5	500	3
Standard Deviation	0.0313295	0.399399	1.6138821	2.3835978	1.4904826	22.173558	0.8164966

Table 4.3.8: Various parameters of Treated Sewage water for the month 11/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-12-22	7.08	26.42	15	40	7		
02-12-22	7.11	26.44	16	37	5		
03-12-22	7.1	26.39	19	41	9		
05-12-22	7.12	26.36	16	38	9		
06-12-22	7.15	26.3	18	43	6	510	4
07-12-22	7.08	26.23	15	44	5		
08-12-22	7.11	26.26	17	39	9		
09-12-22	7.06	26.22	19	36	7		
10-12-22	7.12	26.16	16	42	5		
12-12-22	7.14	26	18	42	8		
13-12-22	7.13	26.04	19	40	6	480	2
14-12-22	7.1	25.94	17	44	8		
15-12-22	7.12	25.97	15	36	8		
16-12-22	7.15	25.95	17	39	5		
17-12-22	7.16	25.82	19	38	7		
19-12-22	7.1	25.92	16	42	9		
20-12-22	7.12	24.08	18	39	7		
21-12-22	7.16	23.81	16	41	6	620	3
22-12-22	7.17	23.56	19	44	7		
23-12-22	7.15	23.33	15	38	9		
24-12-22	7.08	23.19	18	40	9		
26-12-22	7.12	23.21	19	43	6		
27-12-22	7.17	23.14	17	39	8		
28-12-22	7.13	23.1	18	40	6		
29-12-22	7.18	22.98	15	36	7	650	3
30-12-22	7.19	22.92	15	39	5		
31-12-22	7.15	22.88	18	42	7		
Mean	7.1277778	24.985926	17.037037	40.074074	7.037037	565	3
Median	7.12	25.94	17	40	7	565	3
Standard Deviation	0.0334357	1.4596397	1.5059237	2.4639856	1.4272481	82.663978	0.8164966

Table 4.3.9: Various parameters of Treated Sewage water for the month 12/2022

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
02-01-23	7.17	22.81	19	40	9		
03-01-23	7.13	22.78	17	43	8		
04-01-23	7.15	22.81	18	42	8		
05-01-23	7.19	22.75	16	39	6		
06-01-23	7.17	22.74	19	42	7	550	2
07-01-23	7.14	22.7	17	41	9		
09-01-23	7.17	22.69	18	39	9		
10-01-23	7.14	22.66	15	40	6		
11-01-23	7.1	22.54	19	37	8		
12-01-23	7.04	22.51	17	40	5		
13-01-23	7.15	22.56	15	43	7		
14-01-23	7.18	22.48	18	44	9	610	3
16-01-23	7.16	22.47	16	40	7		
17-01-23	7.13	22.48	19	42	9		
18-01-23	7.15	22.1	16	38	8		
19-01-23	7.1	22.16	17	36	9		
20-01-23	7.16	22	16	34	7		
21-01-23	7.18	21.1	18	32	6		
23-01-23	7.16	22.1	17	36	6	550	2
24-01-23	7.12	22.16	16	38	8		
25-01-23	7.2	22.16	17	39	7		
26-01-23	7.1	21.1	18	36	6		
27-01-23	7.16	20.8	16	36	7		
28-01-23	7.16	20.1	17	38	8		
30-01-23	7	21	16	36	7		
31-01-23	7.1	22	17	37	7	600	3
Mean	7.1388462	22.144615	17.076923	38.769231	7.4230769	577.5	2.5
Median	7.15	22.475	17	39	7	575	2.5
Standard Deviation	0.0451067	0.7267034	1.1974332	2.9706254	1.1721118	32.015621	0.5773503

Table 4.3.10: Various parameters of Treated Sewage water for the month 1/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-02-23	7	21	17	36	9		
02-02-23	7.09	21.82	19	40	6		
03-02-23	7.04	21.8	15	40	9		
04-02-23	7.11	21.85	18	38	6		
06-02-23	7.16	21.73	16	42	7		
07-02-23	7.15	21.66	18	44	8	520	2
08-02-23	7.12	21.58	19	40	7		
09-02-23	7	20.1	18	36	8		
10-02-23	7.1	20.89	17	38	7		
11-02-23	7.1	21.1	16	36	9		
13-02-23	7.16	21.16	18	37	6		
14-02-23	7.09	20.98	15	41	8		
15-02-23	7.14	20.85	18	40	5	590	3
16-02-23	7.15	20.56	19	38	7		
17-02-23	7.13	20.51	14	43	9		
18-02-23	7.18	20.43	16	41	6		
20-02-23	7.08	20.38	18	40	8		
21-02-23	7.13	20.31	15	43	5	500	2
22-02-23	7.17	19.98	16	40	7		
23-02-23	7.1	19.93	19	44	7		
24-02-23	7.14	19.91	15	38	9		
25-02-23	7.16	19.86	19	36	6		
27-02-23	7.18	19.83	18	39	9		
28-02-23	7.13	19.81	16	38	7	620	3
Mean	7.1170833	20.75125	17.041667	39.5	7.2916667	557.5	2.5
Median	7.13	20.705	17.5	40	7	555	2.5
Standard Deviation	0.049824	0.7166487	1.5736738	2.502173	1.3014763	56.789083	0.5773503

Table 4.3.11: Various parameters of Treated Sewage water for the month 2/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-03-23	7.18	20.15	15	40	5		
02-03-23	7.14	20.48	19	39	9		
03-03-23	7.11	21.44	16	40	7		
04-03-23	7.15	21.36	14	41	5		
06-03-23	7.16	21.27	18	37	8		
07-03-23	7.19	20.39	17	38	6	570	2
08-03-23	7.13	21.02	19	40	8		
09-03-23	7.11	21.15	15	39	5		
10-03-23	7.15	21.19	17	42	7		
11-03-23	7.16	21.21	16	41	5		
13-03-23	7.19	21.28	19	39	9		
14-03-23	7.18	21.34	14	36	6	520	4
15-03-23	7.12	21.46	17	39	7		
16-03-23	7.16	21.52	18	42	9		
17-03-23	7.11	21.6	15	40	6		
18-03-23	7.17	21.73	19	40	8		
20-03-23	7.1	22.01	18	43	5		
21-03-23	7.18	22.05	16	41	6	650	2
22-03-23	7.15	22.08	19	37	9		
23-03-23	7.12	22.11	15	39	8		
24-03-23	7.17	22.19	14	42	5		
25-03-23	7.2	22.23	17	38	7		
27-03-23	7.14	22.21	19	42	7		
28-03-23	7.19	22.29	18	40	6	500	3
29-03-23	7.18	22.31	19	43	9		
30-03-23	7.16	22.18	16	38	5		
31-03-23	7.19	22.23	18	41	6		
Mean	7.1551852	21.573333	16.925926	39.888889	6.7777778	560	2.75
Median	7.16	21.52	17	40	7	545	2.5
Standard Deviation	0.029531	0.6126111	1.7524911	1.846688	1.4763086	66.833126	0.9574271

Table 4.3.12: Various parameters of Treated Sewage water for the month 3/2023

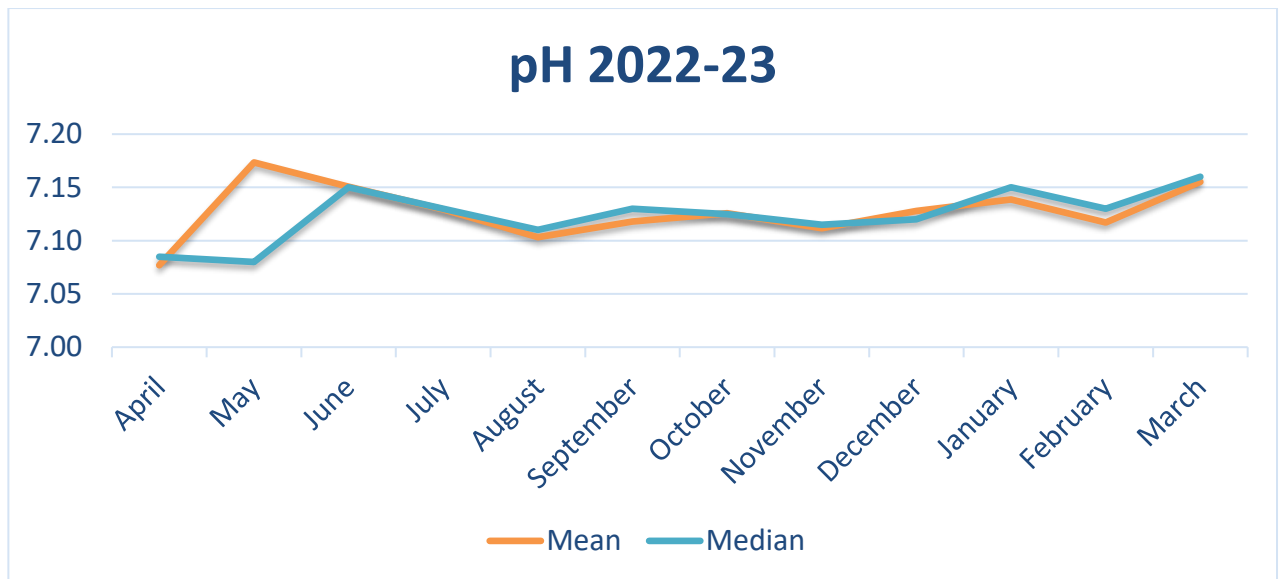


Figure 4.8 : pH value of 10 MLD Sewage Treatment Plant

b) Temperature

The figure shows monthly and average temperatures over a year, providing important information that may be used to assess the suitability of sewage for cement production, especially for environmental and operational considerations. The temperature range also exhibits a similar trend, ranging from 20.71°C in February to 29.8°C in August, with a maximum of 28.64°C in July. These thermometers are important for effect of seasonal temperature on sludge utilization in cement manufacturing Process effects. The data emphasize the importance of controlling temperature fluctuations throughout the year to water efficient handling of dirt while ensuring consistent cement quality and environmental sustainability.

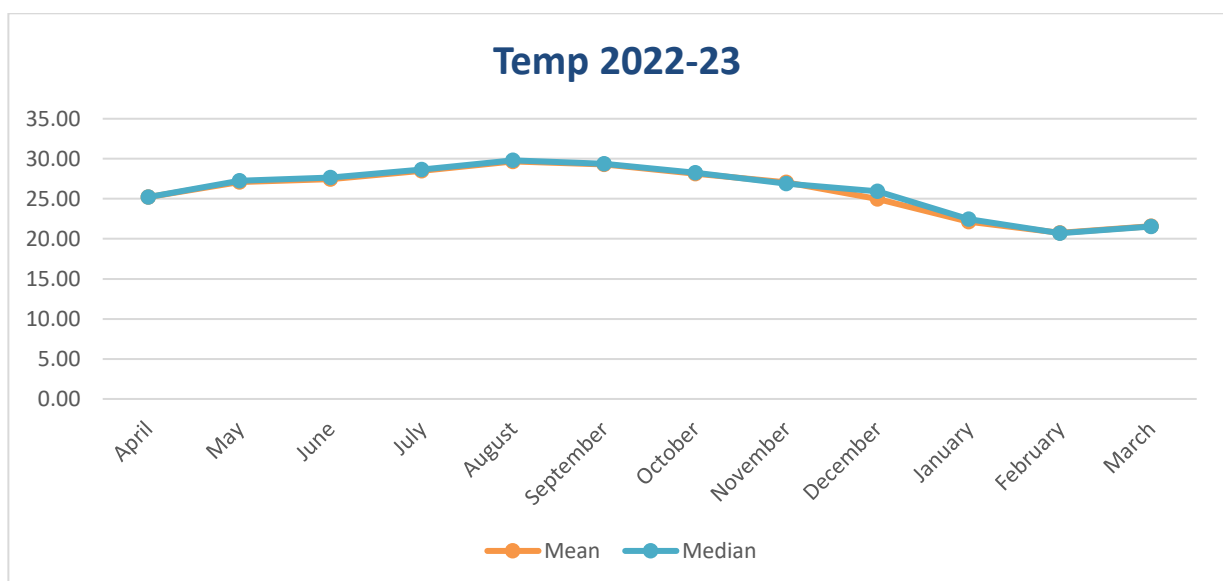


Figure 4.9 : Temp value of 10 MLD Sewage Treatment Plant

c) Total Suspended Solids

The figure shows the monthly variation of total suspended solids (TSS) concentration over a year, which probably reflects the quality of wastewater used in cement production. Average TDS concentration ranges from 16.73 in October to 18.38 in May, allowing for variable amounts of suspended solids throughout the year. The median TDS values also show fluctuations, ranging from 16.5 in October to 18.5 in May, and 17.5 in February and August, indicating a constant mean trend in those months. This measure is important for analysis of the suitability of wastewater for cement production, thereby ensuring compliance with water quality standards to prevent environmental pollution. The data highlights monthly variations in TDS levels, and provides insights in terms of seasonal changes and trends in water quality that are essential for effective industrial environmental management.

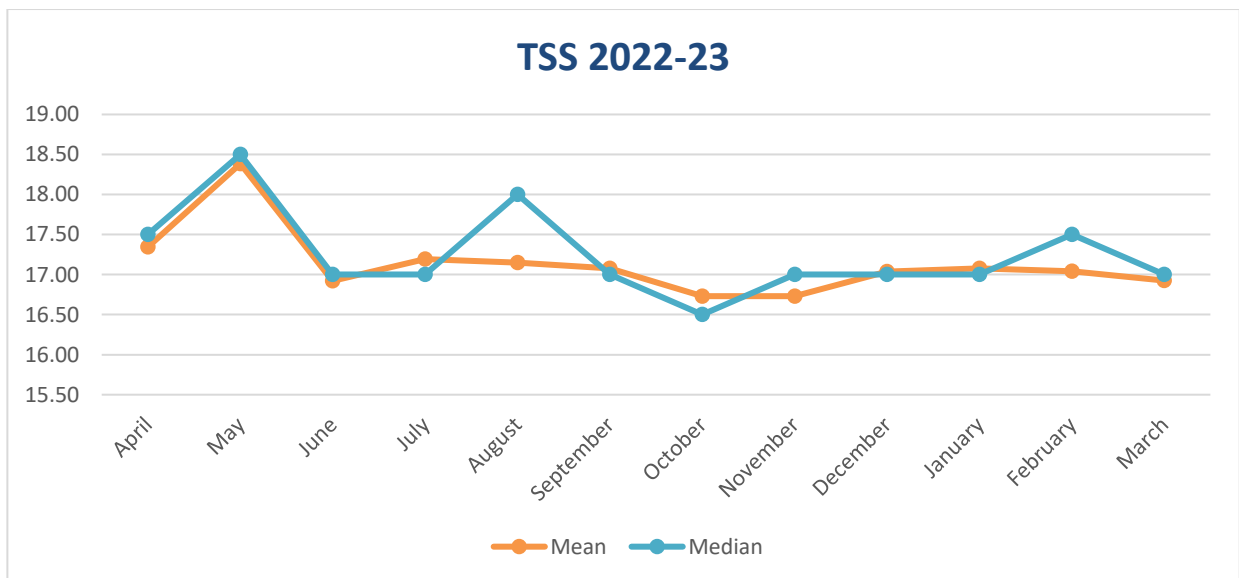


Figure 4.10 : TSS value of 10 MLD Sewage Treatment Plant

d) COD

The figure shows monthly Chemical Oxygen Demand (COD) values from April to March, possibly related to pollution of wastewater used in cement production throughout the year. Consistent COD values are around 40 in most months, indicating a strong intermediate trend in COD levels, except for February where there is a slight decrease to 39 levels.

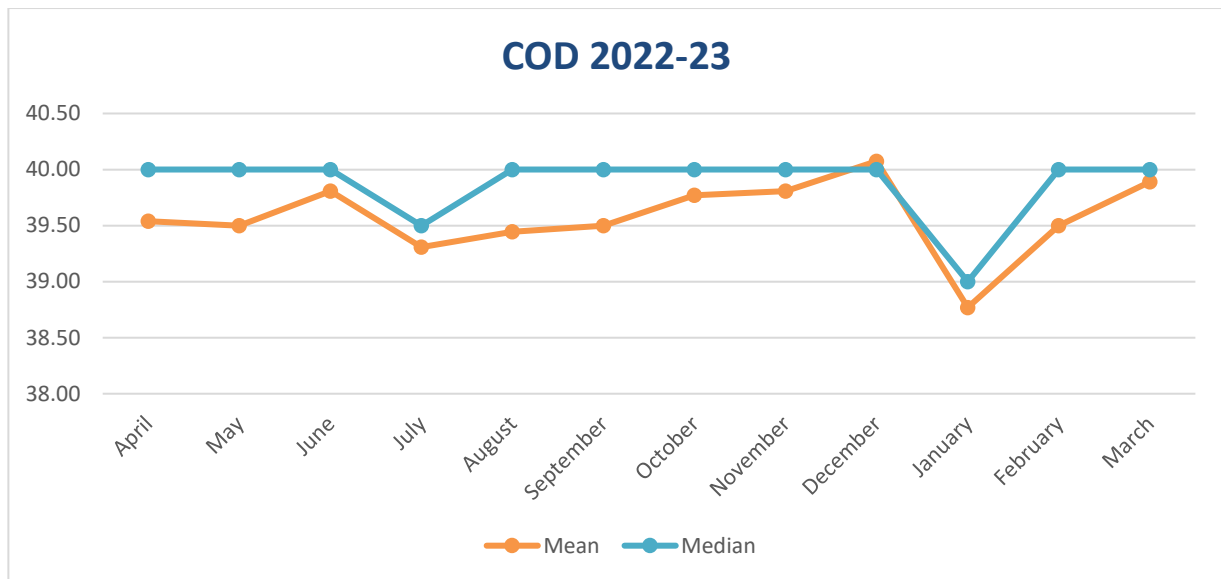


Figure 4.11 : COD value of 10 MLD Sewage Treatment Plant

e) BOD

The table provides a detailed overview of monthly averages and medians of Biological Oxygen Demand (BOD) levels for the period from April to March, likely in the context of assessing sewage water suitability for use in cement production, with considerations for environmental and water quality standards. Mean BOD values range from a low of 6.78 in March to a high of 7.47 in May and June, indicating fluctuating organic pollutant levels throughout the year. Median BOD values exhibit a similar trend, ranging from 7 in April and December to 7.5 in June, July, October, and November, suggesting consistent central tendencies with occasional variations.

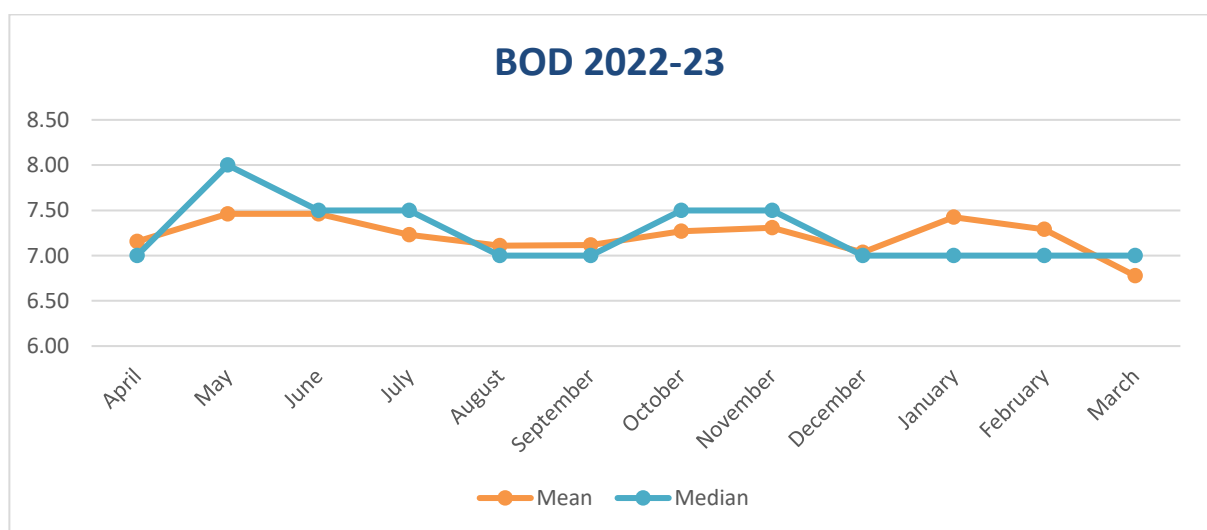


Figure 4.12 : BOD value of 10 MLD Sewage Treatment Plant

f) Faecal Coliform

The figure 4.13 provides monthly mean and standard deviation of fecal coliform (F.Coli) concentration for a year, which can be relevant in assessing the suitability of wastewater for use in cement production of water quality and environmental health standards. The average F. coli count in April was 525, with 510 moderate, indicating a moderate bacterial count. May and June decreased, with averages of 510 and 475, respectively, indicating a permanent bacterial presence in these months, indicating that bacterial a they are permanent in July. August and September have similar values of 520 and 517.5, respectively, with values falling around 510 indicating stability in viral loads. October shows a slight decrease in the median (490) and median (475) numbers, while November and December show an increase in the mean numbers of 507.5 and 565, respectively January and February show additional increases in terms of values of 577.5 and 557.5, respectively, with values of 575 and 555 indicating high levels of bacterial contamination in these months.

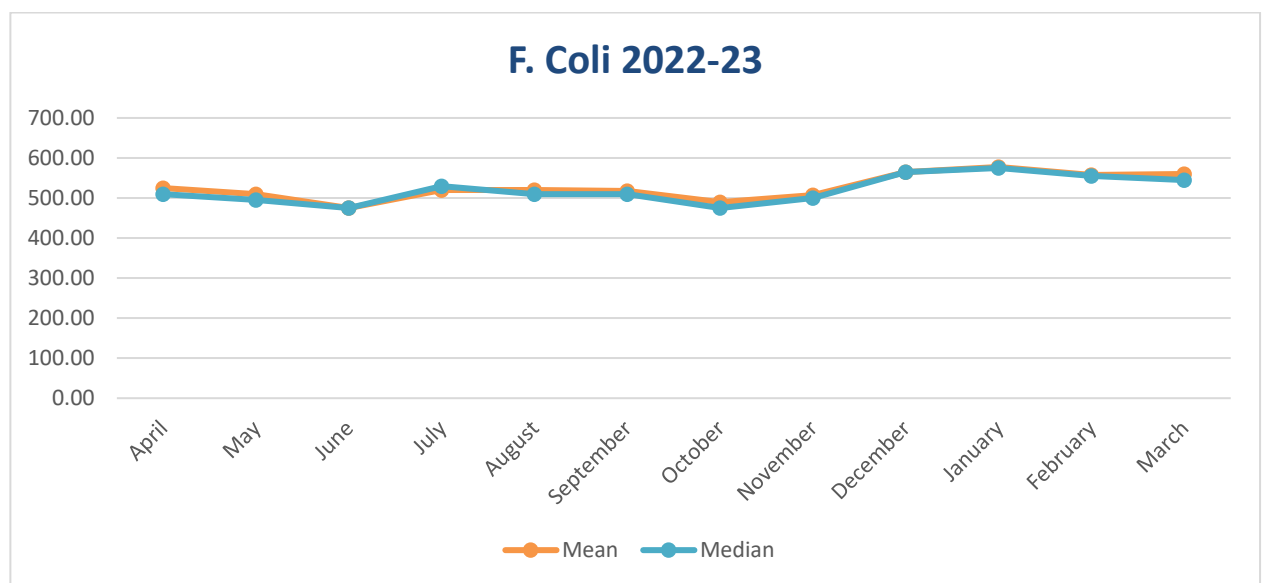


Figure 4.13 : F. Coli value of 10 MLD Sewage Treatment Plant

g) Total Kjeldahl Nitrogen (TKN)

The plot gives the monthly Kjeldahl nitrogen (TKN) concentration and the mean total concentration from April to March, possibly related to the use of wastewater in cement production and its environmental consumption water quality standards, to provide a detailed summary. The average density of TKN fluctuates between 2.5 and 3 in most months, indicating a constant nitrogen level with minor fluctuations. In particular, the average T. from April to November and December to March. Kn-values remain stable at 3, while they decrease slightly in January,

February and March. This model shows the presence of typically stable nitrogen in sewage throughout the year. Median TKN values show a similar trend, usually increasing by about 3 from April to November and December to March, except in July, August, and September, where they drop to 2.5. This means that although on average exactly, nitrogen concentration while still if relatively stable, there are periods in the middle and early years when the distribution of prices exhibits an essential nonlinearity.

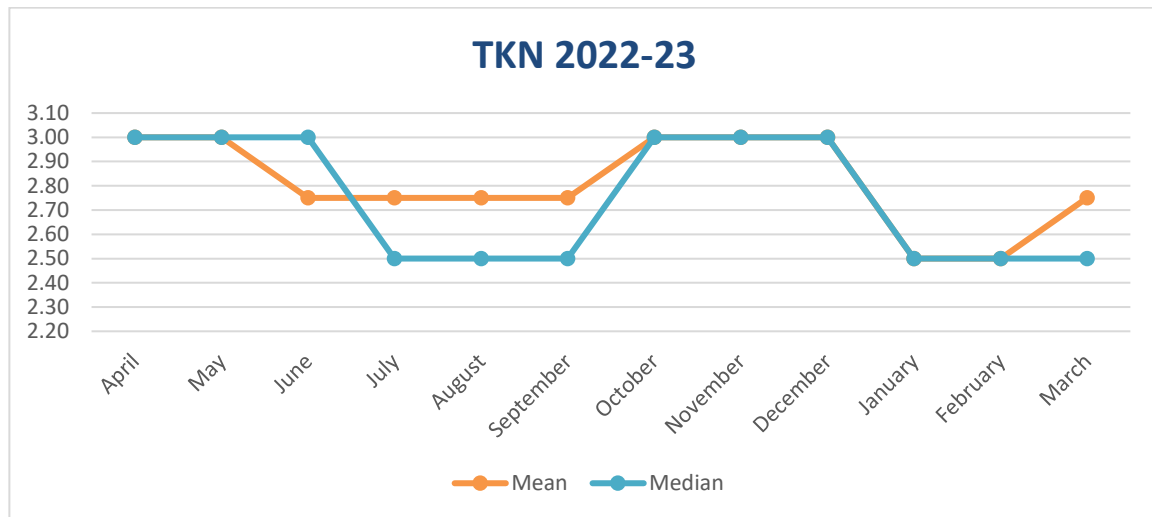


Figure 4.14 : TKN value of 10 MLD Sewage Treatment Plant

4.4 Various parameters of Treated Sewage water from 2023

a) pH

The pH values from April to November 2023 show slight fluctuations, as indicated by the mean and median values. The average pH in April was 7.13, and the mean was 7.14. This was slightly higher in May, with an average of 7.14 and 7.15. In June, the median fell slightly to 7.13, although the median remained stable at 7.14. A more notable improvement occurred in July, with an average of 7.07 and a median of 7.08, and continued through August with the same values of 7.07 and 7.09. In September the pH values increased again, with an average of 7.13 and a 7.13 score. This rise continued in October, with an average of 7.14 and 7.15. Finally, November pH levels dropped slightly to an average of 7.12 and a median of 7.12. Overall, the data show small changes in pH levels over the months, with values generally staying around a neutral pH of 7.

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-04-23	7.13	22.27	17	40	8		
03-04-23	7.18	22.31	19	38	6		
04-04-23	7.1	22.36	14	42	5	480	4
05-04-23	7.15	22.4	18	40	9		
06-04-23	7.08	22.48	19	43	6		
07-04-23	7.12	22.52	18	41	9		
08-04-23	7.15	22.84	15	42	4		
10-04-23	7.18	23.02	17	38	8		
11-04-23	7.11	23.41	17	36	7		
12-04-23	7.08	23.49	19	40	5	550	3
13-04-23	7.19	23.62	16	38	9		
14-04-23	7.13	23.89	19	42	8		
15-04-23	7.16	23.96	16	42	6		
17-04-23	7.08	24.09	15	40	8		
18-04-23	7.14	24.03	18	39	6		
19-04-23	7.12	24.14	14	37	9		
20-04-23	7.14	24.19	18	43	7	610	3
21-04-23	7.13	24.17	16	40	9		
22-04-23	7.08	24.25	19	43	6		
24-04-23	7.14	24.21	15	39	8		
25-04-23	7.15	24.27	17	42	5		
26-04-23	7.16	24.32	18	41	7		
27-04-23	7.18	24.37	18	40	8		
28-04-23	7.12	24.39	15	37	6	500	2
29-04-23	7.14	24.35	17	39	9		
Mean	7.1336	23.574	16.96	40.08	7.12	535	3
Median	7.14	23.96	17	40	7	525	3
Standard Deviation	0.0327719	0.788506	1.6196707	2.0190757	1.5362291	58.022984	0.8164966

Table 4.4.1: Various parameters of Treated Sewage water for the month 4/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-05-23	7.02	24.48	14	42	8		
02-05-23	7.11	24.5	18	40	5		
03-05-23	7.17	24.54	19	40	8		
04-05-23	7.14	24.59	15	43	6		
05-05-23	7.1	24.62	17	37	9		
06-05-23	7.09	24.64	17	39	9	620	3
08-05-23	7.16	24.76	19	42	8		
09-05-23	7.15	24.8	14	40	5		
10-05-23	7.11	24.81	16	43	4		
11-05-23	7.13	24.8	15	39	8		
12-05-23	7.16	24.86	19	36	6		
13-05-23	7.18	24.93	18	43	9		
15-05-23	7.17	24.96	16	40	5	550	4
16-05-23	7.14	24.99	19	42	7		
17-05-23	7.17	25.06	15	40	6		
18-05-23	7.13	25.11	17	39	8		
19-05-23	7.16	25.13	15	37	5		
20-05-23	7.1	25.29	18	43	9		
22-05-23	7.14	25.41	15	41	9	580	3
23-05-23	7.18	25.56	19	43	7		
24-05-23	7.16	25.72	14	36	5		
25-05-23	7.12	25.77	16	39	8		
26-05-23	7.18	25.89	18	42	6		
27-05-23	7.13	25.94	18	42	6		
29-05-23	7.16	26	15	40	8		
30-05-23	7.19	26.11	17	38	7	520	3
31-05-23	7.15	26.14	16	41	5		
Mean	7.1407407	25.163333	16.62963	40.259259	6.8888889	567.5	3.25
Median	7.15	24.99	17	40	7	565	3
Standard Deviation	0.0365772	0.5396152	1.7130303	2.1766699	1.5770794	42.720019	0.5

Table 4.4.2: Various parameters of Treated Sewage water for the month 5/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-06-23	7.14	26.15	18	37	8		
02-06-23	7.19	26.18	15	41	6		
03-06-23	7.16	26.28	17	43	9		
05-06-23	7.12	26.32	19	41	8		
06-06-23	7.09	26.37	14	39	5	500	2
07-06-23	7.13	26.39	16	36	7		
08-06-23	7.1	26.45	19	39	9		
09-06-23	7.16	26.53	17	42	6		
10-06-23	7.18	26.56	15	40	8		
12-06-23	7.08	26.59	19	42	5		
13-06-23	7.12	26.64	16	39	9	470	3
14-06-23	7.14	26.7	16	40	6		
15-06-23	7.16	26.76	18	36	7		
16-06-23	7.08	26.71	17	39	7		
17-06-23	7.14	26.74	15	41	8		
19-06-23	7.09	26.87	18	42	9		
20-06-23	7.04	27.1	19	44	7		
21-06-23	7.04	27.22	17	40	9	530	2
22-06-23	7.09	27.24	15	38	6		
23-06-23	7.14	27.36	19	42	8		
24-06-23	7.16	27.39	15	40	5		
26-06-23	7.15	27.45	16	37	7		
27-06-23	7.11	27.55	18	39	6		
28-06-23	7.14	27.58	18	43	9		
29-06-23	7.15	27.63	15	41	8	490	3
30-06-23	7.18	27.7	19	40	9		
Mean	7.1261538	26.863846	16.923077	40.038462	7.3461538	497.5	2.5
Median	7.14	26.725	17	40	7.5	495	2.5
Standard Deviation	0.0403065	0.4947571	1.6229129	2.1256673	1.3839742	25	0.5773503

Table 4.4.3: Various parameters of Treated Sewage water for the month 6/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-07-23	7.09	25.58	16	37	6		
02-07-23	7.13	25.66	18	36	9		
03-07-23	7.11	25.71	20	41	8		
04-07-23	6.94	25.73	18	37	6		
05-07-23	7.07	24.54	17	42	6		
06-07-23	7.06	24.52	18	40	8	490	4
07-07-23	7.03	24.83	16	42	9		
08-07-23	7.06	24.86	18	40	7		
09-07-23	7.04	25.07	19	39	5		
10-07-23	7.08	25.01	17	37	7		
11-07-23	7.13	24.49	17	37	5		
12-07-23	7.17	24.47	19	39	7		
13-07-23	6.91	25.8	19	42	5		
14-07-23	7.08	25.86	17	40	8		
15-07-23	6.94	27.15	21	40	7	520	5
16-07-23	7.08	27.12	18	42	9		
17-07-23	7.13	27.1	15	37	7		
18-07-23	7.11	27.21	20	40	5		
19-07-23	7.11	25.44	15	40	7		
20-07-23	7.08	27.52	19	43	9		
21-07-23	7	27.6	16	40	6		
22-07-23	7.02	27.49	21	41	5	500	3
23-07-23	6.94	27.15	21	40	7		
24-07-23	7.04	25.78	15	39	9		
25-07-23	7.04	27.15	19	38	8		
26-07-23	7.11	27.24	17	36	6		
27-07-23	7.13	27.31	20	40	6		
28-07-23	7.15	27.4	15	39	8		
29-07-23	7.1	27.44	17	41	9	600	4
30-07-23	7.14	27.54	18	40	7		
31-07-23	7.19	27.51	20	37	9		
Mean	7.0712903	26.234839	17.935484	39.419355	7.0967742	527.5	4
Median	7.08	25.86	18	40	7	510	4
Standard Deviation	0.0698447	1.148085	1.8427422	1.9282841	1.3989243	49.916597	0.8164966

Table 4.4.4: Various parameters of Treated Sewage water for the month 7/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-08-23	6.92	26.72	22	39	9		
02-08-23	6.97	26.86	20	43	5		
03-08-23	7	27.6	16	40	6		
04-08-23	7.02	27.49	21	41	5		
05-08-23	6.97	27.7	15	44	8	520	3
06-08-23	6.93	27.29	18	40	9		
07-08-23	7.04	27.15	19	38	8		
08-08-23	6.94	27.15	21	40	7		
09-08-23	7.08	27.12	18	42	9		
10-08-23	7.13	27.1	15	37	7		
11-08-23	7.11	27.21	20	40	5		
12-08-23	7.1	27.33	21	42	8	450	3
13-08-23	7.01	27.4	17	37	9		
14-08-23	7.07	27.28	20	39	7		
15-08-23	7.08	27.52	19	43	9		
16-08-23	7.1	19.93	19	44	7		
17-08-23	7.14	19.91	15	38	9		
18-08-23	7.16	19.86	19	36	6	490	5
19-08-23	7.18	19.83	18	39	9		
20-08-23	7.13	19.81	16	38	7		
21-08-23	7.11	27.24	17	36	6		
22-08-23	7.13	27.31	20	40	6		
23-08-23	7.15	27.4	15	39	8		
24-08-23	7.1	27.44	17	41	9	600	4
25-08-23	7.14	27.54	18	40	7		
26-08-23	7.19	27.51	20	37	9		
27-08-23	7.06	26.02	16	37	7		
28-08-23	7.09	26	19	41	9		
29-08-23	7.05	26.12	21	36	8		
30-08-23	7.11	26.15	18	39	6		
31-08-23	7.01	26.47	15	36	8	470	2
Mean	7.0716129	25.918065	18.225806	39.419355	7.483871	506	3.4
Median	7.09	27.15	18	39	8	490	3
Standard Deviation	0.0740764	2.7377003	2.1246126	2.3632491	1.3631084	58.566202	1.1401754

Table 4.4.5: Various parameters of Treated Sewage water for the month 8/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-09-23	7.17	22.81	19	40	9		
02-09-23	7.13	22.78	17	43	8		
03-09-23	7.15	22.81	18	42	8		
04-09-23	7.19	22.75	16	39	6		
05-09-23	7.17	22.74	19	42	7	550	2
06-09-23	7.14	22.7	17	41	9		
07-09-23	7.17	22.69	18	39	9		
08-09-23	7.14	22.66	15	40	6		
09-09-23	7.15	22.1	16	38	8		
10-09-23	7.1	22.16	17	36	9		
11-09-23	7.16	22	16	34	7		
12-09-23	7.18	21.1	18	32	6		
13-09-23	7.16	22.1	17	36	6	550	2
14-09-23	7.13	29.35	18	39	8		
15-09-23	7.11	29.3	15	43	6		
16-09-23	7.15	29.29	17	40	5		
17-09-23	7.09	29.05	17	40	8		
18-09-23	7.11	29	19	43	7		
19-09-23	7.06	28.98	15	38	6		
20-09-23	7.13	28.92	19	36	9		
21-09-23	7.16	28.8	16	40	7		
22-09-23	7.12	28.84	18	41	8	480	4
23-09-23	7.13	28.78	18	37	6		
24-09-23	7.08	28.71	16	39	8		
25-09-23	7.16	28.76	15	36	5		
26-09-23	7.13	28.67	19	42	9		
27-09-23	7.16	20.1	17	38	8		
28-09-23	7	21	16	36	7		
29-09-23	7.1	22	17	37	7	600	3
30-09-23	7.09	29.05	17	40	8		
Mean	7.1306667	25.333333	17.066667	38.9	7.3333333	545	2.75
Median	7.135	22.81	17	39	7.5	550	2.5
Standard Deviation	0.0402521	3.504862	1.2847469	2.7461572	1.24106	49.328829	0.9574271

Table 4.4.6: Various parameters of Treated Sewage water for the month 9/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-10-23	7.16	23.81	16	41	6		
02-10-23	7.17	23.56	19	44	7		
03-10-23	7.15	23.33	15	38	9		
04-10-23	7.08	23.19	18	40	9		
05-10-23	7.12	23.21	19	43	6		
06-10-23	7.17	23.14	17	39	8		
07-10-23	7.13	26.04	19	40	6	480	2
08-10-23	7.1	25.94	17	44	8		
09-10-23	7.12	25.97	15	36	8		
10-10-23	7.15	25.95	17	39	5		
11-10-23	7.16	25.82	19	38	7		
12-10-23	7.1	25.92	16	42	9		
13-10-23	7.12	24.08	18	39	7		
14-10-23	7.14	28.66	14	36	8		
15-10-23	7.19	28.71	18	39	6		
16-10-23	7.18	28.69	18	42	5	570	2
17-10-23	7.11	28.78	16	40	9		
18-10-23	7.16	28.91	19	43	7		
19-10-23	7.09	28.97	16	41	5		
20-10-23	7.17	29.02	15	38	9		
21-10-23	7.14	29.11	20	38	8		
22-10-23	7.17	23.56	19	44	7		
23-10-23	7.15	23.33	15	38	9	460	4
24-10-23	7.08	23.19	18	40	9		
25-10-23	7.12	23.21	19	43	6		
26-10-23	7.17	23.14	17	39	8		
27-10-23	7.13	23.1	18	40	6		
28-10-23	7.18	22.98	15	36	7		
29-10-23	7.19	22.92	15	39	5		
30-10-23	7.17	29.02	15	38	9	650	3
31-10-23	7.14	29.11	20	38	8		
Mean	7.1422581	25.624839	17.16129	39.83871	7.2903226	540	2.75
Median	7.15	25.82	17	39	7	525	2.5
Standard Deviation	0.0319071	2.5121463	1.7530312	2.3536748	1.3950758	87.559504	0.9574271

Table 4.4.7: Various parameters of Treated Sewage water for the month 10/2023

DATE	pH	Temp (°C)	TSS (mg/l)	COD (mg/l)	BOD (mg/l)	F.Coli (MPN/100 ml)	T.Kn (mg/l)
01-11-23	7.16	28.33	19	40	7		
02-11-23	7.18	28.37	17	39	9		
03-11-23	7.14	28.29	18	42	8	520	4
04-11-23	7.18	28.3	15	42	9		
05-11-23	7.11	28.24	16	40	6		
06-11-23	7.08	28.21	14	43	8		
07-11-23	7.12	28.26	18	39	5		
08-11-23	7.09	28.2	15	37	7		
09-11-23	7.14	27.89	19	36	5		
10-11-23	7.08	27.9	15	39	9	620	5
11-11-23	7.18	27.84	18	37	7		
12-11-23	7.13	27.8	16	41	8		
13-11-23	7.08	26.92	15	40	9		
14-11-23	7.09	26.9	18	43	6		
15-11-23	7.12	27.65	16	41	9		
16-11-23	7.15	27.6	15	37	6		
17-11-23	7.09	27.62	19	39	8		
18-11-23	7.11	27.55	17	36	9		
19-11-23	7.13	27.53	19	42	5	500	2
20-11-23	7.16	27.6	16	43	8		
21-11-23	7.12	27.51	18	38	6		
22-11-23	7.1	27.5	14	41	9		
23-11-23	7.16	27.48	15	37	7		
24-11-23	7.11	27.21	19	39	9		
25-11-23	7.12	27.19	19	36	5		
26-11-23	7.04	26.46	17	38	8		
27-11-23	7.08	29.9	17	37	8	490	3
28-11-23	7.08	27.9	15	39	9		
29-11-23	7.18	27.84	18	37	7		
30-11-23	7.13	27.8	16	41	8		
Mean	7.1213333	27.793	16.766667	39.3	7.4666667	532.5	3.5
Median	7.12	27.8	17	39	8	510	3.5
Standard Deviation	0.0366468	0.6135266	1.6543221	2.230664	1.4076964	59.651767	1.2909944

Table 4.4.8: Various parameters of Treated Sewage water for the month 11/2023

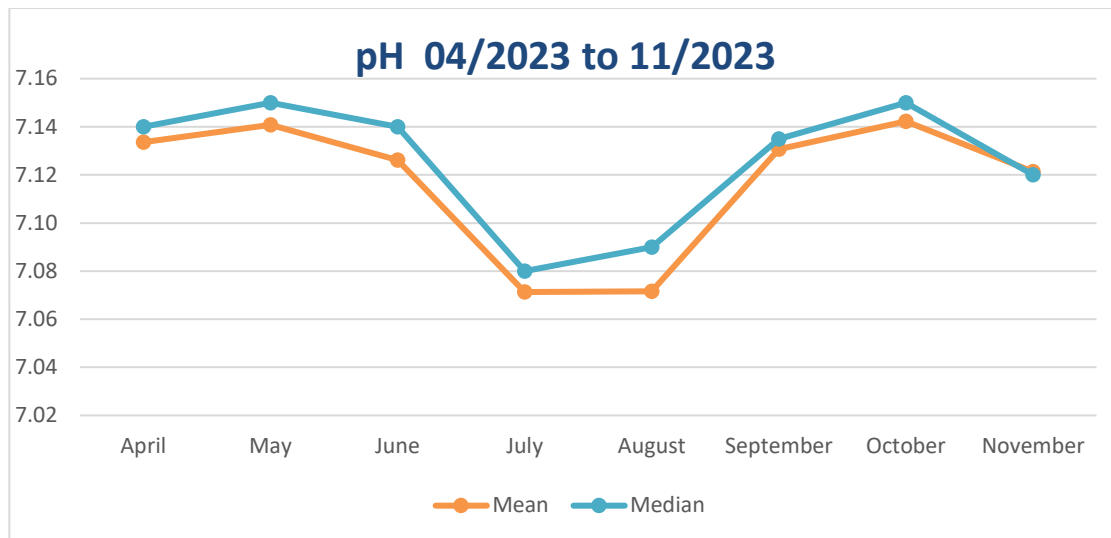


Figure 4.15 : pH value of 10 MLD Sewage Treatment Plant

b) Temperature

The line plot shows the average temperature from April to November 2023. The average temperature in April was 23.574°C, with a mean of 23.96°C may increased, and an average of 25.163 °C, with a mean of 24.99°C. The average temperature for June rose again to 26.864 °C, against average of 26.725°C. The temperature in July was slightly lower at 26.235°C compared to June, which was 25.86°C. The average temperature in August was 25.918 °C, but a significant dip was observed at 27.15°C. The average temperature for September was 25.33 °C, with a sharp drop in the middle to 22.81°C. The average October temperature was 25.62°C, and the average was 25.82°C. In November, the maximum temperatures for the season are 27.80°C and 27.8°C, respectively. These data suggest that temperature stability fluctuates, especially in September and August, where trends deviated significantly from the norm.

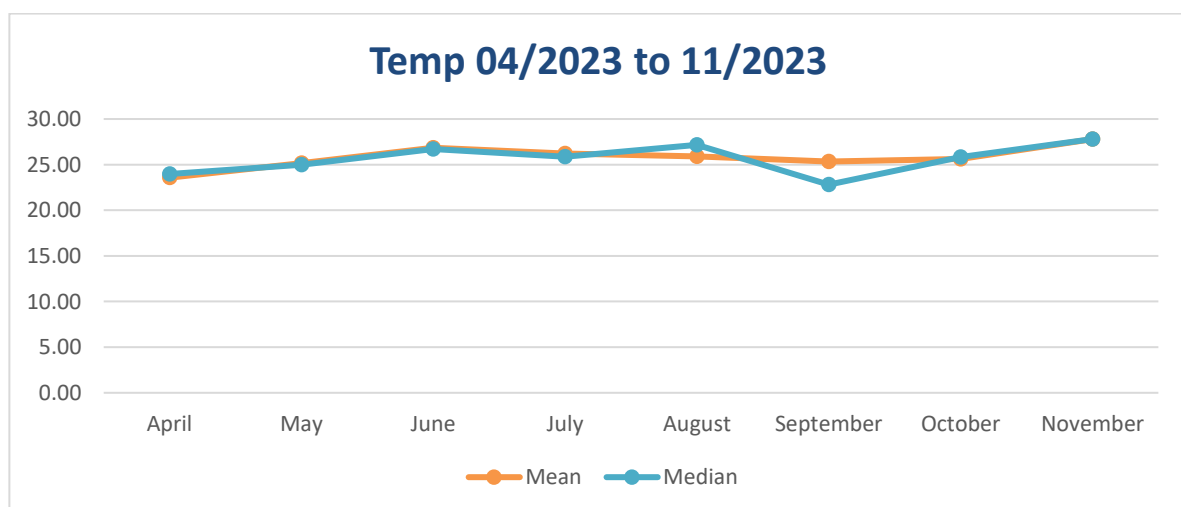


Figure 4.16 : Temp value of 10 MLD Sewage Treatment Plant

c) Total Suspended Solids

The line plot shows the monthly value of Total Suspended Solid (TSS) from April to November 2023. In April, the TSS is 16.96, which is 17. May shows a slight decrease in the median of 16.63, while the median is constant is stable at 17. June average TSS increases to 16.923077, mean is still above mean TSS 17.94 on July 17. and mean increases to 18. Both August metrics show further increases, with mean being 18.23 and median being 18. September shows a low to 17.07, although the 17.16 in October is presented with an average shift of the median at 17. Finally, the average TSS in November is 16.77. with the mean standing at 17. The data show that although the average TSS fluctuates slightly during these months, the average TSS always stands around 17, only July and August except when it grows to 18.

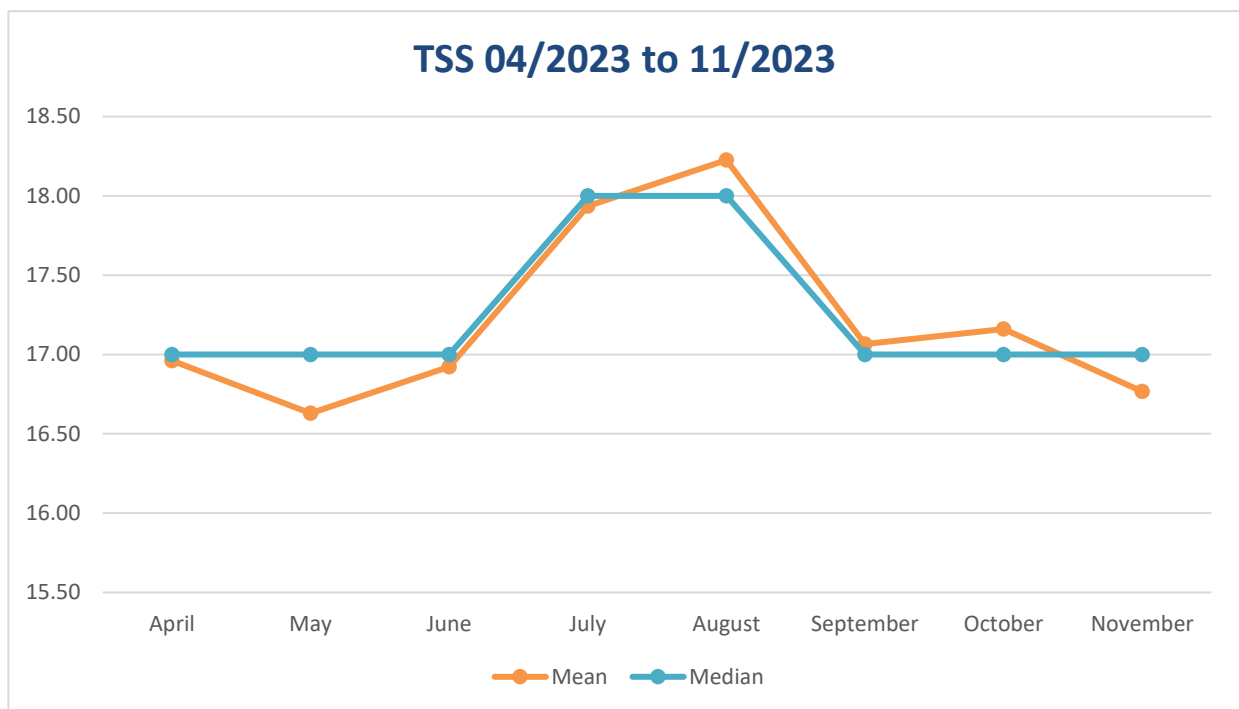


Figure 4.17 : TSS value of 10 MLD Sewage Treatment Plant

d) COD

The line plot representing the mean and median COD (Chemical Oxygen Demand) values from April to November 2023 shows a decrease throughout the months the COD value in April is 40.08, and the median is 40. This is a slight increase to 40 before May. It continues with an average of 26, while it is 40. In June, the averages are 40.04 and 40. July shows a sharp decrease with an average of 39.42, whereas the average of August is 39.42, but a moderate one is reduced to 39. He drops to September with an average of 38.9, the median of 39. The median is 39.42 39 slightly in October rises to .84, with a median of 39. Finally, at In November, the mean and median further decreased to 39.3 and 39, respectively. This trend indicates a steady decrease in

the COD values over the period, and the median range shows comparatively low fluctuations compared to mean.

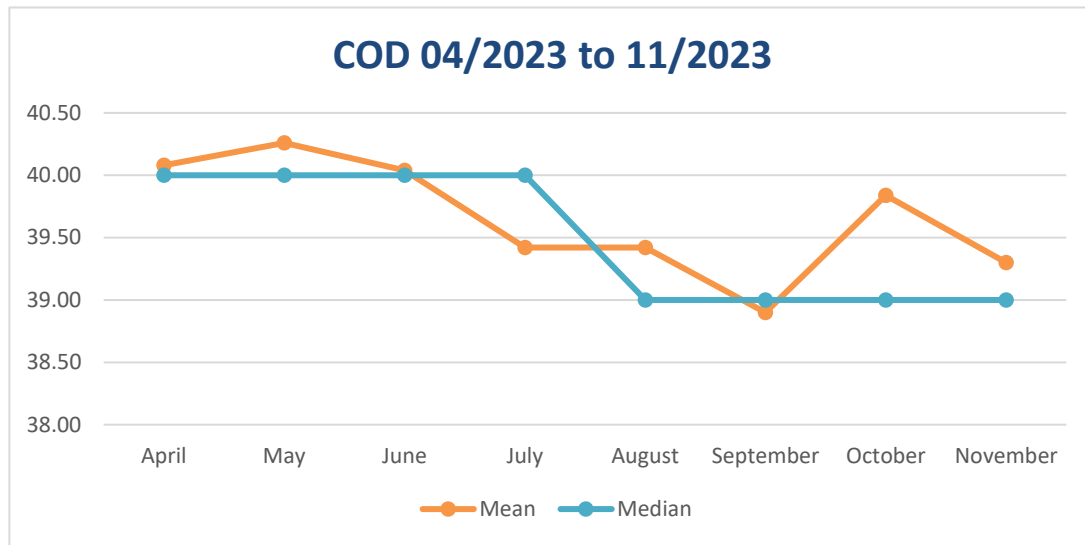


Figure 4.18 : COD value of 10 MLD Sewage Treatment Plant

e) BOD

Line plots of biochemical oxygen demand (BOD) from April to November 2023 show relatively stable trends with some variability. The BOD value in April is 7.12 and the median is 7. The May median decreases slightly to 6.89, although the 7 median remains stable and in June the average increases to 7.35, median rises to 7.5 and July sees a slight decrease in the average to 7.10, while the median returns to 7. A spike is seen in August, where the average reaches 7.48, the average increases to 8. In September, the average rises to 7.33, the average remains 7.5 The average value in October is 7.29, while the mean is 7, especially in August and November.

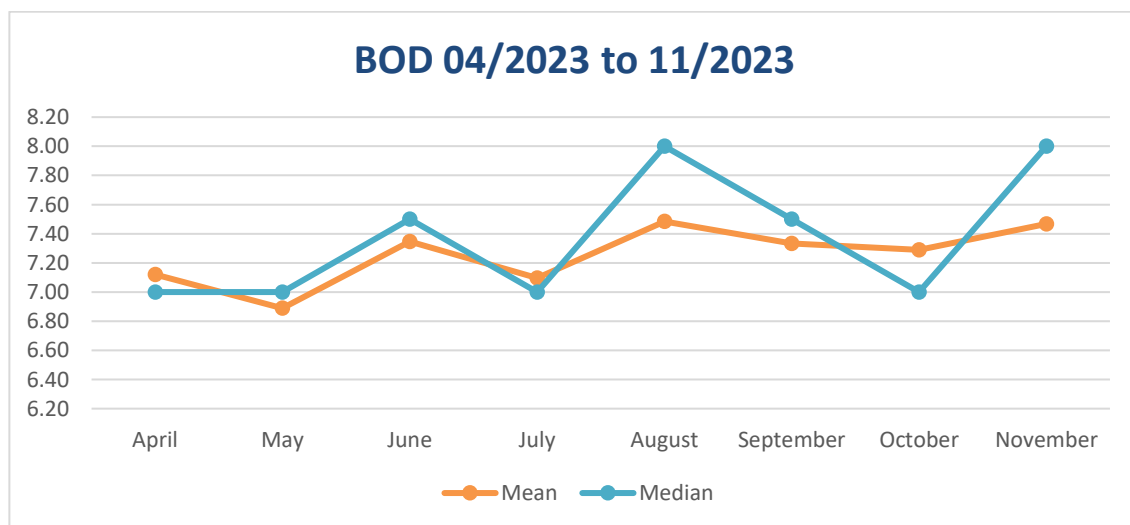


Figure 4.19 : BOD value of 10 MLD Sewage Treatment Plant

f) Faecal Coliform

The line plot of the monthly and median prices of F. coil in 2023 shows a remarkable change in the months from April to November with the average price in April being 535 and the mean being 525. The two prices all rise sharply in May, with a mean of 567.5 and a median of 565. June shows a decrease, with an average of 497.5 and an average of 495. The median was above 550 and in October, the median decreased slightly to 540 while the median settled to 525. Finally in November, the median decreased again to 532.5 and the median decreased to 510. These data exhibit general fluctuations, peaking in May-September and present June-August.

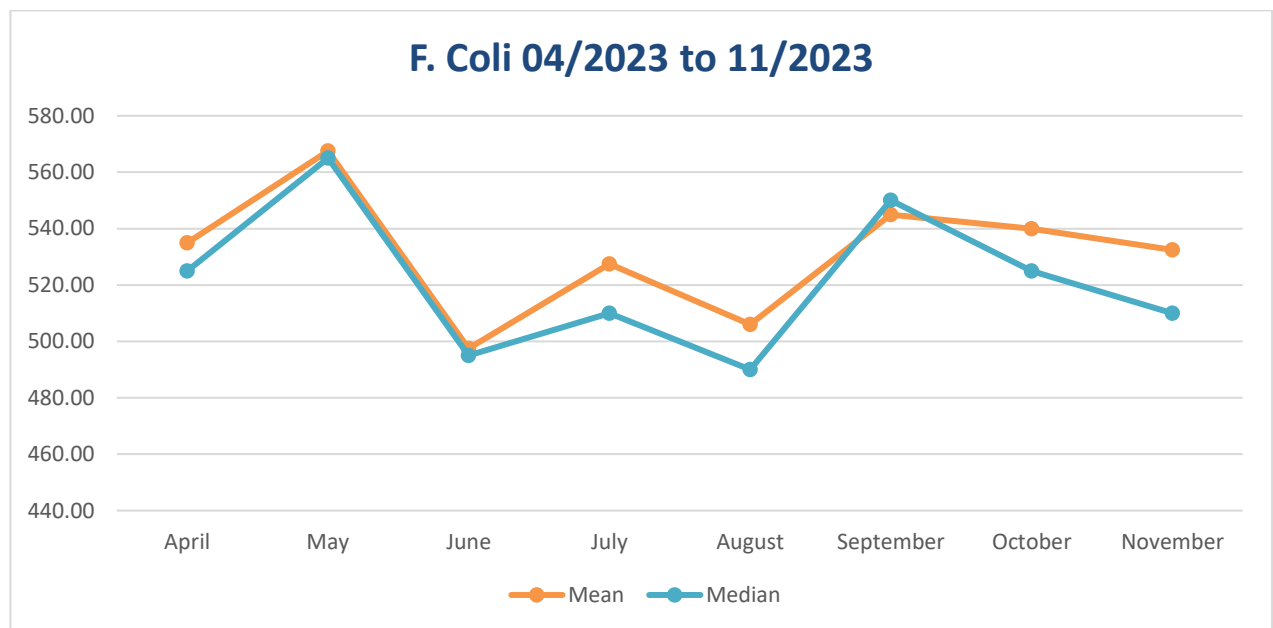


Figure 4.20 : F. Coli value of 10 MLD Sewage Treatment Plant

g) Total Kjeldahl Nitrogen (TKN)

The line plot of TKN in 2023 shows its fluctuations in the months from April to November. In April, the median and median values start from 3. In May, the median rises slightly to 3.25, while the median remains stable from 3. June shows that both measures above decreased, the mean decreases to 2.5 and the mean corresponds to the same value. July is the peak in the data, with an average median of 4. In August, the average decreases slightly to 3.4, but the median is 3. September and October show a trend regularly with an average of 2.75 for both months and 2.75 for both months 2.5.5. Finally, both values rise again in November, averaging 3.5 and 3.5 respectively. These changes indicate general stability of the medians with some changes in the median values during the observed months.

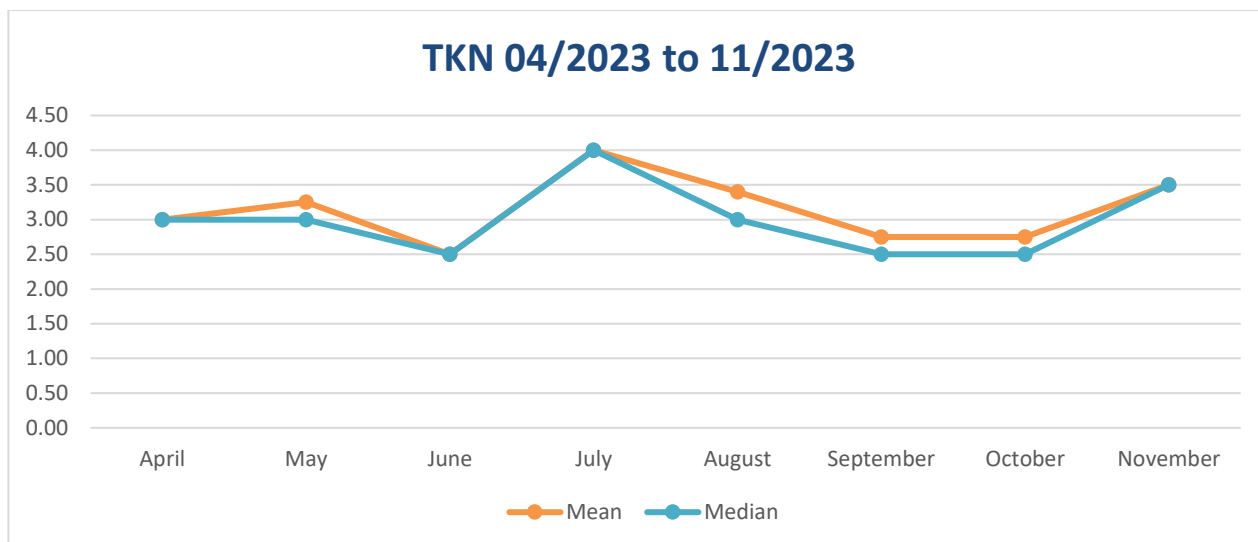


Figure 4.21 : TKN value of 10 MLD Sewage Treatment Plant

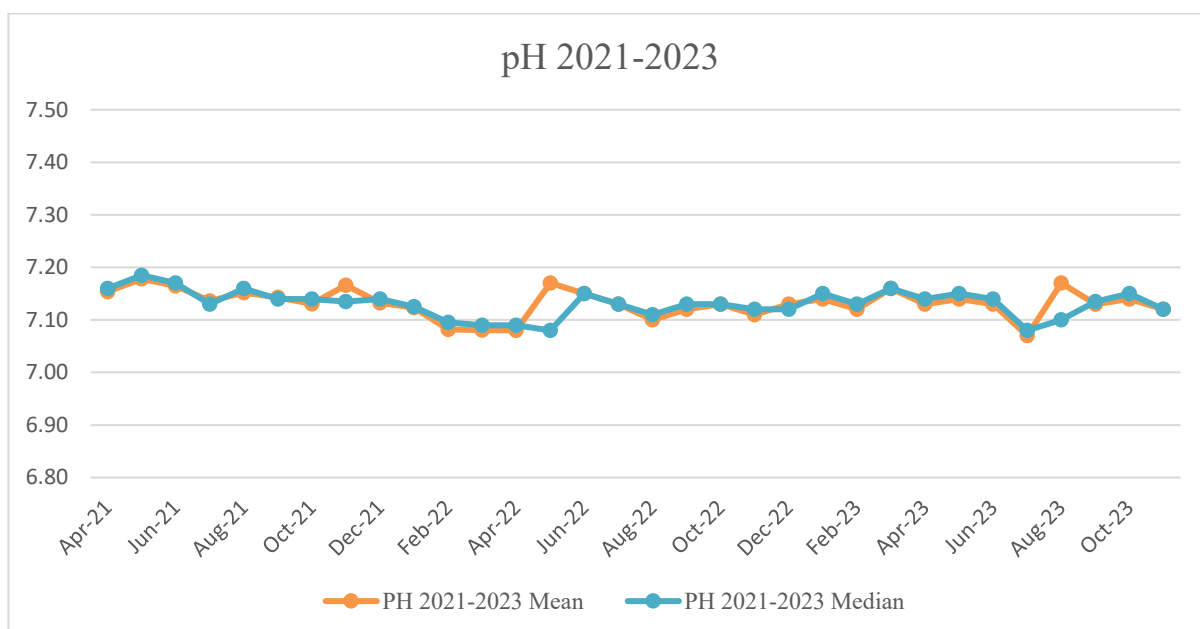


Figure 4.22:pH value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

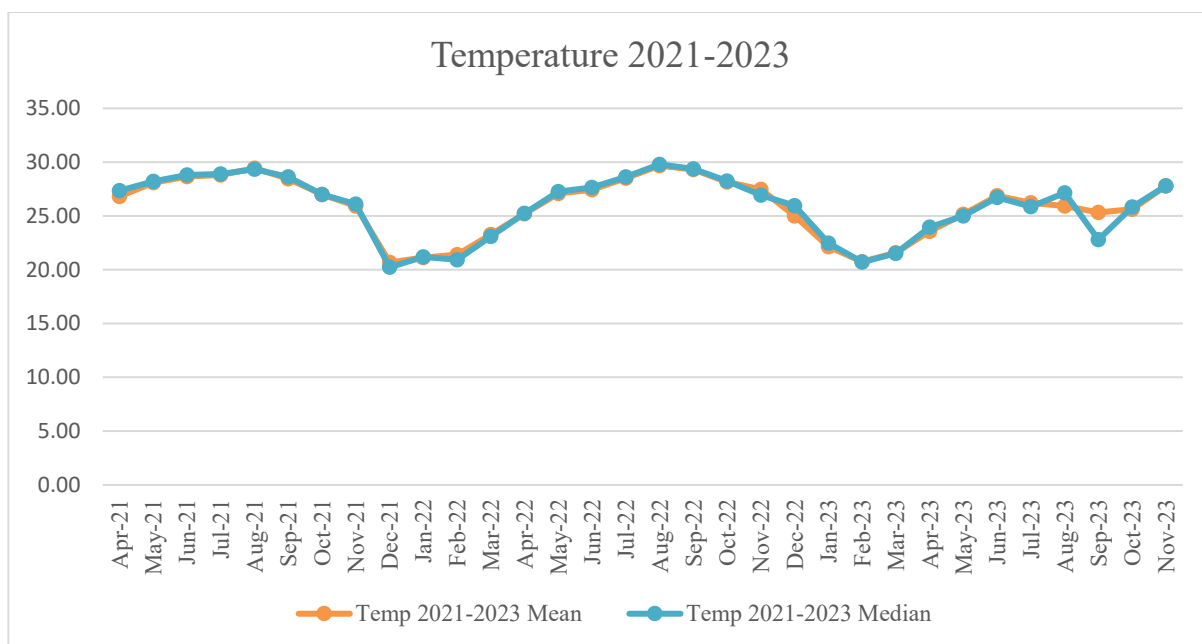


Figure 4.23:Temperature value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

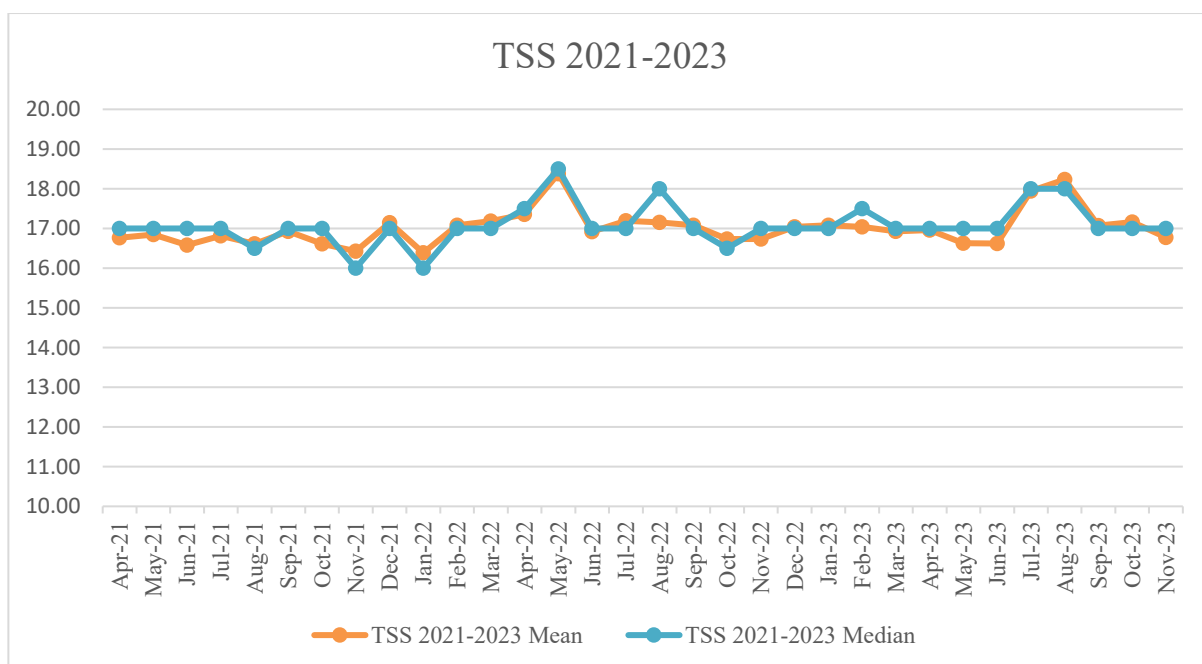


Figure 4.24:TSS value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

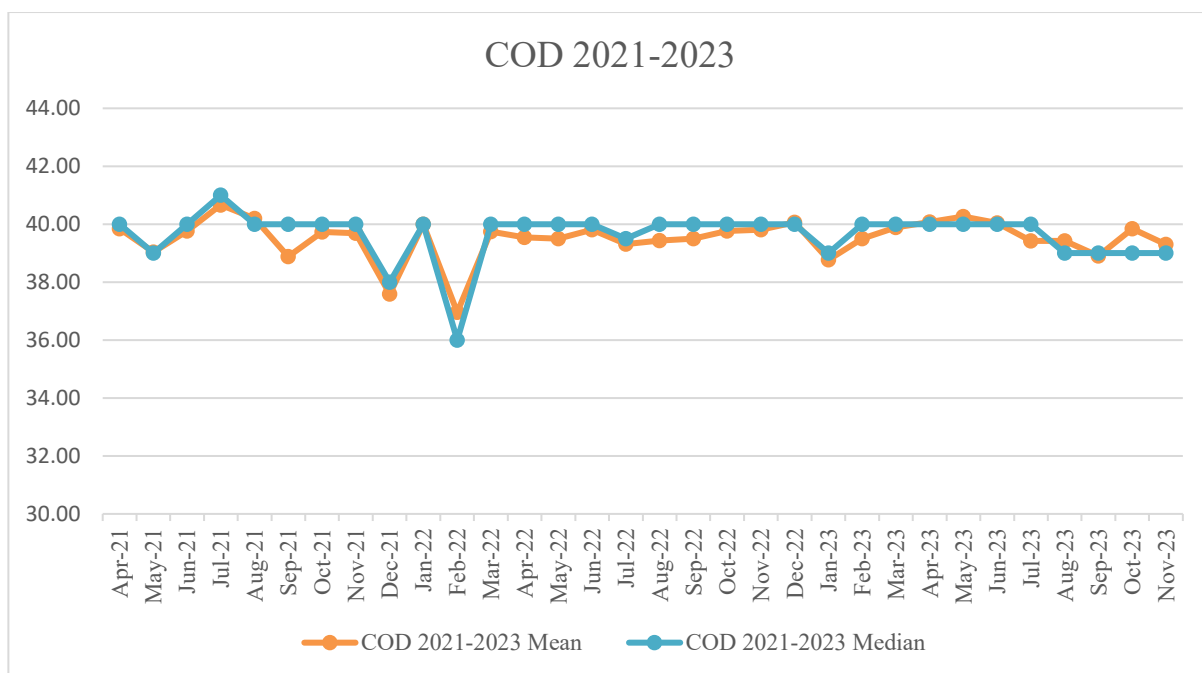


Figure 4.25:COD value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

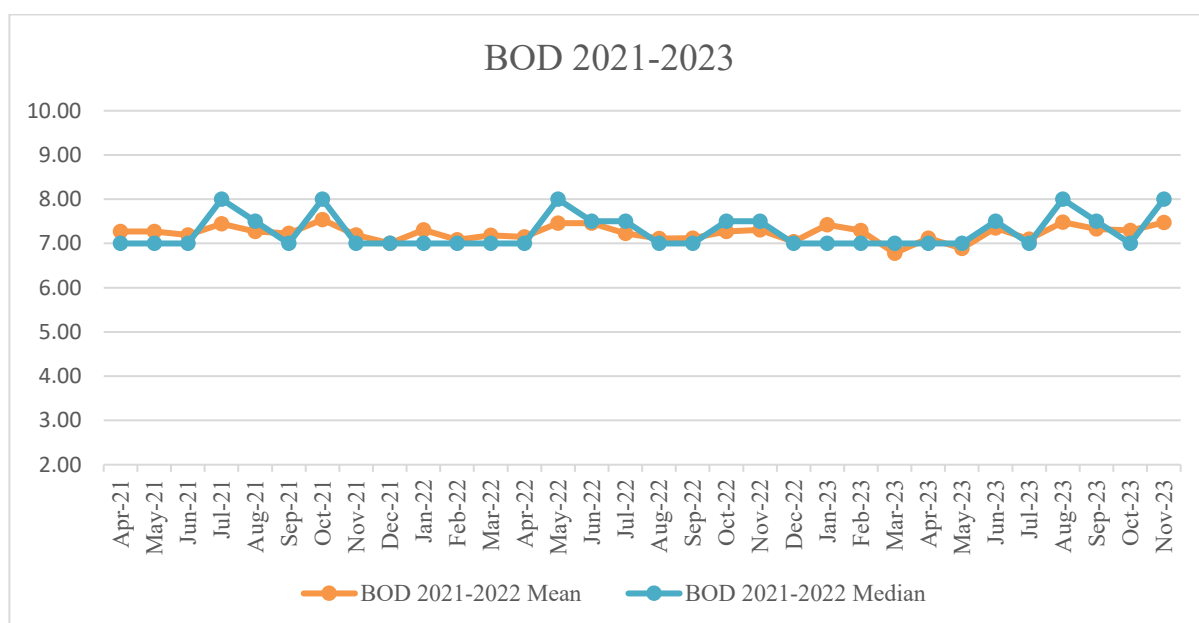


Figure 4.26: BOD value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

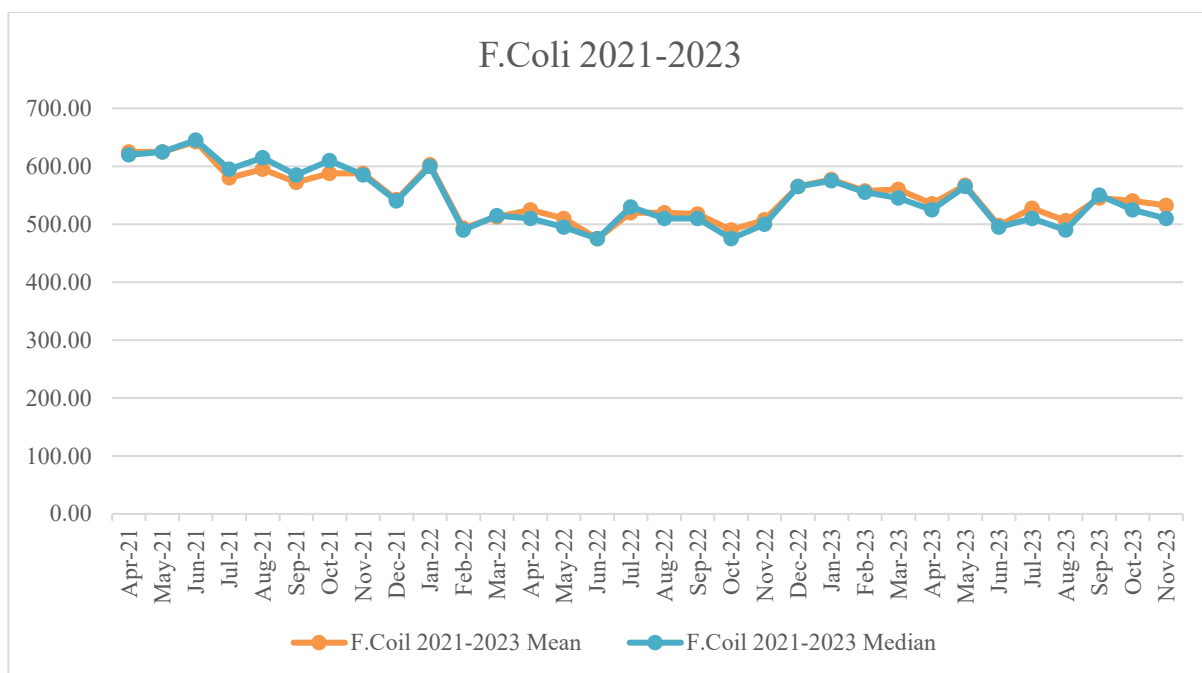


Figure 4.27:F. Coli value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

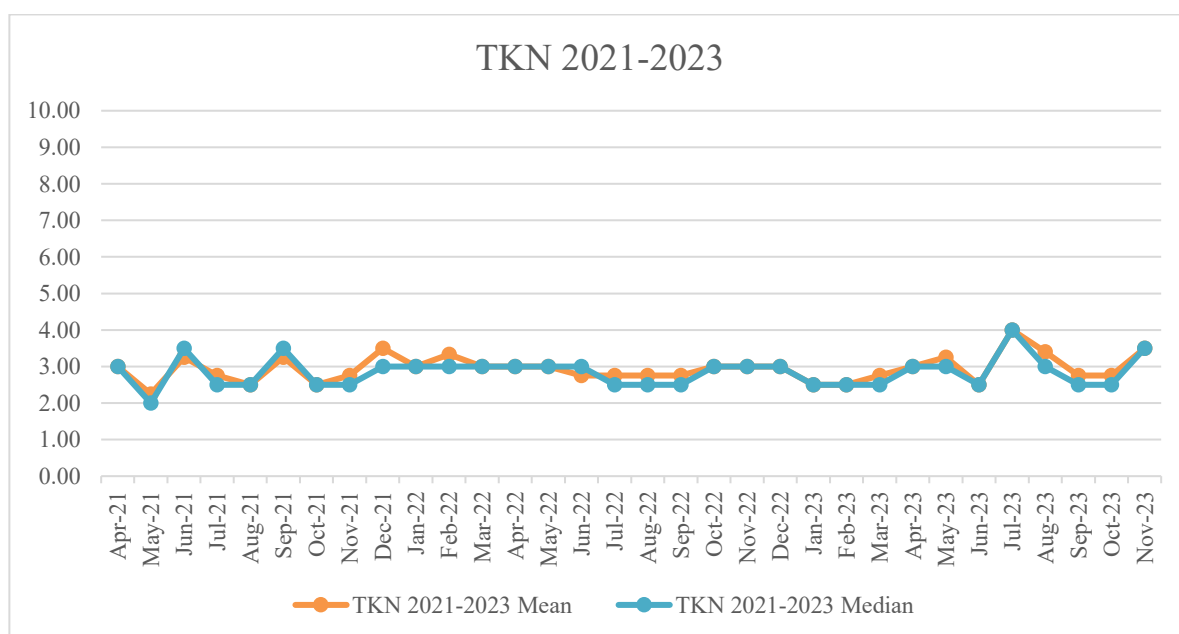


Figure 4.28:TKN value of the treated wastewater from the 10 MLD STP at Bambianwali (2021-2023)

4.5 Results from 225 MLD STP at Jamalpur, Ludhiana

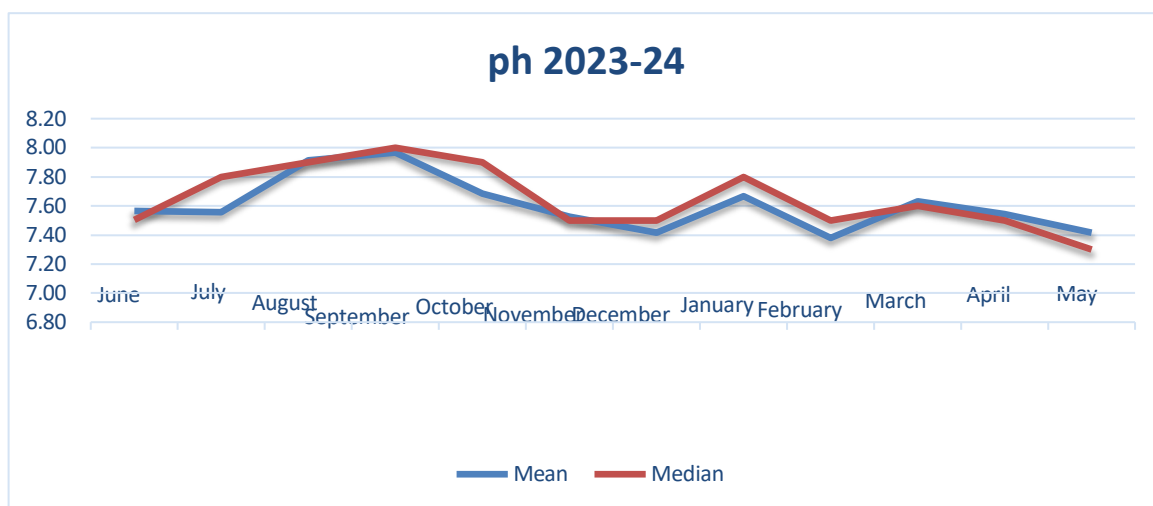


Figure 4.29 : pH value of 225 MLD STP at Jamalpur, Ludhiana

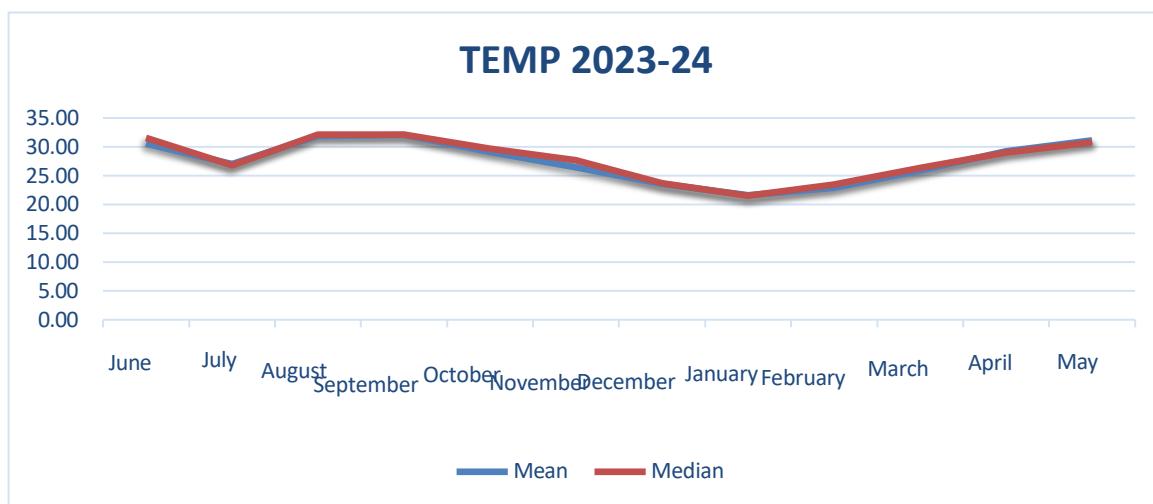


Figure 4.30 : Temp value of 225 MLD STP at Jamalpur, Ludhiana

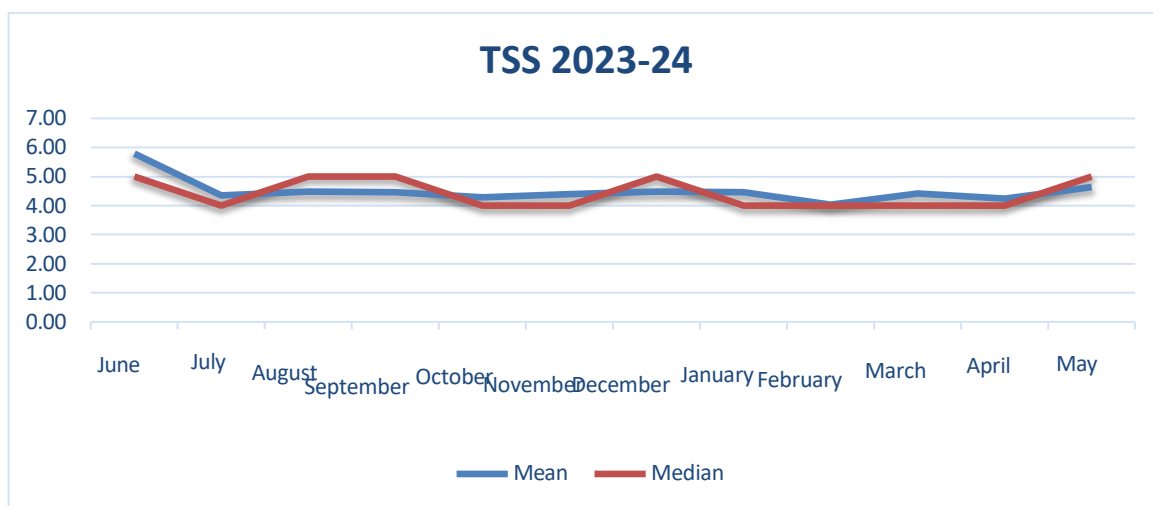


Figure 4.31 : TSS value of 225 MLD STP at Jamalpur, Ludhiana

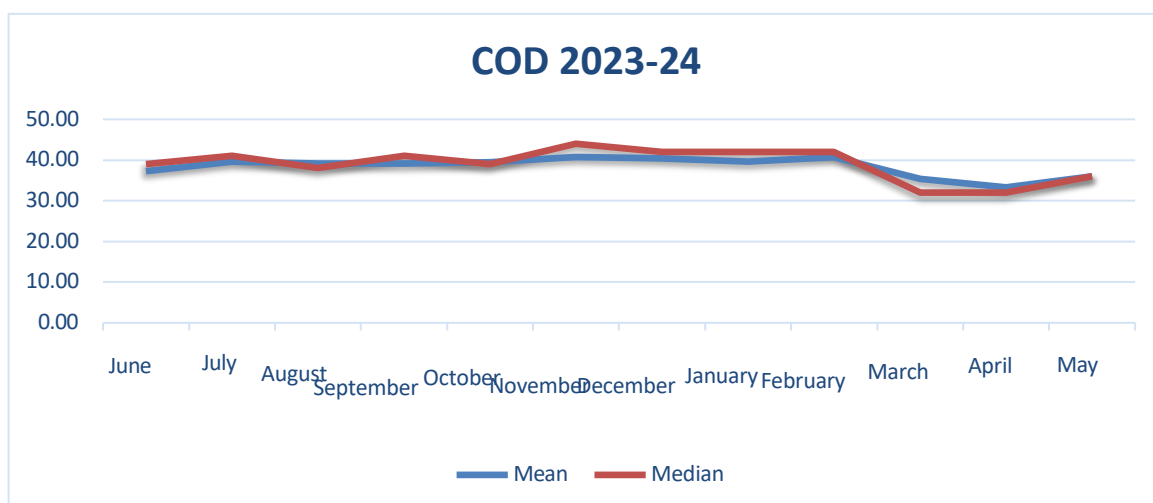


Figure 4.32 : COD value of 225 MLD STP at Jamalpur, Ludhiana

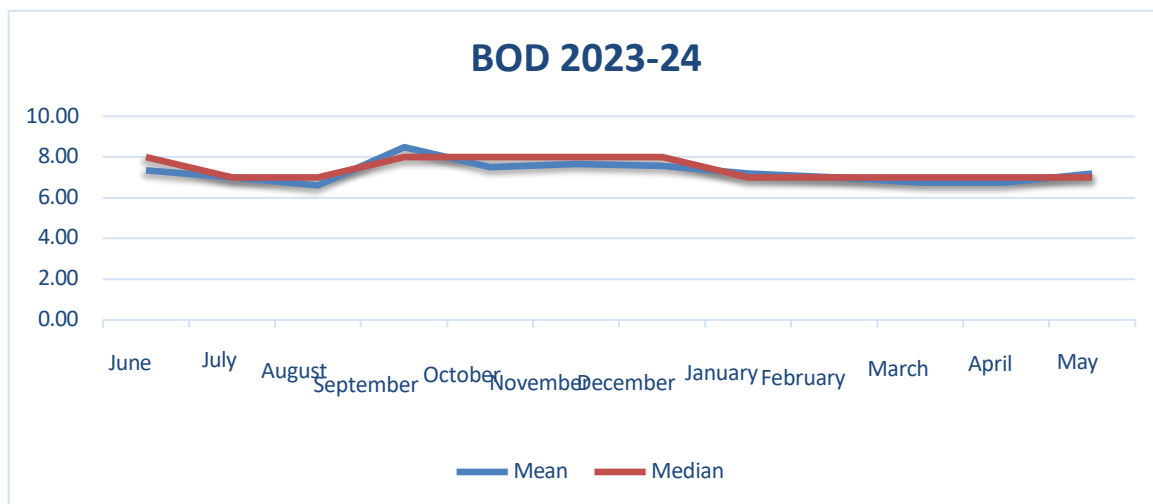


Figure 4.33 : BOD value of 225 MLD STP at Jamalpur, Ludhiana

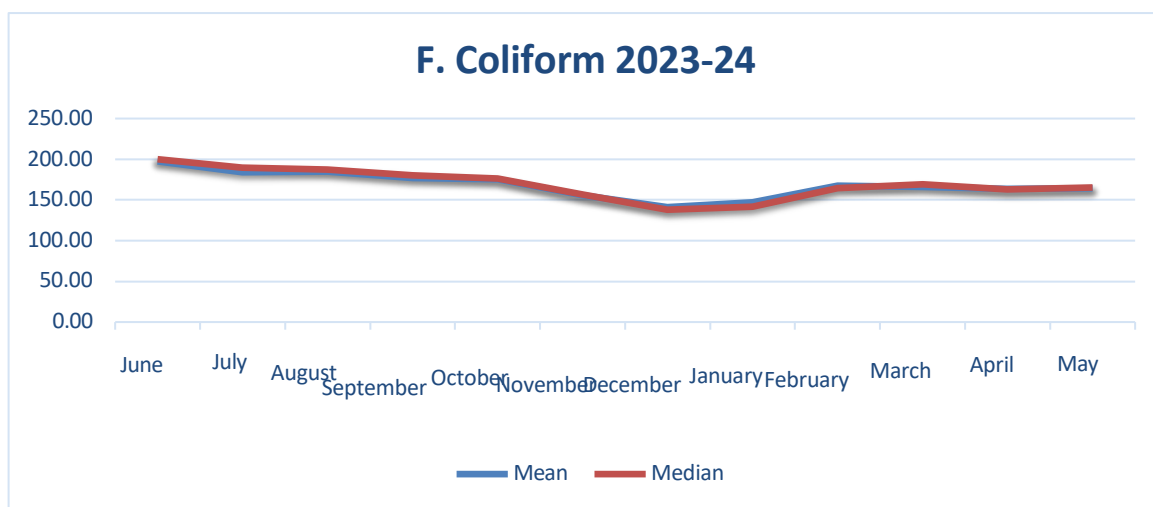


Figure 4.34: F. Coliform value of 225 MLD STP at Jamalpur, Ludhiana

4.6 Results from 95MLD STP at Ghausabad, Amritsar

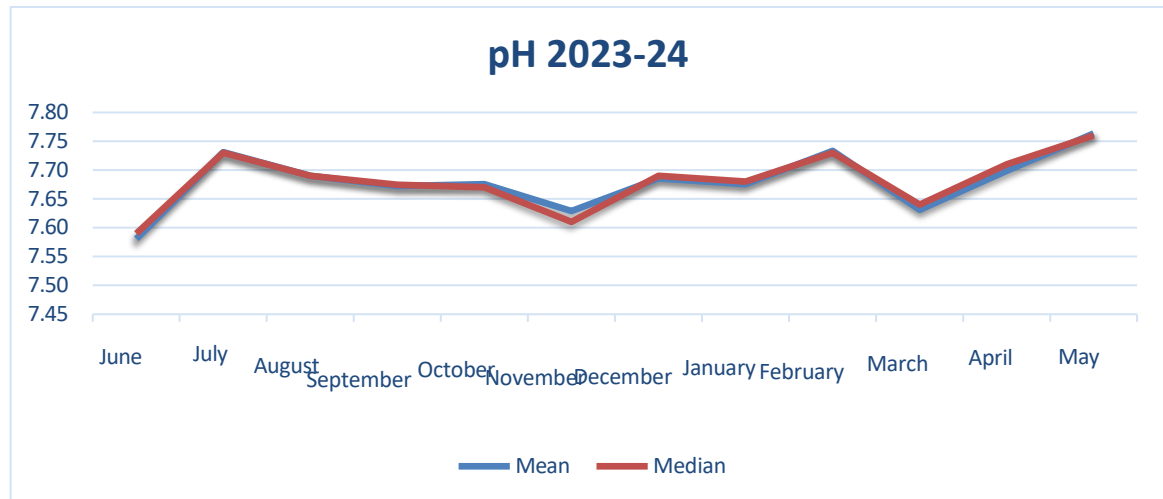


Figure 4.35 : pH value of 95 MLD STP at Ghausabad

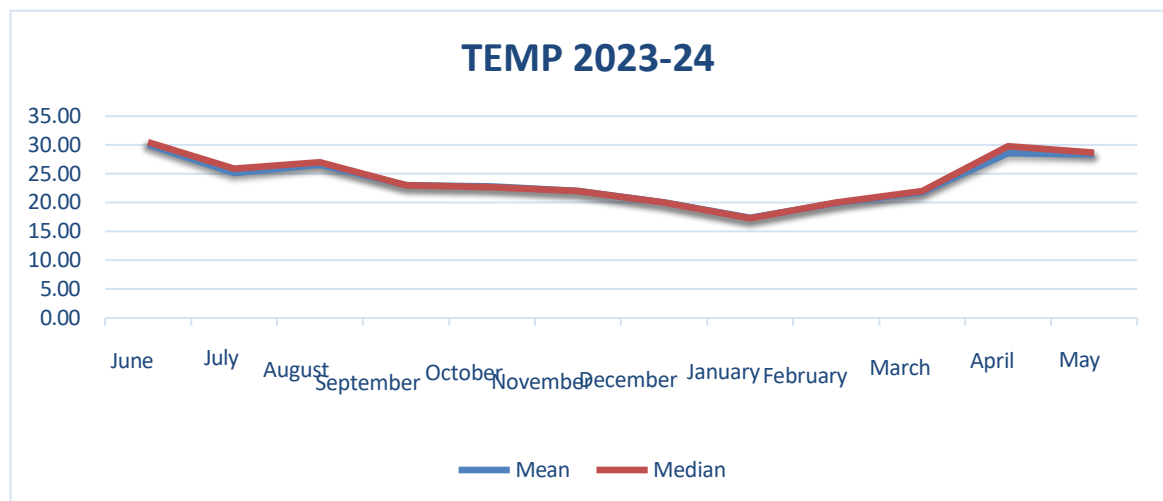


Figure 4.36 : Temp value of 95 MLD STP at Ghausabad

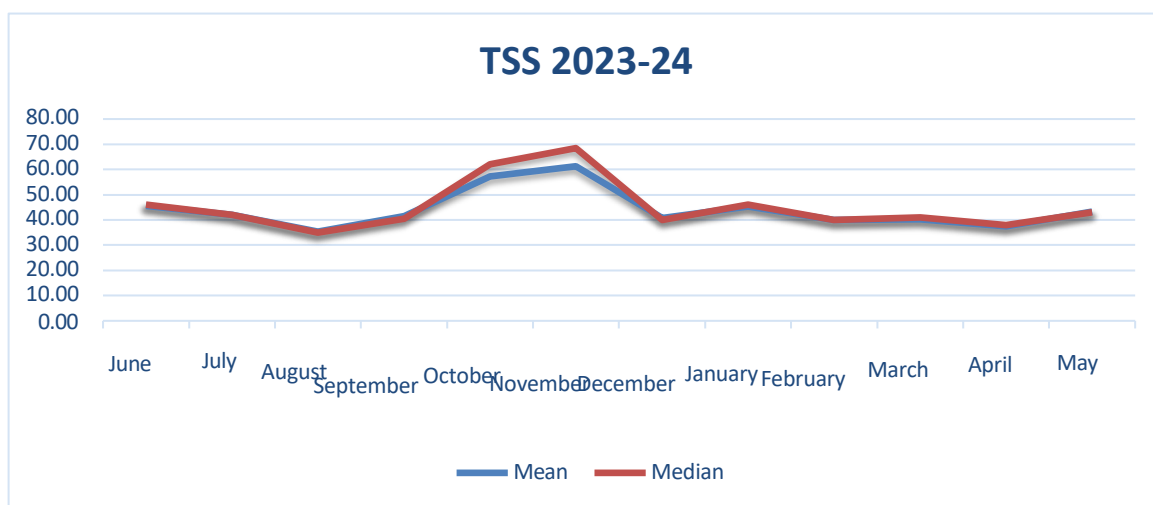


Figure 4.37 : TSS value of 95 MLD STP at Ghausabad

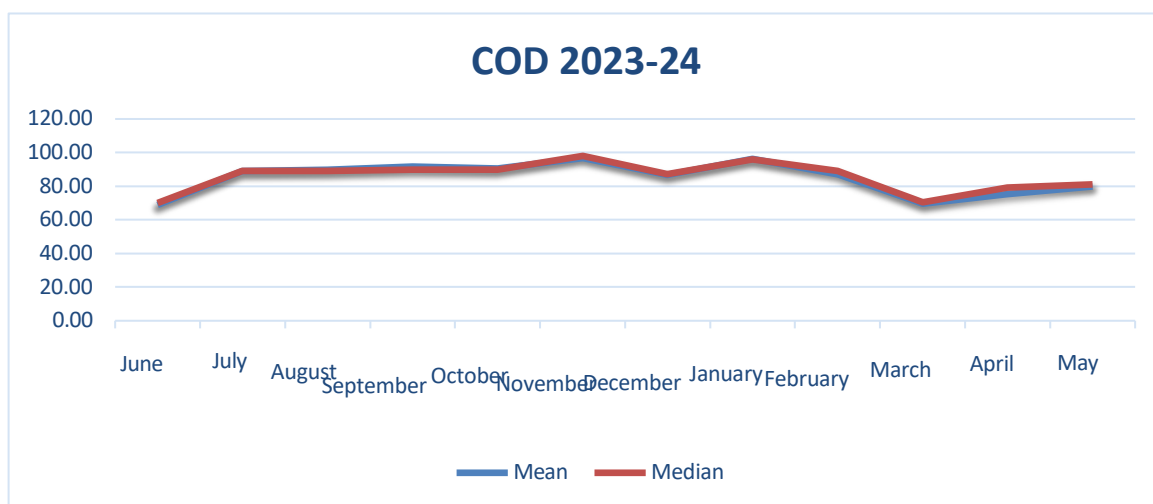


Figure 4.38 : COD value of 95 MLD STP at Ghausabad

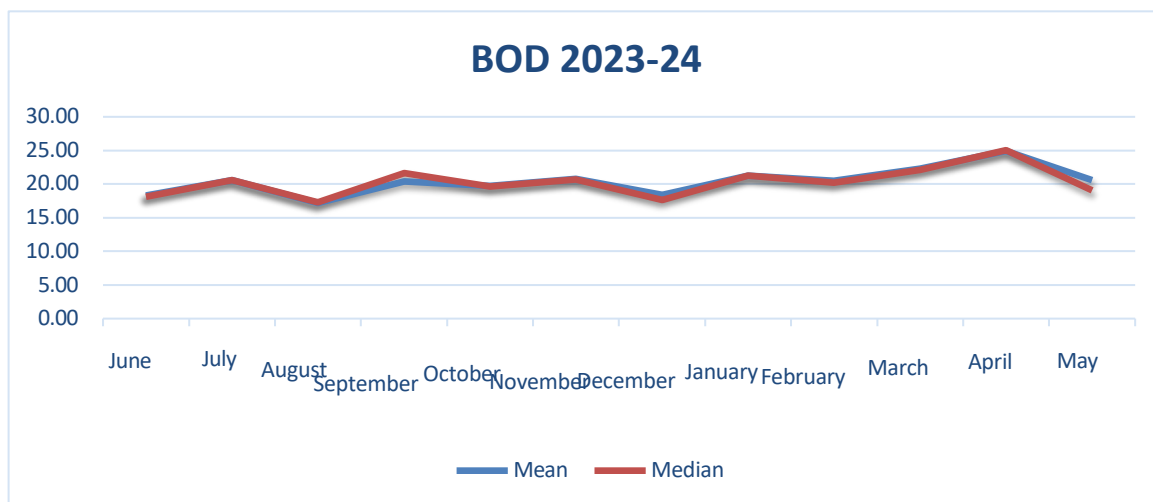


Figure 4.39 : BOD value of 95 MLD STP at Ghausabad

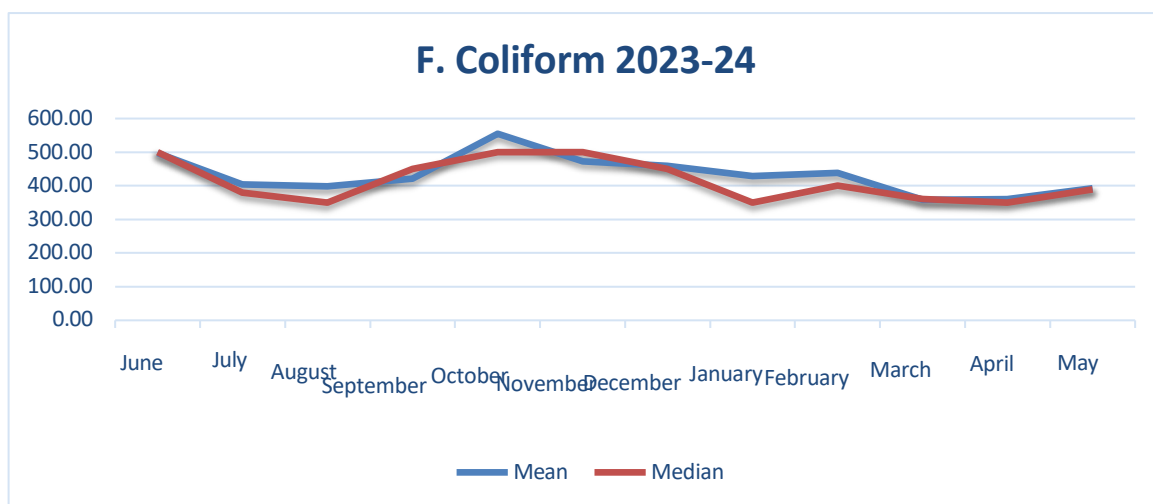


Figure 4.40 : F. Coliform value of 95 MLD STP at Ghausabad

Concrete mixed with Potable Water 100%

The concrete cubes were formed using a mixture of cement, sand, and aggregate, all of which were combined with 100% potable water. The mixture was then poured into a 150mm cube mould. Subsequently, a load test was performed on the cubes to get initial data for future tests, given that this was a manually mixed batch.

Table 4.5 : Showing Strength of Concrete mixed with Potable Water 100%

Compressive strength of concrete(N/mm ²)	After 7 Days	After 28 Days
Cube no. 1	13.11	23.75
Cube no. 2	13.91	24.28
Cube no. 3	13.77	23.85

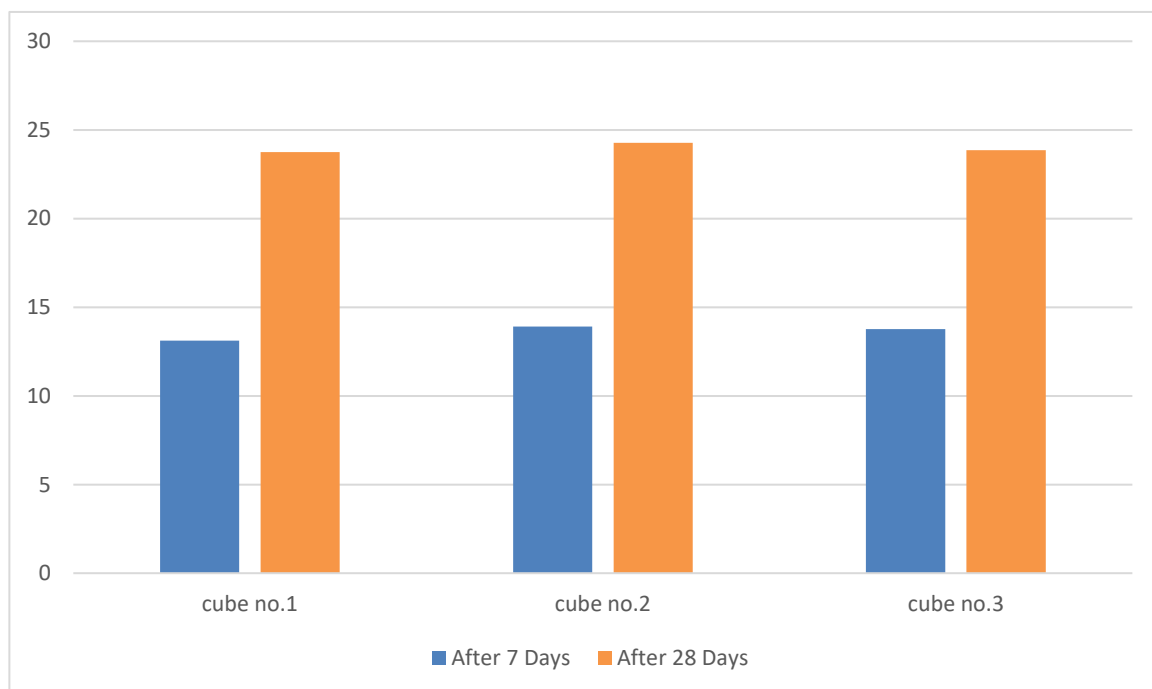


Figure 4.41 : Compressive strength of Concrete mixed with 100% Potable Water

Concrete mixed with Ratio of Primary Treated Waste Water and Potable Water in a Ratio of (60 :40)

Concrete cubes were formed by combining cement, sand, aggregate, and a mixture of Primary Treated Waste Water and Potable Water in a ratio of 60:40. The cubes were casted in a 150mm cube mould and subsequently subjected to a load test. To facilitate comprehension of the results, a bar chart was created.

Table 4.6: Strength of Concrete mixed with Primary Treated Waste Water: Potable Water in ratio 60:40

Compressive strength of concrete (N/mm ²)	After 7 Days	After 28 Days
Cube no.1	13.77	17
Cube no.2	13.77	17.22
Cube no.3	13.44	17.66

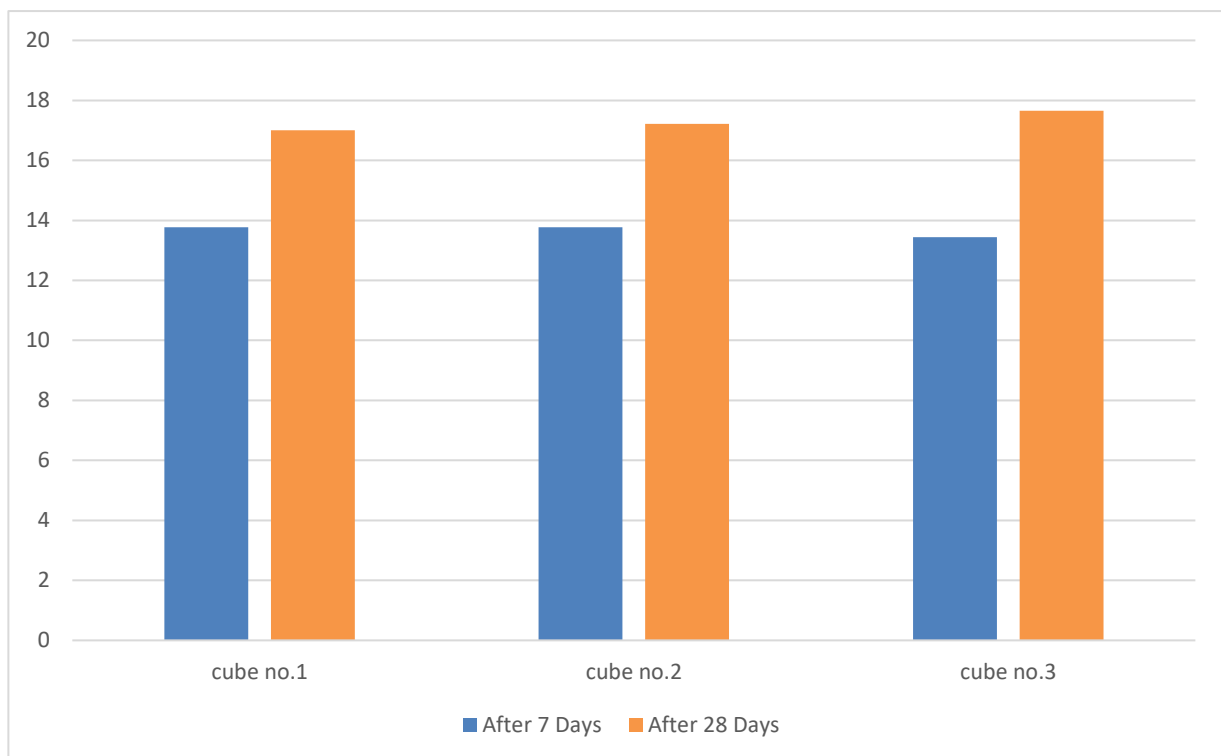


Figure 4.42: Compressive strength of Concrete mixed with Primary Treated Waste Water : Potable Water in a Ratio of 60:40

Concrete mixed with Ratio of Secondary Treated Waste Water and Potable Water in a Ratio of (60 : 40)

Concrete cubes were formed using a mixture of cement, sand, aggregate, and a ratio of 60% secondary Treated Waste Water and 40% potable water. The cubes were casted in a 150mm cube mould and then subjected to a load test. A bar chart was created to provide a clear visualisation of the test results.

Table 4.7: Showing Strength of Concrete mixed with Secondary Treated Waste Water:
Potable Water in ratio 60:40

Compressive strength of concrete (N/mm ²)	After 7 Days	After 28 Days
Cube no.1	13.77	21.99
Cube no.2	13.66	22
Cube no.3	13.22	22.11

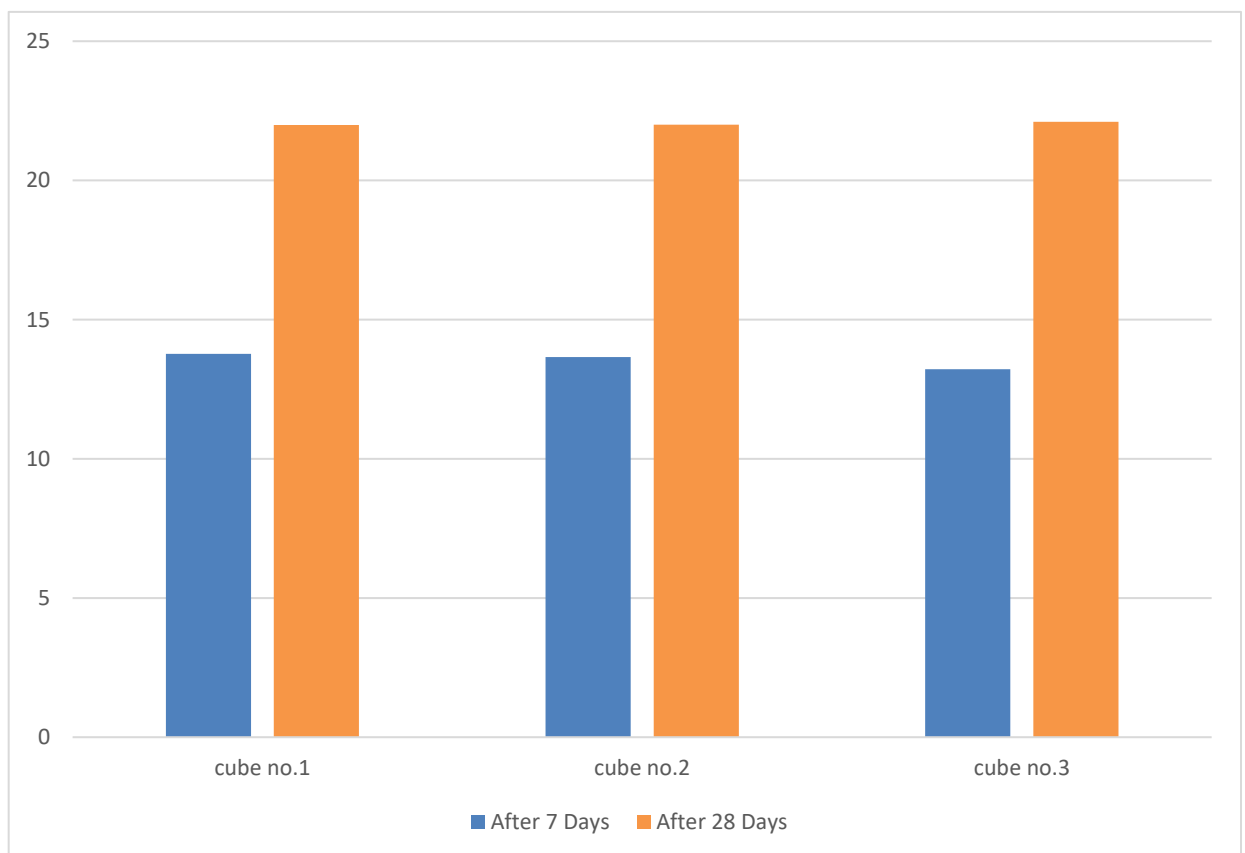


Figure 4.43: Compressive strength of Concrete mixed with Secondary Treated Waste Water : Potable Water in a Ratio of 60:40

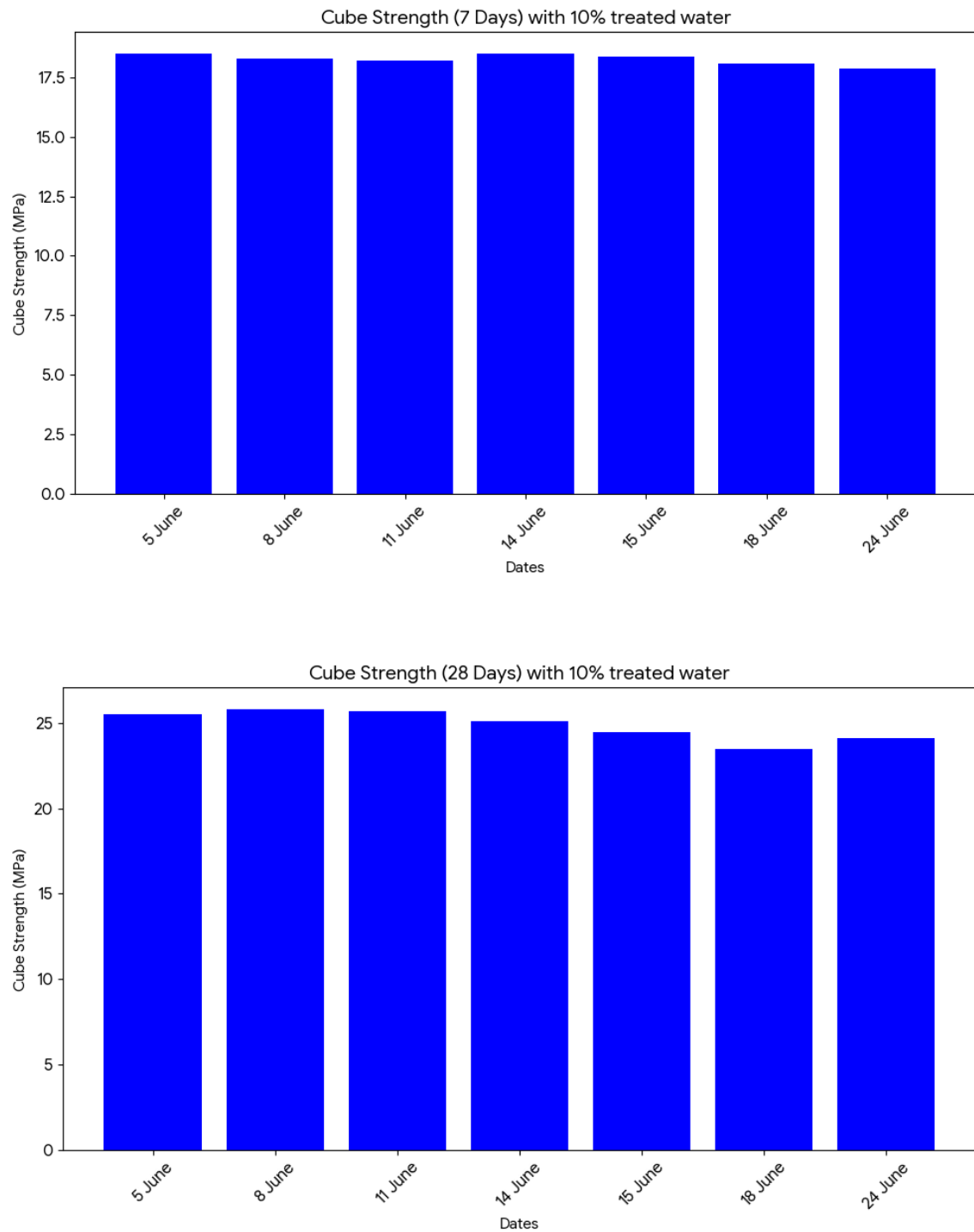


Figure 4.44: Characteristic strength of Concrete mixed with 10% Treated Waste Water for 7 & 28 days (Month June)

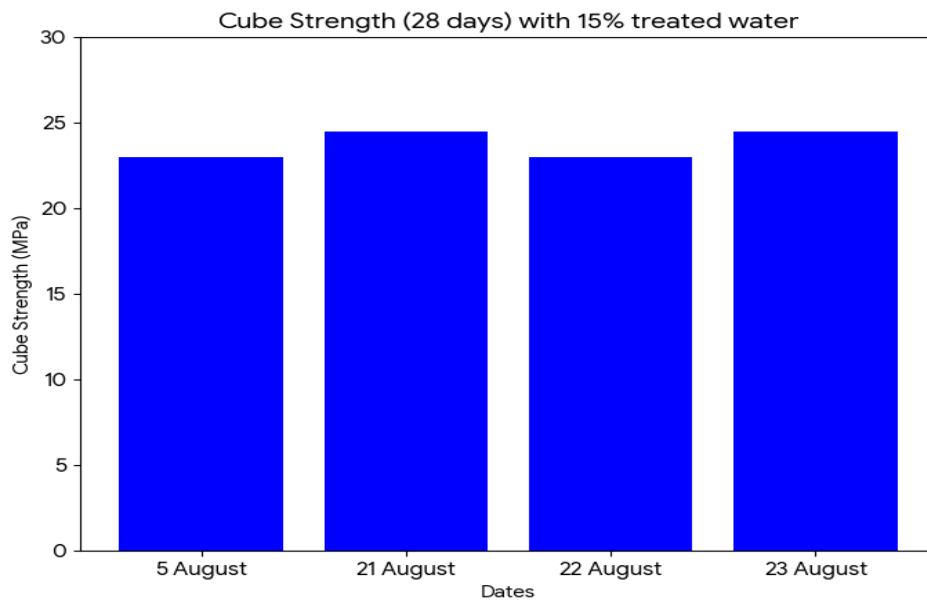
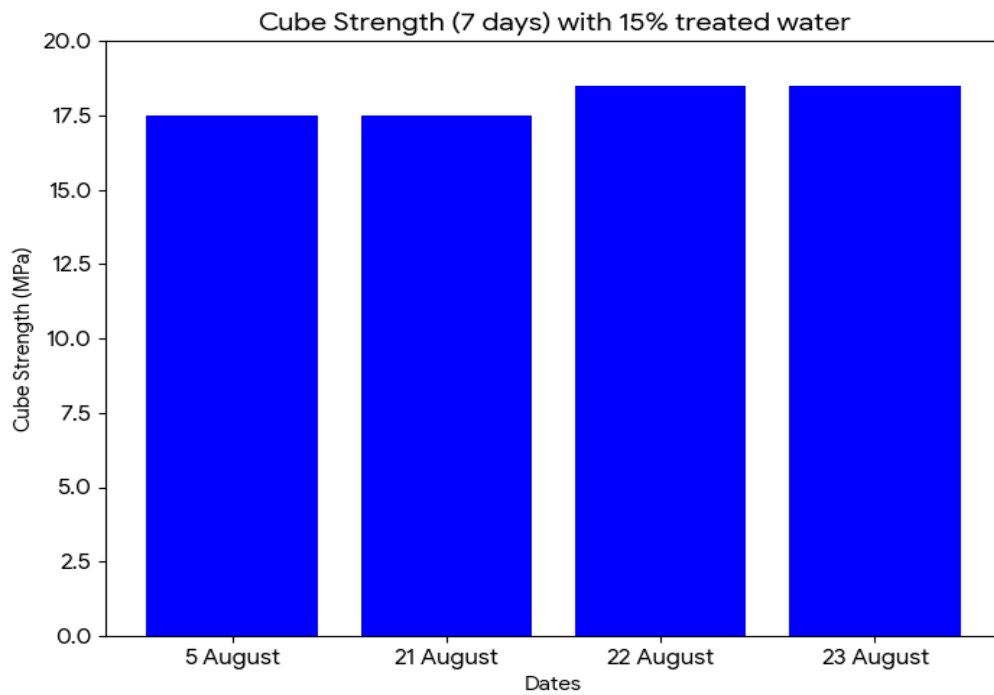


Figure 4.45: Characteristic strength of Concrete mixed with 15% Treated Waste Water for 7 & 28 days (Month August)

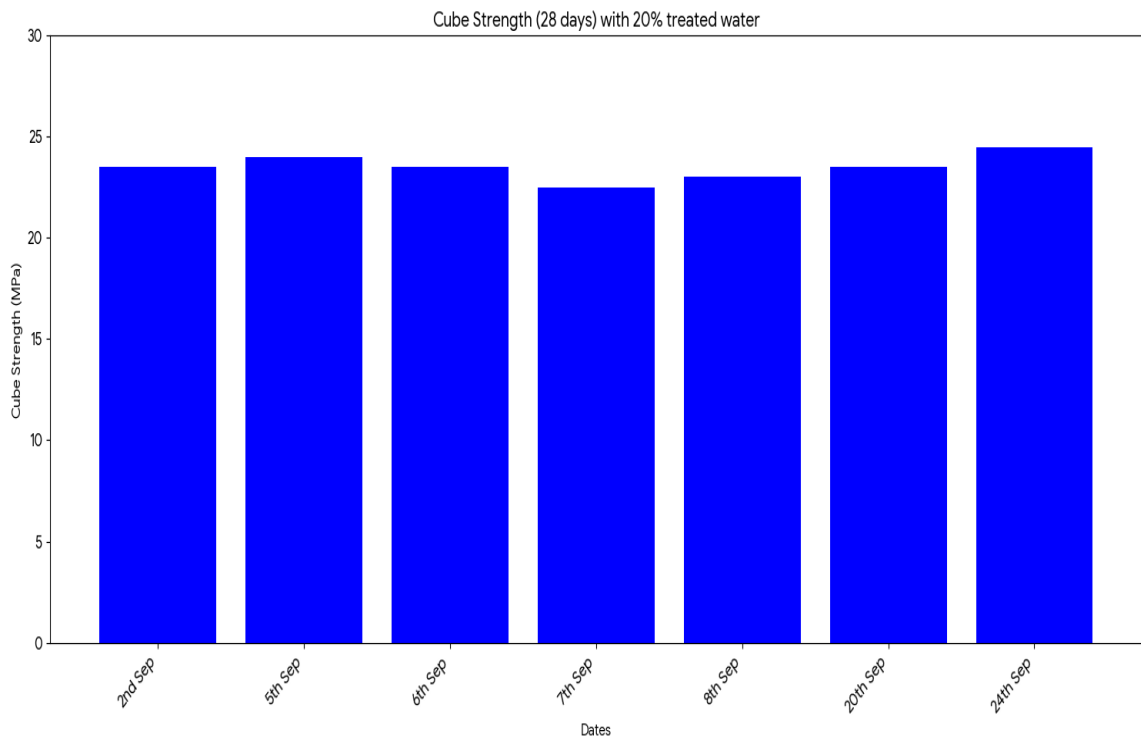
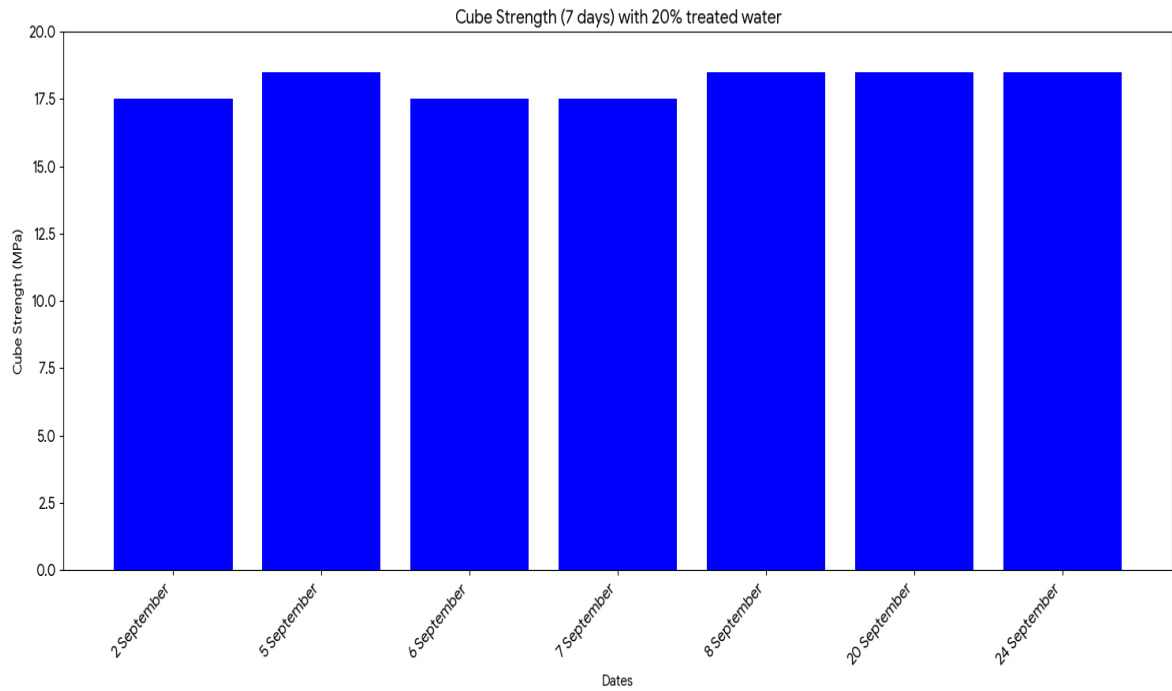


Figure 4.46: Characteristic strength of Concrete mixed with 20% Treated Waste Water for 7 & 28 days (Month September)

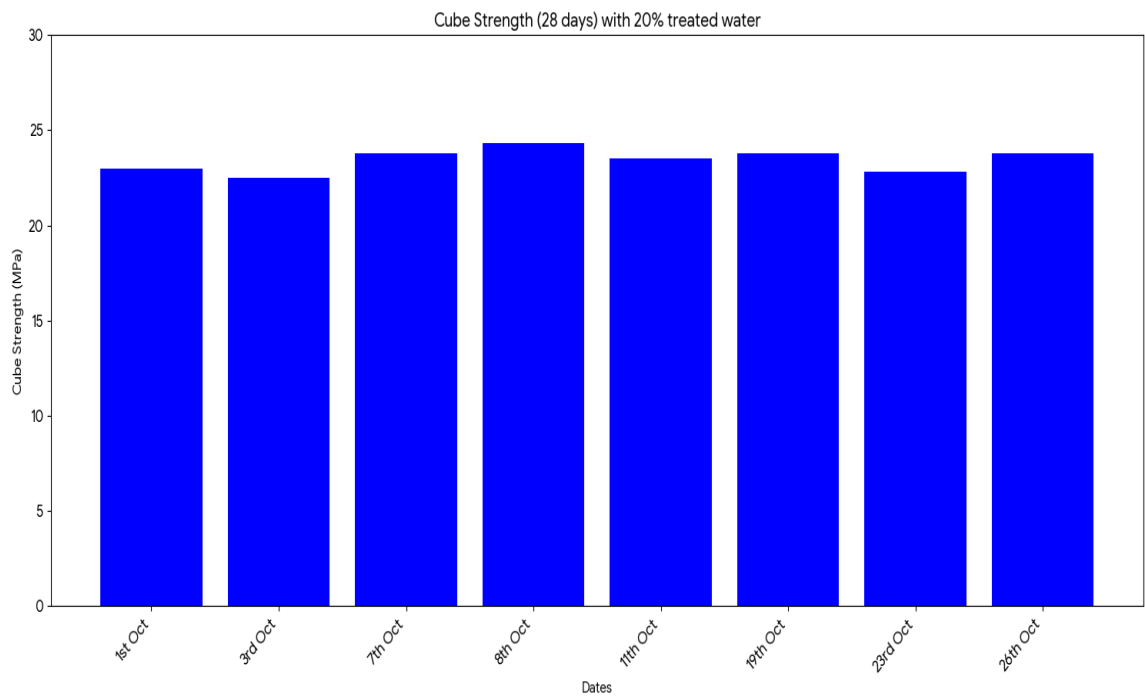
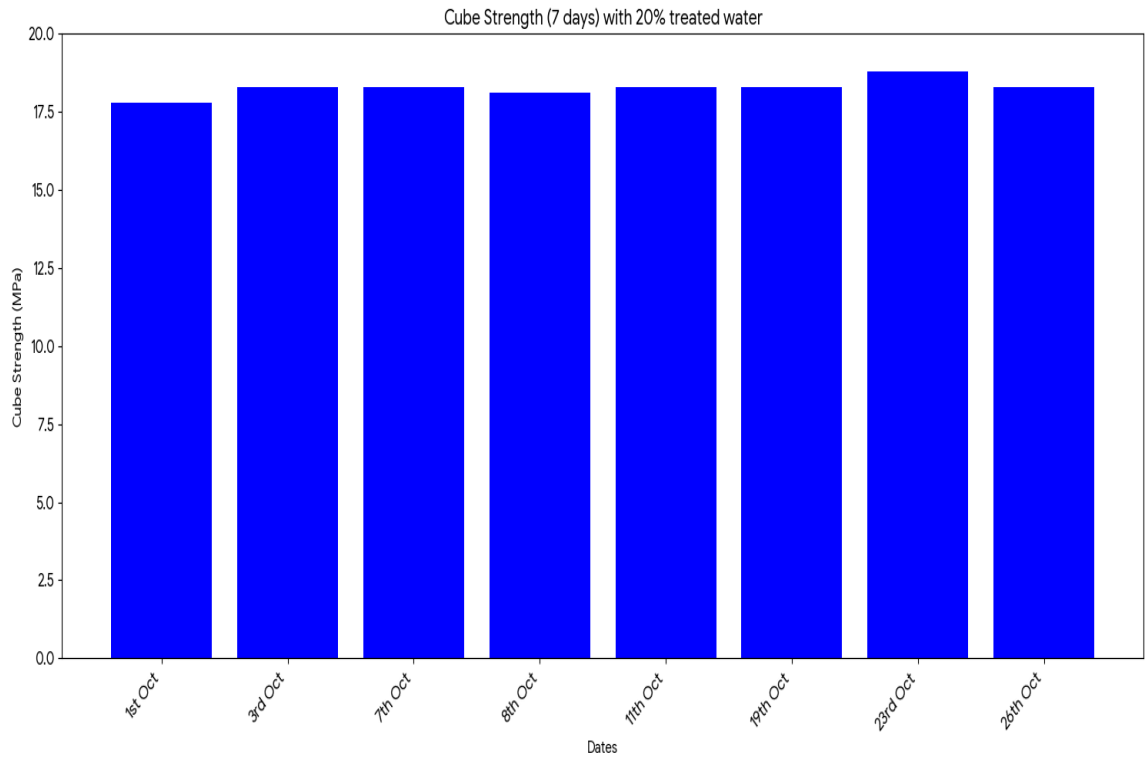


Figure 4.47: Characteristic strength of Concrete mixed with 20% Treated Waste Water for 7 & 28 days (Month October)

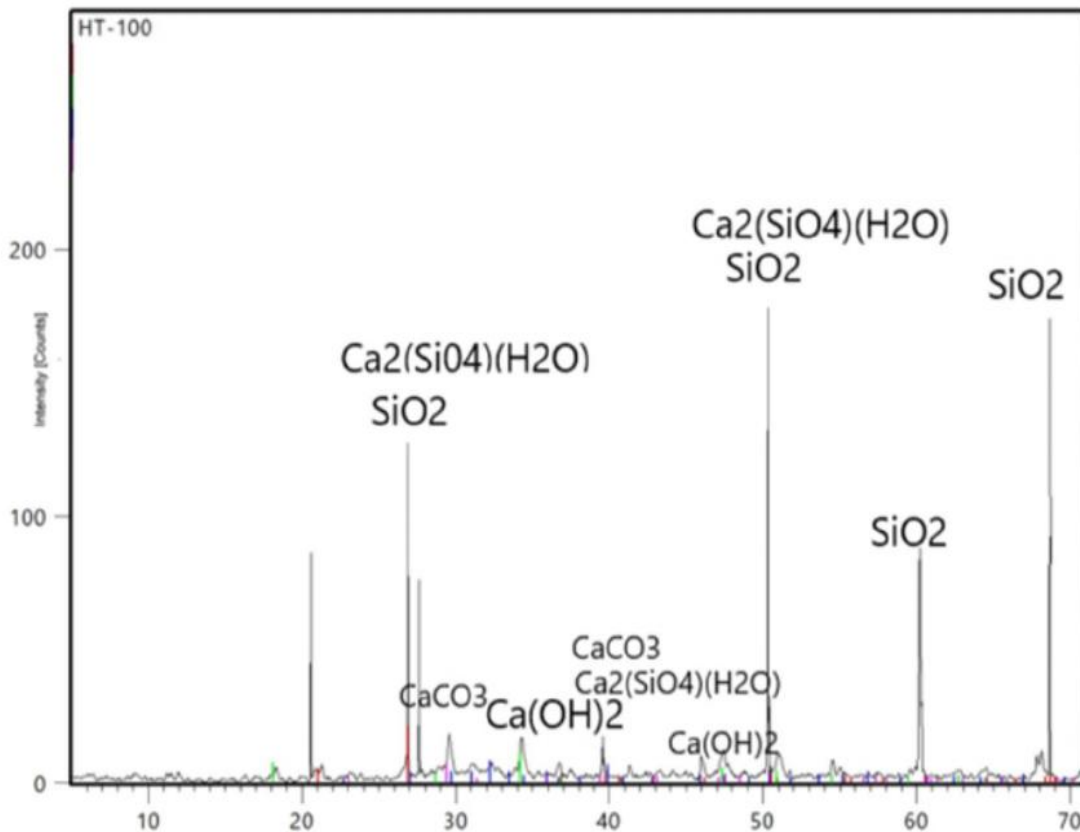


Figure 4.48: XRD Analysis

4.7 Economic Consideration

As per mix design, volume of water for 1 cum of concrete grade M-20 comes out of be 142 litres approximately. Hence the main rationale behind introduction of this and for replacement of potable water with treated sewage is to save potable water. Therefore in approximately every 1 cum of concrete, 142 litres of water is used. Replacing 60% means 85 litres potable water can be saved for every 1 cum of concrete work. Further as per current commercial rates applicable, Rs 20 per 1000 litres is rate of potable water supplied. So in case of 1000 cum of concrete, 142 Kilolitres of potable water is used, which means, 60% replacement can save 85 Kilolitres of potable water, hence saving approximately Rs 1700 per 1000 cum of concrete. A drop of potable water saved is for future generations considering high treatment and distribution cost these days.

Chapter 5 : Summary and Conclusions

The study showcases that the treated sewage water from the Bambianwali plant may efficiently substitute drinkable water in the manufacturing of concrete, hence promoting sustainable water management techniques. The continuous water quality metrics observed throughout the three-year duration confirm the dependability of the treated sewage water for industrial use. The concrete cubes mixed with secondary treated wastewater demonstrated equivalent strength to those mixed with potable water, suggesting its viability for concrete mixing. This strategy not only preserves drinkable water but also encourages the recycling of treated wastewater, in line with objectives for environmental sustainability. This practice ensures potential saving of potable water to the tune of 85 litres per 1 cum of concrete and also saves approximately Rs. 1700 per 1000 cum of concrete. Introduction of replacement of potable water in concrete mix with treated sewage shall ensure potable water available for future generations considering high cost of treatment and distribution. Subsequent research should prioritise the examination of the extended lifespan and effectiveness of concrete produced using treated sewage water in order to confirm its suitability for use in the building sector.

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List of Publications

1. Vasudeva J., Sahoo M.M, Singh J. (2025). Utilization of treated water from Sewage Treatment Plants in Concrete Mix Replacing Potable Water, Asian Journal of Water, Environment and Pollution, Vol. 22, No. 2 (2025), pp. 114-124 doi: 10.36922/AJWEP025060033 (Scopus indexed).
2. Vasudeva J., Sahoo M.M, Singh J. (2025). Analysis of Treated water quality parameters at the outlet of sewage treatment plant using statistical models, AIP Procedia, Scopus Indexed, CTMSE 2025, IEM Kolkata.
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