PERFORMANCE OF MEMBRANE BIOREACTOR VERSUS ACTIVATED SLUDGE AT A DOMESTIC WASTEWATER TREATMENT PLANT IN OMAN

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Abstract: The main objective of this study is to evaluate two wastewater treatment methods that are implemented at a sewage treatment plant (STP) in Oman; Conventional Activated Sludge (CAS) and Membrane Bioreactor Technology (MBR). The CAS STP receives its domestic wastewater through tankers while MBR STP receives its wastewater through sewer network. Samples from influent raw sewage, biological aeration tank and treated effluent from both systems were analyzed for physical, chemical and biological properties. The obtained results showed that the raw sewage of the CAS STP can be categorized as high strength concentration compared to medium strength concentration for the MBR STP. The removal efficiency achieved at the CAS plant for TSS, TN and BOD are 97%, 57% and 98% respectively. The accomplished removal efficiency by the MBR plant is 98%, 82% and 98% for TSS, TN and BOD, respectively. However, the removed amounts of the TSS, TN and BOD in the CAS plant were 437, 40 and 442 kg per 1000 m^3, respectively, compared to 147, 37 and 206 kg per 1000 m^3 respectively, for the MBR plant. Thus, the CAS plant was able to remove higher amounts of pollutants compared to the MBR plant.

1 INTRODUCTION

Wastewater treatment aims at removing different types of contaminant from the collected municipal wastewater before discharging/reusing the treated effluents (TEs). The treatment process involves physical, chemical and biological units according to the final disposal or reuse of the TEs. However, the biological treatment (also referred to as secondary treatment) is considered the core stage of any sewage treatment plant (STP). All biological treatment processes take advantage of bacteria's remarkable ability to use diverse wastewater constituents to provide the energy for microbial metabolism and the building blocks for cell synthesis (Amit and Ghate, 2004). Examples of biological treatment processes include conventional activated sludge (CAS), trickling filters, aerated lagoons, sequence batch reactors (SBR), and membrane bioreactors (MBR). In Oman, most STPs are using CAS system. Recently, MBR units have been added to some STPs. This study aims at comparing the performance of CAS and MBR units in Al-Ansab STP, Muscat, Oman.

Conventional activated sludge (CAS) is a biological wastewater-treatment process that has been used extensively in its original form, as well as with many modifications. There are three basic components in the activated sludge process: a biological reactor in which the microorganisms responsible for treatment are kept in suspension and aerated; a clarifier for liquid solids separation; and a recycle system for returning solids removed from the liquid-solids separation unit back to the reactor (Li, 2013).

The technology of membrane separation commonly known as Membrane Bioreactor (MBR); is the combination of activated sludge treatment together with a separation of the biological sludge by micro-

or ultra-filtration to produce particle free effluent. The latter step replaces final clarifiers and sand filter used in CAS systems (Le-Clech et al., 2006). Although, MBRs found narrow applications in the past century, further improvements in the design and operation have been introduced recently and incorporated into larger plants and wide applications (Melina et al., 2005).

2 PLANT DESCRIPTION

2.1 Process Description of Old Al-Ansab STP

Old Al Ansab STP was designed to treat annual average flow of 12,000 m^3/day with a peak flow of up to 24,000 m^3/day. This STP was commissioned in 1990 and then handed to Haya Water (public company handling wastewater management) in 2006. The plant was designed to treat the wastewater by Conventional Activated Sludge process (CAS) as an extended aeration type. The process was designed to operate at solids retention time (SRT) of 21 days. Since 2010, the plant design capacity was reduced to 8,000 m^3/d after the introduction of the New Al-Ansab STP. The Old Al Ansab STP consists of five main units: Tanker Discharge Area, Pre-treatment facilities, Secondary Biological Treatment, Filtration unit, and Chlorination system.

2.2 Process Description of New Al-Ansab STP

New Al Ansab Sewage treatment Plant (STP), introduced in 2010, is an integral part of the Muscat Wastewater Scheme Project with a plant average capacity of 55,000 m^3/day. This STP, which employs MBR technology, was commissioned to serve the second largest population area of Muscat Governorate (around 192,235 people in the 2010 census). The treatment process of New Al-Ansab STP consists of six main units: preliminary treatment, biological treatment and solids separation, treated effluent storage, sludge dewatering, chemical storage and dosing unit, and odor control system.

3 TEST METHODOLOGY

In order to compare the performance of the CAS and MBR systems, raw wastewater and final effluents from each system were analyzed for total suspended solids, biochemical oxygen demand, and chemical oxygen demand (COD). The conducted tests were based on Standard Methods for Examination of Water and Wastewater (Eaton, 1995). Moreover, the tests were done over a period of 12 weeks (from January to March 2014).

4 RESULTS AND DISCUSSION

4.1 Total Suspended Solid

Figure 1 shows the average total suspended solid results (TSS) of raw sewage (RS) of both old and new STPs over 12 weeks (1^{st} to 12^{th}). The average values are 450 mg/L and 150 mg/L, Respectively. Based on Metcalf & Eddy (2004), raw sewage of conventional activated sludge plant (CAS) can be classified as high strength influent and medium strength influent for New plant. That is attributed to high load of solids received into Old plant by tankers. Figure 2 illustrates the quality of TSS for the treated effluents (TEs) of the two STPs over 12 weeks (1^{st} to 12^{th}). Both TEs at the old and new plants have excellent quality; 10 mg/L and 3 mg/L, respectively (much lower than the Omani limits of 30 mg/L).

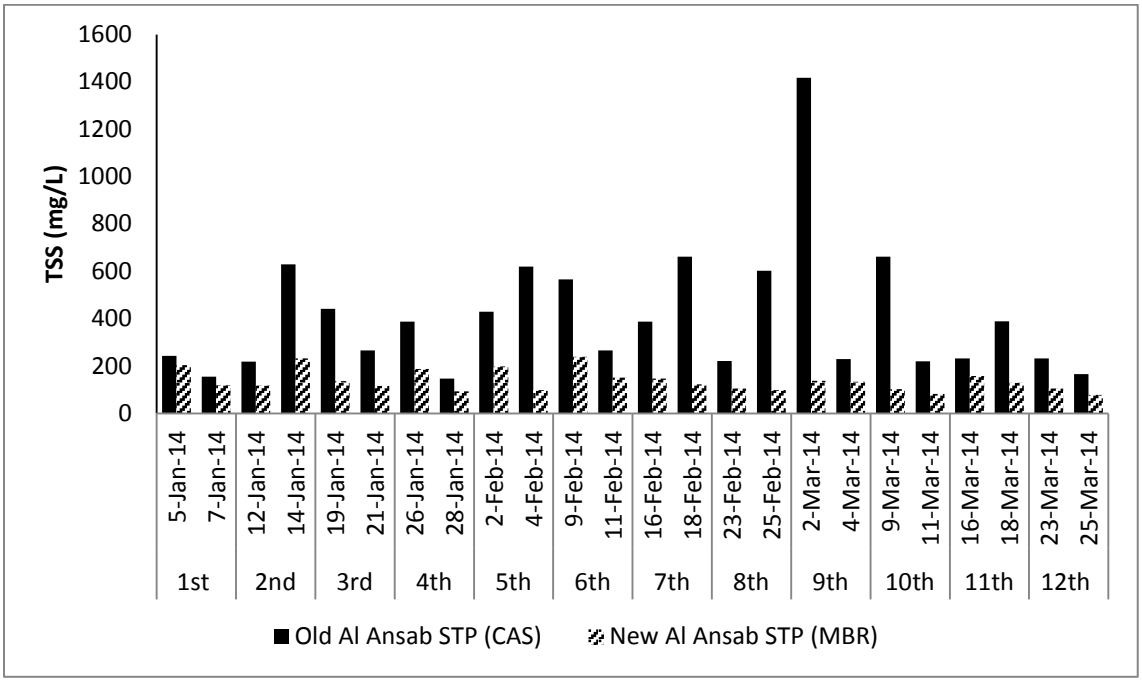

Figure 1. Average TSS results in raw sewage.

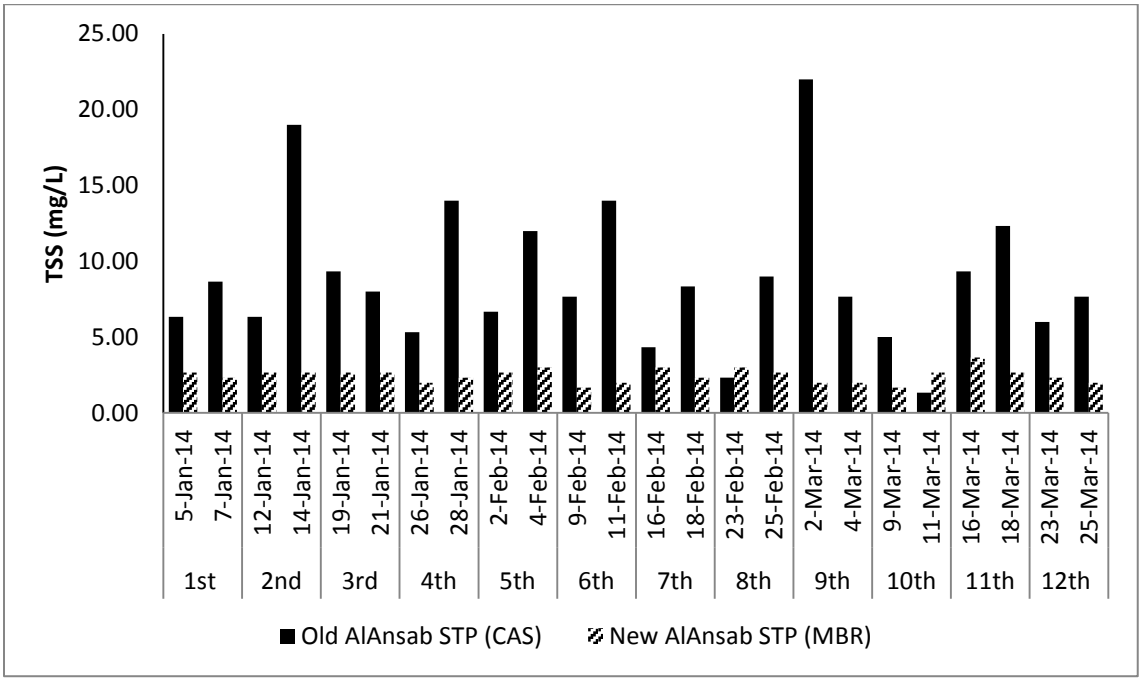

Figure 2. Average TSS results in treated effluents.

4.2 Biological and Chemical Oxygen Demand

The determined average values of BOD_5 and COD over 12 weeks (1^{st} to 12^{th}) from laboratory tests in RS are displayed in Figures 3 and 4, respectively. According to Metcalf & Eddy (2004), the average values of BOD_5 in raw sewage (450 mg/L) is categorized as high strength for Old Al Ansab STP. Whereas, it is classified as medium strength concentration (210 mg/L) for the New Al Ansab STP.

The average values of COD were found 800 mg/L for Old STP and 500 mg/L for New plant. This might be related to the introduction of heavy industrial organic pollutants material that received by tankers at Old Al Ansab STP. Higher concentration of degradable COD values results in a larger aeration basin volume is required; more oxygen transfer is needed and greater sludge production.

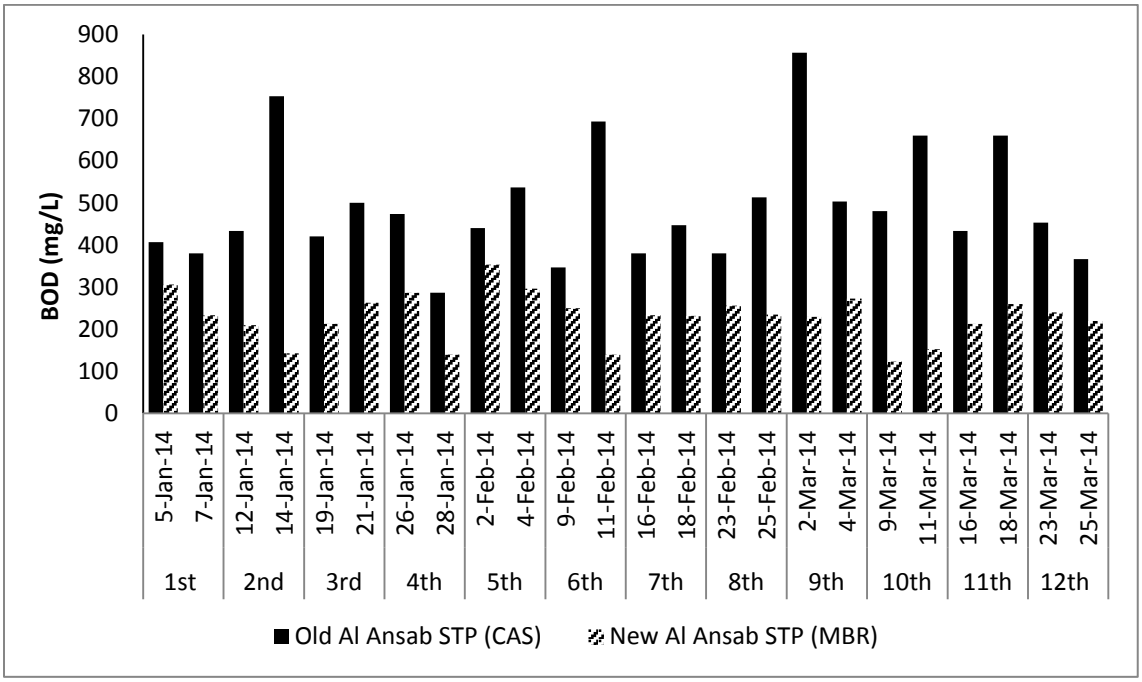

Figure 3. Average BOD results in raw sewage.

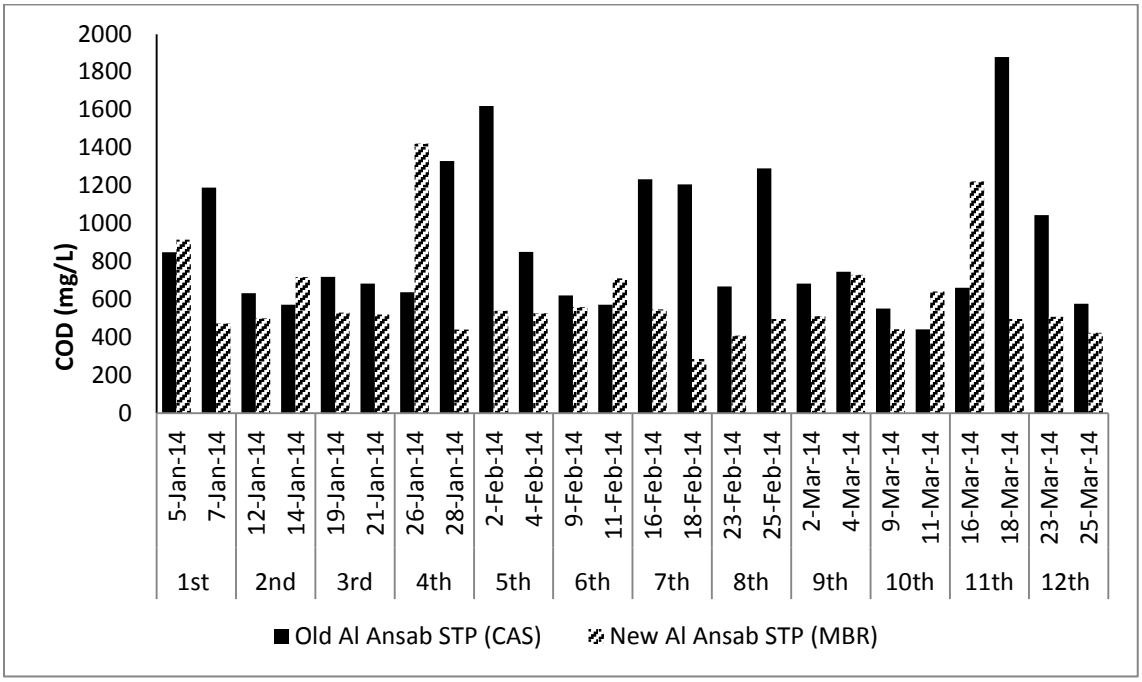

Figure 4. Average COD results in raw sewage.

The compliance of TEs in terms of BOD and COD for both STPs could be achieved by comparing them to the limits of Omani Standards (15 mg/L for BOD and 150 mg/L for COD) for the suitability of reuse it in irrigation purpose or discharge it to the sea. Figure 5 illustrates that BOD quality is 6 mg/L for Old plant and 3 mg/L for New plant which are much lower than the allowed limit. Moreover, Figure 6 demonstrates that the produced water is in compliance with standards for both old and new STPs (35mg/L and 10 mg/L, respectively).

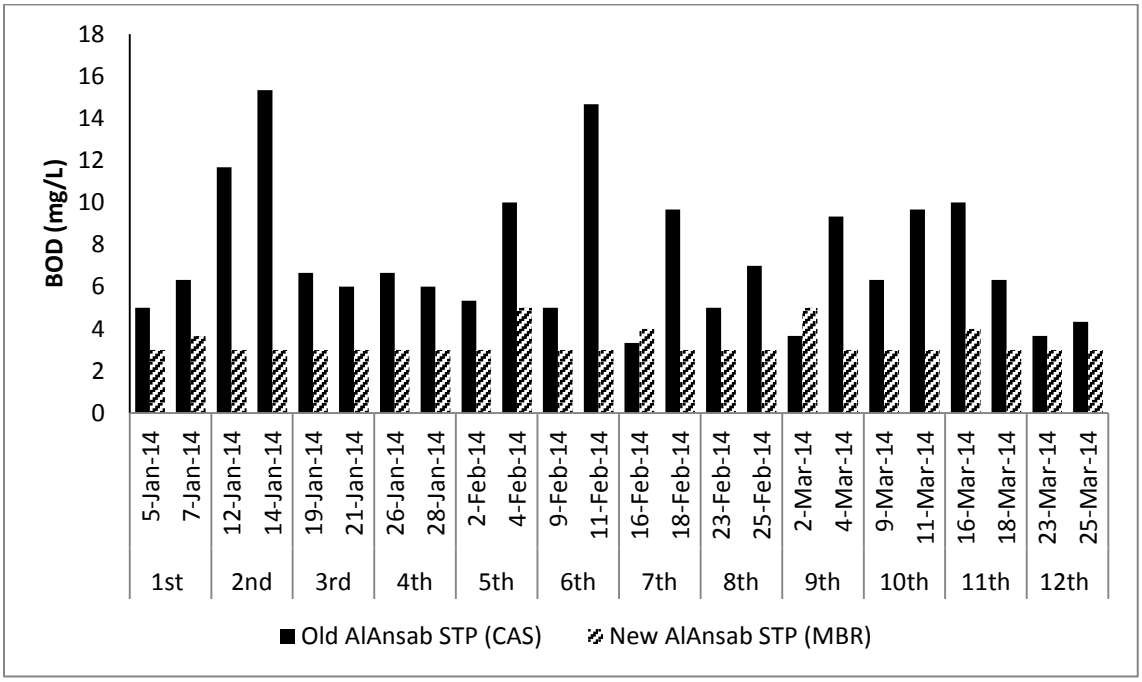

Figure 5. Average BOD results in treated effluents.

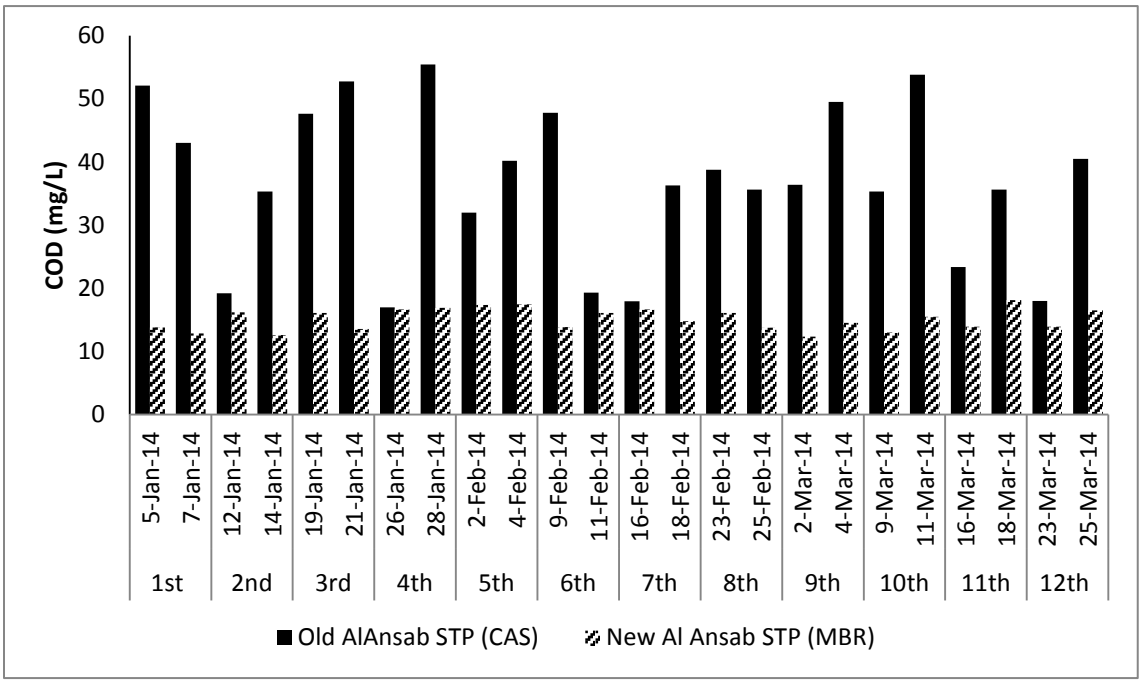

Figure 6. Average COD results in treated effluents.

4.3 Total Nitrogen

The results of total nitrogen (TN) in raw sewage and treated effluents for the two STPS over 12 weeks (1st to 12th) are shown in Figures 7 and 8. The average value of TN in Old and New Al Ansab STPs are 58 mg/L and 47 mg/L, respectively. The treated effluent quality regarding TN at Old Al Ansab STP is about 22 mg/L compared to 16 mg/L at New Al Ansab STP.

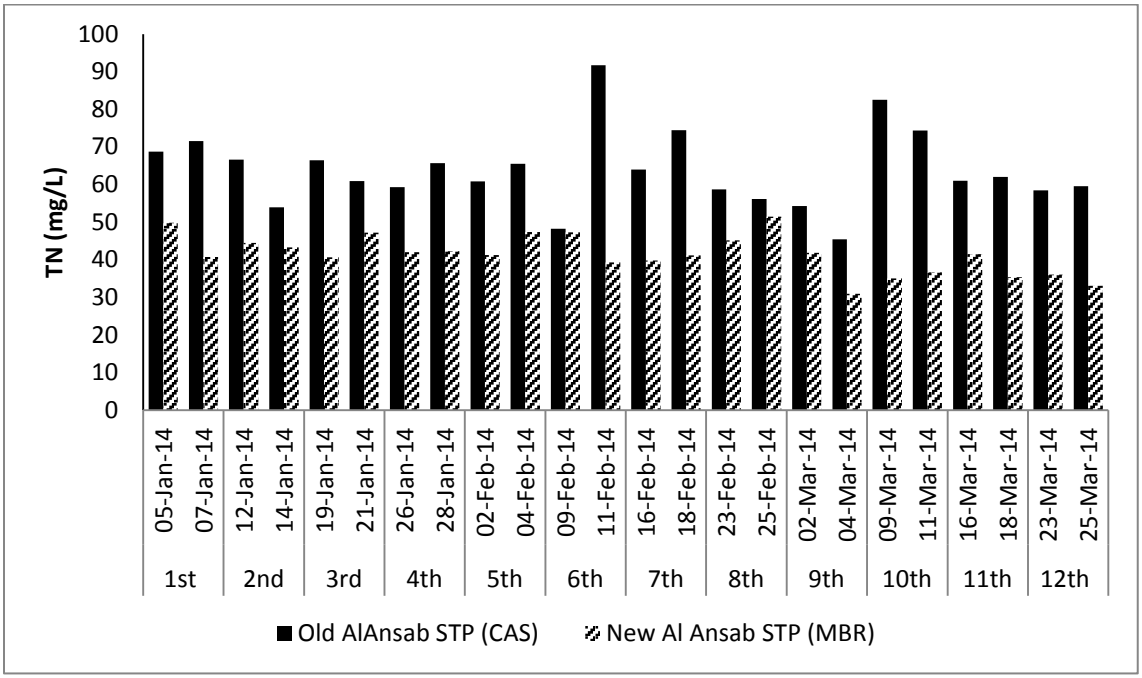

Figure 7. Average TN results in raw sewage.

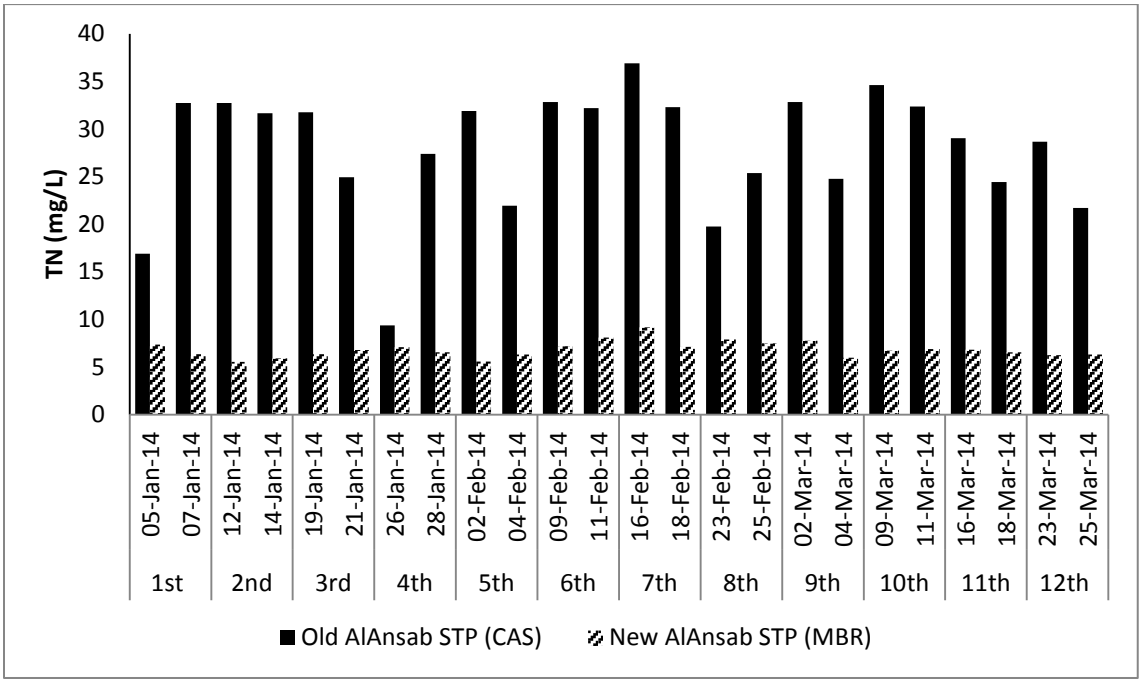

Figure 8. Average TN results in treated effluents.

4.4 Removal Performance

Table 1 shows the removal performance of the two STPS for different parameters. The removal efficiency of TSS in Old Al Ansab STP is 97 % which correspond to the removal of 437 kg of TSS per 1000 m^3 of wastewater (WW). This percentage is slightly lower than New Al Ansab STP (98%). However, the amount of TSS removed in the new STP (MBR technology) in much lower (147 Kg TSS/ 1000 m^3 WW).

It is clear that the removal efficiency of total nitrogen (TN) at New Al Ansab STP is 82% (37 kg TN/ 1000 m^3 WW) which is much better compared to Old STP of 57%. However, the removal amount of TN by CAS was higher than MBR (40 and 37 kg TN/ 1000 m^3 WW, respectively).

The removal efficiency of BOD is approximately identical on both STPs of 98% with removal amounts of 442 kg BOD/ 1000 m^3 at the old STP and 206 kg BOD/ 1000 m^3 WW at the New STP. Therefore, the two plants are capable to remove high load of BOD. Similarly, both Old Al Ansab and New Al Ansab STPs illustrated excellent removal efficiency of COD, 96% and 98%, respectively. Thus, the biological treatment in both CAS and MBR were very effective processes in this area.

Table 1. Removal performance of different parameters in Old (CAS) and New (MBR) Al Ansab STPS.

Parameter	Removal Efficiency (%)		Removed Amount (kg/1000 m^3)	
	CAS	MBR	CAS	MBR
Total Suspended Solids (TSS)	97	98	437	147
Total nitrogen (TN)	57	82	40	37
Biochemical oxygen demand (BOD)	98	98	442	206
Chemical oxygen demand (COD)	96	98	765	490

5 CONCLUSIONS

Based on the obtained results, the followings can be concluded:

- The raw sewage (RS) of Old Al Ansab STP can be categorized as high strength concentration, while as medium strength concentration for New Al Ansab STP.
- Both STPs produce very good quality of treated effluent for almost all parameters.
- Old Al Ansab STP met Omani Standards with the quality concentrations of 10 mg/L TSS, 25 mg/L TN and 6 mg/L BOD. The removal efficiency achieved by the CAS (Old STP) for TSS, TN and BOD are 97%, 57% and 98%, respectively.
- New Al Ansab STP met the standards with the quality concentrations of 3 mg/L TSS, 10 mg/L TN and 3 mg/L BOD. The removal efficiency accomplished at this MBR plant for TSS, TN and BOD were 98%, 82% and 98% respectively.

It can be said that the conventional activated sludge has shown comparable results (and sometime better results) than the membrane bioreactor despite the slightly higher efficiency of the new plant which is attributed to modern design and controlled operation.

6 References

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