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Wastewater Treatment Performance of Aerated Lagoons, Activated Sludge and Aerated Lagoons by oxylague under an arid Algerian Climate

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Abstract

In addition to negatively impacting soil, vegetation, and environmental processes, water pollution decreases the amount of fresh water available, particularly in dry regions experiencing water stress. By raising wastewater quality to a level appropriate for irrigation, wastewater treatment methods seek to lessen environmental deterioration and boost water availability. The technical, environmental, and operational performance of three wastewater treatment facilities (WWTPs) in the Wilaya of Naama is thoroughly examined in this study, an arid region of Algeria: (i) aerated lagoon (AL), (ii) activated sludge (AS), and (iii) aerated lagoon by oxylague.

The statistical study focused on the comparison between the removal rates of the physical (SS) and biological pollutants (BOD_5 and COD) parameters in the three stations during 4 years of exploitation. The data obtained indicate that the AS procedure had the highest removal rates, whereas the AL method had the lowest. The AS process differs significantly from the AL and ALO procedures, as seen by the comparison of removal rates for a particular parameter. There is a difference for the latter two processes, ALand ALO, but it is not statistically significant. This research underscores the importance of adaptive and integrated management of sanitation systems in arid zones.

1. Introduction

Arid and semi-arid regions, covering over one-third of the global land area (UN-Water, 2021), face significant challenges in sustainable water management. Water scarcity, coupled with increasing demand, heightens the necessity for reusing treated wastewater, particularly for agricultural purposes (Qadir et al., 2020; Angelakis et al., 2018). In Algeria, as in many Maghreb countries, WWTPs constitute a critical component in preserving water resources and protecting ecosystems (Bekkari et al., 2019; Haddad et al., 2021).

The Wilaya of Naama, situated in western Algeria, is characterized by an arid climate, low and irregular rainfall, and high dependence on groundwater resources (ANRH, National Water Resources Agency, 2020). In this context, assessing the performance of sanitation infrastructure is strategically vital, not only to ensure compliance with discharge standards but also to optimize the reuse of treated effluent (MREE, 2019; Jaramillo & Restrepo, 2017).

Few studies have focused on the integrated and comparative monitoring of WWTPs over multiple years in Algeria, particularly in arid regions (Boudjema & Khelil, 2020; Saidi & Chibane, 2022). Most research has addressed individual case studies or specific parameters, lacking a systemic analysis of technical, environmental, and managerial performance (Guettala & Houhamdi, 2018; Remaoun & Benhamiche, 2021).

This study aims to address this gap by proposing a multidimensional, multi-year assessment (2021–2024) of three WWTPs in the Wilaya of Naama. The specific objectives are:

- To compare the effectiveness of different treatment processes (aerated lagooning, Aerated lagoon by oxylague and activated sludge).

- To analyze the evolution of technical and environmental performance;

- To evaluate by-product (sludge) management and reuse practices;

- To provide recommendations for sustainable and resilient management.

2. Materials and methods

2.1. Study area:

The Wilaya of Naama is located in western Algeria, between latitudes 32° and 34° North. This steppe region has an arid climate, with average annual precipitation below 200 mm (Directorate of Water Resources and Environment of Wilaya of Naama, 2023). three WWTPs were selected for this study: (Fig. 1).

The three wastewater treatment plants (WWTP) in our study are located in the department of Naama. This department is located in southwestern Algeria, and it is characterized by an arid climate and long periods of drought. Figure 1 shows that the Naama area receives very little rainfall. The yearly average total is 16.3 mm (124.6 mm for 4 years), according to data collected over a 4-year period.

2.2. Presentation of Studied Wastewater Treatment Plants:

The three wastewater treatment plants (WWTP) are distributed in the Naama Department as follows: (i) The aerated lagoon process treatment plant is located in the city of Naama (33° 15' 44" N, 0° 18' 52" E). It is of a conceptual capacity of 34000 inhabitant equivalent (IE), and it treats an average daily volume of more than 3911 m3/day which represents 32671 IE. (ii) The activated sludge process treatment plant is located in the town of Mechria (33° 33' 00", N, 0° 17' 00" E). It has of a conceptual capacity of 92000 IE, and it treats an average volume of 9221 m3/day which represents 65 864 IE. (iii) The Aerated lagoon by oxylague process treatment plant is located in city of Mekmen Ben Ammar (NL) (33° 43' 00"N, 0° 43' 37" E). It has a conceptual capacity of 15 000 IE, and it purifies an average volume of 644 m3/day. Therefore, its inhabitant equivalent is 8000 IE.

2.3. Data Collection and Analysis:

For four years, five-liter grab samples of water were collected once a week at the WWTPs' intake and output. Suspended solids (SS), the 5-day biochemical oxygen demand (BOD_5), the chemical oxygen demand (COD). Were all measured within a day after sample collection. The American Public Health Association (APHA) and the United States Environmental Protection Agency (USEPA) standard methodologies for the assessment of water and wastewater were followed in all studies; these methods are listed in Table 1.

Table 1
Parameters and analysis methods

Pollution Parameters	Test Methods
BOD_5 (mg/)	Standard Methods for the Examination of Water and Wastewater. File 5210B
COD (mg/L)	Standard Methods for the Examination of Water and Wastewater. File 5220B
SS (mg/L)	Standard Methods for the Examination of Water and Wastewater. File 2540D

2.4. Data Analyses Tools:

The three WWTPs utilized in this investigation are not all the same size. As a result, only the purification removal rates of BOD_5, COD, and SS, as well as the quality of the water exiting the stations in relation to the different current criteria, can be compared.

The data recorded at each station's input and output were used to compute each parameter's yearly removal rate in order to facilitate analysis.

Using a graphic method of descriptive statistics by boxplot was carried out to accurately visualize the differences between the various adopted processes.

3. Results

3.1. Influent Characterization

The rate of the organic load, which is the ratio of the pollution received over the nominal capacity of the plant, is given as percentage of the nominal flow in BOD_5. The organic loads of the raw wastewater entering the plants are less than their nominal capabilities, according to the rates calculated for the three plants of the three processes. Furthermore, we infer that the raw wastewater from the three sites is readily biodegradable since the COD/ BOD_5 ratio values are often less than three.

3.2. Biological Oxygen Demand (BOD_5)

One indicator of organic matter contamination of water is the biochemical oxygen demand (BOD_5). It is the quantity of oxygen required by living microorganisms to guarantee the oxidation and breakdown of organic compounds found in wastewater.

Figure 2 uses a boxplot to illustrate how the percentage of BOD_5 removal changed over a four-year period for the three methods under study.

Figure 2 shows that the Mechria station, which employs an activated sludge method, has the highest BOD_5 removal rate, while the Naama station, which utilizes an aerated lagoon process, has the lowest.

The median BOD_5removal rate for the aerated lagoon process (Naama "AL" station) is somewhat up the box. So, there is an asymmetric distribution towards the high removal rate values of BOD_5. The box's length (67.53–78.34%) suggests that the BOD_5 removal rate values from the aerated lagoon method varied greatly during the course of the four-year study."

The length of the box for the activated sludge process (Mechria "AS" station) is comparatively shorter (94.08–96.53%) than that of the aerated lagoon process, indicating that the BOD_5 removal rate values for this process are not very variable. For this activated sludge procedure, the median is entirely at the center of the box.

When compared to the other two processes (Mekmen Ben Ammar "ALO" station), the aerated lagoon by oxylague method has the largest box length (69.35–86.25%), indicating a high degree of variability in the BOD_5 removal rate values.

Figure 3 shows that the Naama aerated lagoon station has the highest BOD_5 levels over the course of four years. The Mechria activated sludge station records the majority of the minimum values throughout a four-year period.

The BOD_5 readings for the aerated lagoon and the aerated lagoon by oxylague change noticeably from year to year. The numbers recorded over the course of the four years for the activated sludge process are extremely similar, with very little variation.

The aerated lagoon process's minimal BOD_5 value was recorded in 2024, but the aerated lagoon by oxylague processes was recorded in 2023. The aerated lagoon process reached its highest values in 2021, while the aerated lagoon by oxylague process reached its highest values in 2024.

The error bars in Fig. 3 clearly demonstrate the significant variation in BOD_5 values across the three methods.

Compared to the various standards relating to treated wastewater, the BOD_5 values of the water from the two processes of lagooning are superior to the Algerian discharge standards (35 mg/L), the standards of the WHO (30 mg/L), and the agricultural reuse standards of the FAO (FAO,2003)

(30 mg/L); only the wastewater purified from the activated sludge meets these three standards.

3.3. Chemical Oxygen Demand (COD)

The biodegradation of organic waste that is readily broken down by bacteria and other microorganisms seen in a natural setting that can quickly deoxygenate an aquatic environment is not replicated by COD. It symbolizes the use of oxygen by potent chemical oxidants to oxidize mineral and organic materials in water (Rejsek, F,2002).

Furthermore, Fig. 4 illustrates the duration of the two lagooning process boxes (56.39–93.89% in AL and 66.23–94.97% in ALO), indicating a considerable degree of variation in the COD removal rate values for the two processes.

Additionally, Fig. 4 demonstrates that, in comparison to the other two stations, the Mechria station has the highest COD removal rates. The Mechia station's maximum removal rates are significantly higher than those of Namma and Mekmen Ben Ammar.

The aerated lagoon by oxylague in Fig. 4, the median is toward the bottom of the box, indicating an unbalanced distribution toward the low COD removal rate values. The activated sludge and the aerated lagoon have symmetric distribution, as evidenced by the medians at the middle of the boxes.

The average COD values for the three sites in our study from 2021 to 2024 are displayed in Fig. 5.

Figure 5 illustrates that the aerated lagoon station of Naama had the highest DOC levels over the course of four years. The Mechria activated sludge station records the lowest levels.

or the aerated lagoon and the aerated lagoon by oxylague, the DOC values vary greatly from year to year, but they are comparatively constant for the activated sludge method. The aerated lagoon by oxylague reached its greatest values in 2021, while the lowest values were noted in 2023.

The error bars in Fig. 5 also show that there is minimal variation in the values recorded over the course of the study's four years.

From a quality perspective, Fig. 5 demonstrates that the COD levels of purified wastewater from the Naama and Mekmen Ben Ammar stations are higher than those of the FAO (FAO.,2003) (40 mg/L), WHO (WHO.,1989) (90 mg/L), and Algerian standard (JORA.,1993) of rejection (120 mg/L). The treated wastewater values for the active sludge in Mechria are generally lower than the WHO (WHO.,1989), (FAO.,2003), and Algerian standard (JORA.,1993).

3.4. Suspended Solids

According to Fig. 6, Mechria station has the highest SS removal rates, whereas Mekmen Ben Ammar has the lowest.

The boxplot of SS removal rates in Fig. 6 demonstrates that the removal rate values for the aerated lagoon by oxylague process vary widely (39.01–57.97%), the removal rate values for the aerated lagoon process vary little (48.68–59.48%), and the removal rate values for activated sludge vary extremely little (93.99–94.93%).

Additionally, Fig. 6 illustrates that the Mechria station records the highest removal rates, while the Mekmen Ben Ammar station records the lowest. The removal rate values for the Mekmen Ben Ammar station and the Naama station are comparable.

The SS data from the various stations are compiled in Fig. 7.

Figure 7 shows that the Ben Ammar station had the highest average SS values at the exit from the stations in our study over the course of the four years, while just one site had the lowest values. The values of SS for the aerated lagoon processes and the aerated lagoon by oxylague vary significantly from year to year. The activated sludge station does not exhibit this variation.

The aerated lagoon process's lowest average value occurred in 2022, while its highest value occurred in 2023. The average value for the aerated lagoon using the oxylague technique is highest in 2024 and lowest in 2022.

The error bars in Fig. 7 indicate that the range of the SS values recorded between 2021 and 2024 is extremely short for the activated sludge processes and quite wide for the aerated lagoon station and aerated lagoon by oxylague.

In terms of the standards, none of the standards included in our study (Algerian discharge) are met by the SS values of the treated wastewater from the aerated lagoon process and the aerated lagoon process by oxylague.

Regarding the standards, none of the standards considered in our study (Algerian discharge standard "35 mg/L," WHO standard (WHO.,1989) "30 mg/L," and FAO standard (FAO.,2003) "70 mg/L") are met by the SS values of the treated wastewater from the aerated lagoon process and the aerated lagoon process by oxylague. However, the activated sludge process's recorded values completely meet all three requirements.

4. General Discussion

The three WWTPs' entry COD, BOD_5, and SS readings are within the range of reference values for raw domestic wastewater (BOD_5 = 500 mg/L, COD = 1000 mg/L, and SS = 600 mg/L) (JORA,2009), with the AL, AS, and PB processes having average COD/ BOD_5 ratios of 2.4, 2.82, and 2.83, respectively. The conclusion that raw wastewater is readily biodegradable is made possible by these ratios being less than three for every operation (Metcalf and Eddy.,1991; Klimiuk et al.,2008).

The average organic loading rates are (i) 83% for the AL process, (ii) 61% for the AS process, and (iii) 66.4% for the ALO process, based on analyses pertaining to raw wastewater. These findings demonstrate that the three WWTPs' nominal capacities are exceeded by the pollutant loads they receive. These findings demonstrate that the three WWTPs' nominal capacities are exceeded by the pollutant loads they receive.

With the exception of the Mechria station, these clearance rates in comparison to those reported in other publications (Hamid et al.,2014; Tahri et al.,2015) are generally unacceptable and do not accurately reflect the relative effectiveness of the treatments used in the study region. The lack of oxygen in the

water and the growth of algae in the finishing basin is caused by a number of issues with the Naama stations, including the stopping of some aerators, which directly affects the concentration of SS at the exit.

For the activated sludge process, the comparison made between the removal rate values of our study and those of (Moussaoui et al.,2023) shows that there was a similitude in the removal rate values of the three parameters compared to the values of 2023. This similitude in the performance of the activated sludge station was the consequence of good functioning in the treatment system during this period.

Air temperature and water temperature are positively correlated, according to Musy and Higy (Musy et al.,2004), Livingstone and Lotter (Livingstone et al.,1998), and Preudhomme and Stefan (Preud'homme et al.,1992). Water temperature rises in response to an increase in air temperature, while dissolved oxygen (DO) content falls in response to an increase in water temperature (Walczyn´ska et al.,2017; Moatar et al.,1999). High amounts of BOD_5, COD, and SS are produced at the system's exit when DO declines because aerobic bacterial activity also declines and organic matter is not broken down (Andreoni.,1989).

5. Conclusions

In order to protect the environment, wastewater treatment can, under some circumstances, be used again for irrigation. The amount and quality of raw sewage, operational expenses, and weather are some of the factors that influence the choice of wastewater treatment method.

Numerous research has examined how well biological systems remediate wastewater without comparing them.

Three biological processes-aerated lagoon, activated sludge, and aerated lagoon by oxylague in a dry climate-were compared in this study.

The results showed that the treatment performance of the three biological processes during the 4 years of the study exceeded 60%, with an advantage for the activated sludge process, where the biological pollutant removal rates were approximately 90%. It also demonstrated that the aerated lagoon process of the city of Naama lost this performance from one year to another due to the continuous breakdowns of the aerators.

For the quality of treated wastewater, the study demonstrated that the activated sludge process and the physical and biological parameters tested at the outlet of this station conform with the various requirements (Algerian, WHO, and FAO). Additionally, it is shown how the climate has a significant impact on the concentrations of these pollution parameters in the aerated lagoon plant and aerated lagoon by oxylague; they rise with rising air temperatures and vice versa.

The results demonstrated the efficacy of the constructed wetland process, but not for the activated sludge procedures.

The concentration levels of the several pollution measures in relation to the activated sludge process are rather steady and unaffected by seasonal variations.

In final conclusion and based on what has been said, the activated sludge method is the most suitable for the climatic conditions of the southwestern department of Algeria.

Declarations

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Conflicts of Interest: The authors declare no conflict of interest

Author Contribution

"A wrote the main manuscript text and,B and C prepared figures ,1-3. All authors reviewed the manuscript.

References

1. **Angelakis, A. N., Asano, T., Bahri, A., et al. (2018)**. Water Reuse: From Ancient to Modern Times and the Future. Frontiers in Environmental Science, 6, 26.
2. **ANRH**, National Water Resources Agency. (2020). Climatological and hydrological bulletin of the Wilaya of Naama. Ministry of Water Resources, Algeria.in French.
3. **Bekkari, H., Laziri, F., & Zeddouri, A. (2019)**. Performance assessment of wastewater treatment plants in Algeria: A case study. Journal of Environmental Management, 251, 109558.
4. **Boudjema, S., & Khelil, M. A. (2020).** Comparative study of wastewater treatment technologies in semi-arid regions: Algeria case. Water Science and Technology, 81(5), 1023-1035.
5. **Directorate of Water Resources and the Environment of the Wilaya of Naama. (2023)**. Climatological and hydrological data 2020-2023.in French

6. **FAO.** Irrigation with Treated Wastewater: User Manual; University of Liège: Liège, Belgium, 2003; 73p. in French.
7. **Guettala, F., & Houhamdi, M. (2018)**. Impact of wastewater discharge on the environment: Case of the Wilaya of El Oued, Algeria. Journal of Fundamental and Applied Sciences, 10(2), 345-360.
8. **Haddad, B., Laffouni, N., & Kettab, A. (2021)**. Evaluation of the performance of natural lagoon systems in arid regions: Case of Algeria. Environmental Science and Pollution Research, 28(15), 19231-19243.
9. **Hamid, C.; El Watik, L.; Ramchoun, Y.; Fathallah, R.; Ayyach, A.; Fathallah, Z.; El Midaoui, A.; Hbaiz, E**. Study of the treatment performance of the aerated lagoon technique applied to the wastewater treatment plant in the city of d'Errachidia-Marocco. *Afr. Sci.* **2014**, *10*, 173-183.in French.
10. **Jaramillo, M. F., & Restrepo, I. (2017).** Wastewater reuse in agriculture: A review about its limitations and benefits. Sustainability, 9(10), 1734.
11. **JORA**. Maximum limit values for substance content harmful effects of non-domestic wastewater when they are released into a network public sewer or in a wastewater treatment plant. *Annex. Alger. Repub. Off. J.* **2009**, *36*, p18.
12. **JORA.** *Norms of the rejected treated wastewater. Annex*. Alger. Repub. Off. J. 1993, 46, p7.
13. **Klimiuk, E.; Łebkowska, M.** *Biotechnologia w Ochronie S´rodowiska*; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2008.
14. **Livingstone, D.M.; Lotter, A.F**. The relationship between air and water temperatures in lakes of the Swiss Plateau: A case study with palæolimnological implications. *J. Paleolimnol.* **1998**, *19*, 181–198.
15. Metcalf and Eddy, Inc. *Wastewater Engineering: Treatment, Disposal, and Reuse*, 3rd ed.; McGraw-Hill, Inc.: Singapore, 1991.
16. **Ministry of Water Resources and the Environment (MREE). (2019)**. National strategy for sanitation and wastewater treatment. Democratic and Popular Republic of Algeria.in French.
17. **Moatar, F.; Poirel, A.; Obled, C**. Analysis of time series of dissolved oxygen and pH measurements on the Loire at the Dampierre nuclear site (Loiret): 1. Understanding of temporal variations in dissolved oxygen contents and pH in relation to hydrometeorological data. *Hydroécol. Appl.* **1999**, *11*, 127–151.in French.
18. **Moussaoui, T. ; Derdour, A. ; Hosni, A. ; Ballesta-de los Santos, M. ; Legua, P. ; Pardo-Picazo, M.Á. (2023)**. Assessing the Quality of Treated Wastewater for Irrigation: A Case Study of Ain Sefra Wastewater Treatment Plant. Journal of Sustainability 2023,15, 11133.
19. **Musy, A.; Higy, C**. *Hydrology: A Science of Nature*; PPUR Presses Polytechniques: Lausanne, Switzerland, 2004; 314p.in French.
20. **Preud'homme, E.B.; Stefan, H.G**. *Relationship between Water Temperatures and Air Temperatures for Central, U.S. Streams*; Project Report No. 333. ST; Anthony Falls Hydraulic Laboratory, University of Minnesota: St. Paul, MI, USA, 1992.

21. **Qadir, M., Drechsel, P., Jiménez, B. et al. (2020)**. Global and regional potential of wastewater as a water, nutrient and energy source. Natural Resources Forum, 44(1), 40-51.
22. **Rejsek, F**. Analysis of Regulatory and Technical Aspects of Waters; CRDP: Aquitaine, France, 2002; 358p.in French.
23. **Remaoun, M., & Benhamiche, N. (2021)**. Public policy challenges in the sanitation sector in Algeria. Mediterranean Journal of Social Sciences, 12(2), 45-56.
24. **Saidi, A., & Chibane, M. (2022)**. Performance indicators for wastewater treatment plants in arid zones: A critical review. Journal of Water Process Engineering, 47, 102789.
25. **Tahri, M.; Larif, M.; Quabli, H.; Taky, M.; Elamrani, M.; El Midaoui, A.; Benazouz, K.; Khimani, M**. Study and monitoring of the performance of primary and secondary wastewater treatment at the Marrakech wastewater treatment plant. *Eur. Sci. J.* **2015**, *11*, 139–154.in French.
26. **UN-Water. (2021)**. United Nations World Report on Water Development 2021: The value of water. UNESCO.
27. **Walczyn´ska,A.; Sobczyk, Ł**. The underestimated role of temperature–oxygen relationship in large-scale studies on size to temperature response. *Ecol. Evol.* **2017**, *7*, 7434–7441.
28. **WHO**. Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture; Technical report, No. 778; World health Organization: Geneva, Switzerland, 1989

Figures

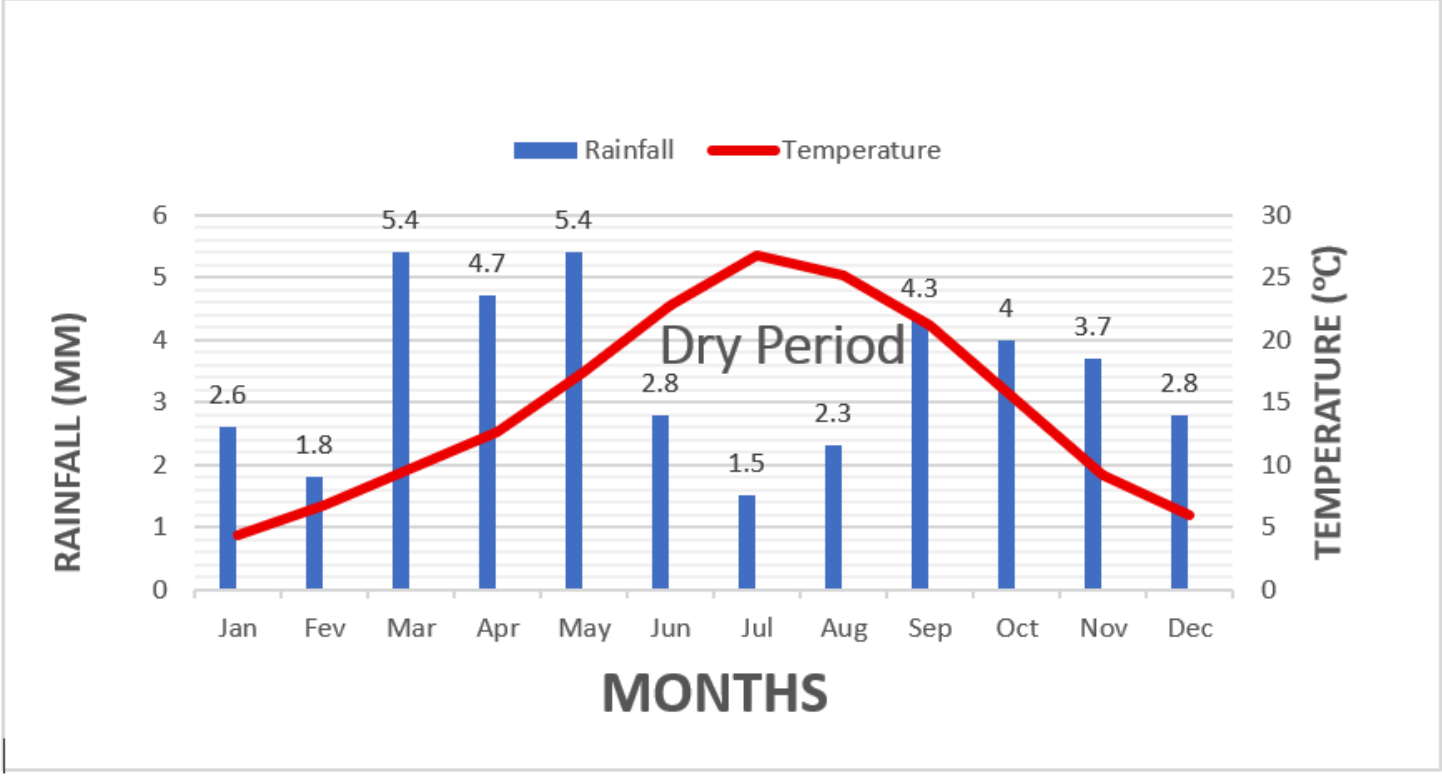


Figure 1

Ombrothermal diagram of Naama Department (2021–2024).

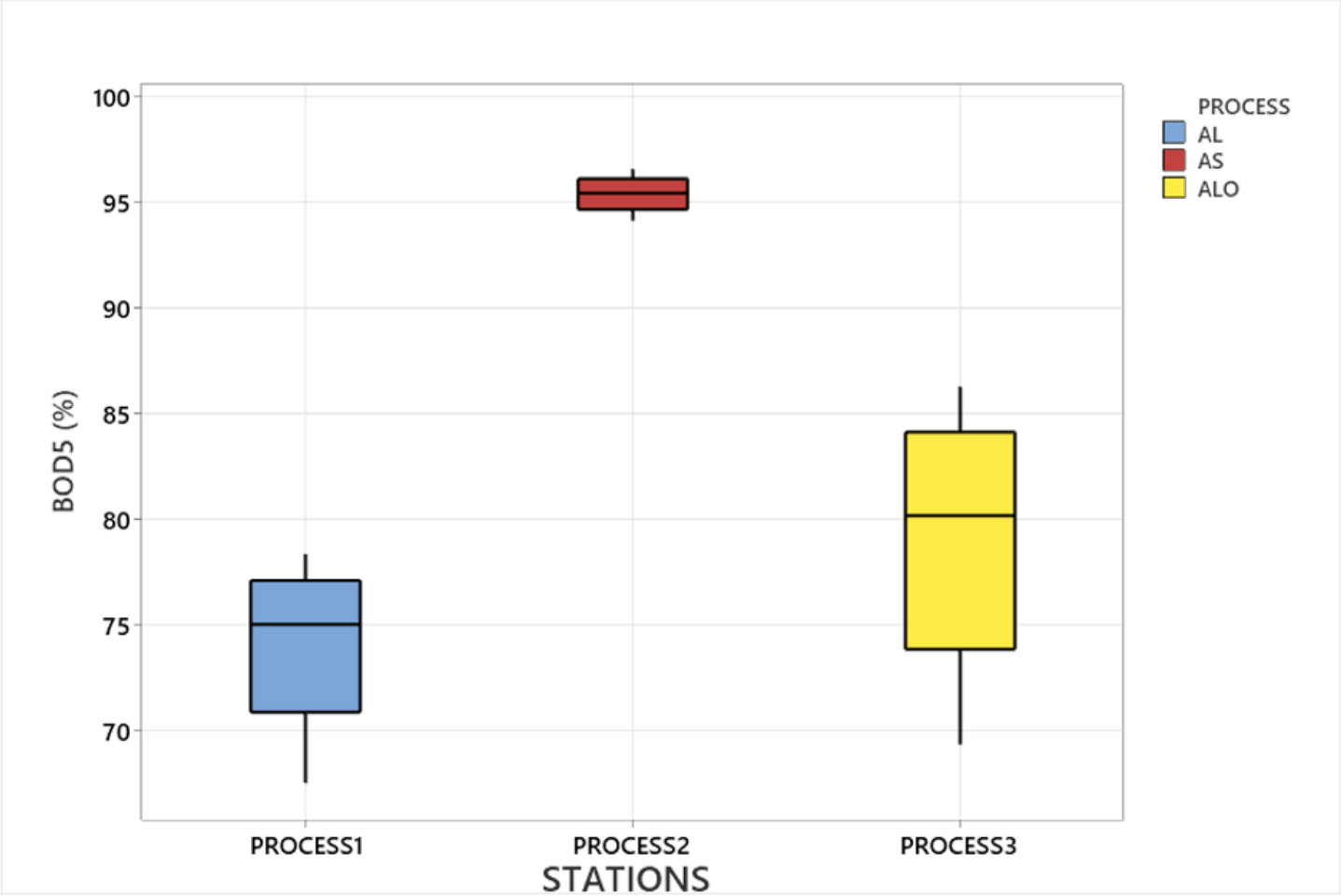


Figure 2

Boxplots showing the three processes' biological oxygen demand in five days (BOD_5) elimination rates

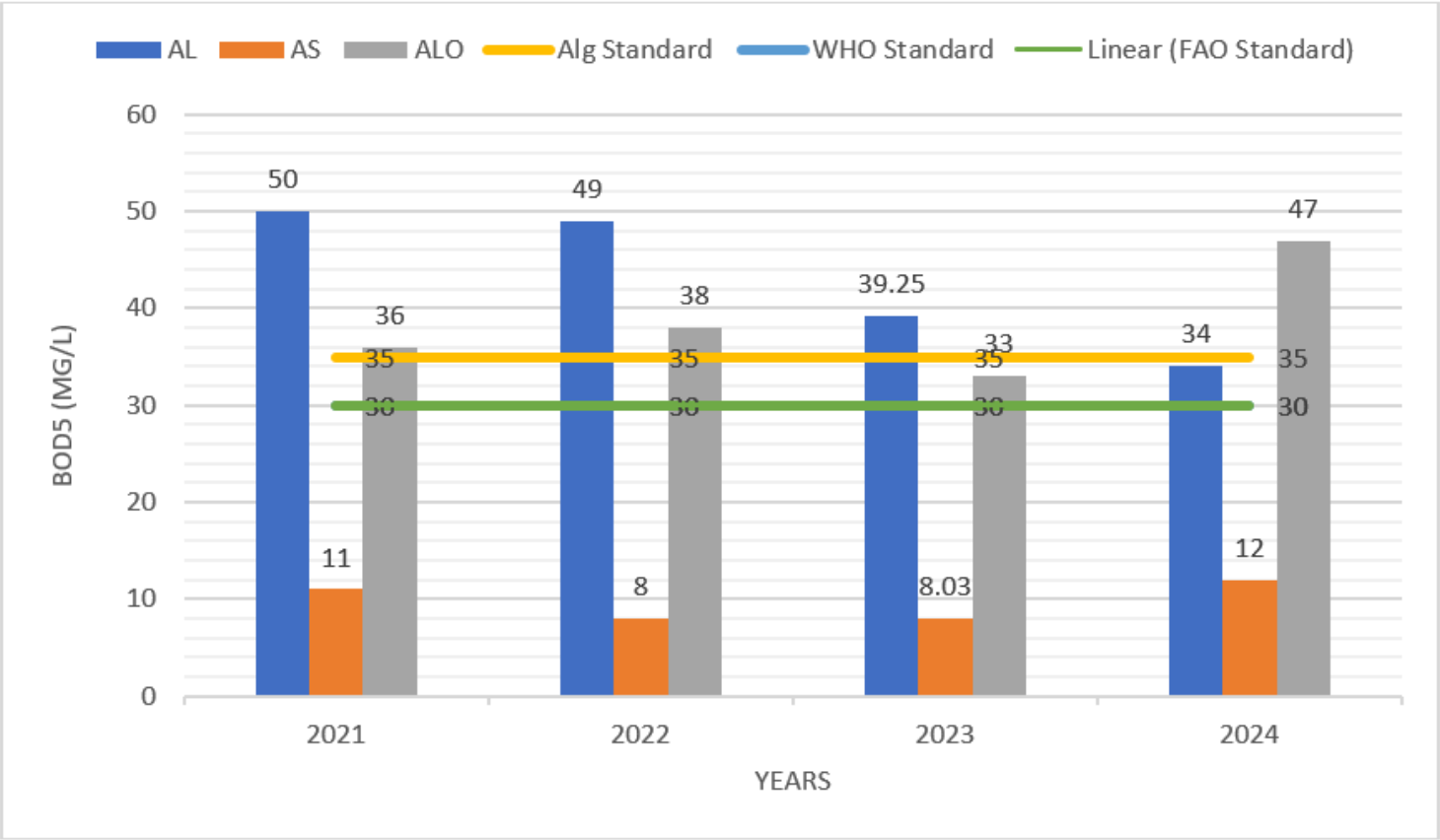


Figure 3

the BOD_5 values at the stations' outputs for the three processes

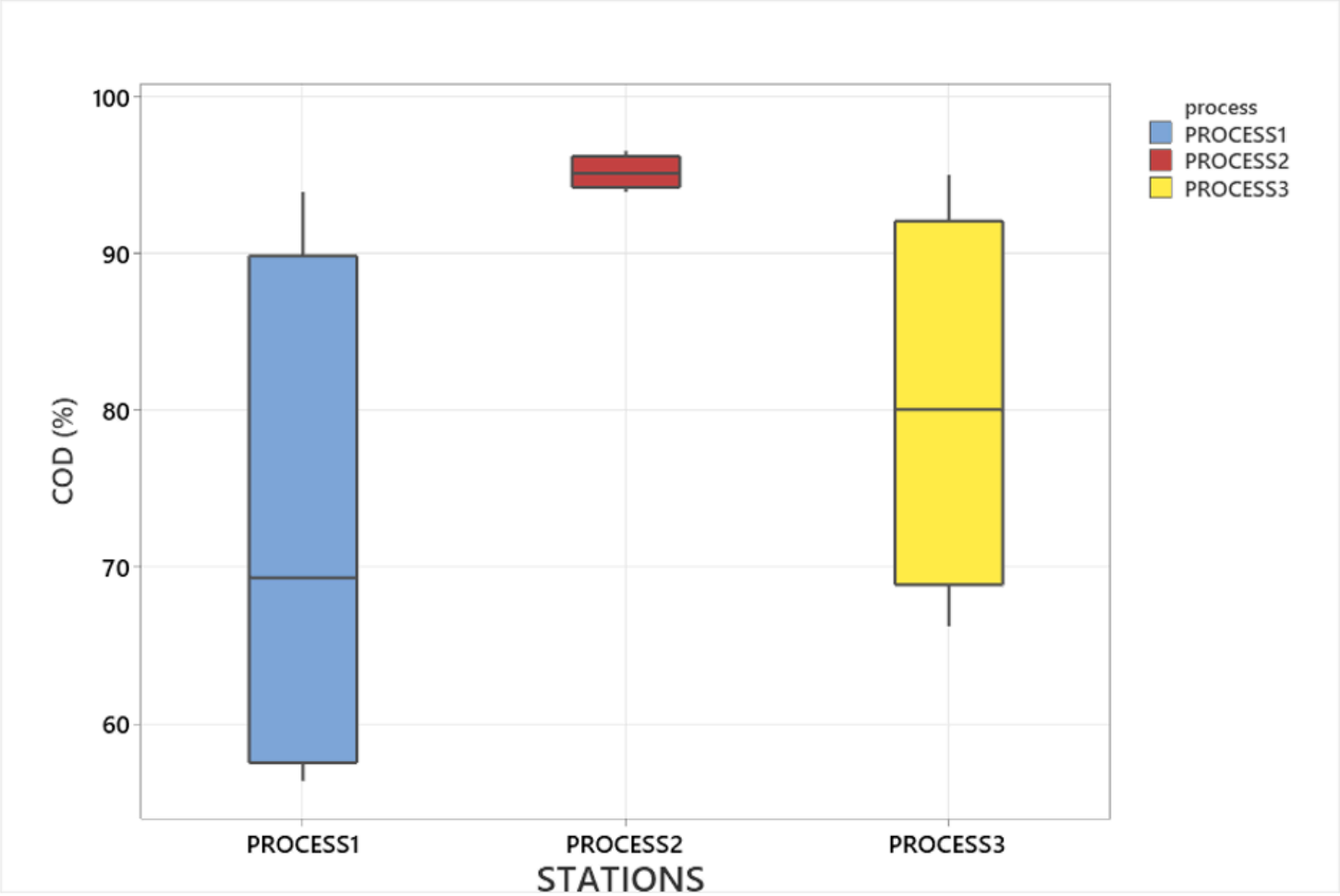


Figure 4

Boxplots showing the three procedures' rates of COD removal

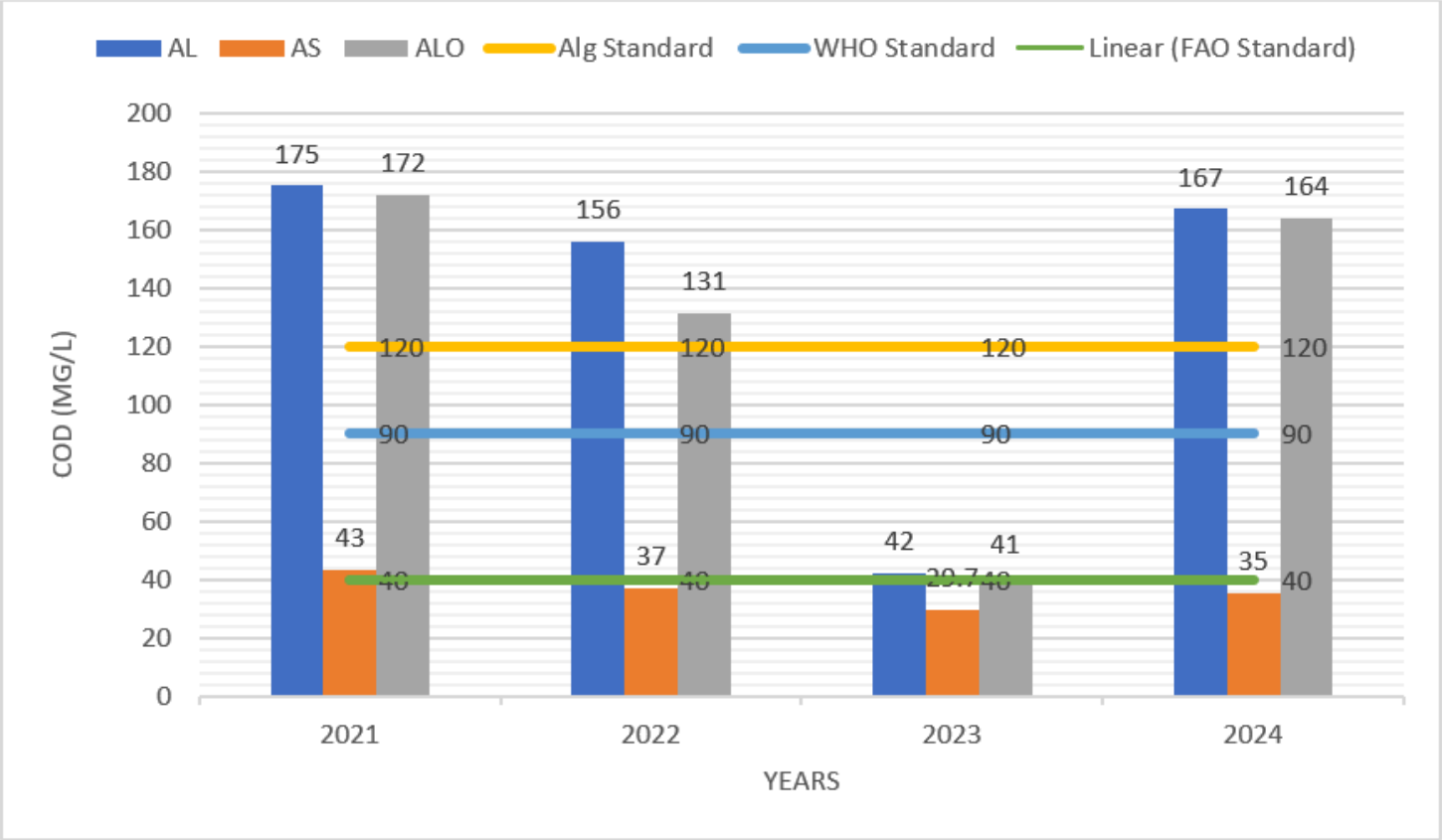


Figure 5

the COD values at the stations' outputs for the three processes.

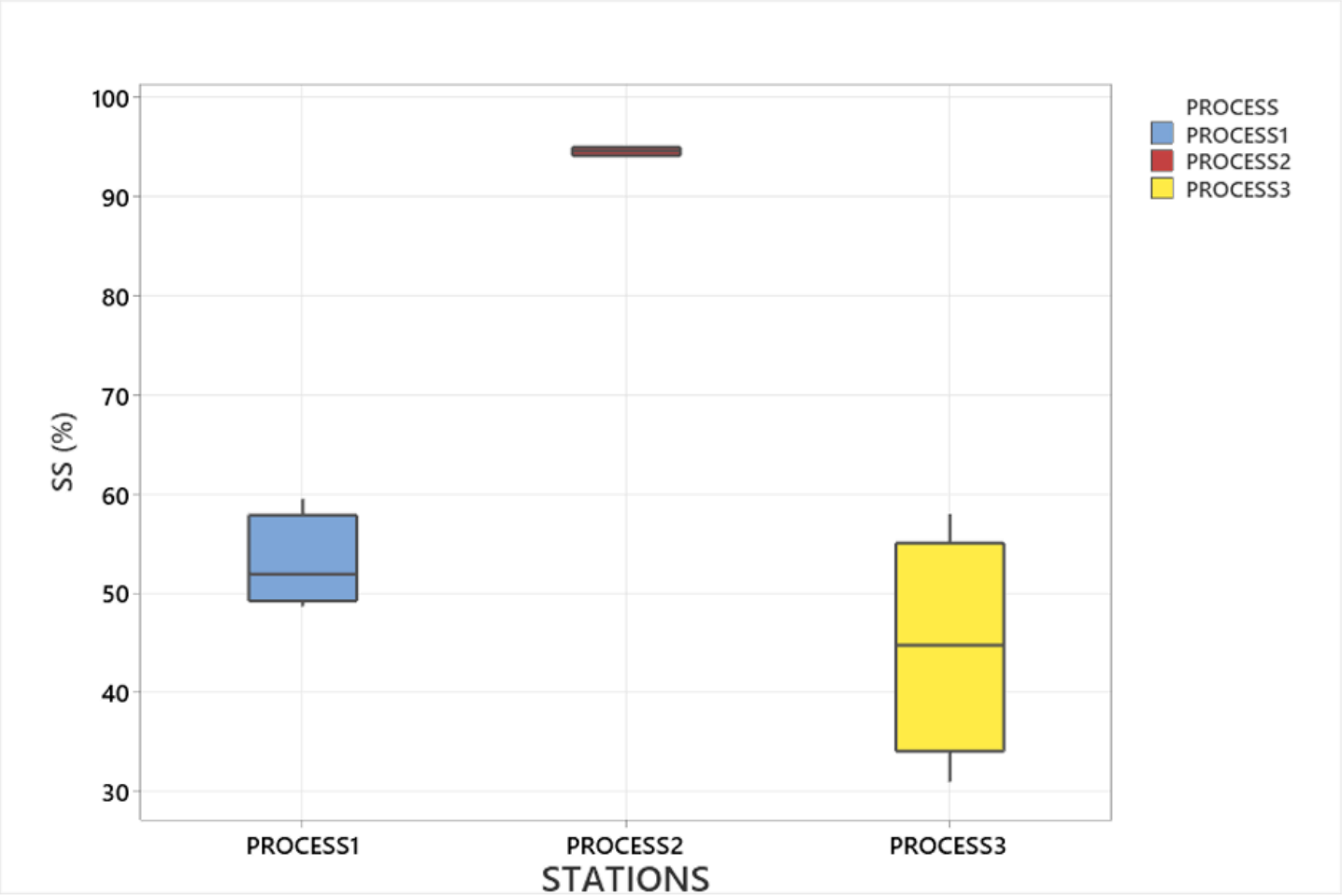


Figure 6

Boxplots showing the three procedures' rates of SS removal

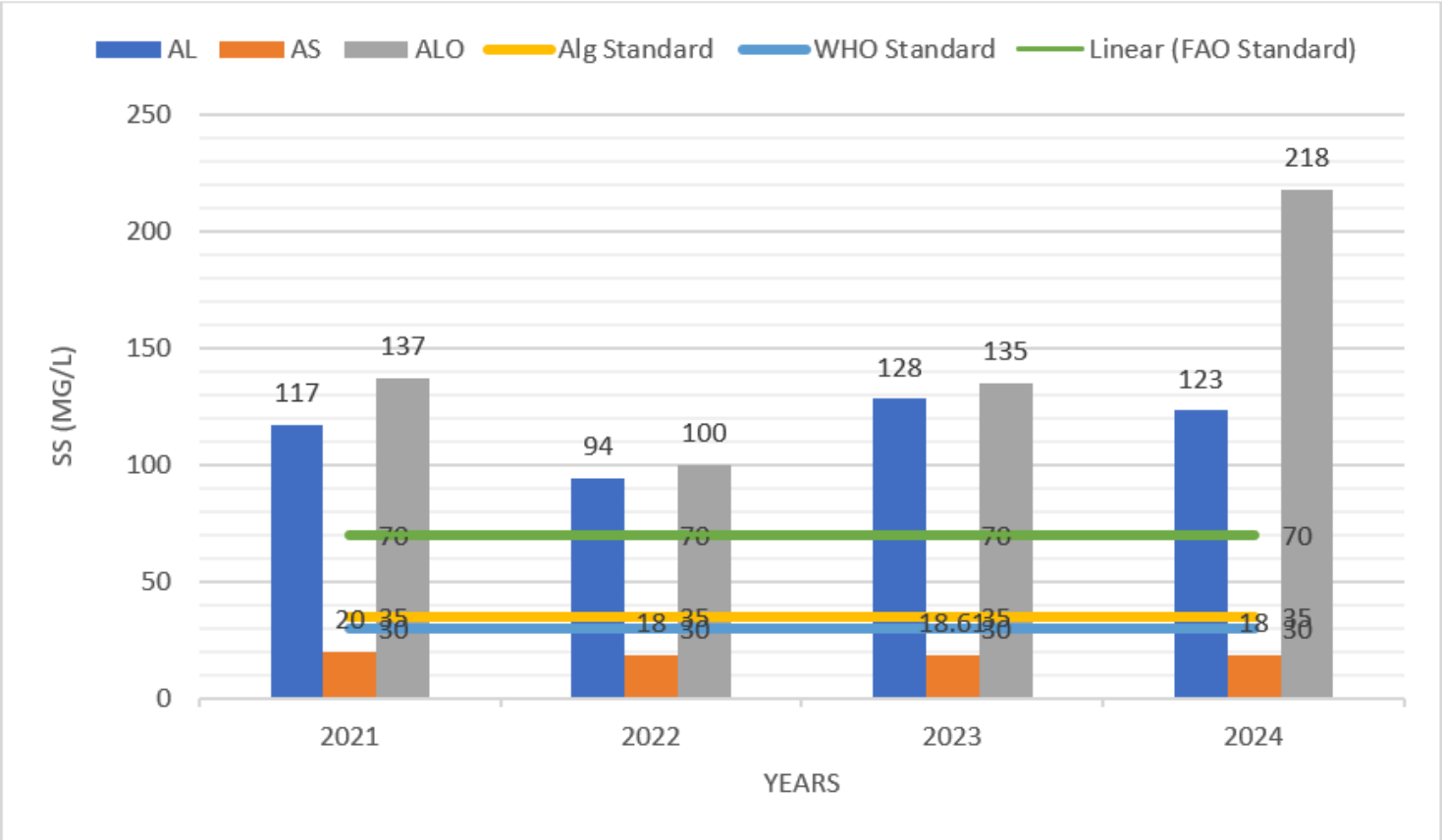


Figure 7

the SS values at the stations' outputs for the three processes.