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A Comparative Assessment of UASB & Anaerobic Filter Treating Dairy Wastewater

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***Abstract**: The majority of agro-industries, including the dairy sector, produce strong wastewater, which is distinguished by high concentrations of chemical and biological oxygen demand, indicating strong organic content. Milk-derived carbohydrates, proteins, and lipids are the primary sources of organic load in the concentrated dairy waste effluents found in the environment. In the present study a **comparative assessment of Upflow Anaerobic Sludge Blanket (UASB) and Anaerobic Filter (AF) reactors in the treatment of dairy wastewater** was done. Dairy wastewater, characterized by high levels of organic matter, poses significant environmental challenges if not treated effectively. This study investigates the performance and efficiency of UASB and AF reactors under varying conditions. Both reactors were evaluated based on key performance indicators such pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Volatile Fatty Acids (VFA), Alkalinity, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS).*

It was revealed from the performance study that the removal efficiencies of wastewater parameters BOD, COD, TSS and TDS were for UASB were 82%, 79%, 60% and 21% respectively for the UASB.
Whereas the removal efficiencies of wastewater parameters BOD, COD, TSS and TDS were for UASB were 78%, 74%, 51% and 12% respectively for the anaerobic filter.
Results indicated that while both reactors demonstrated substantial potential in treating dairy wastewater, differences in their operational mechanisms led to variations in performance outcomes. The UASB reactor exhibited higher COD and BOD removal efficiencies under stable conditions, primarily due to its effective sludge blanket formation and better sludge retention.
The study presents advantages and disadvantages of UASB and AF systems in treating dairy wastewater.

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I. Introduction

This study focuses on a comparative assessment of two widely used anaerobic treatment technologies: the upflow anaerobic sludge blanket reactor and the anaerobic filter. Both methods leverage on the metabolic capabilities of anaerobic microorganisms to degrade organic matter but they differ significantly in their operational mechanisms, efficiency, and suitability for treating specific types of wastewater. Given the varying characteristics of dairy wastewater, including its high concentration of fats, proteins and lactose, it is imperative to evaluate the performance of these two anaerobic treatment systems in this specific context. This comparative assessment aims to analyse the treatment efficiency and overall feasibility of UASB and AF when applied to dairy wastewater.

The study area includes two dairy industries both located in the Punjab region. The main focus of the present work is to study the anaerobic systems used in the treatment of dairy wastewater.

The anaerobic system used for treatment of wastewater in Industry 1 is anaerobic filter. The ETP has a capacity to treat 300 m^3 of wastewater per day. The treatment scheme for industry 1 is as follows :

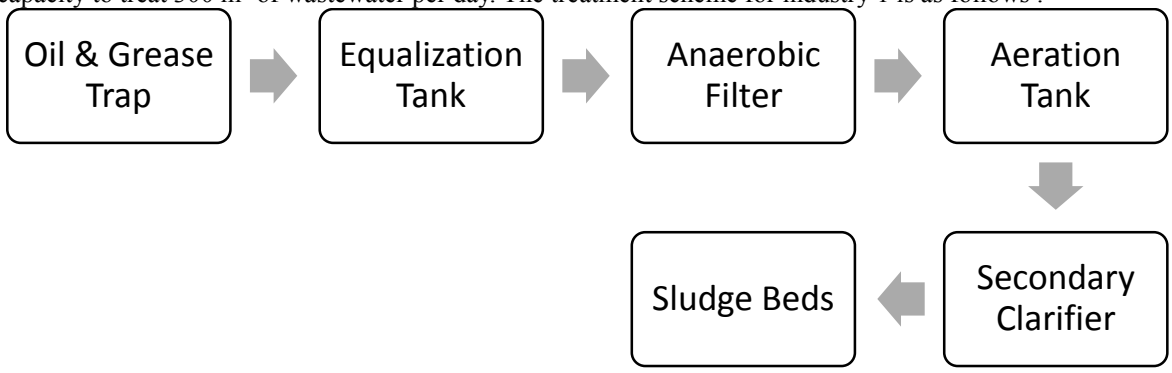

Figure 1.1 Industry 1 Treatment Scheme

The anaerobic system used for treatment of wastewater in Industry 2 is UASB. The ETP is designed to treat 500 m^3 of wastewater per day. The treatment scheme for industry 2 is as follows:

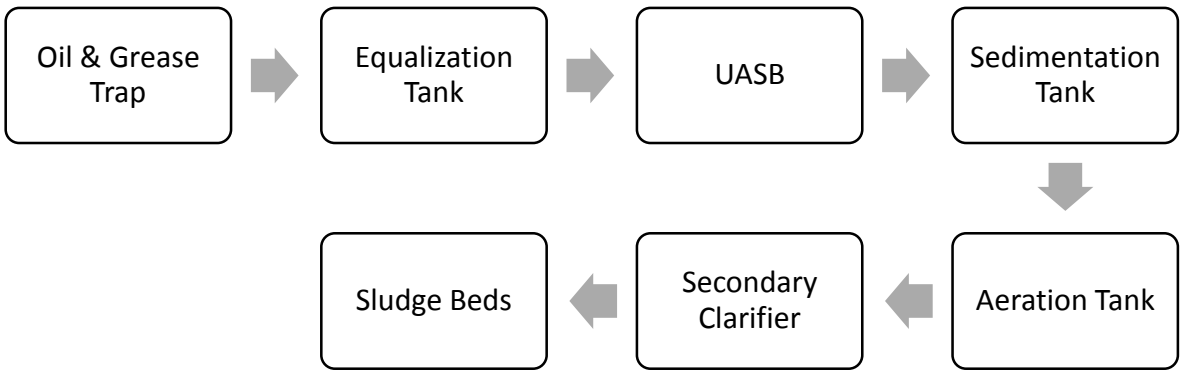

Figure 1.2 Industry 2 Treatment Scheme

II. Materials and Methodology

The samples of dairy wastewater were taken from two separate dairy industries located in the Punjab region referred to as Industry 1 and Industry 2. The anaerobic system used for wastewater treatment in Industry 1 is anaerobic filter whereas the anaerobic system used for wastewater treatment is UASB.

The samples were taken from both industries on a weekly basis over a period of 5 months. The testing of samples was done using the Standard Methods for the Examination of Water and Wastewater (APHA 2017). The parameters that were tested were pH, BOD, COD, Alkalinity, Volatile Fatty Acids, TSS and TDS.

III. Results and Discussion

Industry 1

Figure 3.1 represents the pH variation for the anaerobic filter over the course of the research with maximum inlet pH being 11.8 and minimum inlet pH of 8.5. The average inlet pH was 10.69 in the period of 5 months.

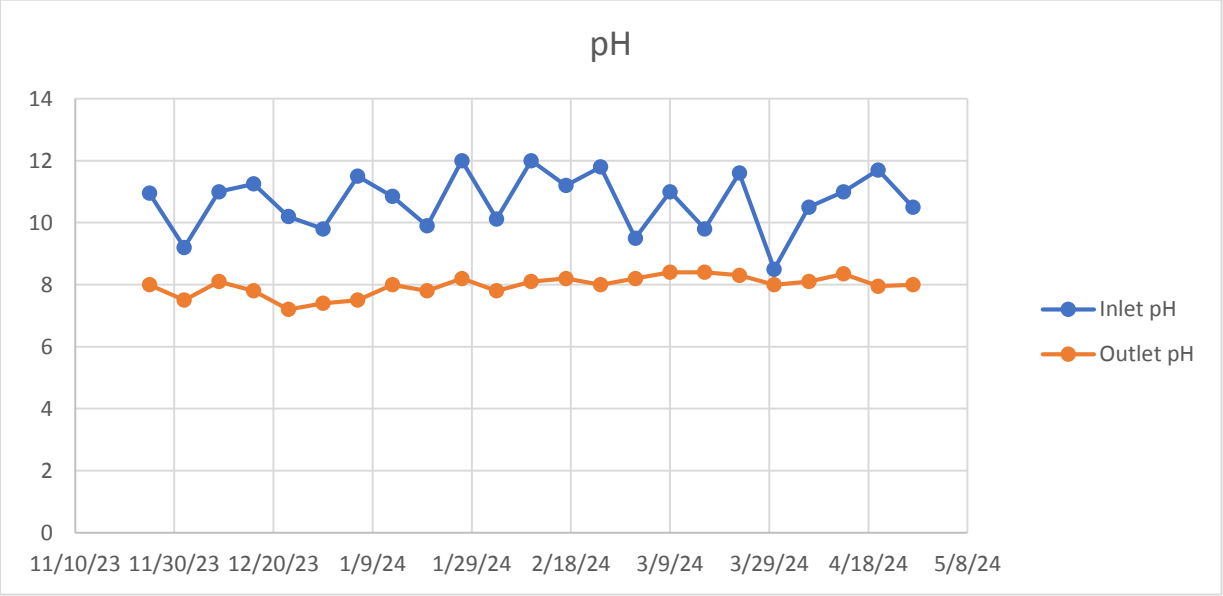

Figure 3.1 AF pH

The pH of anaerobic filter effluent ranges from 7.2 – 8.4 which is within the optimal range. The average outlet pH is 7.96.

BOD

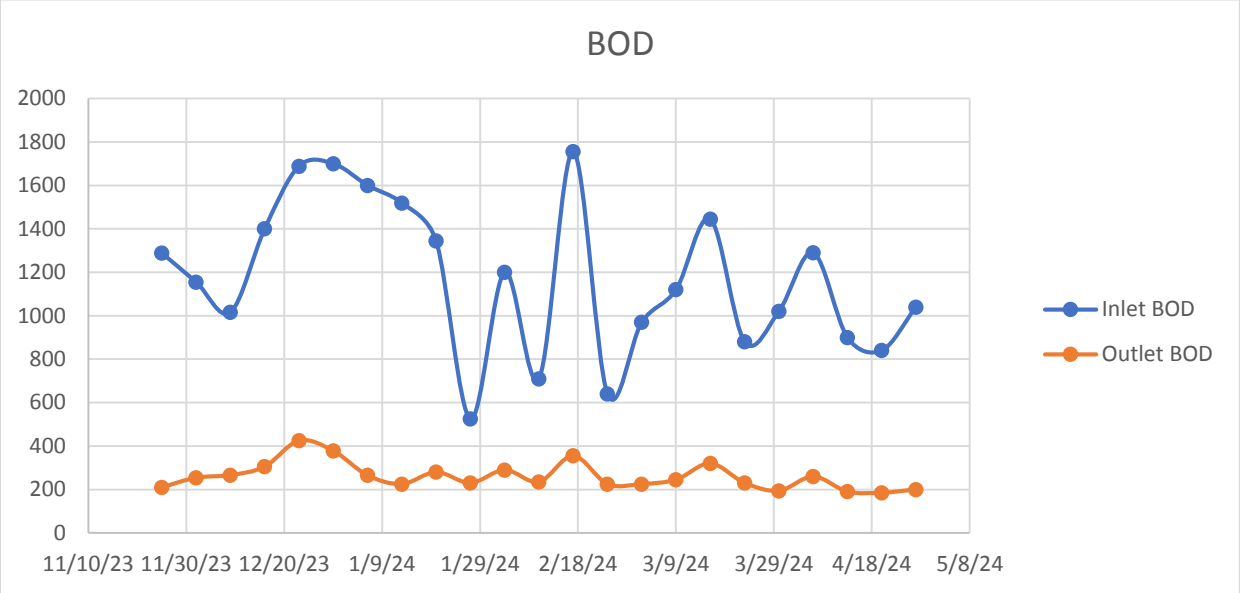

Figure 3.2 AF BOD

Figure 3.2 shows the variation in BOD of the anaerobic filter, with influent BOD ranging from 525 mg/L to 1756 mg/L. The average influent BOD over the entire period of the research was found to be 1175 mg/L.
Figure 3.2 also shows the variation in BOD of anaerobic filter effluent ranging from 185 mg/L to 425mg/L. The average effluent BOD for the entire period of the research was found to be 260 mg/L. The BOD removal was found to be 78 %.

COD

Figure 3.3 depicts the variation of COD of the anerobic filter. The inlet COD was found to be as high as 3488 mg/L and as low as 1200 mg/L. The average COD concentration in the influent was 2308 mg/L.

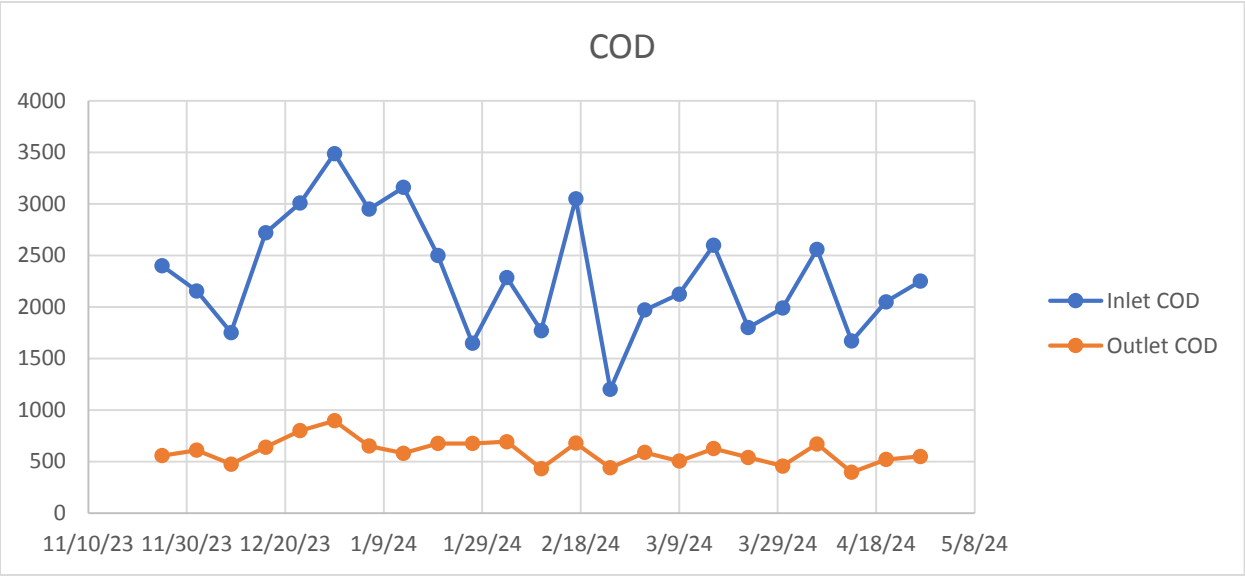

Figure 3.3 AF COD

The effluent COD varied from 396-896 mg/L. The average COD concentration of the anaerobic filter effluent was found to be 593 mg/L. The COD removal was found to be 74%.

Alkalinity

Figure 3.4 represents the variation in alkalinity of the anaerobic filter, minimum inlet alkalinity being 500 mg/L and a maximum alkalinity of 900 mg/L. The average inlet alkalinity was observed to be 734 mg/L.

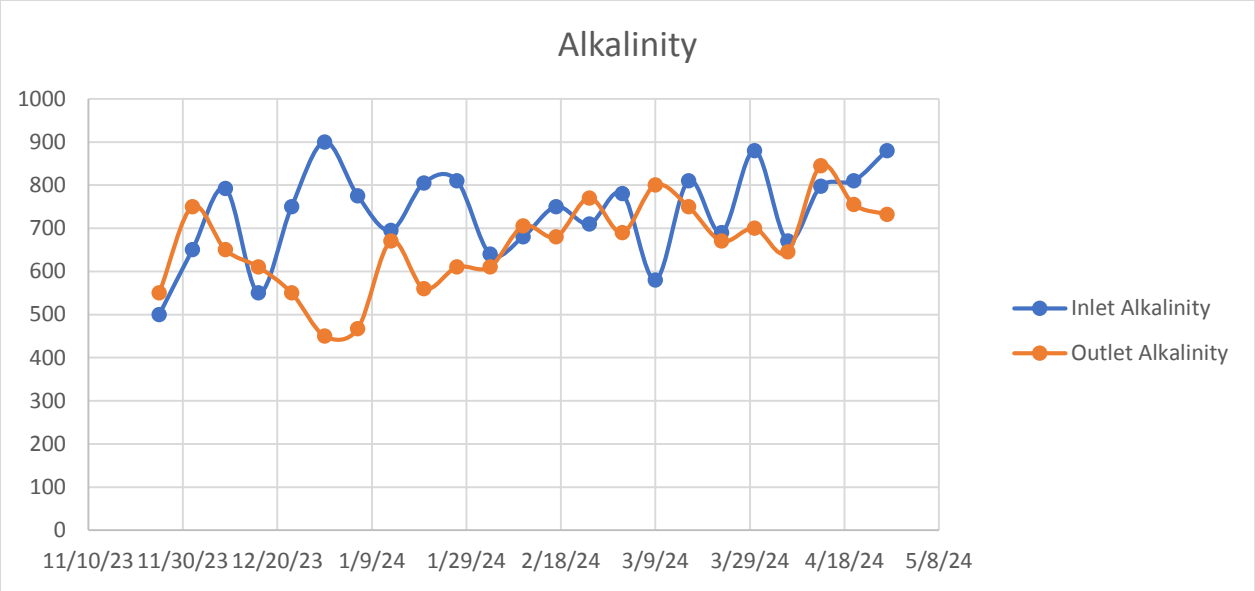

Figure 3.4 AF Alkalinity

Figure 3.4 also represents the alkalinity of anaerobic filter effluent. The alkalinity ranged between 450 mg/L and 845 mg/L, with an average of 661 mg/L.

Volatile Fatty Acids

Figure 3.5 shows the variation of VFA concentration in anaerobic filter, with influent concentration ranging from 245 mg/L to 700 mg/L. The average VFA concentration in anaerobic filter influent was found to be 537 mg/L.

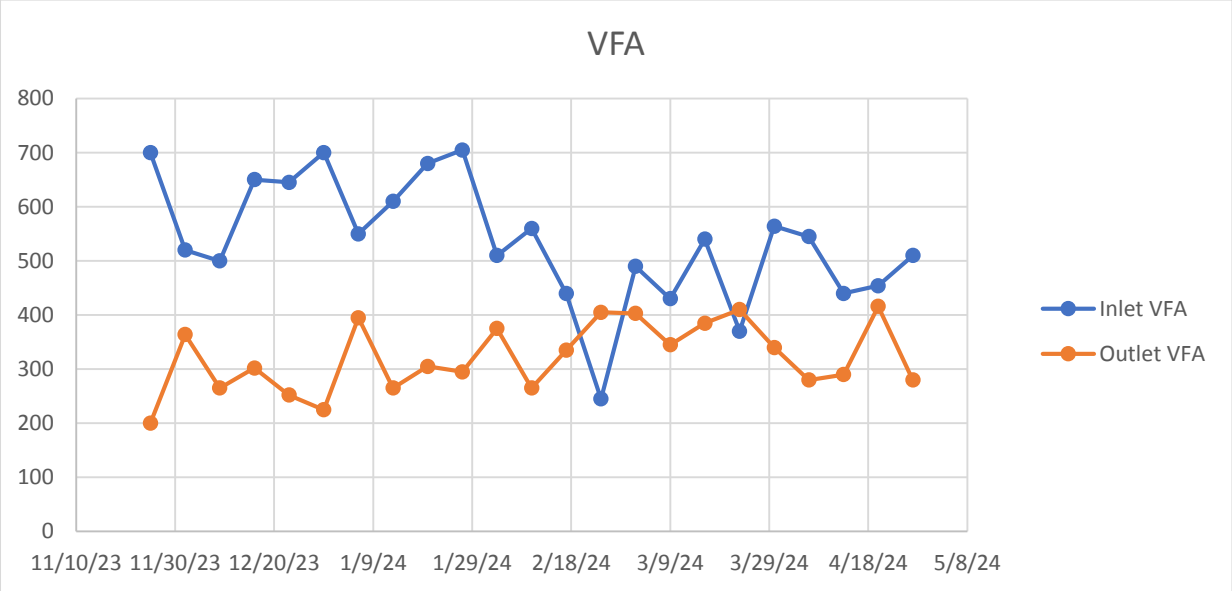

Figure 3.5 AF VFA

Figure 3.5 also shows the variation of VFA's in anaerobic filter effluent ranging between 200 mg/L and 416 mg/L. The average VFA concentration was found to be 321 mg/L.

TSS

Figure 3.6 represents the variation of TSS in anaerobic filter. The influent TSS varied from 390 mg/L to 1315 mg/L. The average TSS in influent were found to be 684 mg/L.

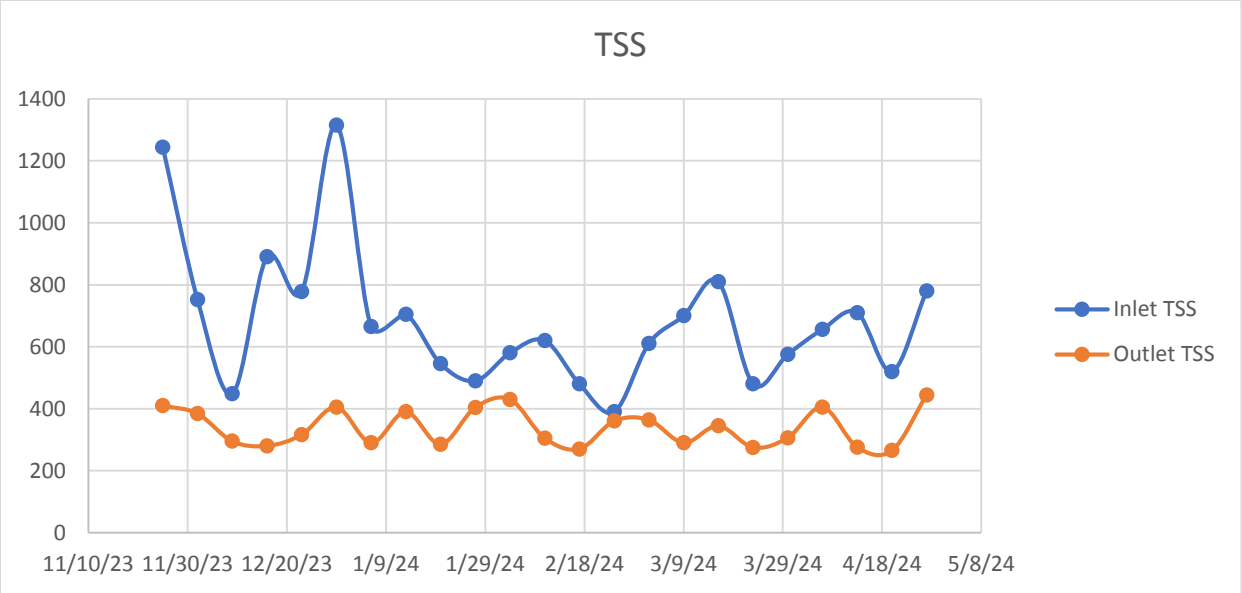

Figure 3.6 AF TSS

Figure 3.6 also shows the variation of TSS in the anaerobic filter effluent, ranging from 265 mg/L to 444 mg/L. The average TSS concentration in effluent was found to be 338 mg/L.

TDS

Figure 3.7 represents the variation of TDS in anaerobic filter. The influent TDS ranged from 1111 mg/L to 1780 mg/L. The average TDS in influent were found to be 1480.5 mg/L.

High Total Dissolved Solids (TDS) in wastewater influent indicates a high concentration of dissolved substances in the water. These dissolved substances can include a wide variety of inorganic salts and small amounts of organic matter. High TDS can also affect the efficiency and lifespan of wastewater treatment infrastructure. For instance, it can cause scaling and corrosion in pipes and equipment, leading to increased maintenance costs and downtime.

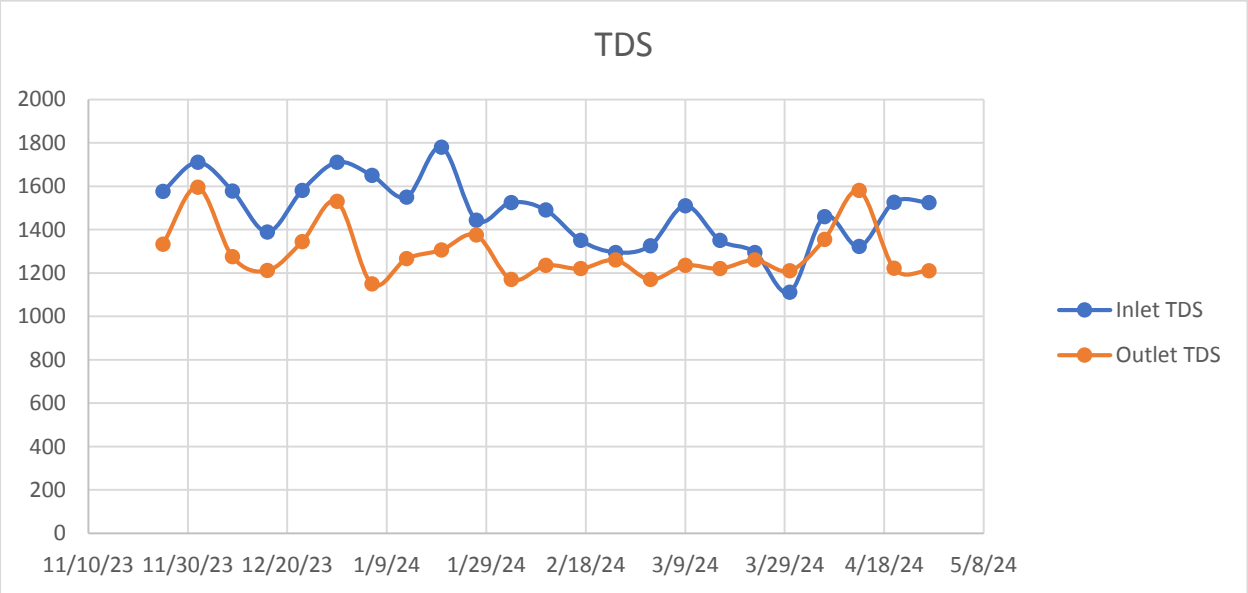

Figure 3.7 AF TDS

Figure 3.7 also represents the variation of TDS in anaerobic filter effluent. The effluent TDS ranged from 1150 mg/L to 1596 mg/L. The average TDS in effluent were found to be 1292.7 mg/L.

Industry 2

pH

Figure 3.8 represents the pH variation for the UASB over the course of the research with maximum inlet pH being 11.9 and minimum inlet pH of 7.88. The average inlet pH was 9.32 in the period of 5 months.

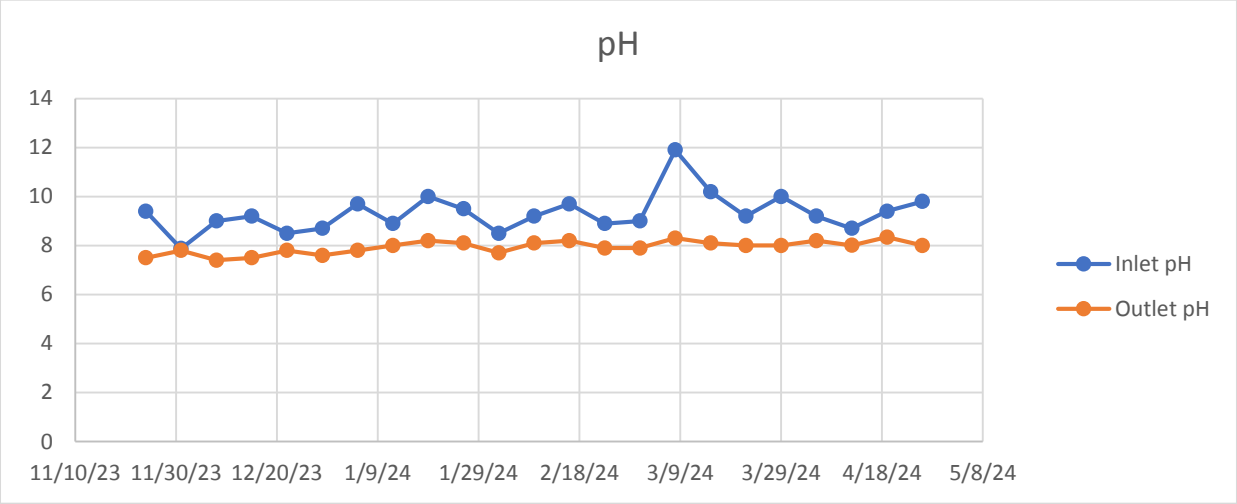

Figure 3.1 UASB pH

Figure 3.8 also represents the pH variation for the UASB outlet over the course of the research with maximum pH being 8.34 and minimum pH of 7.4. The average outlet pH was 7.93 in the period of 5 months.

BOD

Figure 3.9 shows the variation of BOD in the UASB, with influent BOD ranging from 990 mg/L to 2467 mg/L. The average influent BOD over the entire period of the research was found to be 1712 mg/L.

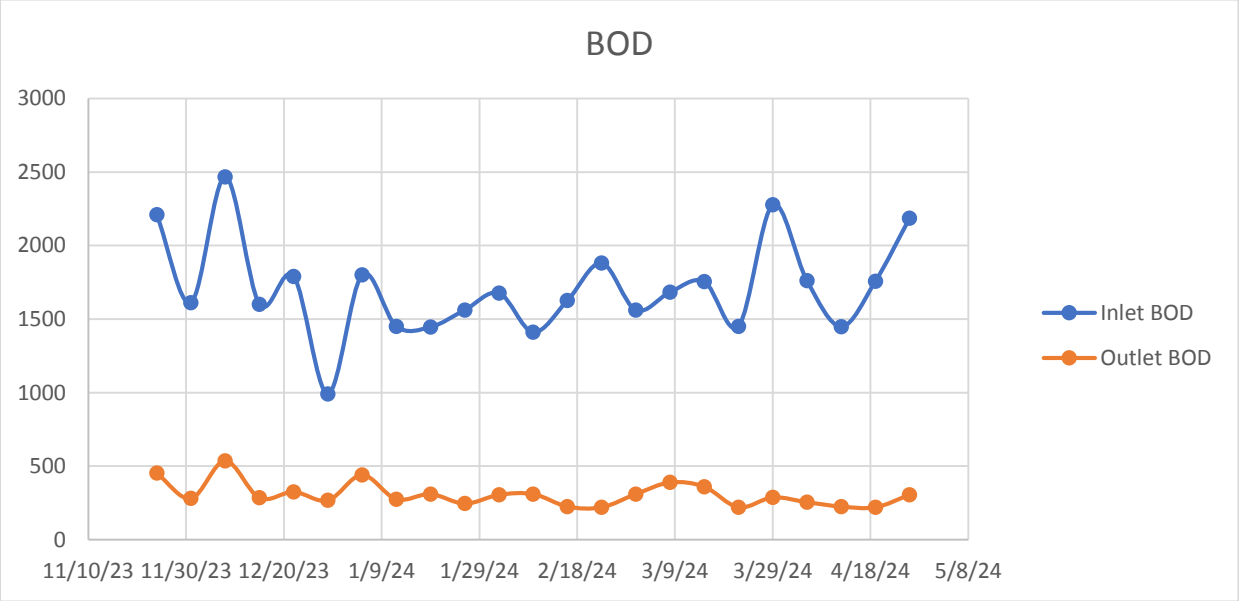

Figure 3.2 UASB BOD

Figure 3.9 also shows the variation in BOD of the effluent ranging from 220 mg/L to 536 mg/L. The average effluent BOD for the entire period of the research was found to be 306.3 mg/L.

COD

Figure 3.10 depicts the variation in COD of the UASB. The inlet COD was found to be as high as 4045 mg/L and as low as 2040 mg/L. The average COD concentration in the influent was 3074 mg/L.

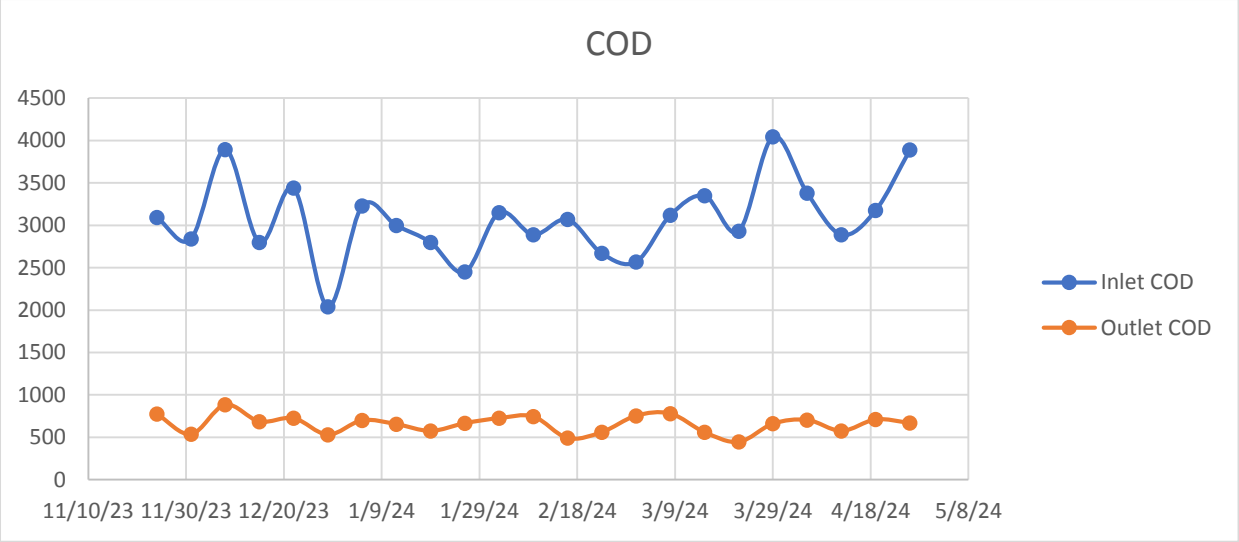

Figure 3.3 UASB COD

Figure 3.10 also shows variation in effluent COD. The effluent COD varied from 445-884 mg/L. The average COD concentration was found to be 657 mg/L.

Alkalinity

Figure 3.11 represents the variation in alkalinity of the UASB, with minimum influent alkalinity being 700 mg/L and a maximum of 1400 mg/L. The average influent alkalinity was observed to be 1041 mg/L.

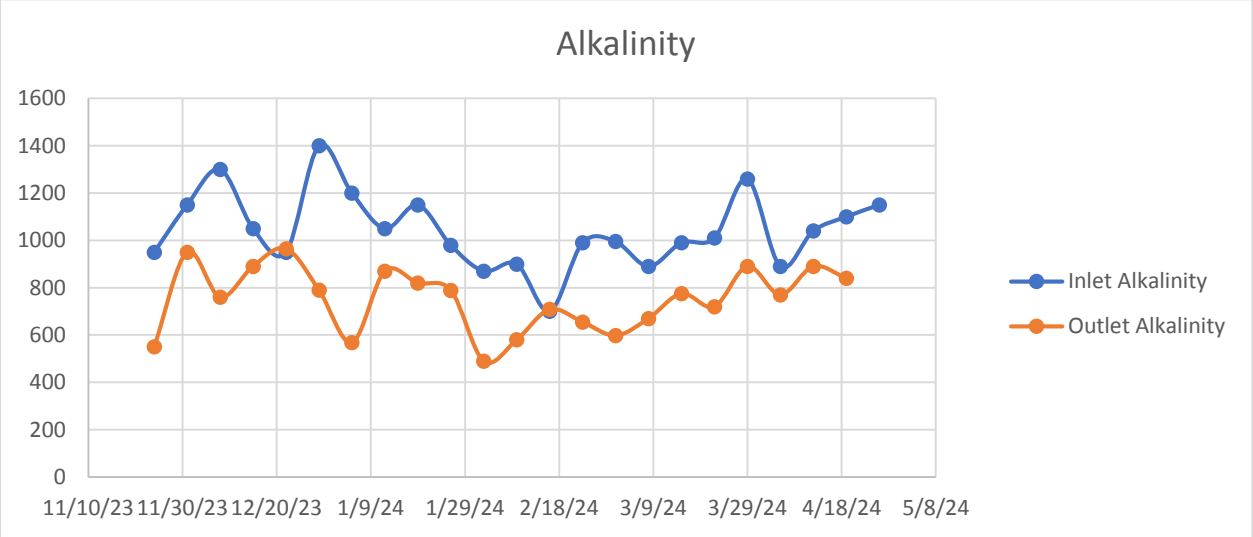

Figure 3.4 UASB Alkalinity

Figure 3.11 also represents the alkalinity of UASB effluent. The effluent alkalinity ranged between 490 mg/L and 1010 mg/L. The average effluent alkalinity was observed to be 762 mg/L.

Volatile Acids

Figure 3.12 shows the variation in volatile acid concentration of the UASB, with influent VFA concentration ranging from 555 mg/L to 1150 mg/L. The average influent concentration was found to be 757 mg/L.

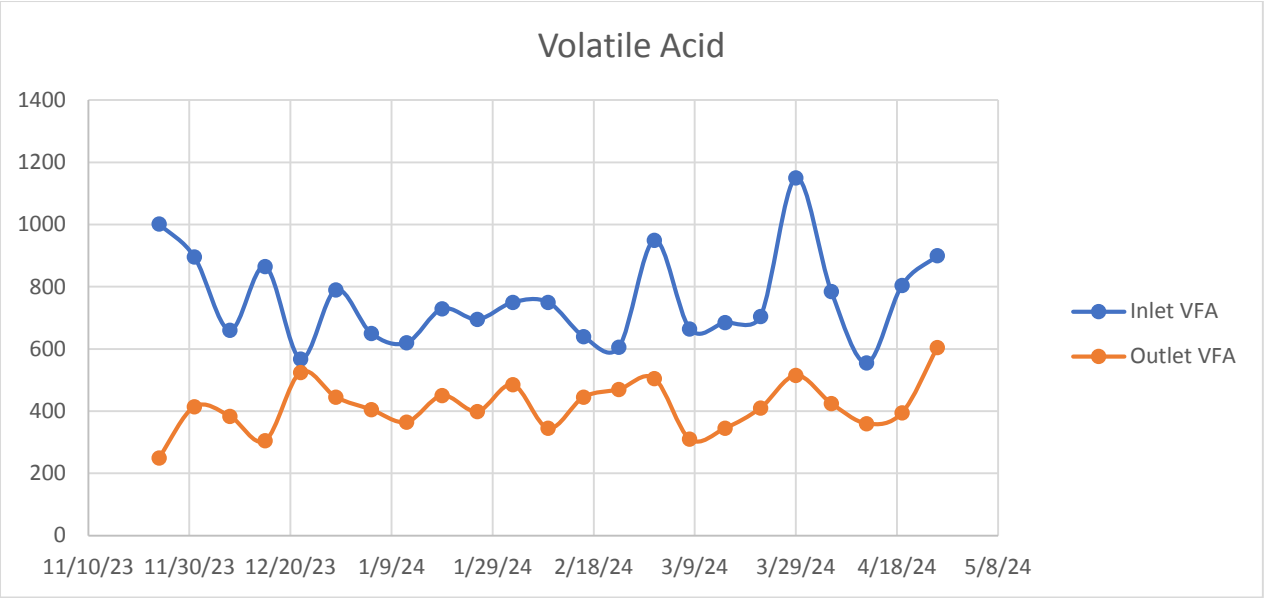

Figure 3.5 UASB VFA

Figure 3.12 also shows the variation of VFA's in UASB effluent ranging between 250 mg/L and 605 mg/L. The average effluent VFA concentration was found to be 415 mg/L.

TSS

Figure 3.13 represents the variation of TSS in the UASB. The influent TSS ranged from 715 mg/L to 1791 mg/L. The average TSS in influent were found to be 1198 mg/L.

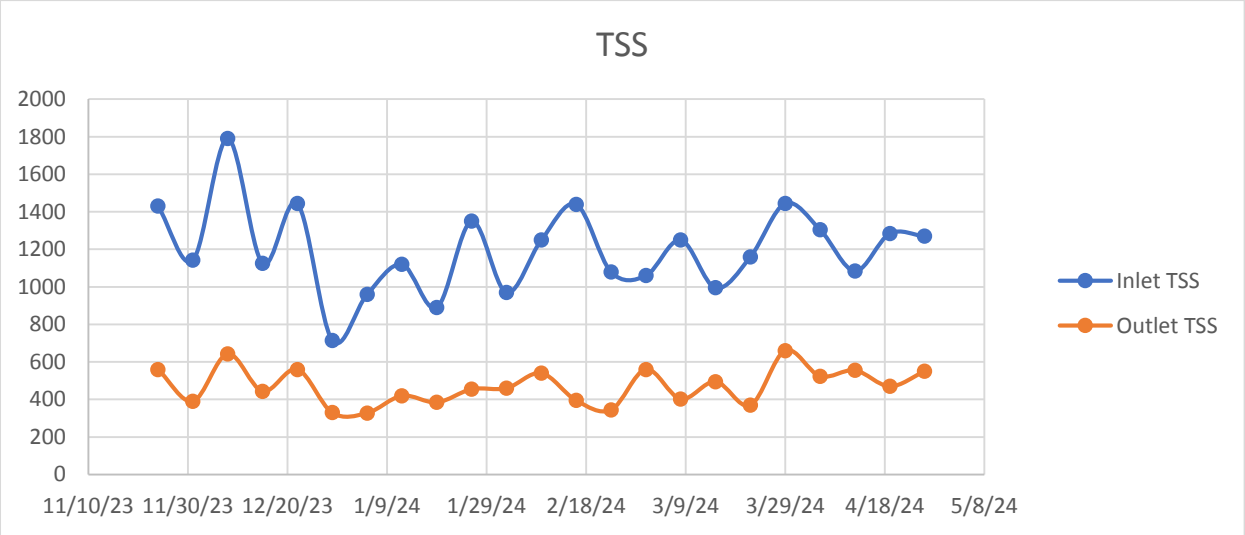

Figure 0.6 UASB TSS

Figure 3.13 also shows the variation of TSS in UASB effluent ranging from 328 mg/L to 660 mg/L. The average TSS concentration in the UASB effluent was found to be 471 mg/L. An average TSS value of 471 mg/L indicates that the UASB reactor has significantly reduced the amount of suspended solids in the wastewater.

TDS

Figure 3.14 represents the variation of TDS in the UASB. The influent TDS ranged from 1635 mg/L to 2350 mg/L. The average TDS in UASB influent were found to be 1932 mg/L.

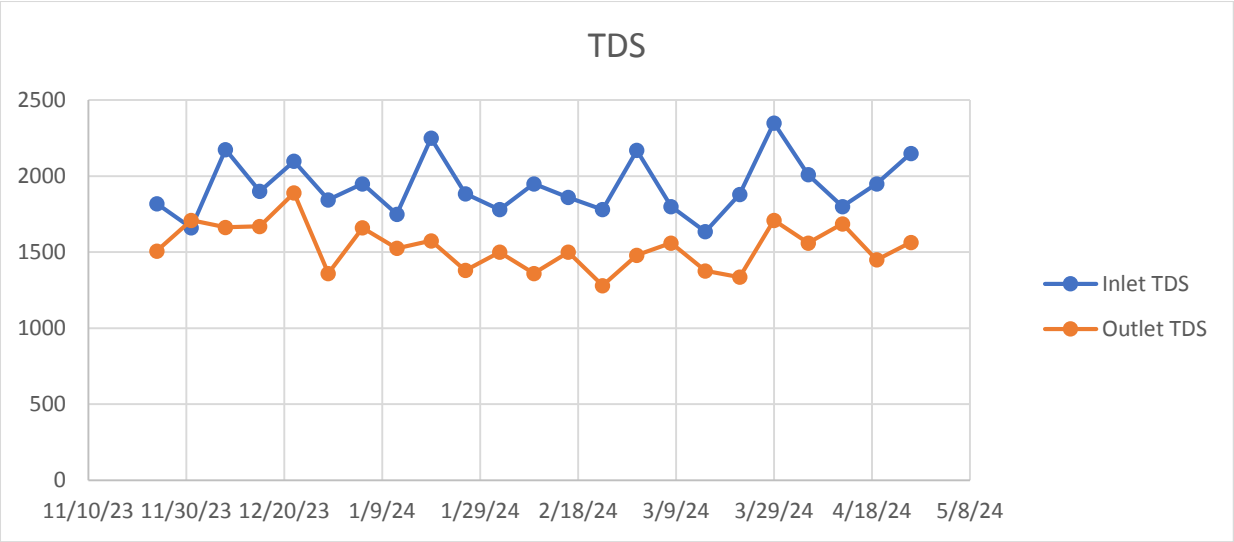

Figure 3.7 UASB TDS

Figure 4.14 also represents the TDS in UASB effluent. The TSS range from 1280 mg/L to 1890 mg/L. The average TDS in UASB effluent were found to be 1535 mg/L.

IV. Discussion :

i. pH – The pH of anaerobic filter influent was found to be a maximum of 11.8 and minimum pH of 8.5. The average inlet pH was 10.69 in the period of 5 months in industry 1. The pH of anaerobic filter effluent varied from 7.2 – 8.4, with an average of 7.96 which is within the optimal range.
The maximum pH of UASB influent was found to be 11.9 with a minimum pH of 7.88. The average inlet pH recorded was 9.32 over the period of 5 months. The UASB effluent ranged between 8.34 – 7.4. The average pH of UASB effluent recorded was 7.93.

ii. BOD - The BOD of anaerobic filter influent was found to be a maximum of 1756 mg/L and minimum BOD of 525 mg/L. The average inlet BOD was 1175 mg/L in the period of 5 months. The BOD of anaerobic filter effluent varied from 185 mg/L – 425 mg/L, with an average of 260 mg/L. The BOD removal was found to be 78 %.
The maximum BOD of UASB influent was found to be 2467 mg/L with a minimum BOD of 990 mg/L. The average inlet BOD recorded was 1712 mg/L over the period of 5 months. The UASB effluent BOD ranged between 220 mg/L – 536 mg/L. The average BOD of UASB effluent recorded was 306 mg/L. The BOD removal was found to be 82 %.

iii. COD - The COD of anaerobic filter influent was found to be a maximum of 3488 mg/L and minimum COD of 1200 mg/L. The average inlet COD was 2308 mg/L in the period of 5 months. The COD of anaerobic filter effluent varied from 396 mg/L – 896 mg/L, with an average of 593 mg/L. The COD removal was found to be 74 %. The maximum COD of UASB influent was found to be 4045 mg/L with a minimum COD of 2040 mg/L. The average inlet COD recorded was 3074 mg/L over the period of 5 months. The UASB effluent COD ranged between 445 mg/L – 884 mg/L. The average COD of UASB effluent recorded was 657 mg/L. The COD removal was found to be 79%.

iv. Alkalinity - The alkalinity of anaerobic filter influent was found to be a maximum of 900 mg/L and minimum alkalinity of 500 mg/L. The average inlet alkalinity was 734 mg/L in the period of 5 months. The alkalinity of anaerobic filter effluent varied from 450 mg/L – 845 mg/L, with the average being 661 mg/L.
The maximum alkalinity of UASB influent was found to be 1400 mg/L with a minimum alkalinity of 700 mg/L. The average inlet alkalinity recorded was 1041 mg/L over the period of 5 months. The UASB effluent alkalinity ranged between 490 mg/L – 1010 mg/L. The average alkalinity of UASB effluent recorded was 762 mg/L.

v. Volatile Fatty Acids - The volatile fatty acids concentration of anaerobic filter influent was found to be a maximum of 700 mg/L and minimum concentration of 245 mg/L. The average inlet volatile fatty acids concentration was 537 mg/L in the period of 5 months. The volatile fatty acids concentration of anaerobic filter

effluent varied from 200 mg/L – 416 mg/L, with the average being 321 mg/L.
The maximum volatile fatty acids concentration of UASB influent was found to be 1150 mg/L with a minimum concentration of 555 mg/L. The average inlet volatile fatty acids concentration recorded was 757 mg/L over the period of 5 months. The UASB effluent volatile fatty acids concentration ranged between 250 mg/L – 605 mg/L. The average volatile fatty acids concentration of UASB effluent recorded was 415 mg/L.

vi. TSS - The TSS in anaerobic filter influent were found to be a maximum of 1315 mg/L and minimum TSS of 390 mg/L. The average inlet TSS were 684 mg/L in the period of 5 months. The TSS in anaerobic filter effluent varied from 265 mg/L – 444 mg/L, with the average being 338 mg/L.
The maximum TSS in UASB influent was found to be 1791 mg/L with a minimum TSS of 715 mg/L. The average inlet TSS recorded were 1198 mg/L over the period of 5 months. The TSS in UASB effluent ranged between 328 mg/L – 660 mg/L. The average TSS in UASB effluent recorded were 471 mg/L.

vii. TDS - The TDS in anaerobic filter influent were found to be a maximum of 1780 mg/L and minimum TDS of 1111 mg/L. The average inlet TDS were 1480 mg/L in the period of 5 months. The TDS in anaerobic filter effluent varied from 1150 mg/L – 1596 mg/L, with the average being 1292 mg/L.
The maximum TDS in UASB influent was found to be 2350 mg/L with a minimum TDS of 1635 mg/L. The average inlet TDS recorded were 1932 mg/L over the period of 5 months. The TDS in UASB effluent ranged between 1280 mg/L – 1890 mg/L. The average TDS in UASB effluent recorded were 1525 mg/L.

V. Recommendations

The following are the recommendations for both industries for better operation of ETP's:

- Implement pH monitoring and control systems in the anaerobic filter to stabilize pH levels, ensuring optimal performance and preventing process upsets.
- Conduct regular monitoring of influent and effluent parameters to detect any deviations and take corrective actions promptly.
- Implement sludge management practices such as periodic sludge removal or recycling to maintain optimal biomass levels in the UASB reactor and prevent excessive sludge buildup.
- Provide comprehensive training to operators on system operation, maintenance, and troubleshooting to enhance operational stability and minimize downtime.
- Implement a routine maintenance schedule for both systems to ensure equipment reliability and prevent unexpected breakdowns.

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