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Conference Paper

Comparison of DAF Pretreatment between Static Mixer and Impeller Mixer for Oil and Grease Reduction

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ABSTRACT

The problem of domestic wastewater originating from restaurants is the largest contributor to organic wastewater in urban waters. Among them are waste water parameters, namely oil, and grease. Oils and grease are compounds that do not dissolve easily in water. However, it can be dissolved with non-polar organic solvents. The carbon chains of oils and grease are also long. So, it is difficult to decompose and takes a long time if processing uses the help of microorganisms. So, the alternative is to use physical-chemical processing. In this research, we tried using a static mixer and an impeller mixer. We conducted a systematic review of DAF techniques in wastewater treatment. We reviewed six indexed databases namely dissolved air flotation, microbubbles, wastewater treatment, and key operational and design parameters involved in the effectiveness of the flotation process. In this pre-treatment, the focus is on the withdrawal/discharge speed in collecting wastewater as a test and the effectiveness of mixing wastewater with coagulants and air pressure. These three aspects are used in equilibrium to achieve the optimum dose for the static mixer use scheme. Meanwhile, the impeller mixer scheme uses rotational speed in mixing with the coagulant, contact time, and Reynolds number to achieve the required turbulence. Apart from that, the use of electrical energy in the pump is also calculated in these two schemes. The results obtained were the amount of weight of oil and grease collected in the static mixer pretreatment of 9.12% w/v and the impeller mixer of 7.63% w/v and the results of the organic content of the Chemical Oxygen Demand (COD) parameter for the static mixer were 86.92 % and mixer impeller 78.86 %. From these results, static mixers have advantages over using impeller mixers in terms of the effectiveness of the oil and grease reduction process.

Keywords: Dissolved air flotation, static mixer, impeller mixer, oil and grease

Introduction

The effects of climate change and increasing global water demand have led to concerning water deficits. The global population is projected to reach nearly 8.6 billion by 2030, and water demand is expected to grow annually by 1%, resulting in a cumulative increase from 20% to 30% by 2050 (UNESCO, 2019). The demands of social development activities require a substantial amount of freshwater, with the agricultural sector estimated to account for 70% of total water consumption, industry at 19%, and the remaining 11% used for domestic and urban needs. Numerous water reclamation methods have been developed, including chemical, biological, and physical techniques such as gravity separation, membrane filtration, flotation, and electrocoagulation (Aziz et al., 2019; Mirshafiee et al., 2018; Nawarkar & Salkar, 2019; Wu et al., 2019).

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In recent years, microbubble (MB) and nanobubble (NB) technologies have been integrated into water clarification processes (Azevedo et al., 2017; Oliveira et al., 2017), particularly in methods such as flotation, disinfection, and further oxidation (Temesgen et al., 2017). The physicochemical properties and free radicals generated by bubbles (Lim et al., 2018) facilitate the easy removal of fine particles (Azevedo et al., 2019; Ruby & Majumder, 2018; Zhang & Guiraud, 2017). This has been demonstrated in wastewater treatment; in the removal of oil, grease, and Total Petroleum Hydrocarbon (TPH) in the oil industry (Oliveira et al., 2017; Lim et al., 2018; Zhang, 2021); and in the elimination of Fats, Oil, and Grease (FOG) from domestic wastewater (Johannesson et al., 2020) Zhang et al., 2014). Microbubble effectively decreases antiviral, antibacterial, anticancer, psychotropic, antihypertensive, analgesic, and antipyretic drugs mixed in water by enhancing removal rates, thereby reducing the discharge of these products into river environments. It also enhances the quality of polluted river water and groundwater containing organic substances (Sun et al., 2018).

Dissolved Air Flotation (DAF) is a reliable method for wastewater treatment (Zhang et al., 2014). It has been applied to treat fluids with varying characteristics, ranging from drinking water and wastewater to industrial water (Satpathy et al., 2020). The efficiency of DAF has led to the integration of hybrid technologies, resulting in positive outcomes in pollutant removal, meeting environmental quality standards for turbidity, color, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD). DAF has also been employed for the removal of oils, fats, and fine particles (Amin et al., 2017; Villar-Navarro et al., 2018).

The application of DAF in wastewater treatment has allowed for technological advancements in recent years (Fonseca et al., 2017; Matsui et al., 1998). DAF is effective in removing low-density components found in elements and chemical compounds, plant compounds, microorganisms, and parasites. In eutrophic waters, DAF has demonstrated consistent removal efficiencies of 80% for turbidity, 72% for total phosphorus, 71% for chlorophyll, and 61% for COD. Additionally, in polluted urban rivers, dissolved oxygen levels can be increased from 0.2 to 2 mg/L and even up to 3.5 mg/L through the dissolution of air in water, reducing negative environmental impacts (Tian et al., 2018).

Other studies have shown removal efficiencies ranging from 11.1% to 77.7% for COD in DAF treatment using aluminum-based coagulants in wastewater produced by cosmetic factories. However, wastewater from UV filter cream production remains resistant to DAF treatment, regardless of the coagulant used (Bogacki et al., 2017). DAF is an excellent supplementary stage. A study tested the efficiency of DAF in conjunction with a high-speed activated sludge system at a pilot scale in a municipal water treatment plant in Aartselaar, Belgium. The sand was initially removed through sedimentation, and then large particles (1 mm in size) were removed using a drum filter. Finally, the liquid was transferred to the DAF unit, where specific conditions were used for further water purification. The results showed a removal of 78% of TSS and 68% of COD. Therefore, reviewing various applications of DAF allows us to indirectly identify the strengths and limitations of this system to optimize techniques. In this study, we conducted tests to assess the effectiveness of DAF in reducing the oil and grease content in restaurant wastewater. The objective of this research is to evaluate an alternative wastewater treatment unit for restaurants that is operationally applicable and effective.

Material and Methods

In the initial pretreatment phase of wastewater treatment, the preparation of materials and equipment is crucial. This research uses wastewater samples from the "Jempol Jaya" restaurant in Sidoarjo Regency as the testing material. Here are the details:

Materials Used

Restaurant Wastewater Samples: These samples are obtained from the "Jempol Jaya" restaurant's activities and serve as the primary research material. These samples are used to measure parameters such as oil, grease, and Total Dissolved Solids (TDS).

Equipment Used

1 Unit of Dissolved Air Flotation (DAF): DAF is the main equipment used in this research. It is a reactor with a capacity of over 60 liters used for the coagulation-flocculation pretreatment of wastewater.

Research variables

In this research, several variables will be observed, including:

Fixed variables

1. Restaurant Wastewater: The wastewater samples from the "Jempol Jaya" restaurant used as research material.
2. Reactor Capacity +60 L (DAF): The capacity of the DAF reactor used in the research.
3. Pre-Treatment Coagulation-Flocculation: The pretreatment method used to remove oil and grease from wastewater.
4. Inlet Oil and Grease Concentration <20 mg/L: The oil and grease concentration at the DAF inlet, which is the target for reduction.

Independent Variables

1. Compressor Pressure: The air pressure applied to the DAF to create air bubbles in the flotation process.
2. Coagulant Dose: The amount of coagulant added to the wastewater to assist in the settling of oil and grease.
3. Diffuser Bubbler: A component used to generate air bubbles in the DAF, affecting the flotation process.

Control Variables

1. pH: The acidity level in wastewater that can affect coagulation-flocculation and flotation processes.
2. Temperature: The temperature of wastewater that can affect chemical reactions and process kinetics.
3. TDS (Total Dissolved Solids): The total concentration of dissolved substances in wastewater that can affect treatment efficiency.

DAF is used in this research as the primary tool for treating restaurant wastewater. DAF is a treatment method that combines dissolved air flotation with coagulation-flocculation to remove dissolved substances, oil, grease, and other particles from wastewater. This process involves creating air bubbles that lift floating particles to the surface for subsequent removal. DAF has broad applications in industrial and restaurant wastewater treatment, as demonstrated in this research. The design of DAF can be seen in Figure 1.

In this research, the aforementioned variables will be tested and controlled to determine the optimal conditions for reducing oil, grease, and TDS in restaurant wastewater. The research results will provide a better understanding of the effectiveness of pretreatment processes and the use of DAF in restaurant wastewater treatment, which can serve as a basis for improvements in waste management and compliance with applicable environmental regulations.

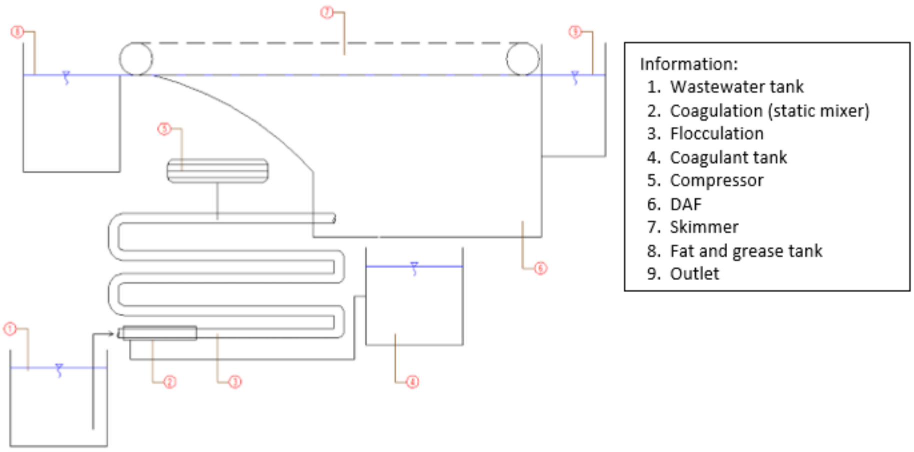

Figure 1. DAF design

Results and Discussion

The results presented in this research regarding the removal of oil and grease in wastewater through static mixer pretreatment and impeller mixer are of significant importance in the field of wastewater treatment. The findings provide valuable insights into the effectiveness of these two methods and shed light on the potential advantages of using static mixers over impeller mixers for the reduction of oil and grease in wastewater. The DAF process scheme can be seen in Figure 2.

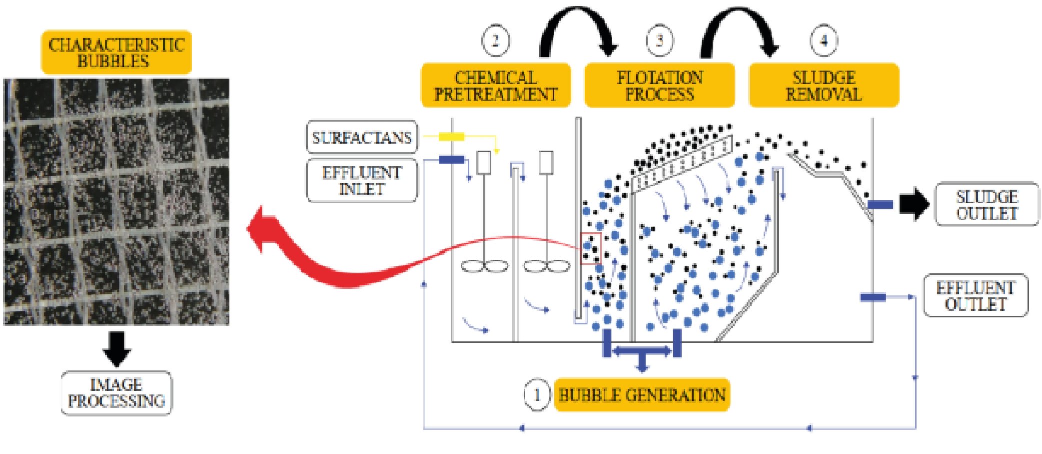

Figure 2. DAF process scheme (Munoz-Alegria et al., 2021)

Firstly, it is essential to discuss the percentage of oil and grease removal achieved through static mixer pretreatment and impeller mixer. The research results indicate that the static mixer pretreatment achieved an impressive oil and grease removal efficiency of 9.12% w/v, whereas the impeller mixer achieved a slightly lower efficiency of 7.63% w/v. This difference in removal rates is noteworthy and underscores the effectiveness of static mixers in capturing oil and grease components from wastewater.

The high oil and grease removal efficiency observed in the static mixer can be attributed to its unique design and operating principles. Static mixers utilize stationary elements within the mixing chamber to induce turbulence and promote the contact between the oil and grease droplets and coagulants or other treatment chemicals. This enhanced contact facilitates the aggregation of oil and grease particles into larger clusters, making them easier to separate from the wastewater during subsequent treatment processes.

On the other hand, impeller mixers rely on mechanical agitation, where a rotating impeller generates flow and turbulence within the wastewater. While impeller mixers can effectively mix chemicals and wastewater, the results suggest that they are less efficient in removing oil and grease compared to static mixers. This may be due to the differences in mixing intensity, contact time, and the ability to create the necessary conditions for effective coagulation and flocculation (Melián et al., 2023).

Furthermore, it is crucial to analyze the results of the Chemical Oxygen Demand (COD) parameter for both static mixer and impeller mixer systems. COD is a key indicator of the organic content in wastewater, and its reduction is essential for mitigating the environmental impact of wastewater discharge (Varbanov et al., 2022).

The research findings reveal that the static mixer achieved a COD reduction of 86.92%, while the impeller mixer achieved a slightly lower COD reduction of 78.86%. These results suggest that the static mixer not only excels in oil and grease removal but also in reducing the overall organic load in wastewater. This is of great significance as it indicates that the static mixer may be more effective in improving the water quality of treated effluent, which is essential for compliance with environmental regulations and protecting receiving water bodies.

The higher COD reduction achieved by the static mixer can be attributed to its ability to provide better mixing and contact between the coagulants and wastewater. The enhanced turbulence and extended contact time in the static mixer promote the formation of larger and denser flocs, which are effective in trapping and precipitating organic particles (Temesgen et al., 2017). This, in turn, leads to a more substantial reduction in the organic content of wastewater as measured by COD.

The results suggest that the static mixer pre-treatment has several advantages over using impeller mixer in terms of the effectiveness of the oil and grease reduction process. Some of these advantages are: (1) creating more uniform and smaller oil and grease droplets than the impeller mixer, which increased their settling or rising velocity and improved their separation efficiency; (2) generating less foam and air bubbles than the impeller mixer, which reduced the entrainment of oil and grease droplets in the water phase and prevented their re-emulsification; (3) having a lower energy consumption than the impeller mixer, which reduced the heat generation and evaporation of water, thus maintaining a higher density difference between the oil and grease and water phases.

Conclusion

In conclusion, the research results strongly support the assertion that static mixers offer advantages over impeller mixers in terms of the effectiveness of the oil and grease reduction process and the reduction of COD in wastewater. The higher removal rates and COD reduction observed in the static mixer system highlight its potential as an efficient and environmentally friendly solution for the pretreatment of restaurant wastewater.

These findings have important implications for the wastewater treatment industry, particularly for facilities dealing with high concentrations of oil and grease, such as those found in restaurant effluents. By choosing static mixers over impeller mixers, wastewater treatment plants can improve the overall performance of their treatment processes, reduce the environmental impact of wastewater discharge, and ensure compliance with regulatory standards.

Future research in this area may explore optimization techniques for static mixer design and operation, further investigate the economic and energy-related aspects of static mixer implementation, and assess the long-term sustainability and reliability of static mixer systems in real-world wastewater treatment applications. Additionally, comparative studies involving a broader range of wastewater parameters and treatment scenarios could provide a more comprehensive understanding of the versatility and advantages of static mixers in wastewater treatment processes.

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