Correlation Between Biochemical Oxygen Demand And Chemical Oxygen Demand, At High Salinity Bioreactor-Based, Wastewater Treatment Plant In Al-Hasa Saudi Arabia.

Majeb Alotaibi[1, *], Faris Munshi[1], Ashraf Refaat[1], Mohamed El Said[2], Mohd Nasir[3]

[1]Department of civil and Environmental Engineering King Saud University, Saudi Arabia.

[2]Assistant lecturer, Housing and Building National Research Center Kairo Egypt.

[3]Department of Chemistry (Industrial Chemistry division) Aligarh Muslim University, India

Research Article

Open Access &

Peer-Reviewed Article

Doi:10.14302/issn.2769-2264.jw-23-4694

Corresponding author:

Majeb Alotaibi, Department of civil and Environmental Engineering King Saud University, Saudi Arabia.

Keywords:

Membrane bioreactor, Industrial effluents, Biodegradability index.

Received: July 28, 2023

Accepted: August 18, 2023

Published: October 25, 2023

Citation:

Majeb Alotaibi , Faris Munshi , Ashraf Refaat , Mohamed El Said , Mohd Nasir (2023).Correlation Between Biochemical Oxygen Demand And Chemical Oxygen Demand, At High Salinity Bioreactor-Based, Wastewater Treatment Plant In Al -Hasa Saudi Arabia. Journal of Water. 1(2):35-47. https://doi.org/10.14302/issn.2769-2264.jw-23-4694

Abstract

This study aims to determine an empirical relationship between the biological and chemical oxygen demands of industrial effluent running through the membrane bio reactor-based Al-Hasa common industrial wastewater treatment Plant. The relationship between these two parameters was investigated over one month (NOV– 2021 to OCT-2022). The values of R^2 show that its impossible to predict the result of BOD5 based on COD, however the result of r in AUG month shows a strong relation between them. The average biodegradability index over the one year is less than 0.6, showing that effluent is highly polluted, and biodegradation will not proceed. The plant's performance in terms of BOD5 and COD removal was very poor over the whole year, however, the months AUG ,SEP and OCT months shows a satisfactory performance, this is because a large amount of Industrial wastewater entering the plant contains both organic and inorganic components.

Introduction

The untreated discharge of effluents from industrial, agricultural, and home activities poses a severe hazard to surface water bodies in developing nations [1]. Wastewater from industries must be strictly cleaned and discharged to the standard necessary to enhance the ecological and economic benefits to achieve zero pollution in industrial production and establish a green ecological industry, hence it is important to identify and eliminate any risks associated with wastewater before discharging it into water bodies [2],[3].

In underdeveloped nations, more study has been conducted in recent years on wastewater treatment utilizing straightforward, affordable, and user-friendly methods, such as activated sludge, aerated lagoons, stabilization ponds, natural and artificial wetlands, trickling filters, and rotating biological contactors (RBCs)

[4].The earliest wastewater treatment procedures were developed in response to the undesirable impacts of wastewater discharge on the environment and public health [5]. Sewage treatment plant(STP) plays a vital role in the process of removing the contaminants from wastewater to produce liquid and solid (sludge) suitable for discharge to the environment or for reuse, many countries in the world contain l imited freshwater re-sources, and hence, after proper treatment of wastewater can be reused for agricultural purposes [6].

The important parameters analyzed to indicate the wastewater's pollution degree are Biochemical oxygen demand(BOD5) and Chemical Oxygen demand(COD) [7]. These two criteria have benefits and drawbacks and the choice is usually based on several considerations, including the results' reproducibil-ity, necessity, and the location of the test [2]. COD values are generally bigger than BOD5 levels, and the ratio between these two parameters varies depending on the different properties of wastewater, this ratio is frequently employed as a biodegradation capacity indicator and it is known as the biodegradability Index (BI), which is considered as the cut-off point between biodegradable and non-biodegradable wastewater [8]. The COD test may be used to forecast BOD5, once a BI for the plant wastewater stream has been determined, the BOD5 to COD ratio is normally 0.5:1 for household wastewater that has not been stabilized, and it may be as low as 0.1:1 for secondary effluent, for various forms of wastewater the BOD5/COD has no defined value [2]. The levels of BOD5 and COD in wastewater might offer potential pollution to aquatic bodies in which they are discharged, the wastewater may be treated biologically with ease if the ratio is larger than or equal to 0.5, and the wastewater may include some hazardous components or adapted microorganisms may be needed for a breakdown if the ratio is less than 0.3 [8]. (Table 1 shows the BI values of different wastewater)

Membrane-based Al -Hasa wastewater treatment plant (WWTP) has been established to treat different wastewater discharges coming from different industries such as soap and detergent production, food and beverage production, textiles, apparel production, building materials production, timber, metals production, chemicals, and plastics production. Therefore, in the current study, the main aim is to determine and establish an empirical relationship between BOD5 and COD by evaluating the correlation coefficient (r) and coefficient of determination (R^2) as well as to calculate the monthly variation of BI, and the performance of the WWTP .

Materials and Methods

WWTP is in Al-Hasa Industrial 1st City on the Dammam expressway north of Al-Hasa province. (Fig 1 represents the flow diagram of the plant). This city serves different types of industrial factories

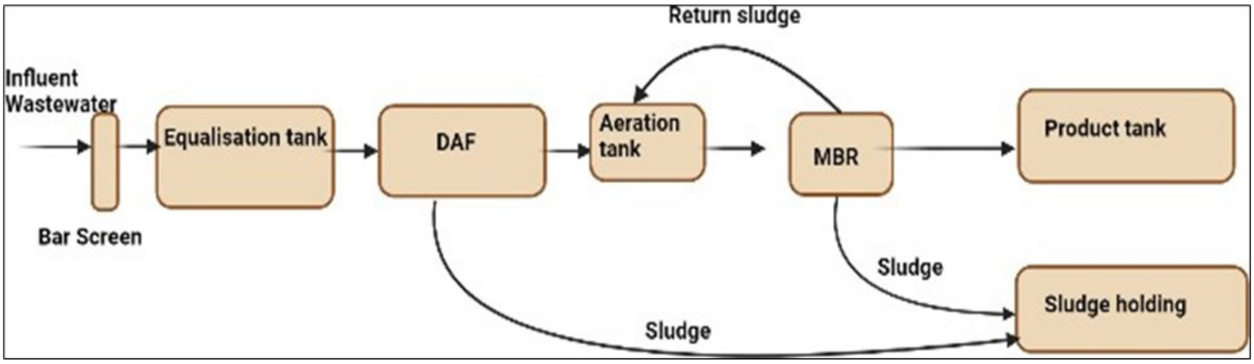

Figure 1.Working of Al-hasa wastewater treatment plant

Table 1.BI of different wastewater.

BI	Type of wastewater	Remark	References
<0.50	Dairy wastewater	Poor biodegradability	[9]
0.48	Municipal wastewater	Poor biodegradability	[10]
0.69	Municipal wastewater	Fair biodegradability	[11]
>0.60	Industrial wastewater	Fair biodegradability	[12]
0.23	Industrial wastewater	Non-Biodegradability	[13]

including paper, chemical, food, and plastic businesses as well as minor quantities coming from the city's residential area. WWTP plant with 1500 m³/day was installed using combined technology-activated sludge with membrane bioreactor (MBR). The influent wastewater passes through a manually cleaned bar screen which removes coarse particle matter, and before being sent to the equalization tank a hand rake is used to physically clean the screen and neutralize the tank effluent before it flows to the next treatment stage, an automatic online pH adjustment device is installed at the equalization tank's output (Dissolve air floatation unit). The output from the dissolved air floatation is fed through a fine screen to filter out the small particles, the output from the fine screen enters a distribution box with two similar outlet streams that feed two identical bioreactor tanks, together with recycled-material from the MBR tanks, an MBR tank is followed by an active sludge aeration tank, in each of the two treatment lines that come after. The treated water tank receives a pumping of the permeation from the MBR tank, and sludge recycling pumps gather the sludge from the MBR tank and separate it into recycled activated sludge and waste-activated sludge.

Aim of Study

This study aims to determine and evaluate the correlation between BOD5 and COD by calculating the R2 and r, mean (x), and standard deviation (SD) and to calculate the BI of each month as well as to evaluate the performance of the plant in terms of BOD5 and COD removal. Microsoft Excel spreadsheets were used for all data statistical analysis. The 95% confidence intervals we

Data Analysis

For four months, including the summer (NOV- 2021 to DEC- 2021) and winter (JAN -2022 to FEB - 2022) seasons, composite samples were taken from the effluent tank of the Al-Hasa wastewater treatment plant. Before collecting the wastewater sample, the water bottle was washed with KMnO4. The estimation of several physicochemical characteristics required the immediate transfer of the wastewater samples to the laboratory.

Sampling methods

The data of this study has been analyzed from the Al- Hasa common industrial wastewater treatment plant for one year NOV-2021 to OCT- 2022, following the standard methods (APHA) [14].

Statistical Analysis

Standard techniques and statistical measures like mean, SD, R^2, and r were used to determine the COD and BOD5 relation in the samples. Microsoft Excel spreadsheets and origin lab were used for all statistical data analysis. The 95% confidence intervals were used.

Coefficient of Determination(R^2)

The coefficient of determination is a word used in regression analysis and analysis of variance (often

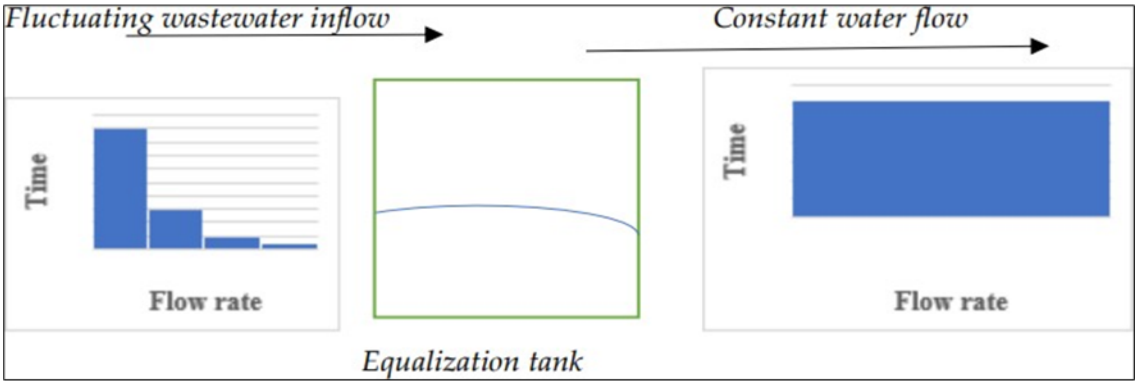

Figure 2. Working of Equalization unit

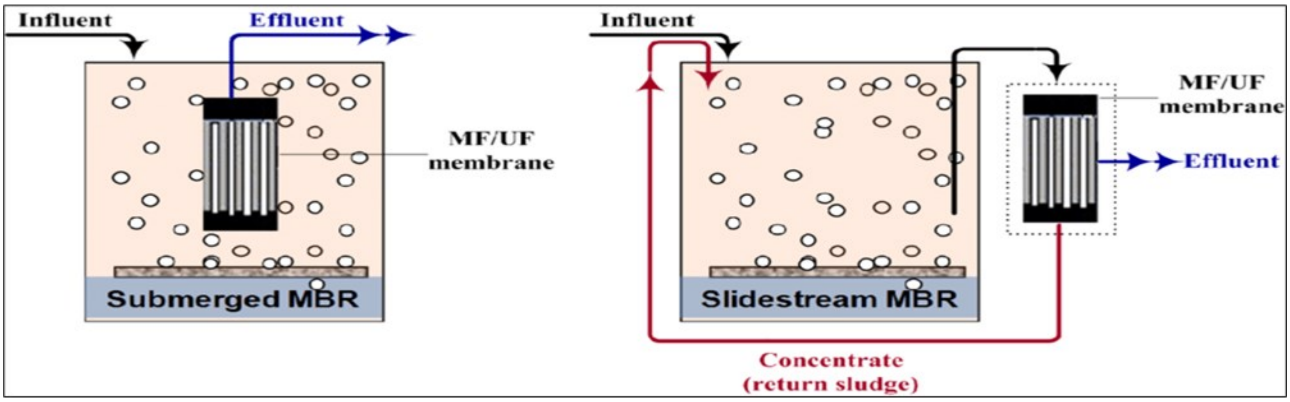

Figure 3. Working of a Membrane bio reactor.

abbreviated R^2)[15]. In traditional regression analysis the usage of R^2, also known as the multiple correlation coefficient, is well-established and its usefulness as a gauge of the effectiveness of predicting the dependent variable from the independent variables is derived from its definition as the proportion of variance "explained" by the regression model [16].

R^2 is a coefficient of determination that assesses the goodness of fit by calculating the proportion of explained variance from the regression equation vs the variance indicated by simply taking the mean value y that is mentioned by x "[17].

Correlation Coefficients(r)

Correlation coefficients describe the strength and direction of an association between variables[18]. The relationship between the two variables is referred to as the correlation and is measured with a value that ranges from -1 to +1. Zero denotes a lack of connection, +1 denotes a full or ideal correlation, and -1 denotes a weak correlation. The correlation's strength rises from 0 to +1 and 0 to -1[19]

Description of each treatment unit-

Equalization tank-

In WWTP, equalizations tanks are generally built, because their primary purpose is to serve as a barrier, to gather the incoming raw wastewater, which is delivered at wildly varying rates, and transport it to the other parts of the effluent treatment plant at a constant flow rate (Figure 2. represents the working of equalization tank)[20].

Membrane bio reactor(MBR)

MBR (Fig is a biological process combined with membrane filtration in this instance, where the breakdown of the biomass takes place inside the bioreactor tank and the membrane module completes the separation of the treated waste water from microorganism [22].

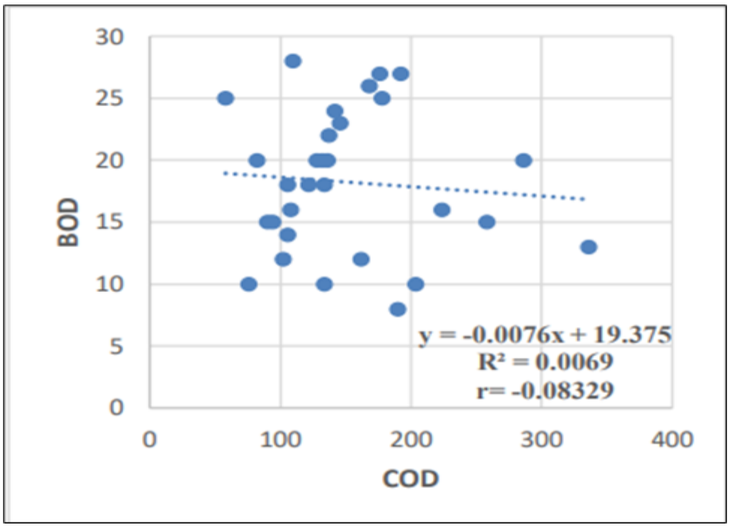

Figure 4. Regression analysis of NOV month

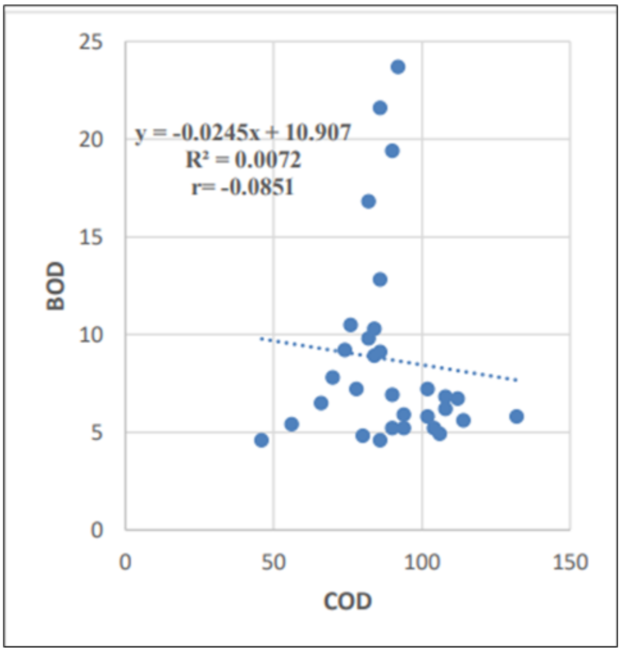

Figure 5. Regression analysis of DEC month

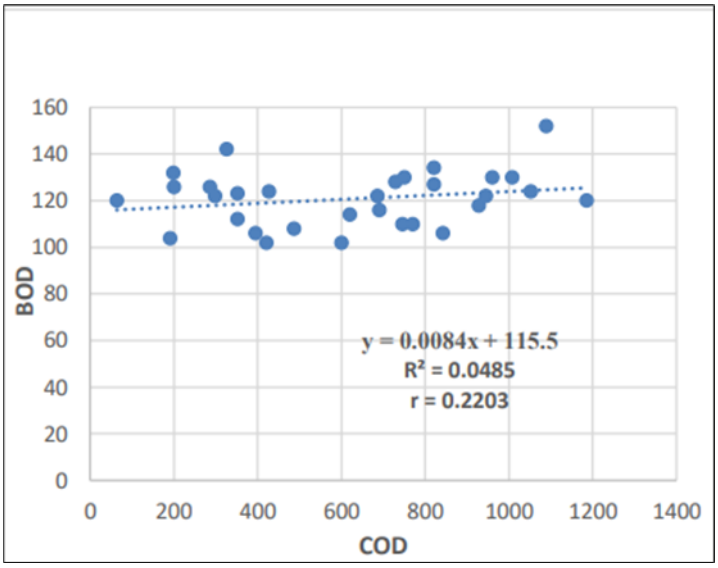

Figure 6. Regression analysis of JAN month

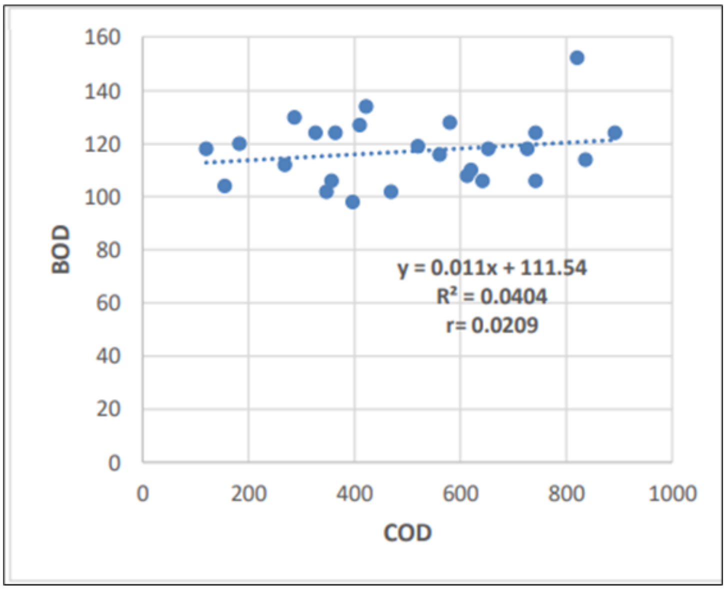

Figure 7. Regression analysis of FEB month

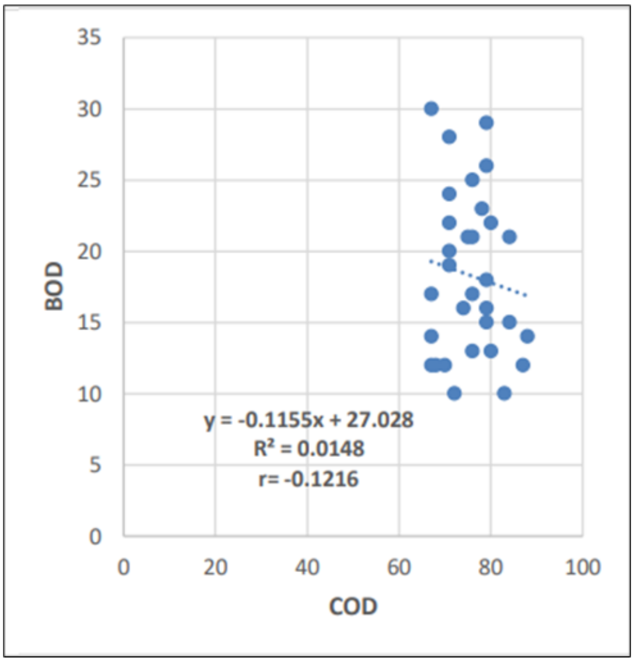

Figure 8. Regression analysis of MAR month

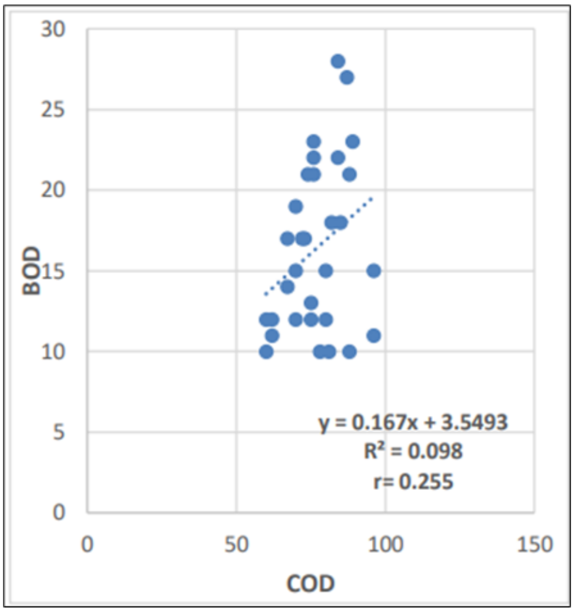

Figure 9. Regression analysis of APR

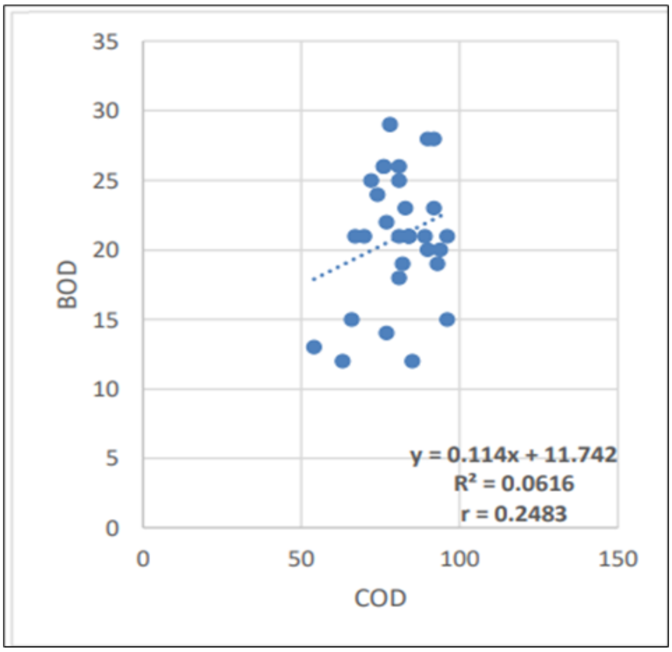

Figure10. Regression analysis of MAY month

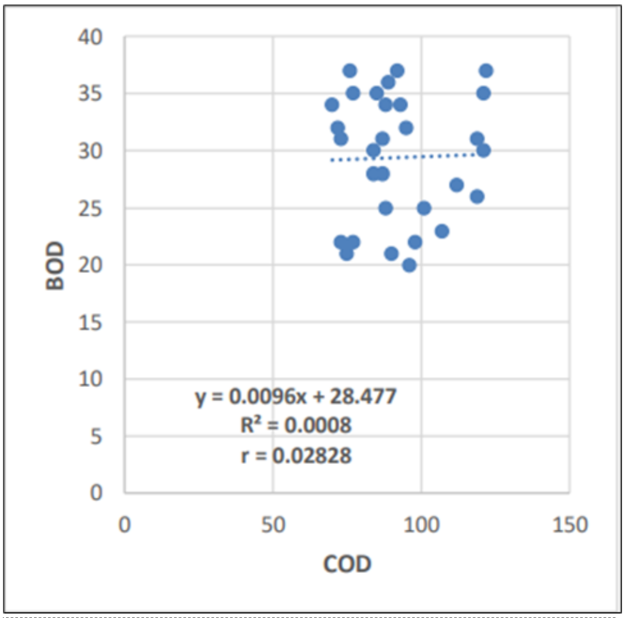

Figure 11. Regression analysis of JUN month

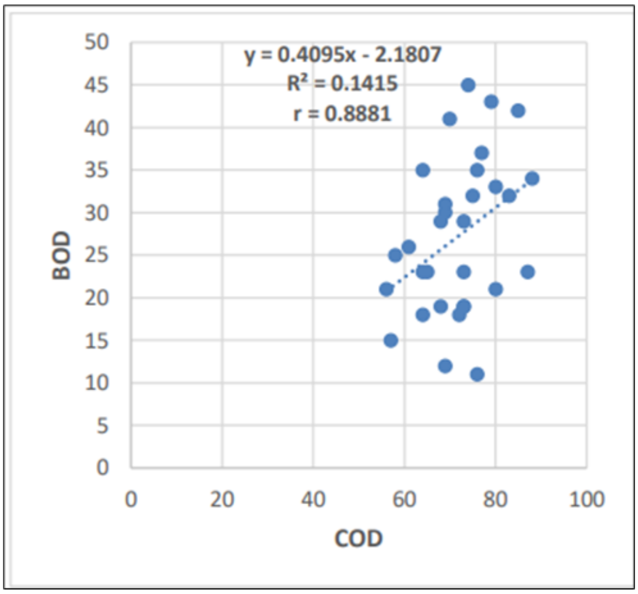

Figure 12. Regression analysis of JUL month

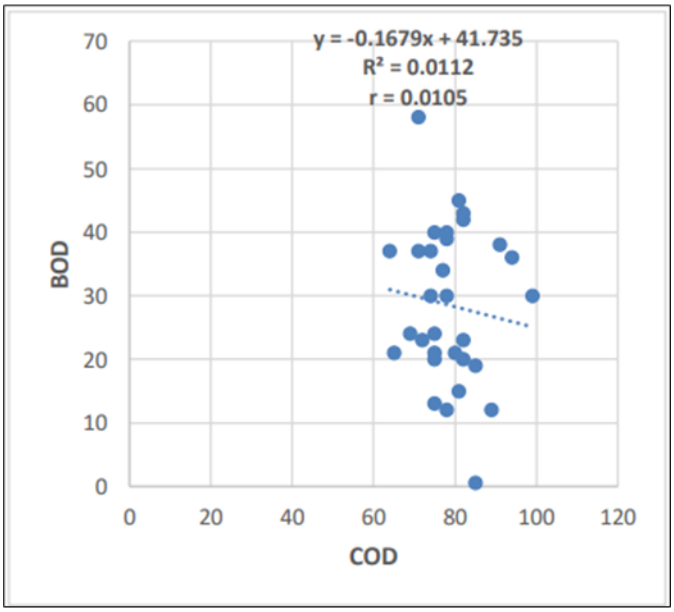

Figure 13.Regression analysis of AUG month

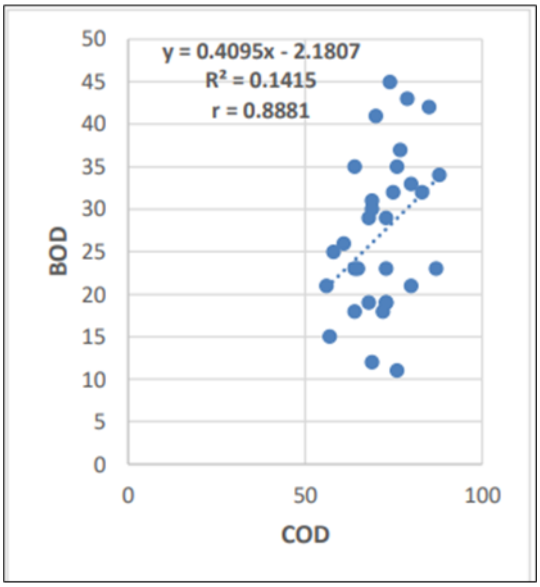

Figure 14. Regression analysis of SEP month

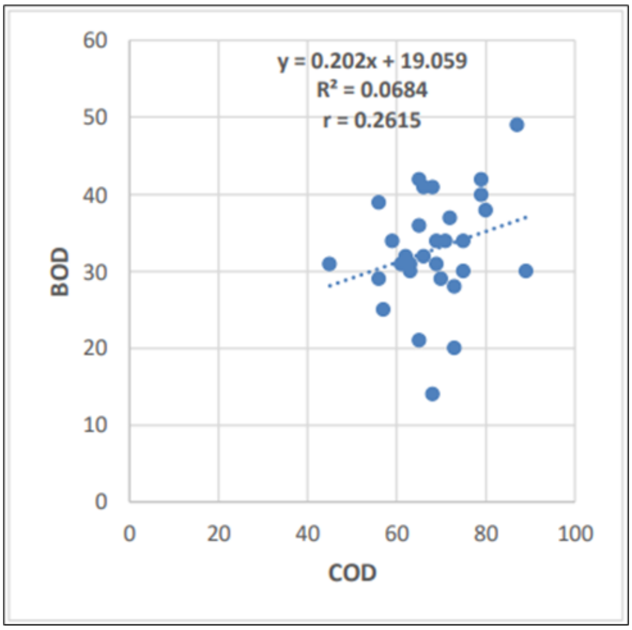

Figure 15. Regression analysis of OCT month.

Table 2. Regression Equations between effluent COD and BOD5 with values of R^2 and r from NOV 2021-OCT 2022

Months	R^2	r	Regression Equations
NOV	0.0069	-0.083	y = -0.0076x + 19.375
DEC	0.0072	-0.0851	y = -0.0245x + 10.907
JAN	0.0485	0.2203	y = 0.0084x + 115.5
FEB	0 .0404	0.2009	y = 0.011x + 111.54
MAR	0.0148	0.1216	y = -0.1155x + 27.028
APR	0.098	0.255	y = 0.167x + 3.5493
MAY	0.0616	0.2483	y = 0.114x + 11.742
JUN	0.0008	0.02828	y = 0.0096x + 28.477
JUL	0.0009	0.0003	y = -0.0005x + 67.09
AUG	0.145	0.8881	y = 0.4095x - 2.1807
SEP	0.0684	0.2615	y = 0.202x + 19.059

Table3. Removal efficiency

Duration	BOD5 (mg/l)		COD(mg/l)		BOD removal efficiency	COD removal efficiency
	Inlet (AVG)	Outlet (AVG)	Inlet (AVG)	Outlet (AVG)		
NOV-2021	211.3	18.03	427.8	150.56	91.03%	64.80 %
DEC-2021	137.70	8.72	427.70	89.03	93.66%	79.18 %
JAN-2022	211.43	161.56	559.26	520.20	23.58%	7.03%
FEB-2022	211.53	116.71	567.53	496.85	23.62.%	12.45 %
MAR-2022	206.12	18.29	352.28	69.42	91.12%	80.29 %
APR-2022	150.06	16.65	1145.73	77.68	88.90%	93.22 %
MAY-22	164	20.96	969.16	80.90	87.21%	91.65 %
JUN-2022	175.43	29.36	1140.8	92.36	83.26%	9.85.%
JUL-2022	866.16	24.26	180.77	67.09	97.19%	62.88 %
AUG-2022	177.0	27.22	177	27.22	85.01%	84.62 %
SEP-2022	190.4	32.83	783.46	68.2	82.75%	91.29 %
OCT-2022	156.51	28.53	781.35	78.61	81.77%	89.93 %

Correlation

The correlations relation are indicated as below in following figures

Table 3, illustrates the R2, r, and regression equation. The value of r from NOV-2021 to OCT-2022 indicates a weak correlation between them, resulting in difficulties in predicting the BOD5 results depending on COD. However, in contradiction the AUG-2022 result shows a strong correlation of r = 0.8881, As BOD5 and COD have a good association, it is simple to anticipate the BOD5 results based on COD in this month. On the other hand, Figure. 4-15 display the correlation between BOD5 and COD of industrial wastewater using the equation of y = MX + c. The confidence interval for the slope in fig 6,7 indicates that 95% confidence in the BOD5 value resides between 14.4 mg/l to 18.3 mg/l and 1.0 mg/l to 13.2 mg/l of BOD5 for months NOV and DEC-2021 respectively, the R2 values reveal that more than 0.69% and 0.72% of the total variance is above the mean of 18.03 mg/l and 8.72 mg/l BOD for the months NOV and DEC-2021 respectively. Whereas for the month of JAN to FEB-2022 at a 95% confidence interval, BOD5 lies between 111.5 to 112 mg/l and 111 to 120 mg/l respectively, and the R2 values reveal that more than 4.85% and 4.04% of the overall variance exceeds the BOD mean 161.5 mg/l and 116.71 mg/l of JAN and FEB-2022 respectively (Fig 8,9). On moving for- ward in the months of MAR ,APR and MAY-2022, values of BOD5 at the same confidence interval lies between 16.24 mg/l to 20.33 mg/l ,14.74 mg/l to 18.52 mg/l and 19.29 mg/l and 22.26 mg/l respectively, and the R2 values shows that more than 1.48% ,9.8% an d6.16 %of the total variance is greater than 18.29 mg/l and 16.65 mg/l respectively. In a similar way months from JUN- to AUG-2022 shows a similar trend ,as per the R2 values more than 0.08%, and 14.15% of the total variance are above the BOD5 mean of 29.36 mg/l, 24.26 mg/l, and 27.22 mg/l, respectively. Finally in months of SEP and OCT-2022 the R2 value depicts that 6.84% and 1.11% of the total variance is greater than the 32.83 mg/l, 28.53mg/l respectively.

These correlations are in accordance with the findings of previous studies, Thambavani ,et al. 2008 [25] evaluates samples from OCT- 2010 to MAR-2021 to determine the relationship between COD and BOD5 of sugar mill effluents, they concluded that both parameters in sugar mill effluents had r of -0.94, indicating a very significant negative correlation between them. Although the R2 reveals a value of 0.88,showing a strong connection between them.

Similar to this, Ahmad ,et al. [26] their study determines a strong link by calculating the R2 between BOD5 and COD of influent samples from the Al Diwaniya WWTP from JAN- 2016 to MAR -2016. The R2 from JAN- 2016 to MAR- 2016 was 0.92, 0.97, 0.90, and 0.77, indicating a stronger correlation between BOD5 and COD. Dahamsheh ,et al. [12] also finds the relationship between the inlet BOD5 and inlet COD of the industrial WWTP at Al-Hussein bin Talal University, the average correlation between the BOD5 inlet and COD inlet, which was determined after collecting the 200 water samples over three years, was R2 = 0.0068, indicating a very weak correlation between them. A similar study was also carried out by Venkatesh, et al. [27] to establish a correlation between BOD5 and COD by collecting domestic sewage; they observed r of 0.98, showing a strong correlation. Whereas a coefficient of determination study was carried out by Haleem, et al.[28] , by taking the samples from the Tigris River in Iran the value of R2= 0.91 shows a strong correlation between the BOD5 and COD. Daniel, et al.[13] con- ducted a similar investigation by collecting the industrial effluent from a wastewater treatment plant in Rome and found that BOD5 and COD had a good association, with an R2 of 0.98 and r = 0.99 showing a strong correlation between them.

Removal efficiency

In terms of effluent quality, the performance and effectiveness of the Al -Hasa WWTP were assessed. Based on measurements of BOD5 and COD taken during plant operations over one year (NOV- 2021 to OCT- 2022) the evaluation was made.

BOD5 removal efficiency

The results in Table shows that, MAR-2022 had the good BOD5 removal efficiency of 91.52%, compared to all other months, however the result of JAN and FEB -22 had the lowest removal efficiency of 23.58% and 23.62% respectively. This low removal efficiency of plant may be due to the excessive organic loading coming to the influents. High or fluctuating salinity were also observed in the effluents of this plant ,which poses a challenge to biological treatment processes, and it is the major cause of plant failure[29].

This analysis was supported by Ali,et al.[30] in Haridwar, India, at an MBBR-equipped common wastewater treatment facility, where 77% of BOD was removed, demonstrating the plant's moderate removal effectiveness. Sundara, et al.[31] also conducted a study at the Nesapaka STP by using activated sludge, this study endured 6 months (JUN -2009 to NOV -2009), and each month they observed a removal efficiency of more than 90% for BOD5, demonstrating the plant's good performance. In addition, Iwano, et al.[32] conducted research to evaluate the efficacy of treating industrial wastewater, this study was conducted at the mechanical-biological wastewater treatment plant in Bystre near Giycko, which receives a mixture of household and dairy wastewater for one year, they found that the plant has an excellent removal efficiency of 97.86% to 99.75% for BOD.

COD removal efficiency

Results shows that JAN- 2022, had low COD removal efficiencies of 7.03% followed by FEB and JUN-22. While MAY-2022, as compared to other months, had the best COD elimination efficiency of 91.22%. Ahmad, et al. [34] conducted a similar study in Tehran using wastewater from a petroleum refinery by using the activated sludge, they observed a 96% COD removal efficiency, showing the plant's good performance. Additionally, a three-year (2006-2008) study by Abma, et al. [35] was carried out at the Olburgen wastewater treatment facility in the Netherlands to evaluate the efficiency of COD removal, for the following three years, they found removal efficiencies of 46%, 67%, and 56%,

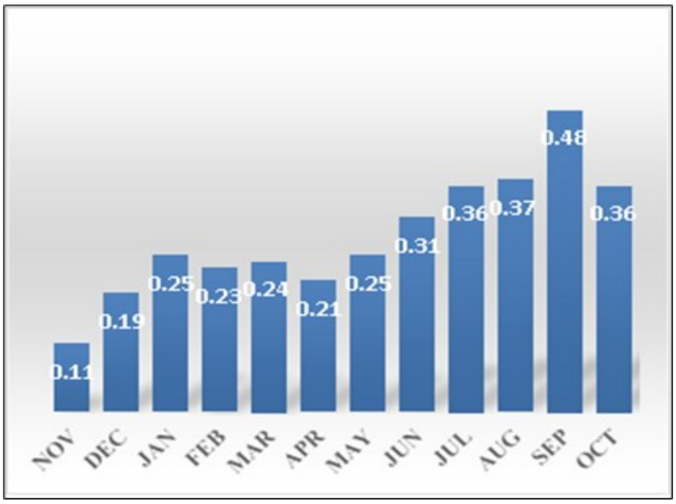

Figure 16. Monthly variation of BI

respectively, demonstrating the plant's moderate removal efficiency. Ashutosh, et al.[36] did an analysis like this one based on removal efficiency at Kaithal, India, from JAN- 2014 to APR- 2014, they found that the plant was operating at a good removal efficiency of 90.84% of COD.

Biodegradability Index

Figure 16. represents the monthly variation of BI of the effluent from the Al-Hasa WWTP. From the month of NOV- 2021 to OCT-22 ,BI lies under the 0.5, this shows that the effluent still does not meet disposal criteria even after the current treatment, necessitating additional treatment options .This finding shows that the treated effluent quality is poor and the current treatment plant is completely unable to raise the effluent requirements to a disposable condition.

Conclusions

Based on the outcomes of the analysis, it is determined that the COD level of the effluent is significantly higher than the BOD5 level due to the different industrial wastewater discharges, which may be the cause of the high-level effluent characteristics concentration, consequently, this causes the sample to have more oxidizable organic material, which decreases the concentration of dissolved oxygen and creates anaerobic conditions that are detrimental to higher aquatic life.

The results of R2 in whole year shows that it is impossible to estimate the results of the BOD5 value based on the COD result. Similarly, the value of the r also shows the same trend except in AUG-2022 which shows a r of 0.88 ,a strong correlation between BOD5 and COD hence we can estimate the results of BOD5 based on COD .BI in all the months from NOV- 2021 to OCT- 2022, the treated effluent of the plant has a BI of less than 0.6, hence biodegradation will not proceed, this because of the different types of industrial influents generated, which inhibits the metabolic activity of bacteria, thus effluent of this plant cannot be treated biologically.

The BOD5 removal efficiency of plant for one year was satisfactory, except in the months of JAN and FEB-2022. Similarly, COD removal efficiency is also good except the months of JAN,FEB and JUN-2022 having the poor removal efficiency. This is due to the influences from the different industries which are comprised of different organic and inorganic components having large amount of salinity.

Acknowledgment

Authors are highly thankful to King Saud University.

References

1. Haydar,S.; Hussain,G.; Nadeem,O.; Haider,H.; Bari, and A. Hayee,(2014) Performance Evaluation of Anaerobic-Aerobic Treatment for the Wastewater of Potato Processing Industry: A Case Study of a Local Chips Factory Treatment of Stormwater for Artificial Groundwater Recharge-Application of a Low-cost Ceramic Filter View project," J. Engg. Appl. Sci, January, 14, 27–37.

2. Zaher,K.; Hammam,G.;(2014) "Correlation between Biochemical Oxygen Demand and Chemical Oxygen Demand for Various Wastewater Treatment Plants in Egypt to Obtain the Biodegradability Indices," Int. J. Sci. Basic Appl. Res. 1, 42–48.

3. Mustafa,G.; Hayder,G.; Solihin,I. Saeed. (2021)"Applications of constructed wetlands and hydroponic systems in phytoremediation of wastewater," IOP Conf. Ser. Earth Environ. Sci. 708, 1.

4. Chen,H.; Lin,Y; J,Fanjiang.; Fan,C.(2013) "Microbial community and treatment ability investigation in AOAO process for the optoelectronic wastewater treatment using PCR-DGGE biotechnology,"Biodegradation, 24, 2,227–243.

5. Salvi,S; Patil,P.(2021) "a Case Study on Sewage Treatment Plant 1," International journal of creative research and thoughts . 9, 5,4216

6. Rajemahadik.,Mendapara,N(2020) ."Performance evaluation of sewage treatment plant (STP)—a case study," Lect. Notes Civ. Eng., 57,10, 55–165.

7. Othman,F.; Sadeghian,S.; Ebrahimi,F;. M. Heydari, (2013)"A Study on Sedimentation in Sefidroud Dam by Using Depth Evaluation and Comparing the Results with USBR and FAO Methods," Int. Proc. Chem. Biol. Environ. Eng. 51, 9, 6.

8. Sulaiman,A.; Khudair,B.;(2018)"CORRELATION BETWEEN BOD5 AND COD FOR AL- DIWANIYAH WASTEWATER TREATMENT PLANTS TO OBTAIN THE BIODIGRABILITY INDICES," 15, 2,1–23 .

9. Leena,A.; Meiaraj,C.; Balasundaram, N(2016). "BOD/COD a Measure of Dairy Waste Treatment Efficiency-A Case Study," IOSR J. Mech. Civ. Eng., 13, 5, 107–114.

10. Elatmani,A.;Elhammoumi,P.;Sibari, M.Elguamri,Y.(201 7) "Prediction of biodegradability ratios in wastewater treatment plant of Skhirat Morocco," Int. J. Environ. Agric. Res. ISSN, 3,12, 6.

11. Sulaiman,A.; Khudair,B.;(2020)"Correlation Between Bod5 and Cod for Al- Diwaniyah Wastewater Treatment," Pak. J. Biotechnol. Vol. 15 423-427 www.pjbt.org, 5, 3, 248–253.

12. Dahamsheh,A.; Wedyan,A.;(2017) "Evaluation and assessment of performance of Al-Hussein bin Talal University (AHU) wastewater treatment plants," Int. J. Adv. Appl. Sci. 4, 1, 84–89.

13. Rudaru,D.; Lucaciu,I.; Fulgheci,A.;(2022) "Article Correlation between BOD 5 and COD – biodegradability indicator of wastewater DANIEL-GHEORGHE RUDARU, IRINA EUGENIA LUCACIU * , ANA-MARIA FULGHECI," 4, 2, 80–86.

14. T. Nineteenth and E. Editions, "Standard methods for the examination of water and wastewater: 20th ed," 37, 05, 37.

15. Bucchianico,D Wiley Stats reference; statistics reference online, Nether land: Wiley, 2008.

16. Nagelkerke,N.;(2008) "A Note on a General Definition of the Coefficient o Determination Miscellanea A note on a general definition of the coefficient of determination," 78, 3, 691–692.

17. Skiera,B.; Reiner,J.; Albers,S;. "Regression Analysis," no. September, 2018.

18. Silva,J.; "What is R2 all about ?," 60–68.

19. Schober,P.; Boer,C.; Schwarte,l.;(200* "Correlation Coefficients: Appropriate Use and Interpretation," 1–6.

20. Raji,N,; Olaleye,J.; Ogunleye,R.; Anibaba,R (2018)"Development of Equalization Tank for flow rate attenuation in small scale Wastewater Treatment System," Eng. Technol. Res. J.,3, 1,11–15.

21. K. Englande, A; Peter,(2020) Wastewater Treatment &Water Reclamation.

22. Al-Asheh,S.; Bagheri,M.; Aidan,A.;(2021) “Membrane bioreactor for wastewater treatment: A review,” Case Stud. Chem. Environ. Eng.,4.

23. Rahman,T.; Roy,H.;Riyazul,islam. ;Tahmid,M. ;Fariha,A. ;Mazuder,A. ;Tasnim,N. ;Parvez,N. ;Islam,S.(2023) “The Advancement in Membrane Bioreactor (MBR) Technology toward Sustainable Industrial Wastewater Management,” Membranes (Basel).13, 2.

24. Hai,F.; Alturki,A.; Nguyen,L.;(2016) Price.; Nghiem, Removal of trace organic contaminants by integrated membrane processes for water reuse applications.

25. Thambavani,D.; Sabitha,M.;(2008) “Multivariate statistical analysis between COD and BOD of sugar mill effluent,” Sch. J. Math. Comput. Sci. 1, 6–12.

26. Sulaiman,A.;Khudair,B.;(2018) “Correlation Between Bod5 and Cod for Al-Diwaniyah Wastewater Treatment Plants To Obtain the Biodigrability Indices,”J. Biotechnol, 15, 2, 423–427.

27. Venkatesh,K.;Rajendran,M.;Murugappan,A.;(2009) “Correlation Study on Physico-Chemical Characteristics of Domestic Sewage,” 8.

28. Alewi, H., Abood,E.; Ali,G(2022) “An inquiry into the relationships between BOD 5 , COD , and TOC in Tigris River , Maysan Province , Iraq,” 20, 1, 37–43.

29. Yogalakshmi,K.; Joseph,k.;(2010) “Effect of transient sodium chloride shock loads on the performance of submerged membrane bioreactor,” Bioresour. Technol. 101,18, 7054–7061.

30. Ali,M.; Almohannaa,A.;Alali,A.; Kamal,M; Khursheed,A.;Kazmi,A(2021) “Common Effluent Treatment Plants Monitoring and Process Augmentation Options to Conform Non-potable Reuse,” 9, 1–16.

31. Sunadar Kumar.;(2010) “Performance Evaluation of wastewater treatment plant,” Int. J. Eng. Sci. Technol., no. , 9–12.

32. Skoczko,I.; Sokołowska,J.; Ofman,P.;(2017) “Seasonal changes in nitrogen, phosphorus, bod and cod removal in bystre wastewater treatment plant,” J. Ecol. Eng., 18, 4,185–191.

33. Wakode,P.; Sayyad,S(2014) “Performance Evaluation of 25 MLD Sewage Treatment Plant (STP) at Kalyan,” 03.

34. Mirbagheri,S.; Ebrahimi,M.; Suburban.;W .; Mohamadi.;(2014) “wastewater using activated sludge contact stabilization process Desalination and Water Treatment Optimization method for the treatment of Tehran petroleum refinery wastewater using activated sludge contact stabilization process,”.

35. Abma,W.;Driessen.;Haarhuis,R.;(2010) Loosdrecht,V “Upgrading of sewage treatment plant by sustainable and cost-effective separate treatment of industrial wastewater,” 1715–1722.

36. Pipraiya,A.;(2017) “Performance Evaluation of Sewage Treatment Plant Based on Mbbr Technology - a Case Study of Kaithal Town Haryana India,” Int. J. Adv. Eng. Res. Dev.,4,06,10689–1069