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A study on the impact of baffle submergence and air flow rate on the separation efficiency of oil and grease from refinery wastewater

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Abstract

The impact of airflow rate, baffle submergence, and baffle position on the efficiency of oil and grease separation in aeration-based wastewater treatment systems was examined in this study. The objective was to optimize the oil separation process by analyzing how these factors influenced separation efficiency. Experiments were carried out at varying airflow rates (0.1, 0.2, 0.4, 0.5, and 0.8 L/s), using a pore diameter of 1.5 mm and baffle submergence of 1, 5, and 10 cm. The presence of both transverse and longitudinal baffles inside the basin was tested at a water depth of 45 cm. The highest separation efficiency of 45.29% was achieved at an airflow rate of 0.4 L/s when a longitudinal baffle was submerged at 5 cm, along with the presence of both transverse baffles. A decrease in efficiency was observed at higher airflow rates due to excessive turbulence and oil emulsification. Additionally, the placement of transverse baffles at both positions was found to enhance separation efficiency to 36.3%, compared to 27.3% and 29.5% when a single baffle was placed individually at the first and second positions, respectively. All tests were performed using a gravimetric method. These findings emphasized the importance of optimizing airflow rates and baffle position for effective oil and grease separation, offering valuable insights into the design and operation of aeration systems in wastewater treatment.

Keywords: Oil and grease separation, Wastewater treatment, Aeration system, Baffles

1. Introduction

The pace at which industrial output and urbanization grew in the 18th century and have accelerated in the recent past marks a drastic expansion in manufacturing capabilities. The results of this expansion are improved living standards. It is pertinent to mention that this expansion has come with its own set of problems, mainly the overexploitation of resources, poor waste disposal methods, and other environmental problems. Water pollution is an environmental issue that stands out among these [1].

The primary class of contaminants and pollutants that are found in water bodies and even in wastewater is identified as "oil and grease". This term encompasses a wide range of organic compounds that tend to be waterinsoluble or hydrophobic. The classification of oil and grease contaminants largely depends on the analytical methods used for their extraction from water, particularly the solvent involved. Their constituents usually include hydrocarbons, fatty acids, soaps, lipids, and waxes [2]. Because oil and grease are treated as pollution within the water, their contamination is proven exceedingly hard due to their intricate structure, as described by Rhee et al.in their statement, ‘one of the most complicated pollutants to remove’ from oil processing wastewater [3].

Almost all of the hydrocarbons belonging to oil and grease compounds are always tagged as non-biodegradable. Their addition to wastewater streams can be very harmful to the environment. The oil that spills over the water surface or thin layers of oil floating in water bodies can have an effect on light penetration and oxygen exchange, which clearly makes it even more disruptive to the aquatic ecosystem. Hence, many countries have imposed rigorous controls to limit oil and grease concentrations in wastewater discharges [4]. If released into the soil in large quantities, oil and grease can adversely affect living organisms and plants, and pose a fire hazard at high concentrations [5].

Oil and grease have proven to be destructive in many aspects and pose issues in wastewater treatment from treatment plants. It hinders biological activity in sludge-activated reactors, and it also causes fouling as well as clogging of pumps and pipelines. Moreover, the presence of oily substances indicates the probability of toxic hydrophobic micropollutants. Some of these compounds are volatile and indeed harmful, as toluene, xylene, and benzene have been found to be headache-inducing in excess concentrations in wastewater treatment from petroleum refineries. Polyaromatic hydrocarbons, mono-aromatic hydrocarbons, and long-chain hydrocarbons have been detected in stormwater runoff. To safeguard the municipal systems from contaminants and to enable the numerous treatment processes, measures have been taken to restrict oil and grease discharge into these systems [6] [7].

Thus, oil and grease-rich wastewater is slated for treatment before its disposal into the environment as well as the sewage network. Research into alternative techniques has been fueled by this requirement for treatment. Municipal wastewater contains oil and grease, usually in small amounts. The main sources of municipal wastewater include cleaning and cooking. Oil and grease contents in domestic wastewater typically range from 50 to 150 mg/L [8]. Similar to this, stormwater typically contains only a few milligrams of oil and grease per liter and is primarily from sources associated with automobiles, such as parking cars and gas stations [6].

However, industrial operations add more oil and grease to wastewater, frequently in the form of colloids or emulsified substances, with concentrations as high as several grams per liter. According to Patterson, several industrial operations are significant causes of oily wastewater [2].

1. Petroleum Industry: Refineries and the production of crude oil are the sources of wastewater. A byproduct of extracting crude oil, oil-field brine is extremely salty and contains hydrocarbons. Additional pollutants such as ammonia, sulfides, chlorides, and phenols are frequently found in refinery effluents [9][3].

2. Metalworking Industry: One of the main sources is the cutting, cooling, and lubricating oils, which are frequently utilized as oil-in-water emulsions stabilized by surfactants. During cleansing, cooling, and washing processes, these emulsions find their way into wastewater streams [10][2].

3. Food Processing Industry: When animal and plant-based items are processed, this industry produces greasy effluent. Oily effluents are produced during the slaughtering and facility-cleaning phases of meat production [15]. The manufacturing and processing of vegetable oil also produce large amounts of wastewater [11][12].

4. Municipal wastewater: Mostly from houses and restaurants, this is a major source of oils and grease. Fats, oils, and grease (FOG) are found in sewer systems as a result of household activities like cooking, cleaning dishes, and discarding dairy and personal hygiene items. Urban discharge and improper disposal from food service businesses make the problem worse by clogging sewers, raising treatment expenses, and polluting the environment [13][14].

The separation of fats from wastewater often employs chemical agents, leading to chemical precipitation processes. However, these methods, while effective, carry significant financial costs and environmental risks. The byproducts released into the water systems pose considerable threats to marine life and terrestrial plants. [15] where the are many researchers who work on that, like Hongbin Xu [16] and Zhang Yuanyuan [17].

Meanwhile, other researchers have turned to dissolved air flotation (DAF) as an alternative to chemical treatment. While DAF is considered more efficient and environmentally friendly than chemical precipitation, it remains a costly method due to the requirement of specialized vessels and equipment. Additionally, its operation demands a significant amount of electrical energy, making it less sustainable in terms of energy consumption [18], where the are many researchers working on that, like M. do Santos Pereira et al. [19], and Muñoz-Alegría et al. [20]. However, few have focused on aeration, such as Hasan Mahdi Mohammed Al-Khateeb [21].

This study aims to evaluate the effectiveness of removing oil and grease from wastewater using a plain aeration system enhanced by controlled flow baffles. Recognizing the imperative to comply with environmental discharge standards, the research focuses on treating these contaminants before the primary, secondary, and tertiary stages of wastewater treatment by analyzing the effect of the total airflow rate injected into the aeration tank on oil and grease removal efficiency and evaluating the impact of baffles within the tank on the overall removal process efficiency. An experimental model was constructed based on the geometric similarity of the proposed preliminary aeration basin.

Previous research has explored oil and grease removal using various physical, chemical, and biological methods. Husain et al. [22] reviewed conventional oil and grease treatment techniques, emphasizing chemical and biological processes, while Kumar et al. [23] and Houweling et al. [24] highlighted the role of baffle configuration and hydraulic behavior in aerated systems. Al-Ahmady [25] and Rosso et al. [26] analyzed aeration dynamics, focusing on oxygen transfer efficiency and system energy demands, whereas Mukandi et al. [27] emphasized the impact of diffuser design and bubble dynamics on system performance. Al-Khateeb [21] demonstrated the benefits of combining pre-aeration and transversal baffles in enhancing physical separation in a municipal grit chamber. While these studies provided valuable insights, they mostly addressed individual aspects in large-scale or complex systems. However, no prior study has investigated the combined effect of plain aeration and controlled hydraulic flow through baffling on the separation of oil and grease in a simplified rectangular aeration basin, as presented in the current study. This research addresses a significant knowledge gap by experimentally evaluating the influence of airflow rate, air jet velocity, baffle submergence, and baffle position on oil and grease separation efficiency under practical operational conditions.

Although the maximum separation efficiency achieved in the present study is considered moderate compared to advanced treatment technologies such as DAF or membrane filtration, the proposed method offers critical advantages in cost, operational simplicity, and scalability. While dissolved air flotation systems can operate without chemicals, they are often enhanced by coagulants or flocculants, and they require high-pressure air systems, mechanical components, and trained personnel for maintenance. In contrast, the plain aeration system developed here with flow-directing baffles and low-pressure air supply represents a practical and low-cost pre-treatment solution, especially suitable for refinery wastewater in resource-limited or decentralized applications. This research, therefore, addresses a significant gap in the literature by offering an experimentally validated, hydraulically optimized system that enhances physical separation performance using accessible and low-maintenance components.

2. Research method

The wastewater used in this study is generated from the Najaf refinery, originating from the washing of tanks, distillation towers, and various side equipment cleaning processes. This wastewater is collected and directed to sedimentation basins, from which samples were taken for treatment. The experimental setup included a blower, pollutant tank, treatment basin, two control valves, and a flow meter to measure the airflow rate. The gravimetric method was utilized to evaluate the efficacy of pollutant separation both before and after the treatment process.

Each test required a sample volume of 500 mL, and the analysis was performed in duplicate to ensure the accuracy of the results. A total of 45 experiments were conducted to comprehensively assess the impact of operational parameters on oil and grease separation efficiency.

The basin is made of glass with dimensions of 60 × 20 cm and a thickness of 6 mm to facilitate the observation of the treatment process, as shown in Figure 2 below. It has three openings: two located at the midpoint of the side glass panels, serving as inlets and outlets for contaminants, and a third opening on the longitudinal side at a height of 45 cm. Additionally, the basin contains four longitudinal baffles, each measuring 45 cm in height, 9 cm in width, and 4 mm in thickness, arranged in an alternating pattern. Each pair of them is placed opposite each other, with a slot of 2 centimeters wide along the barrier. One is located 20 centimeters away from the entry of the basin wall, and the other is 40 centimeters away from the entry of the basin wall. There is also one transverse baffle measuring 60 cm in length, 20 cm in width, and 4 mm in thickness. The basin is adhesive to prevent any leakage of contaminants outside. It also contains aluminum glass clips that help support the upper baffle for stability and control the depth of the longitudinal baffle immersion. These aluminum glass clips are located at the center of the basin, 10 cm away from the wall, while other protrusions control the positioning of the longitudinal baffle. The experiments were conducted at a water depth of 45 cm.

The process began with wastewater flow from the additional tank into the treatment basin through a 5-centimeter diameter pipe. The wastewater flow rate was controlled using a control valve. The aeration system was activated using a blower, where air was injected through distribution pipes with a diameter of 2.5 centimeters. The pipes contained 11 evenly spaced openings, with a distance of 5 centimeters between each opening. The aeration pipe was positioned at the bottom of the treatment basin, as shown in Figure 1. The injection of air created a circular flow pattern within the treatment basin, promoting the accumulation of oils and greases on the surface of the installed baffles. Finally, the treated water was discharged through an outlet on the opposite side of the basin. The experiment duration was 30 minutes.

Figure 1. Process flow of oil and grease separation from refinery wastewater

Figure 2. Aeration basin of the treatment process

3. Results and discussion

3.1. Effect of air flow rate and baffles on oil and grease separation efficiency

The air flow rate and the position of baffles significantly influenced the efficiency of oil and grease separation in aeration-based treatment systems. Adjusting the air flow rate improved the mixing, oxidation, and oil flotation. Higher air flow rates enhanced oil fragmentation and promoted flotation to the surface [28] [29]. This was evident in the experimental results, where increasing the air flow rate from 0.05 to 0.4 L/s showed a significant increase in separation efficiency, peaking at 45.29% at 0.4 L/s. This optimal rate provided sufficient turbulence to lift oil droplets without causing excessive emulsification.

However, when the air flow rate was further increased to 0.8 m^2/s, the efficiency dropped to 36.3%, likely due to excessive turbulence that led to emulsification, hindering the upward flotation of oil droplets [28] [29]. The addition of baffles was observed to further enhance removal efficiency by reducing short-circuiting and improving bubble distribution. Properly positioned baffles ensured uniform aeration and increased interactions between bubbles and oil droplets, thereby enhancing flotation. In contrast, systems without baffles exhibited uneven flow patterns and dead zones, limiting bubble-oil interactions. The highest oil separation efficiency (45.2%) occurred when the longitudinal baffle was submerged at 5 cm. Lower efficiencies were observed at 1 cm (43%) and 10 cm (41.5%) under operational conditions at 0.4 L/s, with a pore diameter of 1.5 mm and transverse baffles installed at both positions, as shown in Figure 5.

When transverse baffles were tested individually, the first baffle placed 20 cm from the pollutant inlet resulted in a separation efficiency of 27.3% as shown in Figure 3, while the second baffle placed 20 cm downstream resulted in 29.5% as shown in Figure 4. These results suggest that while each baffle contributed to flow management and bubble distribution, they were not as effective when used alone. However, when both transverse baffles were installed together, the efficiency increased to 36.3%, indicating that using both baffles reduced dead zones and improved water flow, thereby enhancing bubble-oil interactions [24][21].

These findings are consistent with previous studies, which emphasized the importance of hydraulic control elements in wastewater treatment systems. Strategically placed baffles were shown to generate circular flow patterns and reduce short-circuiting, improving bubble-oil interactions and oil and grease separation efficiency [24][21][30][31][32]. Throughout the experiments, a circular flow pattern was induced by controlling the water flow rate, with a constant water depth of 45 cm and an aeration pipe pore diameter of 1.5 mm, all contributing to stable hydrodynamic conditions and consistent aeration performance.

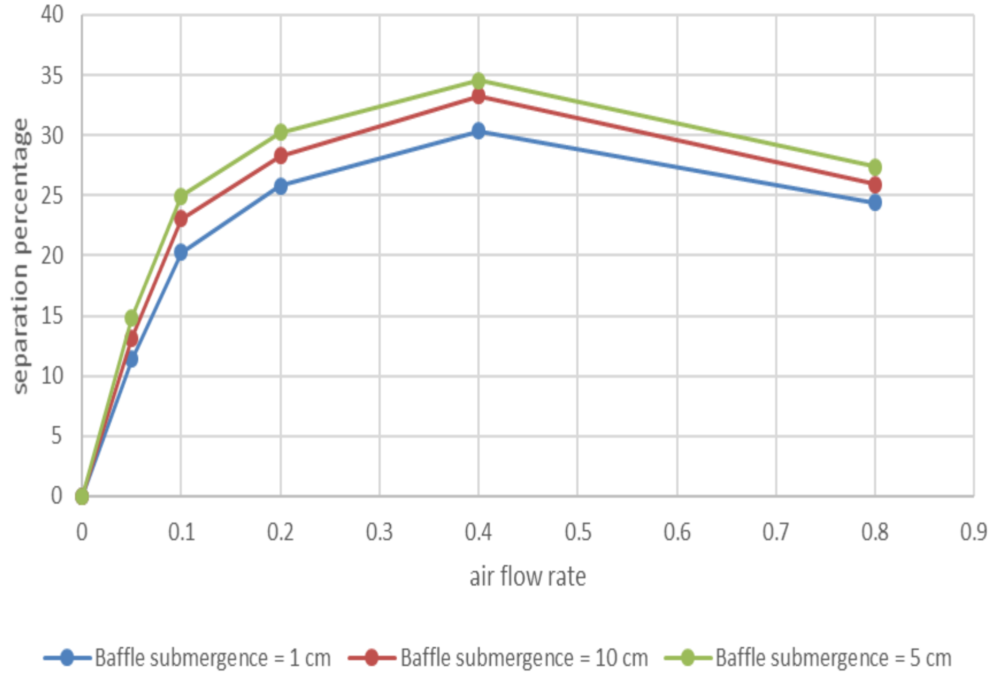

Figure 3. Effect of airflow rate (0.05, 0.1, 0.2, 0.4, 0.8 L/s) on oil and grease separation percentage at various baffle submergence depths (1, 5, 10 cm) using a single baffle in the first position

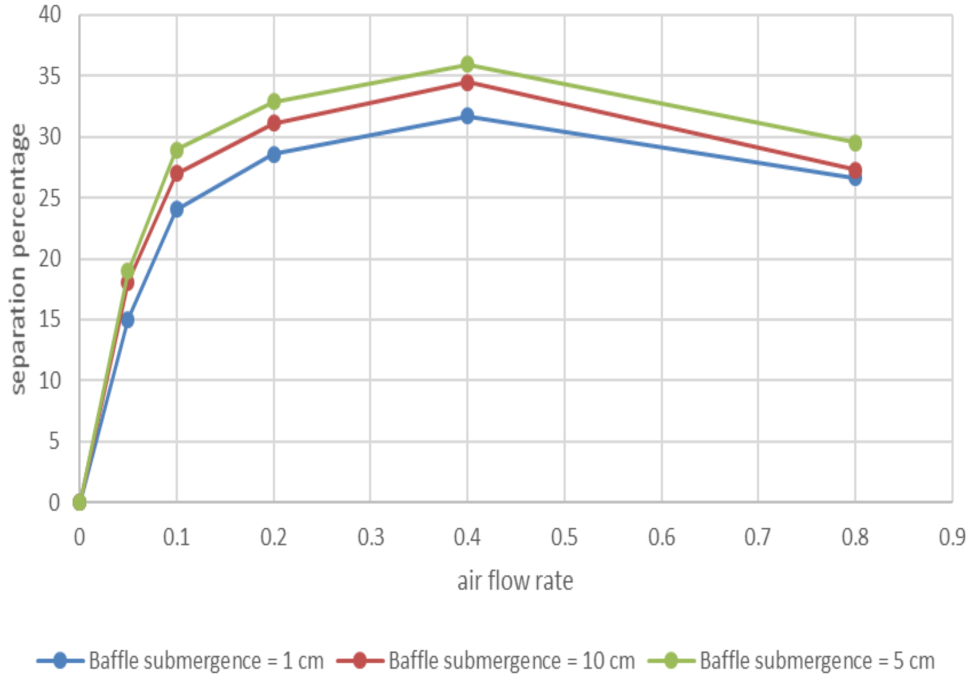

Figure 4. Effect of airflow rate (0.05, 0.1, 0.2, 0.4, 0.8 L/s) on oil and grease separation percentage at various baffle submergence depths (1, 5, 10 cm) using a single baffle in the second position.

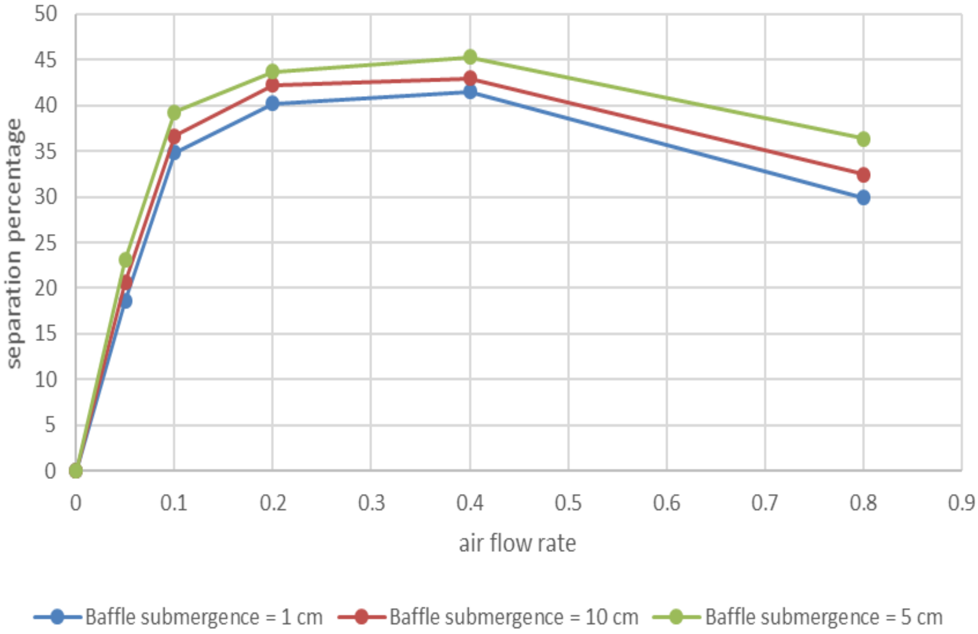

Figure 5. Effect of airflow rate (0.05, 0.1, 0.2, 0.4, 0.8 L/s) on oil and grease separation percentage at various baffle submergence depths (1, 5, 10 cm) using two baffles at both positions.

3.2. Summary of regression model findings and main influencing factors

Based on the results of the statistical analysis and nonlinear regression modeling conducted using SPSS software, a predictive mathematical model was developed that incorporates linear, quadratic, and interaction effects of operational variables to estimate oil and grease removal efficiency from contaminated wastewater. The developed model demonstrated a strong agreement between observed and predicted values ($R^2 = 0.903$), indicating its high accuracy in representing the real behavior of the system under varying operational conditions. Among the studied parameters, total airflow rate was identified as the most influential factor, contributing 34.26%, followed by water depth (25.48%) and baffle location (24.61%). In contrast, baffle submergence depth and diffuser pore diameter showed relatively minor effects, each contributing 7.83%, reflecting their limited influence under the tested conditions.

4. Conclusions

The results of this study highlight the significant impact of both the air flow rate and baffle configuration on the efficiency of oil and grease separation in aeration-based wastewater treatment systems. It was found that increasing the air flow rate up to 0.4 L/s significantly improved separation efficiency, reaching a peak of 45.29%. However, further increases in the air flow rate beyond this threshold caused a decrease in separation efficiency due to excessive turbulence and oil emulsification. These findings confirm the importance of optimizing aeration conditions to achieve the highest separation efficiency while avoiding the negative effects of over-aeration. Furthermore, the study demonstrates the crucial role of baffles in enhancing separation efficiency by improving bubble distribution and reducing short-circuiting. The optimal efficiency of 45.2% was achieved when the longitudinal baffle was submerged at 5 cm. The results also indicate that using a combination of transverse baffles further enhances oil removal efficiency, achieving an efficiency of 36.3% when both baffles were employed together. This suggests that strategically placed baffles contribute to better flow management and bubble-oil interaction, which in turn enhances flotation and oil separation. These findings are consistent with previous studies, which emphasize the importance of hydraulic control elements, such as baffles, in optimizing oil and grease removal. The creation of circular flow patterns and the reduction of dead zones are key factors that improve bubble-oil interactions and, consequently, separation efficiency. Overall, the results of this study provide valuable insights into the optimization of aeration-based systems for oil and grease removal, contributing to the development of more efficient wastewater treatment processes.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author contribution

Karrar H. Kazm has performed the experimental work, collected and analyzed data, written the first proof, submitted the manuscript, responded to the reviewers' notes, and prepared and submitted the revised manuscript Hasan Mahdi Mohammed Al-Khateeb has supervised the project, analyzed data, and read and revised the first proof. Ahmad Moheb has supervised the project, analyzed data, and read and revised the first proof.

References

[1] M. Strokal *et al.*, "Urbanization: an increasing source of multiple pollutants to rivers in the 21st century," *npj Urban Sustain.*, vol. 1, no. 1, 2021, https://doi.org/10.1038/s42949-021-00026-w

[2] j.w patterson, *Industrial Wastewater Treatment Technology*. 1985.

[3] C. H. Rhee, P. C. Martyn, and J. G. Kremer, "Removal of Oil and Grease in Oil Processing Wastewaters," *Proceedings 42nd Purdue Ind. Waste Conf.*, pp. 1–15, 1989, [Online]. Available: http://infohouse.p2ric.org/ref/02/01442.pdf

[4] R. Wahi, L. A. Chuah, T. S. Y. Choong, Z. Ngaini, and M. M. Nourouzi, "Oil removal from aqueous state by natural fibrous sorbent: An overview," *Sep. Purif. Technol.*, vol. 113, pp. 51–63, 2013, https://doi.org/10.1016/j.seppur.2013.04.015

[5] F. Ahmed and A. N. M. Fakhruddin, "A review on environmental contamination of petroleum hydrocarbons and its biodegradation," *Int. J. Environ. Sci. Nat. Resour.*, vol. 11, no. 3, pp. 1–7, 2018, https://doi.org/10.19080/IJESNR.2018.11.555811

[6] M. K. Stenstrom, G. S. Silverman, and T. A. Bursztynsky, "Oil and Grease in Urban Stormwaters," *J. Environ. Eng.*, vol. 110, no. 1, pp. 58–72, 1984, https://doi.org/10.1061/(ASCE)0733-9372(1984)110:1(58)

[7] I. Kanu and E. Anyanwu, "Impact of hydrophobic pollutants' behavior on occupational and environmental health.," *ScientificWorldJournal.*, vol. 5, pp. 211–220, 2005, https://doi.org/10.1100/tsw.2005.28

[8] F. L. Burton and H. David Stensel, *Wastewater Engineering - Treatment and Reuse*, vol. 65, no. 2–3. 1990.

[9] L. Yu, M. Han, and F. He, "A review of treating oily wastewater," *Arab. J. Chem.*, vol. 10, pp. S1913–S1922, 2017, https://doi.org/10.1016/j.arabjc.2013.07.020

[10] J. MacAdam *et al.*, "Incorporating biodegradation and advanced oxidation processes in the treatment of spent metalworking fluids," *Environ. Technol. (United Kingdom)*, vol. 33, no. 24, pp. 2741–2750, 2012, https://doi.org/10.1080/09593330.2012.678389.

[11] O. Dkhissi *et al.*, "Vegetable Oil Refinery Wastewater Treatment by Using the Cactus as a Bio-flocculant in the Coagulation-Flocculation Process," *Water. Air. Soil Pollut.*, vol. 234, no. 5, 2023,

https://doi.org/10.1007/s11270-023-06337-1

[12] A. I. Adetunji and A. O. Olaniran, “Treatment of industrial oily wastewater by advanced technologies: a review,” *Appl. Water Sci.*, vol. 11, no. 6, pp. 1–19, 2021, https://doi.org/10.1007/s13201-021-01430-4

[13] M. El-Khateeb *et al.*, “Sustainable municipal wastewater treatment using an innovative integrated compact unit: microbial communities, parasite removal, and techno-economic analysis,” *Ann. Microbiol.*, vol. 73, no. 1, 2023, https://doi.org/10.1186/s13213-023-01739-2

[14] C. T. K. Finnerty *et al.*, “The Future of Municipal Wastewater Reuse Concentrate Management: Drivers, Challenges, and Opportunities,” *Environ. Sci. Technol.*, vol. 58, no. 1, pp. 3–16, 2024, https://doi.org/10.1021/acs.est.3c06774

[15] A. Niu, X. Sun, and C. Lin, “and Treatment of Oily Sludge : A Systematic Review,” *Molecules*, pp. 1–23, 2022.

[16] H. Xu, S. Wei, G. Li, and B. Guo, “Advanced removal of phosphorus from urban sewage using chemical precipitation by Fe-Al composite coagulants,” *Sci. Rep.*, vol. 14, no. 1, pp. 1–12, 2024, https://doi.org/10.1038/s41598-024-55713-2

[17] Z. Yuanyuan, “Chemical Precipitation: A Fundamental Process in Water Treatment and Environmental Remediation Applications of chemical precipitation,” vol. 14, no. 1000475, pp. 1–2, 2023, https://doi.org/10.35248/2157-7048.23.14.475

[18] A. Mohammed and A. Qarani, “Dissolved Air Flotation (DAF) operational parameters and limitations for wastewaters treatment with cost study,” *Reciklaza i Odrziv. Razvoj*, vol. 16, no. 1, pp. 91–97, 2023, https://doi.org/10.5937/ror2301091a

[19] M. do S. Pereira, A. C. Borges, G. L. Muniz, F. F. Heleno, and L. R. D. A. Faroni, “Dissolved air flotation optimization for treatment of dairy effluents with organic coagulants,” *J. Water Process Eng.*, vol. 36, no. November 2019, p. 101270, 2020, https://doi.org/10.1016/j.jwpe.2020.101270

[20] J. A. Muñoz-Alegría, E. Muñoz-España, and J. F. Flórez-Marulanda, “Dissolved Air Flotation: A Review from the Perspective of System Parameters and Uses in Wastewater Treatment,” *TecnoLógicas*, vol. 24, no. 52, p. e2111, 2021, https://doi.org/10.22430/22565337.2111

[21] H. M. M. Al-khateeb, “Pre-aeration and Transversal Baffling Effect on Aerated Grit Chamber Performance of Kufa Wastewater Treatment Plant,” *Int. J. Sci. Res.*, vol. 5, no. 3, pp. 1799–1810, 2016, https://doi.org/10.21275/v5i3.nov162334

[22] I. A. F. Husain, M. F. Alkhatib, M. S. Jami, M. E. S. Mirghani, Z. Bin Zainudin, and A. Hoda, “Problems, control, and treatment of fat, oil, and grease (FOG): A review,” 2014. https://doi.org/10.5650/jos.ess13182

[23] B. Kumar, T. T. Devi, A. K. Patel, and A. Bhatla, “Optimal Geometric Configuration for Power Consumption in Baffled Surface Aeration Tanks,” vol. 5, no. 2, pp. 87–93, 2010.

[24] D. Houweling, F. Chazarenc, R. Leduc, and Y. Comeau, “Effect of baffles on nitrification in aerated facultative lagoons in a cold climate,” *Water Sci. Technol.*, vol. 55, no. 11, pp. 73–79, 2007, https://doi.org/10.2166/wst.2007.345

[25] K. K. Al-Ahmady, “Analysis of oxygen transfer performance on sub-surface aeration systems,” *Int. J. Environ. Res. Public Health*, vol. 3, no. 3, pp. 301–308, 2006, https://doi.org/10.3390/ijerph2006030037

[26] D. Rosso, L. E. Larson, and M. K. Stenstrom, “Aeration of large-scale municipal wastewater treatment plants: State of the art,” *Water Sci. Technol.*, vol. 57, no. 7, pp. 973–978, 2008, https://doi.org/10.2166/wst.2008.218

[27] M. R. Mukandi, M. Basitere, B. I. Okeleye, B. S. Chidi, S. K. O. Ntwampe, and A. Thole, "Influence of diffuser design on selected operating variables for wastewater flotation systems: A review," *Water Pract. Technol.*, vol. 16, no. 4, pp. 1049–1066, 2021, https://doi.org/10.2166/wpt.2021.061

[28] G. Tchobanoglous, F. L. Burton, and D. H. Stensel, *Metcalf &Eddy : Wastewater Engineering: Treatment and Reuse*, no. 7. 2014.

[29] The U.S. Environmental Protection Agency (EPA), *Evaluation of energy conservation measures*, vol. 4, no. 2–3. 2010.

[30] M. Abu-Orf, G. Tchobanoglous, H. D. Stensel, R. (Author, F. (Author, and B. Pfrang, *Wastewater Engineering: Treatment and Resource Recovery*. 2013.

[31] M. Kizar, A. H. F. Mohsen, S. Abdulsattar, A. M. Suhad, and L. Abdulrasool, A. A., "Study of emitted gases from incinerator of Al-Sadr hospital in Najaf city," *Open Engineering*, vol. 12, no. 1, pp. 102–110, 2022, https://doi.org/10.1515/eng-2022-0016.

[32] L. A. Mahdi, W. H. Mahdi, and Q. A. Jebur, "Mechanical properties of waste aggregate-steel fiber reinforced concrete modified with waterproof admixture," *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 9, no. 11, pp. [page numbers not specified], 2018. [Online]. Available: http://www.iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_9_ISSUE_11/IJCIET_09_11_088.pdf