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EVALUATION OF A LAB-BASED SUBMERGED AND SIDE-STREAM MEMBRANE BIOREACTOR FOR THE TREATMENT AND RECYCLING OF DOMESTIC WASTEWATER

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Abstract

As a viable solution for the treatment and recycling of sewage from residential areas, this research presents membrane bioreactors (MBRs) systems, both immersed and side-stream. These systems are offered as viable options. This study's objective is to analyse the overall performance of each membrane bioreactor in terms of its capacity to meet water reuse requirements. This will be accomplished with the assistance of water quality indices such as total suspended solids (TSS), biological oxygen demand (BOD), and chemical oxygen demand (COD). It is obvious from the data that the MBR system is capable of producing permeate water of a high quality and that the MBR technology is efficient in reducing total suspended solids (TSS). COD and BOD rejection rates in the submerged MBR were, on average, 92.76% and 94.46%, respectively. This was the case. Comparatively, the percentages of COD and BOD that were rejected in the side-stream MBR were 87.54 percent and 88.98 percent, respectively. It has been discovered through the examination of COD and BOD that the removal of the submerged MBR system is preferable to the removal of the side-stream MBR system.

Keywords: Domestic sewage, Submerged MBR, Side-stream MBR, Treatment and Reuse.

الخلاصة: يتم تقديم أنظمة المفاعلات الحيوية الغشائية (MBRs)، سواء المغمورة أو الجانبية، في هذه الورقة كبدائل قابلة للتطبيق لمعالجة وإعادة تدوير مياه الصرف الصحي المنزلية. باستخدام مؤشرات جودة المياه مثل إجمالي المواد الصلبة العالقة (TSS)، الطلب على الأكسجين البيولوجي (BOD) والطلب على الأكسجين الكيميائي (COD)، فإن الهدف هو فحص الأداء العام لقدرة كل مفاعل حيوي غشائي لتلبية متطلبات إعادة استخدام المياه. توضح النتائج أن نظام MBR يولد مياه متخللة عالية الجودة وأن تقنية MBR فعالة في إزالة TSS. كانت معدلات رفض COD و BOD 92.76% و94.46% (في المتوسط) في MBR المغمور، ولكن في MBR الجانبي، كانت معدلات رفض COD و87.54% BOD و88.98% (في المتوسط). تظهر نتائج COD و BOD أن إزالة نظام أن إزالة نظام MBR المغمور أفضل من إزالة نظام MBR الجانبي.

1. INTRODUCTION

As a result of the growing concerns about water scarcity that are being expressed worldwide [1], there is an increased focus on the recovery and repurposing of wastewater emanating from urban and industrial areas because these concerns are becoming more widespread. Over the past few years, due to recent advancements in industry and urbanization, wastewater recovery and reuse have emerged as major solutions worth considering. Consequently, there was a reduction in the quantity of water available due to the accumulation of contaminants in the water. If it is cleaned and recycled appropriately, wastewater can serve as a valuable alternative water source that can lessen the demand for fresh water and the demand imposed on the environment [2]. This supply of water could be beneficial to the environment.

Recently, the term "domestic sewage" has been used to refer to water that is exploited by a community and may have been contaminated. A community may have used this water. It is a relatively recent classification. Membrane separation technology is reaching the water and wastewater treatment industries at a rising rate [3].

This is because it has been demonstrated to be effective in removing a wider range of contaminants. When it comes to treating and reusing wastewater, this membrane bioreactor (MBR) offers a solution that delivers a far more effective solution than the typical bio-treatment methods. In this method, a membrane unit and a suspended biological growth reactor are utilized to produce a separation between the water that has been treated and the biomass that has been made. Compared to traditional methods, MBR systems provide many benefits, such as significant improvement in effluent quality, increased organic loading, reduced footprint occupation, and decreased sludge development [4].

MBR installations can be broken down into two categories: the most common ones are the external and immersed membrane variants. The submerged membrane bioreactor has recently garnered much attention in treating effluents from industrial and residential sources [5, 7]. This is because it generates less sludge and increases effluent quality compared to conventional activated sludge, which is the typical method of treating effluent. In situations where discharges are directed into recreational waterways, where the plant has a limited amount of land, or where an update of an existing installation is necessary, these systems are robust, compact, and provide flowing quality that is exceptionally favorable. In many different places, this is becoming an additional desirable characteristic. Because they have a lower energy consumption than side-stream MBRs, immersed membranes (iMBRs) are also preferred [8, 9].

Among the causes is this. This study aims to evaluate how well different permeate fluxes of residential wastewater can be recovered and utilized by the submerged MBR system in conjunction with the side-stream MBR system. This study's main goal is to do this. The pollutant clearance rates will carry out the assessment.

2. EQUIPMENT AND TECHNIQUES

2.1 Experimental Configuration

A submerged bioreactor (shown in Figure 1) and a side-stream bioreactor (shown in Figure 2) are the two categories of MBR bioreactors that are utilized in this investigation. The side-stream reactor tank had a volume of 8 liters, while the submerged reactor tank had a height of forty centimeters and a width of sixteen and a half centimeters. The operational volume of the submerged reactor tank was 8.5 liters, while the side-stream reactor tank had 8 liters. While it was installed on the exterior of the aeration tank in the MBR, it was installed on the interior. Polyvinylidene fluoride was utilized for the construction of the ultrafiltration membrane. This membrane included filtration holes that were 0.01 micrometers in size and had an area that was 0.8 square meters in length. Table 1 has a comprehensive listing of all of the features of the ultrafiltration membrane. Specifically, the wastewater fed into the bioreactor came from the municipal wastewater pumping pipe outlets of the residential unit in the Hai Al-Zahraa neighborhood, which is situated in Badra district of Wasit governorate of Iraq. This neighborhood is located in Iraq. The organic pollutants were then subjected to biological degradation, which was carried out with the help of the bioreactor. The ultrafiltration membrane sludge was recycled back into the side-stream MBR reactor using a recirculation pump. The usage of the recirculation pump accomplished this. An air dispenser positioned beneath the bioreactor proved to be of considerable aid in aerating and mixing the effluent that may be produced.

A peristaltic pump was used to put the wastewater into the side-stream bioreactor, and a recycling pump was used to put the sludge back into the bioreactor. Both of these processes were carried out to recycle the wastewater. A peristaltic pump is also positioned in the submerged membrane where the ultrafiltration membrane and the reactor meet. The feed tank and the bioreactor are separated by a peristaltic pump located in the middle of the two. The water level sensor device operated the feed pump, which appeared to be identical to the suction pump in terms of its build and the type of pump. During the experiment, this was done to guarantee that the amount of water contained within the bioreactor did not change. To maintain a consistent water temperature within the range of 25 degrees Celsius to ± 1 degrees Celsius, a temperature controller was utilized in both submerged and side-stream bioreactors at all times. The bioreactor was employed to conduct laboratory tests on residential wastewater.

Hydraulic retention time (HRT): the amount of time the liquid phase takes to flow through a tank. Solids retention time (SRT): the duration of the solid (particulate) phase's passage through a tank. Typically, these two parameters the system biokinetics—that is, the rate at which the active microorganisms in the MLSS break down the components of the sewage. Long SRTs typically result in more of the slower-growing microorganisms and less sludge, which makes them attractive from a biokinetic perspective. Because the membrane completely retains the suspended particles, operation at long SRTs is made feasible. Then, HRTs may be adjusted in accordance with the microbiology and biokinetics of the system; the system biokinetics is what links HRT and SRT [10].

The HRT was set at three days, the SRT was set at thirty days, and the DO level was set at 7.8 ± 0.3 mg/L. When the MBR system finally reached a stable condition, it took around three weeks for the testing to start. The system was operational during this period. Daily monitoring was performed on mixed liquid suspended solids (MLSS) concentrations. The estimated values for submerged MBR were approximately 4300 mg/L, while the estimated values for side-stream MBR were about 4000 mg/L. Both of these values were determined to be approximately correct. After that, the process of eliminating sludge was initiated to guarantee that the amounts of MLSS in the system would continue to be in a regular state. As a result of the accumulation of sludge on the surface of the UF membrane unit, it was essential to execute routine cleaning of the unit to remove the sludge deposit. The operational features of the submerged MBR are listed in Table 2, while the functional characteristics of the side-stream MBR are listed in Table 3. Both tables provide similar information. The recommendations from References [11, 12, 13, and 14] have been considered when selecting the layout of these tables.

Table 1 Ultrafiltration membrane features that were used in this research.

Membrane type	**Ultra-filter**
maximum operating temperature	5 -40°C
The surface area of the membrane	0.8 m^2
membrane pore size	0.01 μm
Type of the materials	Hollow fiber
manufacturers	Korea

Table 2 The operational parameters of the submerged MBR.

Variable	**Unit**	**Value**
Running mode	-	Continuous
Permeating flow	LMH(L/m^2/h)	0.139
Feed flow	L/day	2.67
HRT	day	3
SRT	day	30

MLSS	mg/L	4300
MLSS temperature	ºC	25 ± 1
DO	mg/L	7.8±0.3
pH	-	7.4- 8.5

Table 3: The operational parameters of the side-stream MBR.

Variable	Unit	Value
Running mode	-	Continuous
Permeating flow	LMH(L/m^2/h)	0.139
Feed flow	L/day	2.67
HRT	day	3
SRT	day	30
MLSS	mg/L	4000
MLSS temperature	ºC	25 ± 1
DO	mg/L	7.8±0.3
pH	-	7.4- 8.5

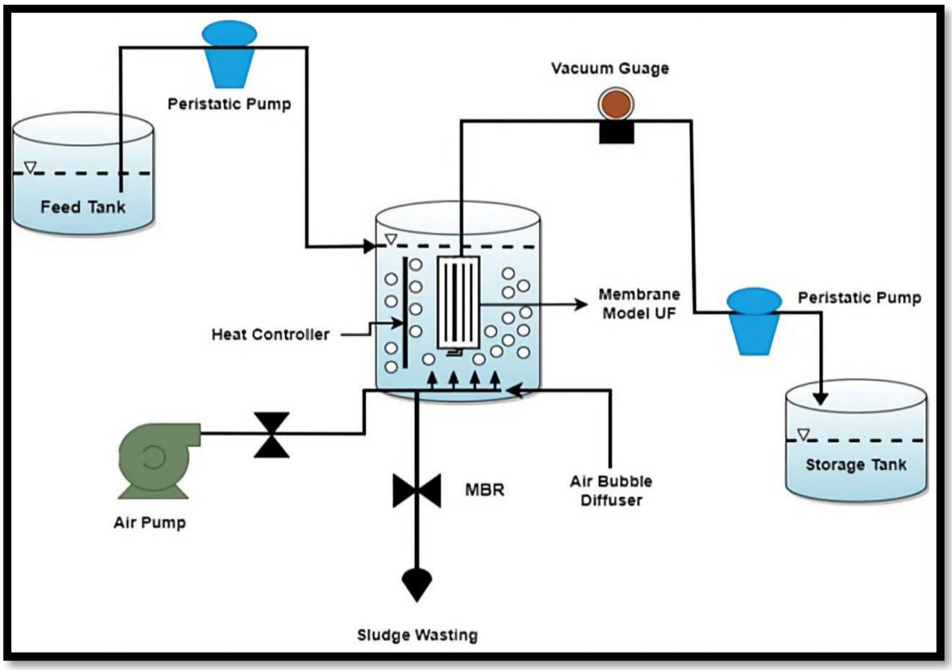

Fig. 1 A pilot scale unit consists of a submerged MBR.

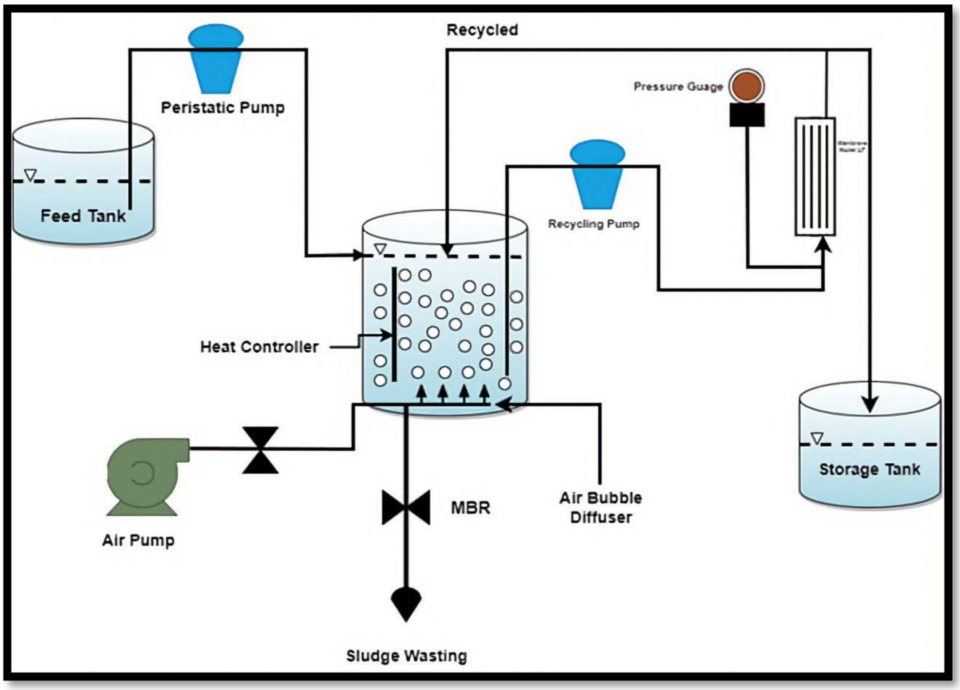

Fig. 2 A pilot scale unit consists of a side-stream MBR

2.2 Wastewater

Every day, by the HRT value, raw domestic wastewater was gathered from the municipal wastewater pumping pipe outlets of the residential unit in the Hai Al-Zahraa neighborhood, which is situated in Badra district, which is one of the districts that comprise Wasit governorate in Iraq. This was done to ensure that the HRT value was maintained. After that, the wastewater was moved to the bioreactor designed for treatment in a laboratory before being put into the plant facilities. Table 4 contains the findings of analyses conducted in the laboratory on effluent samples from residential areas. An evaluation of the wastewater's physical and chemical characteristics was the purpose of these analyses, which were carried out.

Table 4 Characteristics of the domestic effluent that supplied the membrane.

Factors	Daily Values
COD (chemical oxygen demand)	157-527 mg/L
BOD5 (biological oxygen demand)	200-348 mg/L
TSS (total suspended solids)	230-415 mg/L
TDS (total dissolved solids)	960-1457 ppm
Turbidity	97-216 NTU
EC (electrical conductivity)	1549-1768 µS/cm
DO (dissolved oxygen)	1.2-1.9 mg/L
pH	6.8-8.6

2.3 Analysis methods

Several activities were carried out, including investigating the characteristics of untreated wastewater used as MBR effluent. After collecting water through the use of the volumetric flask technique, the water was then subjected to the analysis of analytical instruments to determine the permeate flow for MBR effluents. The Standard APHA 2540E method was utilized in the analysis process to ascertain the MLSS content. It was determined that a DO meter was necessary to verify the amount of DO present. A Lovi bond pH meter, produced in Germany, was utilized to ascertain the pH of the solution. Spectrophotometric methods were used to determine the COD concentrations. The equation presented below [14], which can be seen below, illustrates the process followed to compute the elimination efficiency (% R) for each species involved.

$$R = \frac{C1-C2}{C1} \quad (1)$$

Where:

R: removal ratio,

C1: Feed concentration (mg/L),

C2: Permeate concentration (mg/L).

During the experimental run to quantify the flux across the membranes using Equation 2:

$$J=\frac{QP}{A} \quad (2)$$

Where:

J: The permeating flux (L/m2.h),

Qp: The quantity of permeate that flows in an hour.

A: membrane's active area (m^2).

3. RESULTS AND DISCUSSION

Stage1: Submerged MBR Findings

Within thirty days of the system's inception, a performance evaluation of the submerged MBR revealed that it could produce high-quality permeate water. The quality of the input and outflow, as well as the amount of COD, BOD, and TSS that was eliminated, were the sole factors that resulted in this conclusion being reached. Figures 3 through 5 illustrate the COD, BOD, and TSS concentrations present in the submerged MBR inflow and outflow on days when the facility is active. COD values in the influent ranged from 157 to 527 mg/L, BOD values ranged from 200 to 348 mg/L, and total soluble solids (TSS) values ranged from 230 to 415 mg/L. Figure 3 illustrates the speed at which the MBR system removes COD from both the influent and effluent. Home sewage contains organic components capable of undergoing chemical oxidation, and the COD provides an estimate of the quantity of oxygen present in these organic components. Regarding sewage treatment, COD is an important statistic since it offers a trustworthy indication of the presence of organic pollutants. Coefficient of determination (COD) was included in this investigation as a measure of organic contamination as a consequence of this. It was found that the COD level of the influent varied from 157 to 527 mg/L, with an average of 329.8 mg/L having been found. Compared to the effluent, which had a COD level from 19 mg/L to 37 mg/L and a removal rate of over 91%, this data is in stark contrast. Based on this evidence, it would appear that the submerged MBR system can extract organic components efficiently and lower COD to a high degree. As evidenced by the considerable reduction in COD, it is possible that the membrane filtering process caused a decrease in the requirement for COD, both biodegradable and non-biodegradable.

Both the influent and the effluent are shown in Figure 4 to illustrate how effective the iMBR system is at removing BOD from the medium. The quantity of oxygen present in organic matter in the effluent capable of undergoing chemical oxidation is referred to as the biological oxygen demand, additionally abbreviated as BOD. The BOD concentration of the effluent ranged from 7 to 21, and the clearance rate was greater than 92%. This is because the BOD concentration falls within the range of 7 to 21. The influent water's biological oxygen demand (BOD) varied from 200 to 348 mg/L, with the average value being 260.6 mg/L across the board. The fact that the submerged MBR system was able to remove organic components successfully and unquestionably accomplish a significant level of BOD reduction was demonstrated by the fact that this outcome occurred. One can conclude that the membrane filtration technology successfully reduced the demand for both non-biodegradable and well-biodegradable BOD. This conclusion is based on the high BOD drop that was observed.

Figure 5 illustrates how the MBR technique produces good solids separation. MBR permeated at a TSS rate of 4.3 mg/L after TSS was eliminated at a rate of >98%. The membrane appears to have been in outstanding condition based on the MBR's notable removal of TSS [15, 16, 17, 18].

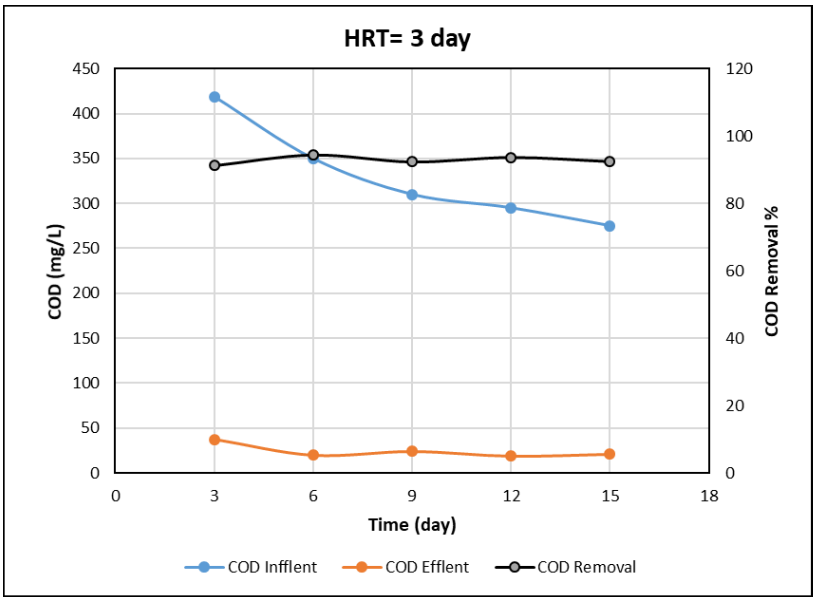

Fig. 3 A ratio of removal percentages (when HRT/day) to COD concentration in influent and effluent.

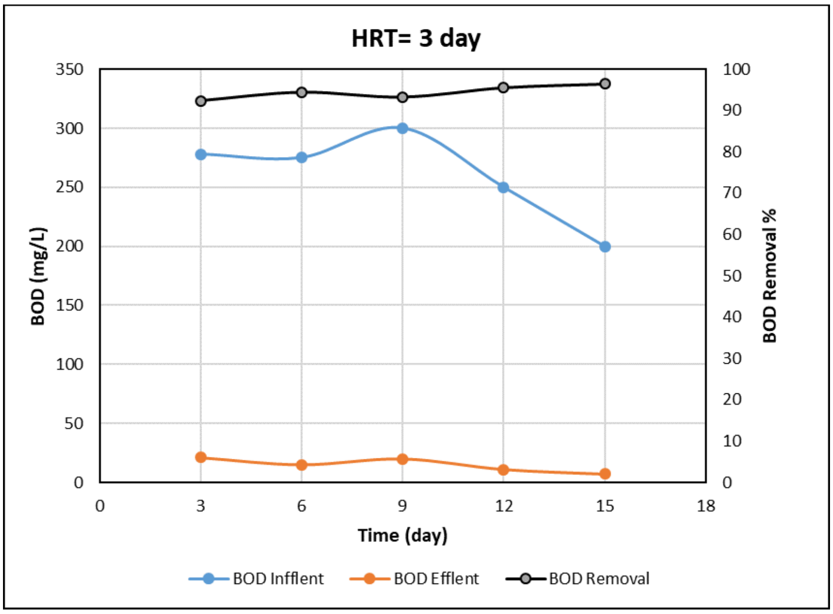

Fig. 4 A ratio of removal percentages (when HRT/day) to BOD concentration in influent and effluent.

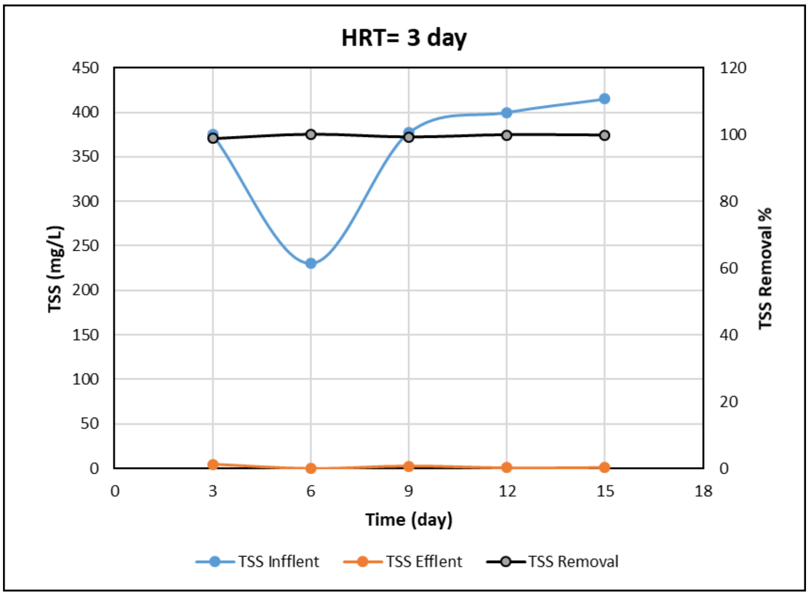

Fig. 5 A ratio of removal percentages (when HRT/day) to TSS concentration in influent and effluent.

Stage2: Side-stream MBR findings

A performance analysis was carried out solely based on the quality of the water that was taken in and discharged, as well as the percentage of total soluble solids, biological oxygen demand, and chemical oxygen demand that was removed within the first thirty days after the bioreactor was started up, determined that the side-stream MBR system is capable of producing high-quality permeate water. This was determined by the fact that the analysis was carried out. On days when operations are taking place, COD, BOD, and TSS concentrations are present in the side-stream MBR input and outflow. These concentrations are depicted in Figures 6–8. On the other hand, the COD values in the influent ranged from 157 to 527 mg/L, the BOD values ranged from 200 to 348 mg/L, and the TSS values ranged from 230 to 415 mg/L. It was found that the influent contained these three different ranges of values. Figure 6 illustrates the coefficient of determination (COD) removal rate for the influent and effluent flowing through the MBR system. The chemical oxygen demand (COD) is a measurement of the amount of oxygen present in organic waste susceptible to chemical disintegration. This assessment is performed on sewage from residential areas.

The chemical oxygen demand (COD) is an important indicator because it is vital. It is a reliable predictor of organic pollutants in the treatment of sewage. Because of the reasons discussed earlier, COD was incorporated into this investigation as a marker of organic contamination. In contrast to the effluent, which had COD concentrations that varied from 33.6 mg/L to 59 mg/L and a removal rate that was greater than 85%, the influent had a COD level that averaged 329.8 mg/L and fluctuated between 157 and 527 mg/L. The effluent had a removal rate that was greater than 85%. After considering all of those above, it would appear that the side-stream MBR system can properly remove organic components and remove COD to a large degree. It would appear that the process of membrane filtering has reduced the need for COD, both biodegradable and non-biodegradable, as seen by the considerable reduction in COD.

Figure 7 depicts the effectiveness of BOD removal by displaying both the influent and effluent of the MBR system. This figure contains both of these components. The biochemical oxygen demand, often known as BOD, refers to the amount of oxygen present in organic matter in the effluent and capable of undergoing chemical oxidation. After conducting an analysis, it was found that the effluent's biological oxygen demand (BOD) content varied between 18.2 and 35.4, suggesting that the clearance rate was more than 87%. The BOD concentration of the influent water was 260.6 mg/L on average, with concentrations ranging from 200 to 348 mg/L. This demonstrated that the side-stream MBR system could successfully remove organic components and achieve a large reduction in the biological oxygen demand (BOD). Evidence that the membrane filtration strategy successfully reduced the demand for BOD that is deemed both biodegradable and non-biodegradable is shown by the high BOD drop observed.

Figure 8 is a visual representation of how the MBR approach works to provide efficient separation of solids. At a TSS rate of 7.4 mg/L, MBR could enter the water at more than 98% after TSS was eliminated. According to references 15, 18, 19, and 20, the membrane was in excellent condition, as evidenced by the high TSS removal percentage achieved by the MBR.

In conclusion, the majority of the components that were not biodegradable were removed by using waste from sludge. A small amount of a chemical that was not biodegradable made its way beyond the barrier. Some other locations have also published results that are comparable to these [21].

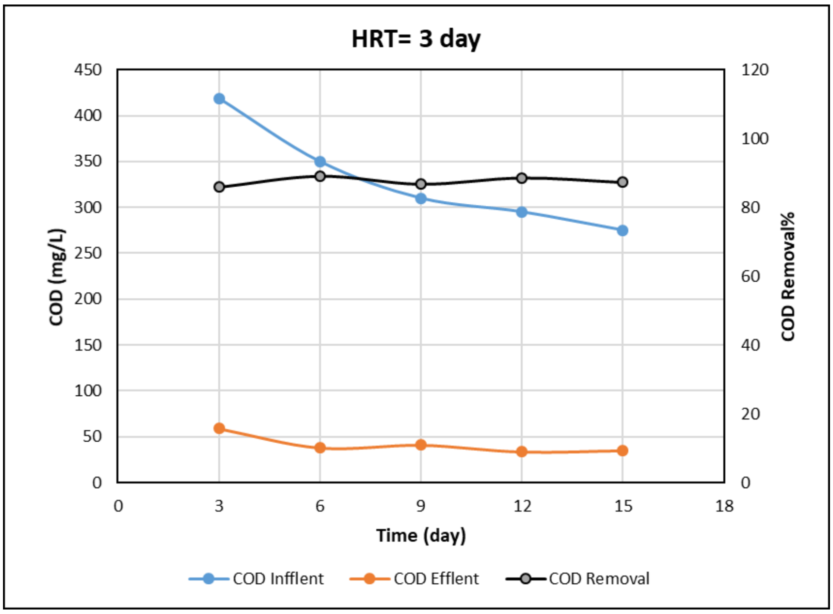

Fig. 6 A ratio of removal percentages (when HRT/day) to COD concentration in influent and effluent**.**

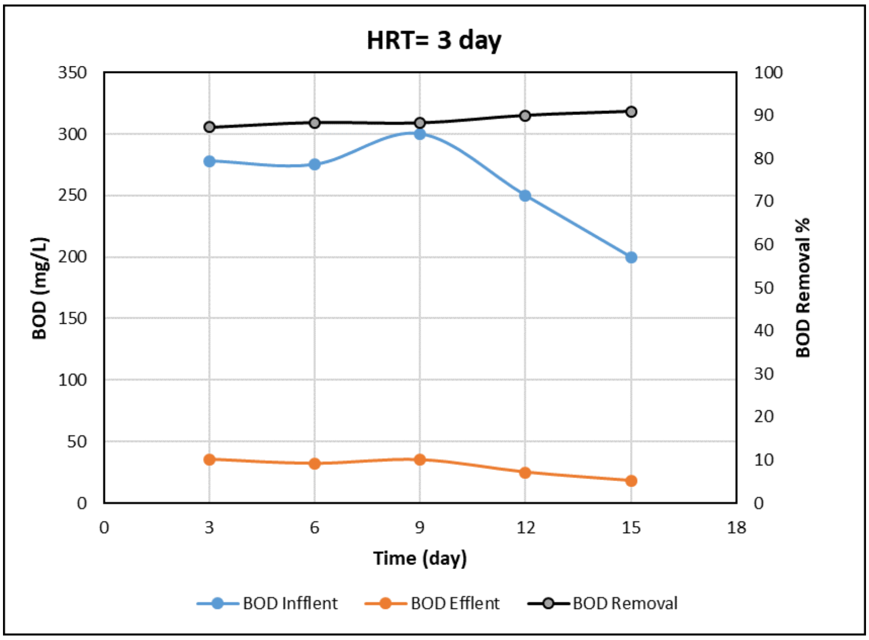

Fig. 7 A ratio of removal percentages (when HRT/day) to BOD concentration in influent and effluent.

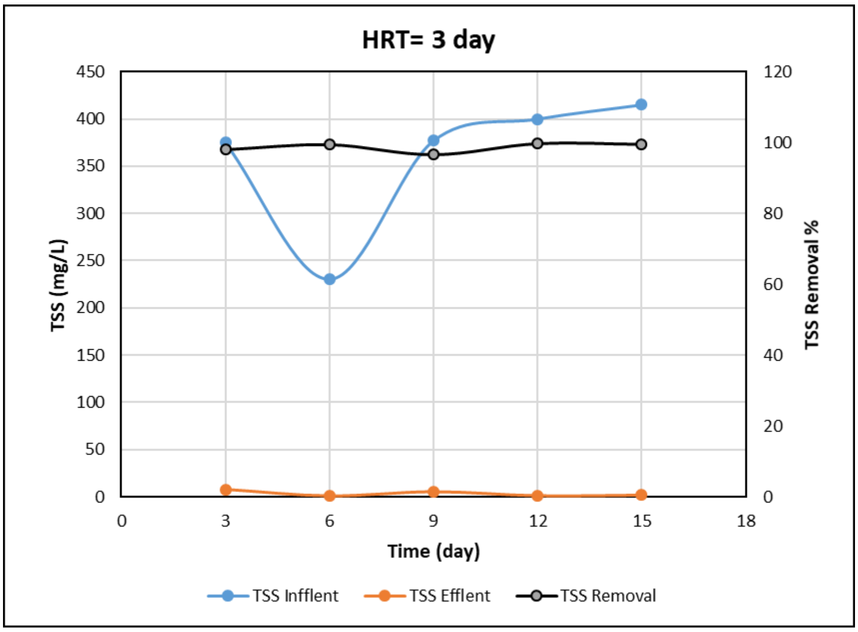

Fig. 8 A ratio of removal percentages (when HRT/day) to TSS concentration in influent and effluent.

4. CONCLUSION

To demonstrate that side-stream and submerged MBR technology are effective in removing contaminants from wastewater that is collected from residential areas, the goal of this research was to provide evidence that evidence. This inquiry yielded several findings, each representing a different outcome. When it comes to residential sewage treatment, one of the best options available is the treatment of submerged MBR with 4300 mg/L of mixed liquid suspended solids (MLSS). Nevertheless, side-stream MBR that contains 4,000 mg/L of MLSS is another option that can be employed.

When employing submerged and side-stream MBR permeates containing varied TSS levels, the removal of TSS was successful. This was the case when the processes were conducted. The substance passed through the ultrafiltration membrane, as demonstrated by the exceptional separation of solids performed by the material. According to the information that MBR provided, there was a considerable decrease in the amount of organic and biodegradable components.

An effluent with a COD that ranged from 19 to 37 mg/L was produced as a result of the removal of the BOD at an average rate of 94.46% in submerged MBR and the removal of the COD at an average rate of 92.76% at the same time.

An effluent with COD levels ranging from 33.6 to 59 mg/L was produced due to the removal of approximately 87.54% of COD in side-stream MBR. On the other hand, the elimination of BOD by this technique represented an average of 88.98%. When it comes to removing organic pollutants, it has been proved that the technology of submerged MBR is more effective than the technology of side-stream MBR. That is the case.

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