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# Use of Textile Bio Reactor (TBR) For Enhancement of ActivatedSludge System

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***ABSTRACT:*** *The aim of this study is to achieve the maximum possible increase in efficiency of the existing Conventional Activated Sludge (CAS) wastewater treatment plants using an artificial low-cost material inside theaeration tank simulating the submerged Membrane Bio Reactor (MBR) system.*
*The material used is textile sheets that were used in a previous study are made from mix of natural and artificial textile sheets used in curtains industry. Different numbers of sheets were applied (3, 6 and 9 sheets) with equal distances between them according to their number.*
*The suitability of using this material is determined by testing the system under variable number of sheets with constant Dissolved Oxygen (DO) value of average 2.5 mg/L and constant retention time of 8 hours and then comparing the removal efficiencies of the Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD)and Total Suspended Solids (TSS) with previous studies.*
*The average removal efficiencies for the CAS system reached 78.02%, 83.81% & 72.24% for BOD, COD & TSS respectively. The removal efficiencies for the 3 sheets reached 81.15%, 85.92% & 76.00%. For the 6 sheets, the removal efficiencies reached 85.92%, 87.95 % & 77.73%. For the 9 sheets, the removal efficiencies reached 82.12%, 86.19% & 75.53%. These results make the textile effective with promising results for BOD, COD and TSS removal.*

***KEYWORDS:*** *Wastewater treatment, Conventional activated sludge, CAS, Membrane Bio Reactor, MBR, Textile Bio Reactor, TBR, WWTP, Enhancement, Upgrading.*

**NOMENCLATURE**

| Symbol | Description | Unit |
|---|---|---|
| *Q* | Wastewater flow "without regard to recirculation flow" | *L/hr* |
| *V* | Liquid volume | *L* |
| *RT* | Retention time | *hr* |

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## I. INTRODUCTION

Wastewater treatment can be defined as the process of removing pollutants from the wastewater to be suitable for releasing back into the environment [1]. The biological treatment process of wastewater treatment removes the dissolved organic material from wastewater. The Activated Sludge Process is one of several biological wastewater treatment alternatives. When Activated Sludge is added to wastewater, the organisms in this mixed liquor quickly decompose the wastes in the wastewater being treated. After a required period of aeration and agitation in the aeration tank, the mixed liquor usually flows to a separate tank called a sedimentation tank where the activated sludge is allowed to settle out and the remaining liquid is discharged as effluent [2].

One of the alternative technologies for wastewater treatment is the use of membrane biological reactors. It is a combination of biological process with membrane filtration that is called Membrane Bioreactor (MBR). In this case, the degradation of biomass occurs inside the bioreactor tank while separation of treated wastewater from microorganisms is completed in a membrane module.

Over the last two decades, MBR has attracted lots of attention due to its potential to produce high quality effluent and is currently considered as a mature technology to treat wastewater [3].

In 1969, Smith et al. was the first one who introduced the MBR technology through Dorr-Oliver research program. The aim was to treat sewage produced from a manufacture for 6 months with high equality effluent. Ultra-filtration membrane was installed instead of sedimentation tank outside the bioreactor tank (side stream MBR) to separate treated water and activated sludge.

Although this configuration generated a very high-quality effluent, its widespread was restricted due to the high energy cost and membrane fouling associated with it at that time [4].

In 1972, Gas-permeable porous membranes were used to aerate the mixed liquor in the aeration tank by bubble less oxygen mass transfer. At the same time, they can be used for fine bubble aeration [5].

However, higher energy costs to maintain the crossflow velocity led to the next stage of development which is submerging the membranes in the reactor itself (submerged MBR) and withdrawing the treated water through membranes. In this development, membranes were suspended in the reactor above the air diffusers. The diffusers provided the oxygen necessary for treatment to take place and scour the surface of the membrane to remove deposited solids. In a parallel attempt to save energy in membrane coupled bioreactors, the use of jet aeration in the bioreactor has been investigated [5].

To get most of the MBR system benefits with low cost, previous research was made by Zein El Din, M., (2021), during his study of several techniques to achieve the maximum possible increase for both capacity and efficiency for the existing conventional activated sludge wastewater treatment plants used a textile material instead of the epoxy at the final sedimentation tank simulating the side stream MBR.

This material has proven to be effective with promising results for BOD, COD and TSS removal compared with other hybrid systems. Accordingly, in this study, the textile material was deeply studied as an alternative and determined its efficiency.

## II. MATERIAL AND METHOD

The study experimental work was done on a pilot located in the Sanitary Laboratory, Faculty of Engineering, Ain Shams University using the preliminary treated wastewater from El-Berka WWTP as a wastewater source and the analysis of samples was made in Central Laboratory Unit, Faculty of Science, Ain Shams University.

The results were evaluated by comparing it with previous studies to determine the system suitability.

The pilot made from acrylic simulated four parallel conventional activated sludge aeration tanks with the ability to apply textile sheets (Textile Biological Reactor TBR) in any tank at its last 15% of the tank length according to the operation program as illustrated in fig.1.

The pilot was 4 parallel lines, each line consisted of one aeration tank with ½ inch inlet pipe enters the inlet channel to distribute water through weir.

The water flows from the aeration tank to an outlet channel through weirs. The outlet channel disposes water by ½ inch outlet pipe as shown in fig.2.

The four aeration tanks are each of dimensions (75 cm length X 25 cm width X 12 cm water depth) and equipped with:

a) Perforated pipes for aeration.

b) Return sludge pump.

The textile sheets that were used in a previous study are made from a mix of natural and artificial textile strips used in curtains industry shown in fig.3. They are erected at the last 15% of the aeration tank length to simulate MBR system. Different numbers of sheets were applied for each tank (no sheets illustrated in tank number 1 as this tank was working as CAS system, 3 sheets for tank number 2, 6 sheets for tank number 3, 9 sheets for tank number 4) with equal distances between them according to their number. All sheets are above the aeration tank bottom by 2 cm.

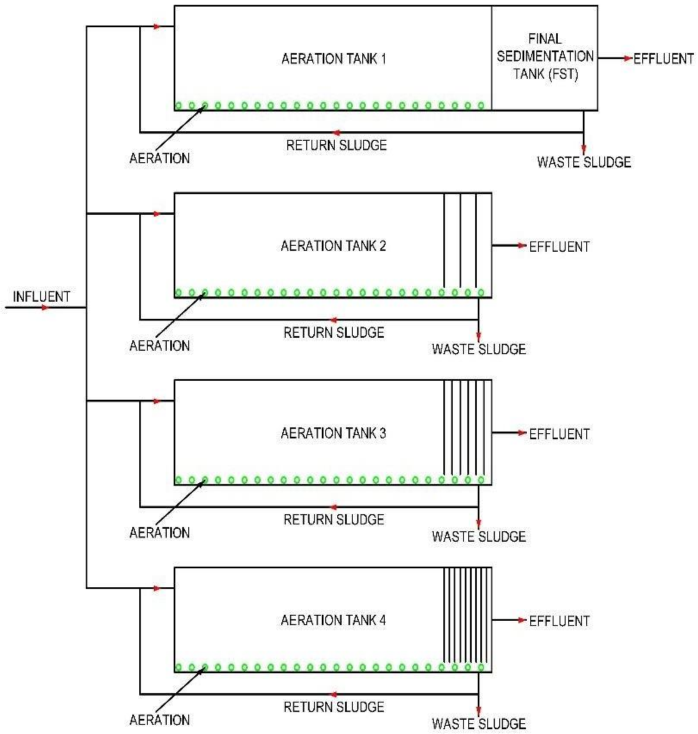


**Fig. 1 Schematic diagram of the pilot**

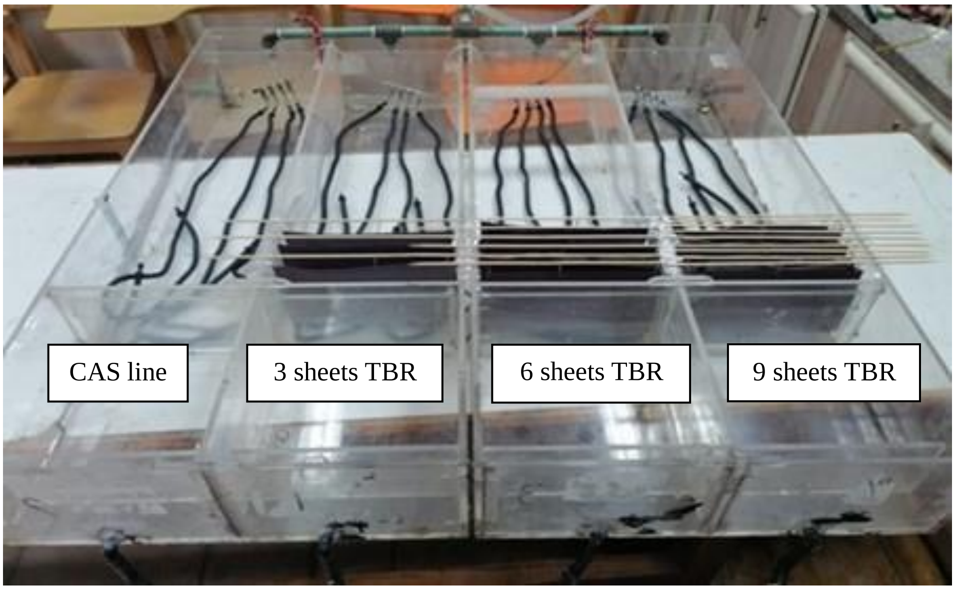


**Fig. 2 Photo of the pilot**

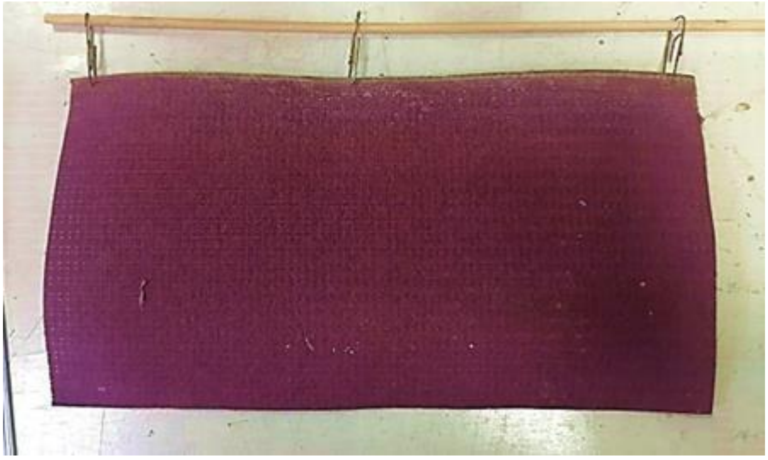

**Fig. 3 Photo of the textile sheet**

The pilot was operated on continuous inflow for 1-month total experimental duration. The positioning of the sheets was vertical and for installation, wooden sticks were used to ensure the textiles stability.
The sheets were applied in any tank at its last 15% of the tank length. So, the available length for sheets was 15% x 75 cm = 11.25 cm and the spacing between sheets was calculated by dividing 11.25 cm by the number of sheets illustrated.

The experiment was operated for constant retention time of 8 hours and average DO of 2.5 mg/L.
Using the following equation:

$$Q(L/hr) = \frac{V\ (L)}{\text{RT (hr)}}$$

Knowing that the assumed pilot dimensions were 75 cm length X 25 cm width X 12 cm weir depth and RT = 8 hours,

$$Q = \frac{(75 * 25 * 12)/1000}{8} = 2.8\ L/hr/stream$$

So, Q total = 2.8 * 8 hours * 4 streams = 90 L/d

Samples were taken at the inlet at the operation start time and at the outlet after the retention time duration after system stabilization. This sampling system was repeated every other day.

## III. RESULTS AND DISCUSSION

The experimental results are illustrated in tables 1 to 4 and figures from 4 to 7 illustrate the results summary for the measured parameters BOD, COD, TSS & DO respectively.

**Table 1: The BOD Concentration During the Experimental Work (mg/L)**

| Date | Influent | Effluent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CAS | Removal Efficiency % | 3 Sheets TBR | Removal Efficiency % | 6 Sheets TBR | Removal Efficiency % | 9 Sheets TBR | Removal Efficiency % |
| 10/2/2024 | 250 | 73 | 70.80 | 64 | 74.40 | 45 | 82.00 | 57 | 77.20 |
| 13/2/2024 | 250 | 72 | 71.20 | 62 | 75.20 | 44 | 82.40 | 58 | 76.80 |
| 15/2/2024 | 250 | 70 | 72.00 | 59 | 76.40 | 43 | 82.80 | 52 | 79.20 |
| 17/2/2024 | 241 | 65 | 73.03 | 54 | 77.59 | 42 | 82.57 | 54 | 77.59 |
| 19/2/2024 | 241 | 59 | 75.52 | 51 | 78.84 | 44 | 81.74 | 50 | 79.25 |
| 20/2/2024 | 241 | 58 | 75.93 | 47 | 80.50 | 41 | 82.99 | 47 | 80.50 |
| 24/2/2024 | 235 | 57 | 75.74 | 45 | 80.85 | 38 | 83.83 | 44 | 81.28 |
| 27/2/2024 | 235 | 48 | 79.57 | 42 | 82.13 | 30 | 87.23 | 40 | 82.98 |
| 29/2/2024 | 235 | 44 | 81.28 | 39 | 83.40 | 27 | 88.51 | 38 | 83.83 |
| 2/3/2024 | 265 | 35 | 86.79 | 35 | 86.79 | 22 | 91.70 | 33 | 87.55 |
| 4/3/2024 | 265 | 32 | 87.92 | 30 | 88.68 | 20 | 92.45 | 29 | 89.06 |
| 6/3/2024 | 265 | 36 | 86.42 | 29 | 89.06 | 19 | 92.83 | 26 | 90.19 |

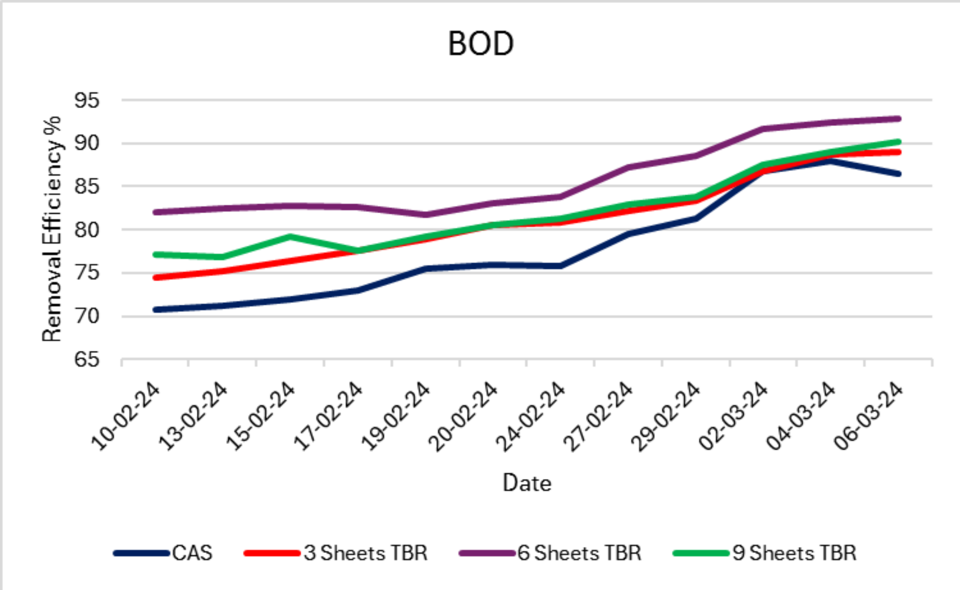


**Fig. 4 BOD removal efficiency**

In general, it was noticed that the system stability takes the first two weeks then the removal efficiency slightly increased at the second two weeks till its steady values at the last 3 days.
Generally, the applied TBR sheets application had achieved better results for BOD removal than CAS system by 3 – 6 % in addition to canceling the final sedimentation tank after aeration tank.
Also, the use of six sheets distributed on equal distances in the 15% area from the aeration tank had achieved the higher removal ratios for BOD compared with the other applied two arrangements due to achieve the best surface area and the suitable air amount for the bacterial activity inside the aeration tank.
The effect of filtration of the TBR helps in canceling the final sedimentation tanks and raise the tank BOD removal efficiency due to bacterial growth on the TBR surfaces as other Membranes effects in MBR system.

**Table 2: The COD Concentration During the Experimental Work (mg/L)**

| Date | Influent | Effluent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CAS | Removal Efficiency % | 3 Sheets TBR | Removal Efficiency % | 6 Sheets TBR | Removal Efficiency % | 9 Sheets TBR | Removal Efficiency % |
| 10/2/2024 | 485 | 115 | 76.29 | 83 | 82.89 | 71 | 85.36 | 75 | 84.54 |
| 13/2/2024 | 485 | 100 | 79.38 | 81 | 83.30 | 71 | 85.36 | 77 | 84.12 |
| 15/2/2024 | 485 | 101 | 79.18 | 76 | 84.33 | 75 | 84.54 | 74 | 84.74 |
| 17/2/2024 | 510 | 84 | 83.53 | 72 | 85.88 | 69 | 86.47 | 72 | 85.88 |
| 19/2/2024 | 510 | 77 | 84.90 | 75 | 85.29 | 72 | 85.88 | 70 | 86.27 |
| 20/2/2024 | 510 | 72 | 85.88 | 65 | 87.25 | 68 | 86.67 | 64 | 87.45 |
| 24/2/2024 | 460 | 76 | 83.48 | 71 | 84.57 | 56 | 87.83 | 75 | 83.70 |
| 27/2/2024 | 460 | 65 | 85.87 | 62 | 86.52 | 51 | 88.91 | 62 | 86.52 |
| 29/2/2024 | 460 | 65 | 85.87 | 60 | 86.96 | 45 | 90.22 | 60 | 86.96 |
| 2/3/2024 | 448 | 60 | 86.61 | 59 | 86.83 | 40 | 91.07 | 55 | 87.72 |
| 4/3/2024 | 448 | 57 | 87.28 | 52 | 88.39 | 38 | 91.52 | 54 | 87.95 |
| 6/3/2024 | 448 | 56 | 87.50 | 50 | 88.84 | 38 | 91.52 | 52 | 88.39 |

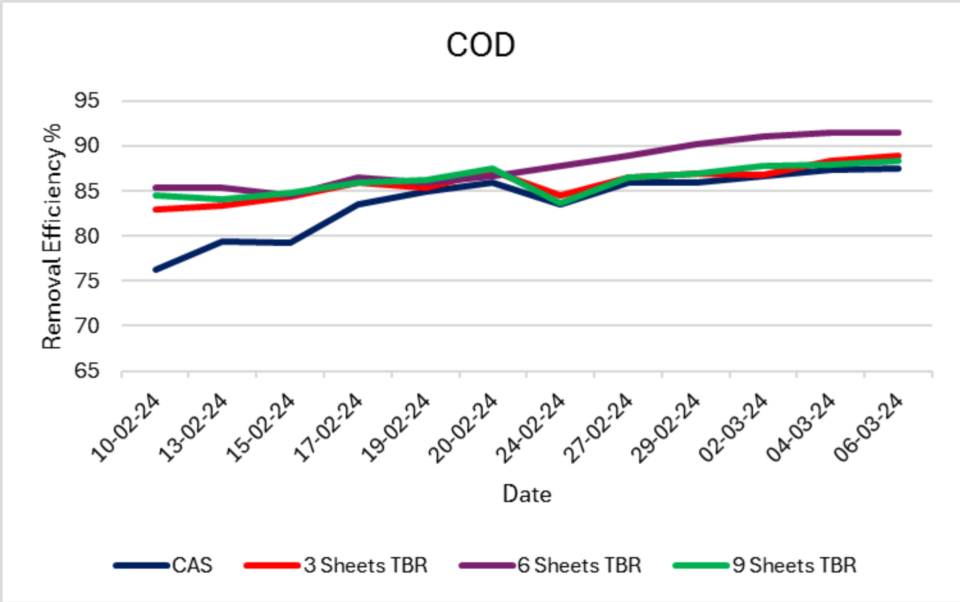


**Fig. 5 COD removal efficiency**

As summary, it was noticed that the system stability takes the first two weeks then the removal efficiency slightly increased at the second two weeks till its steady values at the last 3 days.
Generally, the applied TBR sheets application had achieved better results for COD removal than CAS system by 3 – 8 % in addition to canceling the final sedimentation tank after aeration tank.
Also, the use of six sheets distributed on equal distances in the 15% area from the aeration tank had achieved the higher removal ratios for COD compared with the other applied two arrangements due to achieve the best surface area and the suitable air amount for the bacterial activity inside the aeration tank.
The effect of filtration of the TBR helps in canceling the final sedimentation tanks and raise the tank COD removal efficiency due to bacterial growth on the TBR surfaces as other Membranes effects in MBR system.

**Table 3: The TSS Concentration During the Experimental Work (mg/L)**

| Date | Influent | Effluent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | CAS | Removal Efficiency % | 3 Sheets TBR | Removal Efficiency % | 6 Sheets TBR | Removal Efficiency % | 9 Sheets TBR | Removal Efficiency % |
| 10/2/2024 | 180 | 64 | 64.44 | 60 | 66.67 | 59 | 67.22 | 44 | 75.56 |
| 13/2/2024 | 180 | 55 | 69.44 | 64 | 64.44 | 56 | 68.89 | 44 | 75.56 |
| 15/2/2024 | 180 | 60 | 66.67 | 58 | 67.78 | 50 | 72.22 | 45 | 75.00 |
| 17/2/2024 | 200 | 67 | 66.50 | 58 | 71.00 | 49 | 75.50 | 49 | 75.50 |
| 19/2/2024 | 200 | 65 | 67.50 | 52 | 74.00 | 57 | 71.50 | 54 | 73.00 |
| 20/2/2024 | 200 | 64 | 68.00 | 49 | 75.50 | 45 | 77.50 | 58 | 71.00 |
| 24/2/2024 | 220 | 62 | 71.82 | 44 | 80.00 | 50 | 77.27 | 63 | 71.36 |
| 27/2/2024 | 220 | 60 | 72.73 | 46 | 79.09 | 42 | 80.91 | 55 | 75.00 |
| 29/2/2024 | 220 | 50 | 77.27 | 45 | 79.55 | 38 | 82.73 | 51 | 76.82 |
| 2/3/2024 | 200 | 37 | 81.50 | 32 | 84.00 | 30 | 85.00 | 42 | 79.00 |
| 4/3/2024 | 200 | 42 | 79.00 | 30 | 85.00 | 27 | 86.50 | 45 | 77.50 |
| 6/3/2024 | 200 | 36 | 82.00 | 30 | 85.00 | 25 | 87.50 | 38 | 81.00 |

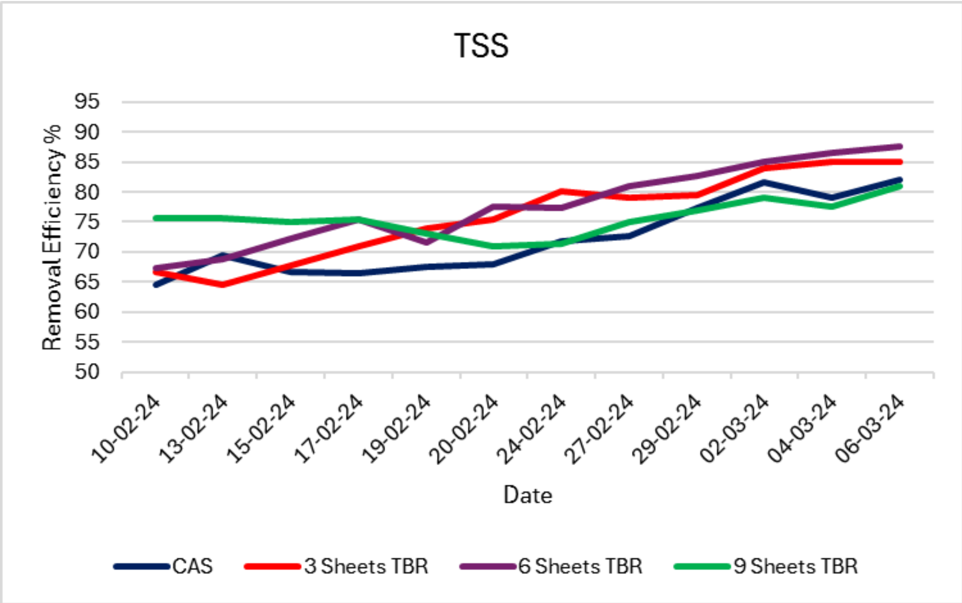


**Fig. 6 TSS removal efficiency**

As summary, it was noticed that the system stability takes the first two weeks then the removal efficiency slightly increased at the second two weeks till its steady values at the last 3 days.
Generally, the applied TBR sheets application had achieved better results for TSS removal than CAS system by 3 – 6 % in addition to canceling the final sedimentation tank after aeration tank.
Also, the use of six sheets distributed on equal distances in the 15% area from the aeration tank had achieved the higher removal ratios for TSS compared with the other applied two arrangements.
The effect of filtration of the TBR helps in canceling the final sedimentation tanks and raise the tank TSS removal efficiency.

**Table 4: The DO Concentration During the Experimental Work (mg/L)**

| Date | Influent | Effluent | | | |
|---|---|---|---|---|---|
| | | CAS | 3 Sheets TBR | 6 Sheets TBR | 9 Sheets TBR |
| 10/2/2024 | 0.2 | 2.31 | 2.35 | 2.41 | 2.44 |
| 13/2/2024 | 0.2 | 2.57 | 2.52 | 2.66 | 2.65 |
| 15/2/2024 | 0.2 | 2.58 | 2.55 | 2.52 | 2.57 |
| 17/2/2024 | 0.4 | 2.52 | 2.54 | 2.44 | 2.48 |
| 19/2/2024 | 0.4 | 2.55 | 2.58 | 2.54 | 2.38 |
| 20/2/2024 | 0.4 | 2.38 | 2.41 | 2.47 | 2.49 |
| 24/2/2024 | 0.3 | 2.43 | 2.44 | 2.58 | 2.54 |
| 27/2/2024 | 0.3 | 2.55 | 2.56 | 2.55 | 2.29 |
| 29/2/2024 | 0.3 | 2.56 | 2.62 | 2.55 | 2.40 |
| 2/3/2024 | 0.3 | 2.50 | 2.52 | 2.57 | 2.59 |
| 4/3/2024 | 0.3 | 2.58 | 2.55 | 2.49 | 2.50 |
| 6/3/2024 | 0.3 | 2.49 | 2.51 | 2.67 | 2.45 |
| **Average** | **0.3** | **2.50** | **2.51** | **2.54** | **2.48** |

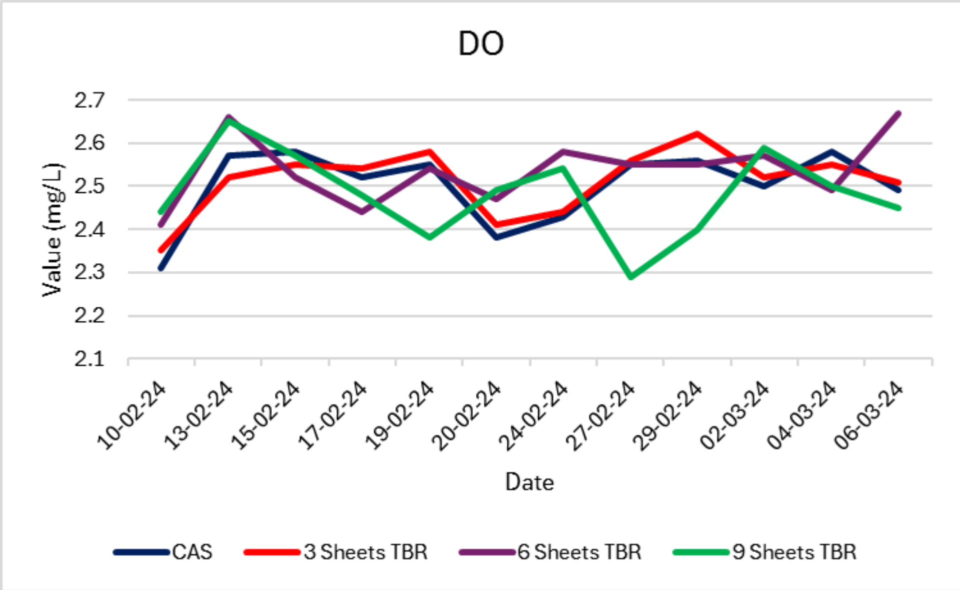


**Fig. 7 Effluent DO**

As summary, the DO values were kept almost constant as the average value for the four streamlines wasabout 2.5 mg/L.

## IV. CONCLUSION

In general, it was noticed that the system stability takes the first two weeks then the removal efficiency slightly increased at the second two weeks till its steady values at the last 3 days.
Generally, the applied TBR sheets application had achieved better results for BOD, COD & TSS removal than CAS system by 3 – 6 % in addition to canceling the final sedimentation tank after aeration tank.
Also, the use of six sheets distributed on equal distances in the 15% area from the aeration tank had achieved the higher removal ratios compared with the other applied two arrangements due to achieve the best surface area and the suitable air amount for the bacterial activity inside the aeration tank.
The effect of filtration of the TBR helps in canceling the final sedimentation tanks and raise the tank removal efficiency due to bacterial growth on the TBR surfaces as other Membranes effects in MBR system.

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