Applied Water Science (2023) 13:74
https://doi.org/10.1007/s13201-023-01877-7

ORIGINAL ARTICLE

Experimental study of the biological treatment process of the exit wastewater from flocculation reactor

Alireza Baghizade[1] · Farshad Farahbod[2] · Omid Alizadeh[1]

Received: 17 October 2022 / Accepted: 17 January 2023 / Published online: 4 February 2023

Abstract

This study investigates biological treatment of outlet wastewater from flocculation reactor. This stream has an unpleasant odor. So, a biological treatment unit has been used to separate biological contaminants. Results show that 35 min can be considered as optimum oxygen injection time. Results show that the reduction of nitrate and phosphate is 67% and 60.8% with increasing oxygenation time, respectively. Results show that BOD and COD decrease by about 1.8% and 1% with increasing oxygenation time from 35 to 40 min, respectively. Studies show that organic carbon and petroleum hydrocarbons decrease from 20.1 to 4.8 mg/l and 0.14–0.4 mg/l by increasing oxygen injection time from 5 to 35 min, respectively. Results show that wastewater turbidity decreasing is from 4.3 NTU to 2.1 NTU in biological unit. Results show that range of pH is between 9.9 and 10.4.

Keywords Saline wastewater · Biological treatment · Microorganism · pH · BOD · COD

Introduction

Industrial wastewater treatment is done in several stages. These steps include physical, chemical and biological treatment (Ebrahimi et al. 2018). Suspended solids in wastewater are removed by means of screening processes (Farahbod 2022). Also, colloidal particles and hydrocarbons in wastewater are collected using chemical and physical methods (Ines et al. 2019). These methods are not able to remove organic compounds. So, only solution is biological methods (Farahbod 2020a). The biological methods can be used to treat wastewater due to excellent performance (Francisco et al. 2020). Today, biological methods are used to treat industrial and municipal wastewater in different countries (Farahbod 2020b). The biological treatment of wastewater is designed based on removal of organic compounds and microorganisms (Mohammad et al. 2021). A biological process is performed if aerobic and anaerobic microorganisms are removed by organic compounds (Taherizadeh et al. 2020). Microorganisms have different properties and their growth mechanism is different (Khan et al. 2020). Some microorganisms decompose organic compounds with oxygen (Zeynali et al. 2019). Eventually, they grow and multiply in this way (Farahbod 2020c). Another group of microorganisms in anaerobic conditions hydrolyze wastewater and produce acid, acetate and methane (Taherizadeh Mahmoud and Farahbod 2020). In fact, behavior of these bacteria in the face of oxygen has led to biological treatment process (Byeongwook et al. 2022). In addition, the main pollutants that can be removed by various biological methods are heavy metals, nitrogen, and phosphorus (Bian Xueying et al. December 2022; Feini et al. December 2022; Qambar Abdulaziz Sami AlKhalidy Mohammed Majid, 2022) (Fig. 1).

This research evaluates biological treatment of outlet wastewater from flocculation reactor. A biological treatment unit has been used to separate biological contaminants. The BOD, COD, phosphate, nitrate and pH of wastewater are measured in this work. This study shows that oxygen injection plays a significant role in the biological treatment of the exit wastewater from flocculation reactor.

✉ Farshad Farahbod
mf_fche@yahoo.com; Farshad.Farahbod@iau.ac.ir

[1] Department of Chemistry and Chemical Engineering, Rasht Branch, Islamic Azad University, Rasht, Iran

[2] Department of Chemical Engineering, Firoozabad Branch, Islamic Azad University, Firoozabad, Iran

Table 1 Characteristics of wastewater entering to the biological unit

Characteristics	Unit	Value
Turbidity	NTU	4.63
Nitrate	ppm	0.26
Phosphate	ppm	0.59
BOD	ppm	26.23
COD	ppm	67.45
TDS	ppm	743.9
pH		10.4
TOC	ppm	24.3
TPH	ppm	0.19

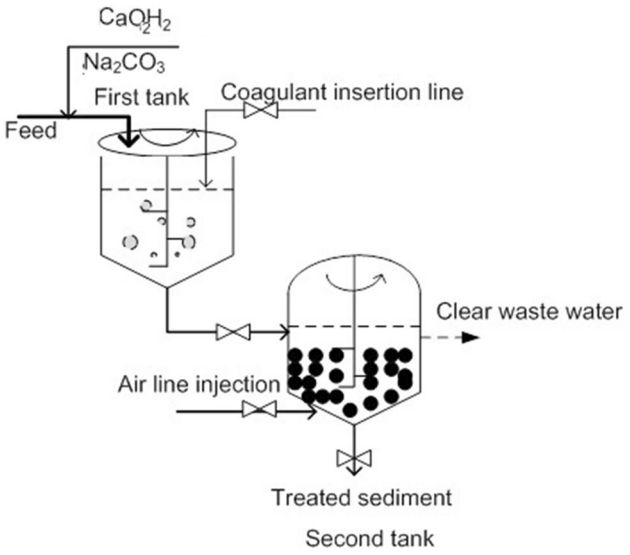

Fig. 1 Schematic of flocculation and biological reactors

Materials and methods

Study of biological treatment unit

The output stream from flocculation reactor has an unpleasant odor. So, a biological treatment unit has been used in this research. The microorganisms and bacteria decompose organic compounds using oxygen in biological unit. Oxygenation operation is performed using an oxygen blower. In this unit, main variables of the treatment process are measured. The variables of pH, COD, BOD, phosphate, nitrate, TOC, petroleum hydrocarbons, turbidity and TDS have been studied, experimentally. In this work, duration of oxygen injection is considered 40 min. Studies show, this time is suitable for decomposition of biological contaminants. The schematic 1 shows output stream from flocculation reactor. This stream is feed of biological reactor.

The model of oxygen generator is ACO-5503. The brand of oxygen generator is HAILEA. The power of oxygen generator is 4 W. This blower has two outlets for oxygen. The efficiency of this device is 2.5 lit/min and noise is less than 40 decibels.

Characteristics of the wastewater entering to biological reactor

The characteristics of the output stream from flocculation reactor that enters to biological reactor are presented in Table 1.

Results and discussion

The variables such as pH, COD, BOD, phosphate, nitrate, TOC, TPH, turbidity and TDS have been measured in this section. Finally, treatment efficiency has been evaluated.

Study of wastewater pH

Figure 2 shows the effect of oxygenation on pH of wastewater. Results show that the range of pH is between 9.9 and 10.4. Results show that pH does not change much with oxygen blowing. In other words, the concentration of OH^- and H^+ does not change much.

Study of nitrate and phosphate of wastewater

The nitrate and phosphate changing have been analyzed in biological treatment process. Results show that amount of nitrate and phosphate is between 0.2 to 0.066 mg/l and 0.51 to 0.2 mg/l, respectively. Results show that amount of nitrate and phosphate decreases with increasing oxygen injection time. Results state that the reduction of nitrate and phosphate is 67% and 60.8%, respectively. In fact, increasing oxygen increases activity of microorganisms. Therefore, more phosphate and nitrate are decomposed.

Figures 3 and 4 show the effect of oxygenation injection on the amount of nitrate and phosphate, respectively. Studies show that reduction rate of nitrate and phosphate with increasing oxygenation time is 1.5% and 4.8%, respectively. Because the rate of oxygen consumption is important, the time 35 min is introduced as optimum value.

Study of BOD and COD of wastewater

Undoubtedly, microorganisms need oxygen to activity. Also, the BOD decreases as time of oxygen injection increases. Figure 5 shows BOD changes versus oxygenation time. Results show that increasing oxygen injection time increases activity of microorganisms and reduces BOD. Figure 6 shows decrease in COD with increasing oxygenation time. Figure 5 and 6 show that reduction rate of BOD and COD

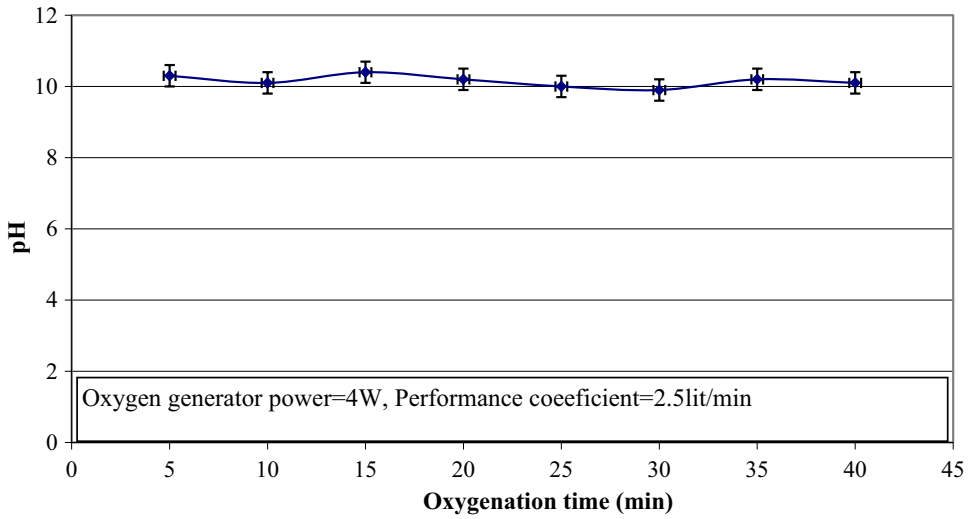

Fig. 2 Effect of oxygenation on the pH of wastewater

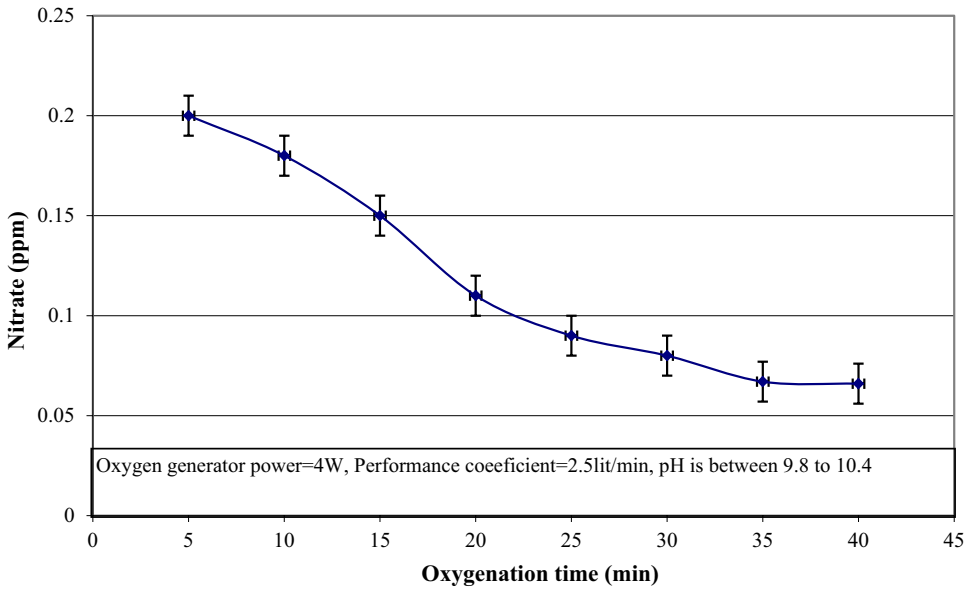

Fig. 3 Effect of oxygenation on the amount of nitrate

by increasing oxygenation time from 35 to 40 min is 1.8% and 1%, respectively. Therefore, the optimal time to reduce BOD and COD is 35 min.

Study of TOC and TPH of wastewater

Figure 7 and 8 show the effect of oxygen injection time on TOC and TPH, respectively. This section confirms that activity of aerobic microorganism's increases with increasing oxygen. Therefore, more organic carbon is consumed. Figure 7 and 8 show that decreasing trend of organic carbon and petroleum hydrocarbons is noticeable with increasing oxygen injection time from 5 min to 35 min. The decreasing trend of TOC and TPH is 20.1–4.8 mg/l and 0.14–0.4 mg/l, respectively. However, decreasing trend of TOC and TPH in this time range is a relatively smooth line.

Study of turbidity and TDS of wastewater

The turbidity and TDS of wastewater are basic parameters in determination of the treatment efficiency. Figure 9 and 10 show the effect of oxygen injection time on the turbidity and TDS, respectively. Figure 9 shows that turbidity of wastewater decreases from 4.3 NTU to 2.1 NTU with increasing oxygenation time from 5 min to 35 min. The decreasing trend can be due to the removal of dissolved ions and removal of TOC and TPH. Figure 9 shows that decreasing trend of turbidity is noticeable in the range of 5–35 min. However, this trend is almost constant in the

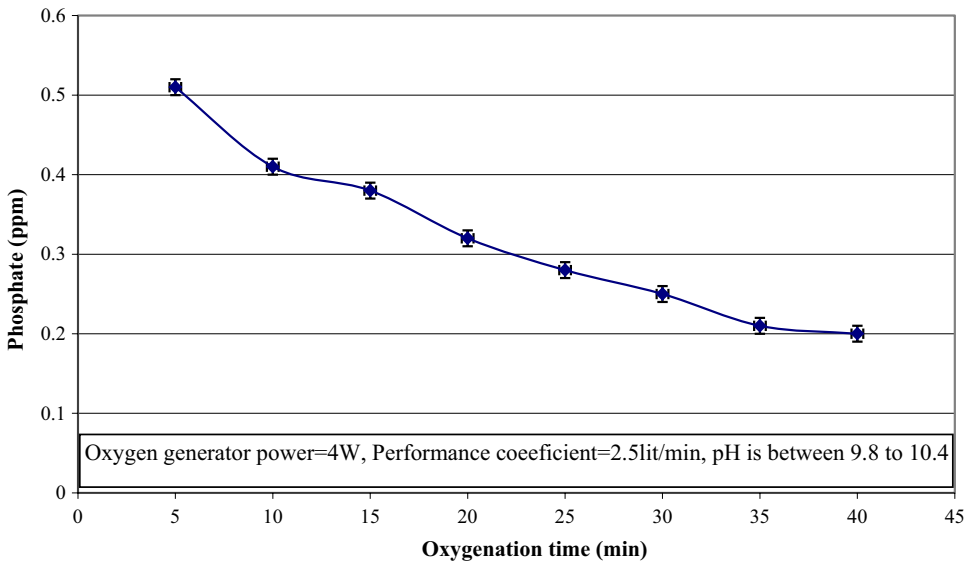

Fig. 4 Effect of oxygenation on the amount of phosphate

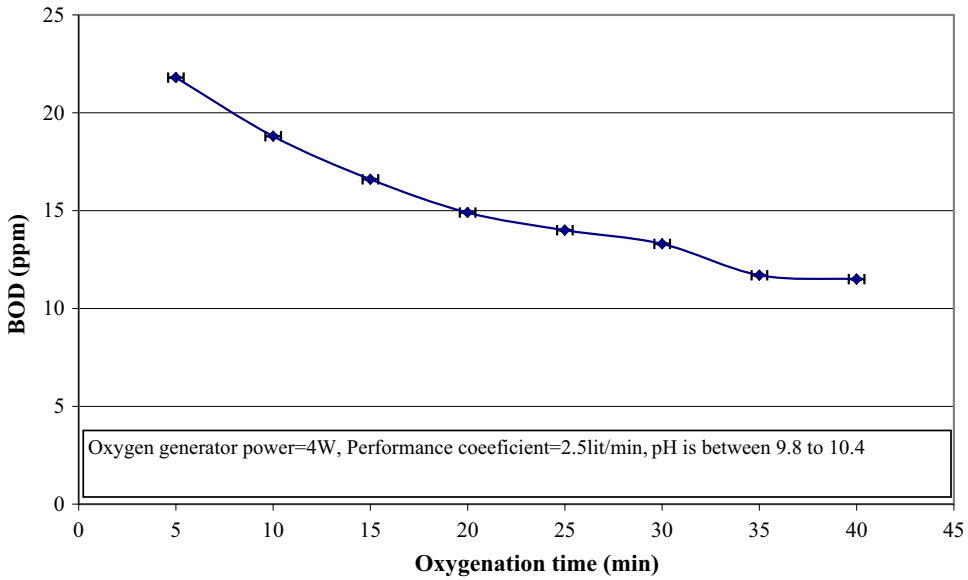

Fig. 5 Effect of oxygenation on the BOD

time range 35–40 min. Results showed a 5 min increase in time did not play a significant role in turbidity reduction.

Figure 10 shows oxygenation time effect on TDS. Studies show that pH of wastewater is between 9.8 and 10.4. Results show that TDS decreases from 727.8 to 674.1 mg/l in a time period 5–40 min. Also, TDS decreases with reduction of dissolved ions. Results show that TDS reduction up to 35 min is favorable and is 7.2%. But, TDS reduction from 35 min to 40 min is almost linear. Figure 10 indicates that increasing oxygenation time did not play a significant role in reducing TDS. So, the time 35 min can be considered as the optimal time in the biological treatment process.

Conclusion

Results show that range of pH is between 9.9 and 10.4. This study shows that pH does not change by blowing oxygen, significantly. Results show that reduction of nitrate and phosphate is 67% and 60.8%, respectively. This study shows that rate of nitrate and phosphate reduction with increasing oxygenation time is 1.5% and 4.8%, respectively. Results show that reduction rate of BOD and COD with increasing oxygenation time is 1.8% and 1%, respectively. This research shows that decreasing trend of TOC and TPH is noticeable with increasing oxygen injection

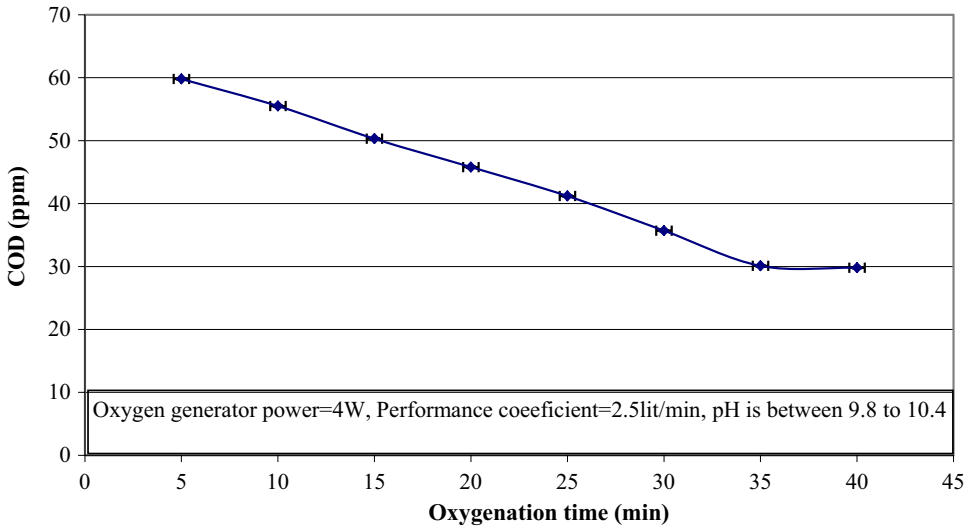

Fig. 6 Effect of oxygenation on the COD

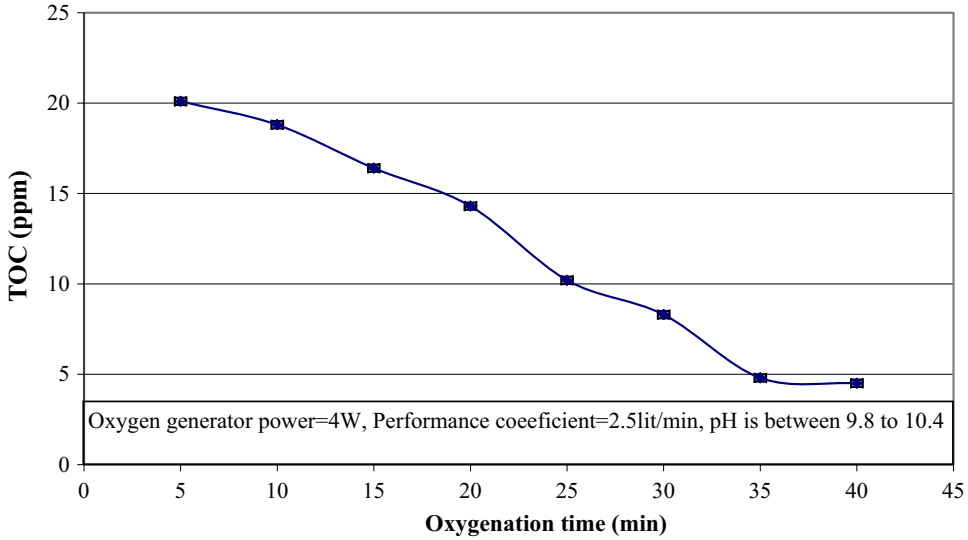

Fig. 7 Effect of oxygenation on the TOC

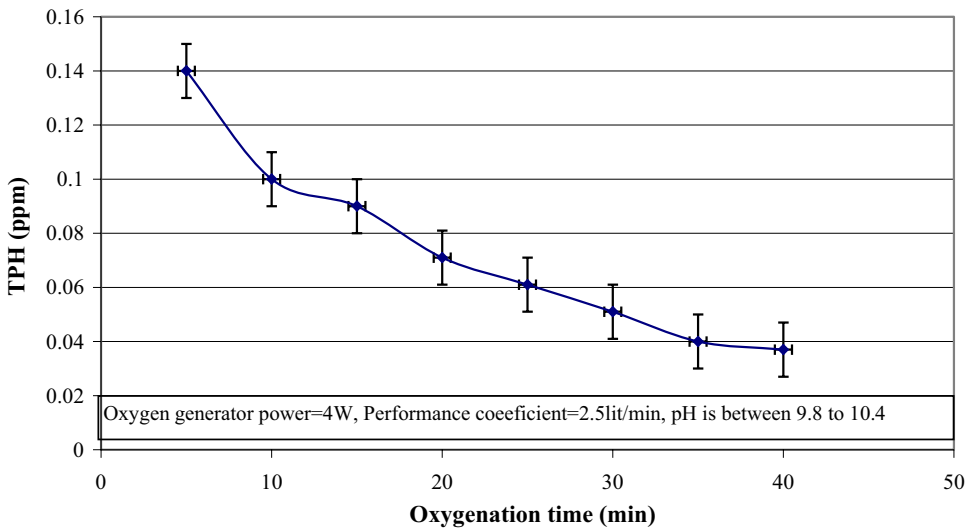

Fig. 8 Effect of oxygenation on the TPH

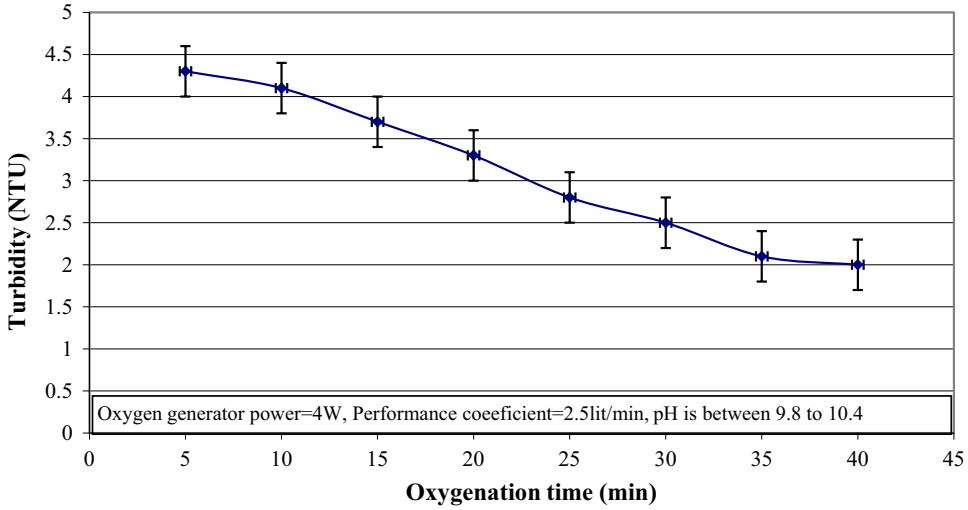

Fig. 9 Effect of oxygenation on the turbidity of the wastewater

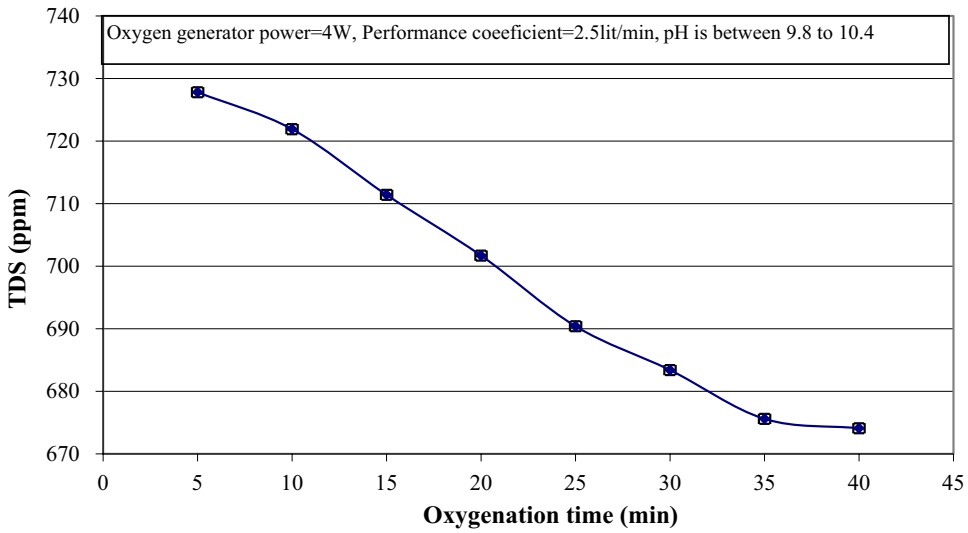

Fig. 10 Effect of oxygenation on TDS

time. This study shows that range of TOC and TPH is between 20.1 mg/l and 4.8 mg/l and between 0.14 mg/l and 0.4 mg/l, respectively. Results illustrate that turbidity of wastewater decreases from 4.3 NTU to 2.1 NTU by increasing oxygenation time. Also, experimental results show that TDS reduction up to 35 min is favorable and is 7.2%. But, TDS reduction from 35–40 min is almost linear. So, time 35 min can be considered as optimal time in biological treatment process.

Acknowledgements This research did not receive any specific funding.

Funding The author(s) received no specific funding for this work.

Code availability Not applicable.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare no conflicts of interest.

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Bian Xueying Wu, Yaodong LJ, Muchen Y, Dongyue Li, Hanbo P, Song C, Wei G (2022) Effect of dissolved oxygen on high C/N wastewater treatment in moving bed biofilm reactors based on heterotrophic nitrification and aerobic denitrification: Nitrogen removal performance and potential mechanisms. Biores Technol 365:128147

Byeongwook C, Tae-Yong J, Sungjong L (2022) Application of jetventurimixer for developing low-energy-demand and highly efficient aeration process of wastewater treatment. Heliyon 8(10):e11096

Ebrahimi A, Najafpour GD, Yousefi Kebria D (2018) Performance of microbial desalination cell for salt removal and energy generation using different catholyte solutions. Desalination 432:1–9

Farahbod F (2020a) Simultaneous use of mass transfer and thermodynamics equations to estimate the amount of removed greenhouse gas from the environment by a stream of water. Environ Model Assess. https://doi.org/10.1007/s10666-020-09740-8

Farahbod F (2020b) Practical investigation of usage of nano bottom in the production of fresh water from brackish wastewater in a closed shallow solar basin. Environ Prog Sustain Energy 40(2):e13496. https://doi.org/10.1002/ep.13496

Farahbod F (2020c) Mathematical investigation of diffusion and decomposition of pollutants as a basic issue in water stream pollution. Arab J Geosci 13(18):1–9. https://doi.org/10.1007/s12517-020-05890-x

Farahbod F (2022) Experimental evaluation of nano-zinc oxide coating applying on inner surface of a rotary dryer to produce NaCl. Int J Environ Sci Technol. https://doi.org/10.1007/s13762-022-03943-0

Feini H, Wenqing Li, Wenhao S, Panagiotis S, Yi M, Jean-Pierre C (2022) A hierarchical intelligent control strategy for greenhouse gas reduction in wastewater treatment process of paper mill. J Clean Product 379(2):134818

Francisco JGC, José MPC, Quetzalcoatl HE, Fernando CP (2020) Determination of the drying rate and effective diffusivity coefficients during convective drying of two-phase olive mill waste at rotary dryers drying conditions for their application. Renew Energy 153:900–910. https://doi.org/10.1016/j.renene.2020.02.062

Ines M, Paolo P, Roberto F, Mohamed S (2019) Experimental studies on the effect of using phase change material in a salinity-gradient solar pond under a solar simulator. Sol Energy 186:335–346

Khan NA, Khan SU, Ahmed S, Farooqi IH, Yousef M, Mohammadi AA, Changani F (2020) Recent trends in disposal and treatment technologies of emerging pollutants-a critical review. TrAC Trends Anal Chem 122:115744

Mohammad K, Yousef AG, Malgorzata N (2021) Comparison of different drying techniques and their carbon emissions in greenpeas. Chem Eng Process 160:108274. https://doi.org/10.1016/j.cep.2020.108274

Sami QA, Majid AM (2022) Prediction of municipal wastewater biochemical oxygen demand using machine learning techniques: a sustainable approach. Process Saf Environ Protect 168:833–845

Taherizadeh M, Farahbod F, Ilkhani A (2020) Experimental evaluation of solar still efficiencies as a basic step in treatment of wastewater. Heat Transf Asian Res 49(1):236–248. https://doi.org/10.1002/htj.21608

Taherizadeh Mahmoud F, Farahbod IA (2020) Empirical evaluation of proposed treatment unit for saline wastewater softening. J Appl Water Eng Res. https://doi.org/10.1080/23249676.2020.1787248

Zeynali A, Akbari A, Khalilian M (2019) Investigation of the performance of modified organic Rankine cycles (ORCs) and modified trilateral flash cycles (TFCs) assisted by a solar pond. Sol Energy 182:361–381