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Green Innovation: Harnessing Photovoltaic Power in a Novel Mechanical Mixer for Wastewater Treatment

Alaa Faris Obaid Al-Dirawi
Al-Muthanna University / College of Engineering

Abstract: The potential of photovoltaic solar energy in Iraq is plentiful but remains largely untapped, leaving many rural communities without grid access. There is an opportunity for stand-alone photovoltaic systems tailored to the electrical load, solar radiation, and location of underserved residential areas. The high upfront yet low operating costs of solar stand-alone systems can competitively electrify households. This article analyzes the design and economic feasibility of installing stand-alone solar photovoltaic systems to power residential areas currently off the grid in Iraq. Location-specific solar radiation data informs optimal system sizing. The electrical load demands of a typical Iraqi household determine the required system specifications. Detailed system sizing calculations and economic projections reveal the large upfront but ultimately worthwhile investments for solar electrification in rural Iraq. The article additionally examines mechanical mixing design, exploring the fluid dynamic forces exerted on impellers and consequent stresses on shafts and gear reducers. Transient flow asymmetries induce dynamic loading. The impeller-vessel interaction proves critical. Oil removal via coagulation-flocculation treatment shows promise, achieving heightened oil removal with a particular 4-bladed impeller system. Experiments systematically vary impeller speed and pH to optimize treatment conditions. The kinetics reveal key insights into maximizing treatment efficacy. Altogether, tailoring photovoltaic technology to rural areas and optimizing mixing reactor design usher renewable, off-grid electricity and improved wastewater treatment.

Keywords: Photovoltaics, Solar energy, Mixer design, Impellers, Wastewater treatment.

1. Introduction

Mixing substances has historically been a crucial process in numerous engineering applications [1]. It has had a significant impact on many industries, including pharmaceutical, biomedical, consumer product, petrochemical, and paint. These industries use active or passive methods to combine two or more substances [2]. Mechanical and process operation must be considered when designing mixing equipment. Despite the fact that mixer design starts by a emphasis on procedure supplies, design of mechanical is critical aimed at fruitful process [3]. A skilled maker of mixing equipment usually takes care of the mechanical design. However, there are process conditions that may place substantial mechanical stresses, such as when an impeller operates near the liquid's surface [4]. The procedure's setting also has an effect on the motor enclosure options. The process supplies may impact mechanical design in several ways. The equipment designer still takes into account other aspects, such as the typical occurrence of a mixer shaft, as necessary [5]. While most people see a single piece of machinery—like a pump—in reality, a mixer really consists of several different mechanisms—such as a motor, gear reducer, seal, shaft, impellers, and tank—that are often built and purchased separately [6]. Mixers may be tailored to meet specific needs, but in reality, they are often just a mixture of generic parts that have been

tweaked here and there and often have distinguishing features like shaft length [7]. Given the detrimental social and environmental impacts as well as the value volatility of fossil fuels, one of the world's main issues is figuring out how to reduce energy usage from these sources [8]. One of the insufficient methods remains toward upsurge renewable energy bases like solar by way of an alternative clean basis toward protect the setting, adhere toward global and national policies indorsing clean energy growth, and upsurge energy admission in city and rural areas [9]. Solar energy remains ecologically outgoing and plentiful. Solar technologies harness the sun power toward deliver heat, light, and electricity aimed at national and manufacturing requests [10],[11]. With the disturbing rate of reduction of main conservative resources of energy for example coal, petroleum, and natural gas, mutual with the ecological squalor caused through the procedure of harnessing these energy bases, it has develop a crucial need toward capitalize in renewable energy incomes that would power the upcoming adequately deprived of degrading the setting through greenhouse gas emissions [12], [13]. The sun's energy possible is huge, nonetheless despite this limitless reserve, reaping it is problematic because of the incomplete competence of array cells. Solar energy can remain rehabilitated toward electricity or heat by means of one of two skills: a photovoltaic system or a solar collector. Solar energy remains mostly used to generate electricity or heat for commercial or residential purposes [14], [15]. One of the five areas of global financial growth with the most conclusive power in the twenty-first century remains new energy skill. Solar energy is a spotless, well-organized, and renewable source of energy. Administrations will usage resources of solar energy by way of a national sustainable growth strategy in the novel reality. The cohort of photovoltaic power remains safe and dependable, crops no noise or contamination, remains less constrained, has a little disappointment rate, remains simple to uphold, and consequently on [16],[17]. Because of the instability of oil prices, emerging countries' capacity toward mount solar photovoltaic (PV) panels has augmented meaningfully aimed at additional than a decade [18]. However, because of their numerous advantages, solar photovoltaic (SPV) generators can be used for a variety of energy applications. SPV isolated systems are low-cost, secure, and simple solutions for decentralized energy supply. They enable the installation of secure and decentralized electrical sources in areas remote from power plants [19]. There are many different sources of oil-contaminated wastewater, including crude oil production, oil plants, petrochemical manufacturing, emollients, cooling agents, and restaurants, among others. This is because the amount of oil being rummaged and sold is increasing due to industry expansion [20]. Pollutants in oily wastewater may cause cancer and genetic mutations in people and other animals. Phenols, polyaromatic hydrocarbons, and petroleum hydrocarbons are some of the toxic substances present in this wastewater [21],[22]. Instead of being a distinct chemical compound that can be extracted using solvents like hexane, oil and grease are more accurately described as mixtures of related components [23]. Because they are not polar, they are hydrophobic. The oil-phase in effluent from refineries may take on many forms depending on the circumstances, but oil is usually soluble in water [24], [11].Oily waste is a major and common source of contamination in natural water, soil, and the atmosphere [25]. Recovery or ultimate disposal of oily wastes may protect the environment from these contaminants. The aims of this research are threefold. First, to promote renewable photovoltaic systems as an eco-friendly alternative minimizing fossil fuel dependence and environmental impacts. Second, the study explores the mechanical design of mixers, assessing performance across different impeller configurations. Finally, building on the mixing analysis, the research examines treatment outcomes of oily wastewater via coagulation and flocculation processes

2. Experimental Work

The experimental work included three stages; the first stage is solar photovoltaic system. the second stage was mixing processes, the third stage include oily wastewater treatment by coagulation-flocculation, and sedimentation processes

2.1 Composition of Solar Photovoltaic System

After studying the solar photovoltaic power cohort's values, scientists developed solar photovoltaic components that could produce energy according to their specific tasks. As seen in Figure 1, a solar photovoltaic system may directly generate electrical energy by using solar power via a solar cell module. By harnessing the electrical characteristics of semiconductors, a device known as a solar cell may achieve the P-V transition. The solution may be easily implemented in most off-grid settings using user-powered lights of life system. It is also possible to accomplish complementarity in some industrialized nations by using it in tandem with the regional power grid. Here are some elements to consider while developing a solar photovoltaic scheme:

1. Consider solar photovoltaic system locations and solar radiation conditions.
2. It is necessary toward deliberate how much load power the solar photovoltaic system should carry.
3. The use of DC or AC power aimed at the system's output voltage must remain careful.
4. The amount of time each day that the plans are crucial for getting things done.
5. How many consecutive days of sunshine must the system provide while it's raining?
6. The beginning current magnitude and whether the load is completely resistive, capacitive, or inductive should be taken into account [26].

Power generation systems consist of many components such as solar cells, batteries, charge controllers, inverters, AC power distribution cabinets, automated solar tracking systems, dust removal systems, solar modules, and more.

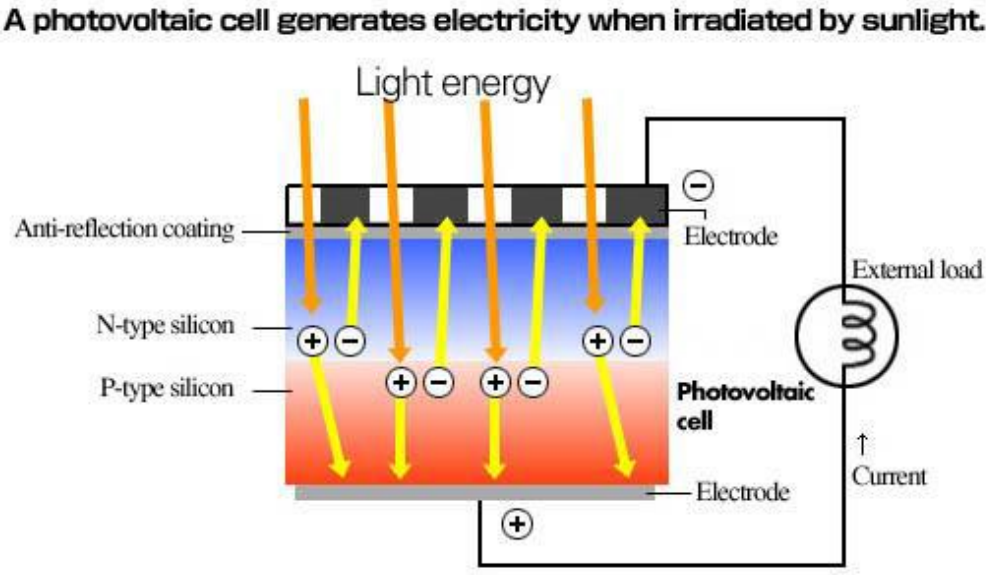

Figure 1: Photovoltaic cell.

2.2 Mixing Processes

Impellers, a shaft, a power source, a prime mover, and a gear reduction unit are the standard components of a mixer. The free end of most of the installations' overhung shafts isn't supported by a solid bearing. The configuration of the impeller and shaft are subject to the forces mentioned. Due to these several processes, the fluid velocity in the reactor is not stable. All of the components—the motor, shaft, reducer, and individual impeller blades—are subject to ever-changing stresses. Typically, the motor's current fluctuates between 5% to 15% of its mean. This is almost double the normal load variation on the shaft, and four times the load fluctuation at the motor, which happens on the impeller blades. A design engineer's duty is to keep in mind how these very fluctuating loads affect the components of the mixer as a result of the mixing process.

2.3 Coagulation and flocculation

One of the most important physiochemical processes used by water is coagulation. For a look at how this process rummage-sale works, go to Figure 2. The goal is to destabilize and aggregate tiny particles into bigger ones. Electrostatic charges are the primary mechanism by which water contaminants, such as ions (heavy metals) and colloids (both organic and inorganic), are retained in solution.

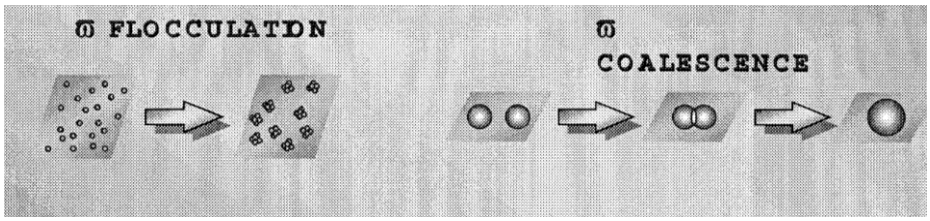

Figure 2: Illustrates the coalescence and flocculation of colloidal particles.

The charge on organic and organic colloids remains characteristically negative when oil particles are suspended in water. The negative colloid charge attracts positive ions due to electrostatic forces. Figure 3 shows how coagulants reduce the electric charge on the colloidal surface, permitting colloidal particles toward join together.

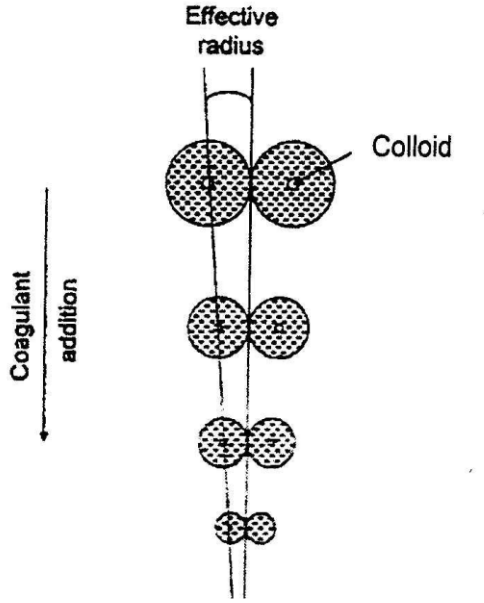

Figure 3: Charge neutralization (coagulation).

2.4 Materials

The materials rummage-sale in the present study can be exemplified by way of the following:

Two coagulant materials used in the education are shown in Table 1.

Table 1: Coagulant used and their specification, chemical name, and composition.

NO.	Coagulant and its specification	Chemical name	Composition %
1	Ferric sulphate is a strongly cationic, high molecular weight, solid coagulant.	Ferric sulphate	100

Commercial flocculent used is polyelectrolyte (polyacrylamide), France, it's physical and chemical properties are shown in Table 2.

Table 2: Physical and chemical properties of polyacrylamide.

Property	Value
Form	Powder
Odor	Odorless
Color	White
Bulk density	600 kg/m^3
Solubility in water	Forms a viscous solution
Mwt	5,000,000 gm/gmol
Formula	$(C_3H_5NO)n$
Purity	(99%),
Melting point	84 ^oC

CCl_4 is used for the analysis. The properties of CCl_4 are shown in Table 3.

Table 2: Properties of CCl4 solvent.

Property	Value
Physical state	liquid
Molecular weight	153.82
Color	Colorless
Odor	Aromatic, sweet
Melting point	-23 °C
Boiling point	76.5 °C
Formula	CCl_4
Purity	99%

2.5 Process of Tests

With the goal of decisive which coagulant remains suitable aimed at oily waste water action toward reduce turbidity. In the trials, two coagulants are used. The upper layer of treated oily waste water was then sampled and examined aimed at turbidity by means of the turbidity meter show shown in Figure 4. The first section of this work's experimental section involves measuring the turbidity of oily waste water. Transfer the contents of the beaker into a sample tube using a magnetic stirrer, being careful not to introduce any air bubbles into the oily waste water sample. Put the sample tube into a calibrated turbid meter and take readings.

In a 250 mL beaker that had a magnetic stirrer, coagulation and flocculation tests were conducted. One hundred fifty milliliters of similarly greasy, murky effluent water (210 NTU) was added to the beaker. Various amounts of ferric sulphate (10, 20, 30, and 40 mg/L) and polyacrylamide reagent (1, 1.5, 2, 2.5, and 3) were added to the beaker as coagulants and flocculents, respectively. After 2 minutes of adding the coagulant, the beaker was mixed quickly (120 rpm), and after 20 minutes of adding the flocculants, it was mixed slowly (50 rpm). The suspension was given 20 minutes to settle once the agitation was turned off, as per ASTMD2035. Finally, a pipette was used to extract a sample from the supernatant in order to test the oily effluent for turbidity and oil content. The organic content in the oily wastewater was determined using the UV 1800 in Figure 5, which remained a rummage-sale in this study. The water was treated with CCL4 in order to extract the oil.

Figure 4: Turbidity meter.

Figure 5: The UV 1800 photo picture.

2.6 Determination of organic concentration

A stock solution was prepared by dissolving 0.4523 g of crude oil in 50 mL of carbon tetra chloride. Through dilution with CCl4, various amounts were obtained. In Figure 6, we can see the results of the absorbance measurements taken at 277 nm using a UV spectrophotometer on those samples. For the concentration range (100 to 700 mg/L) shown here, the concentration-absorptance relationship is linear.

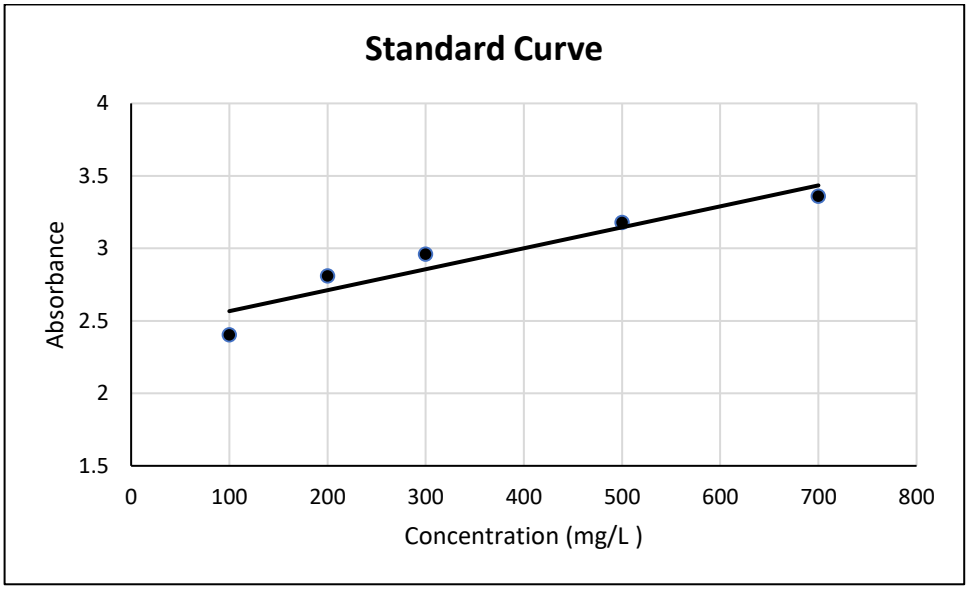

Figure 6: Calibration curves of crude oil

The oil emulsion was broken by adding 0.2 gram of NaCl to 40 mL of greasy water left over in the sifting funnel. Rapidly shaking the mixture for 2 minutes after adding 5 mL of CCl4 was the next step. After 25 minutes, the solution split into two layers. The absorption measurement was done using the bottom (organic) layer. The starting percentage of oil in OWW was obtained from the calibration spectrum.

3. Results and Discussion

The experimental results are demonstrated and discussed in this chapter. In the first place, we have oily waste water and how different doses of flocculents and coagulants affect its turbidity and oil content, as well as their relationship, were investigated. Second, the effect of various parameters such as mixing time, rpm, and blade effect on impeller design for coagulation and flocculation refinery wastewater treatment.

3.1 Photovoltaic energy

Because of continuous technical expansion and reduction of cost, photovoltaic solar projects that generate electricity from solar radiation are predicted by way of a knowledge option that will meaningfully contribute to the maintainable energy supply [10]. Figures 7 and 8 show the average monthly irradiation with time on the horizontal plane in (Wh/m2/day) for a site in northern Iraq (37° N - 43°E). It has been discovered that the maximum solar radiation occurs between June and July, with a slight difference between the two months influenced by the air mass of this site and weather conditions.

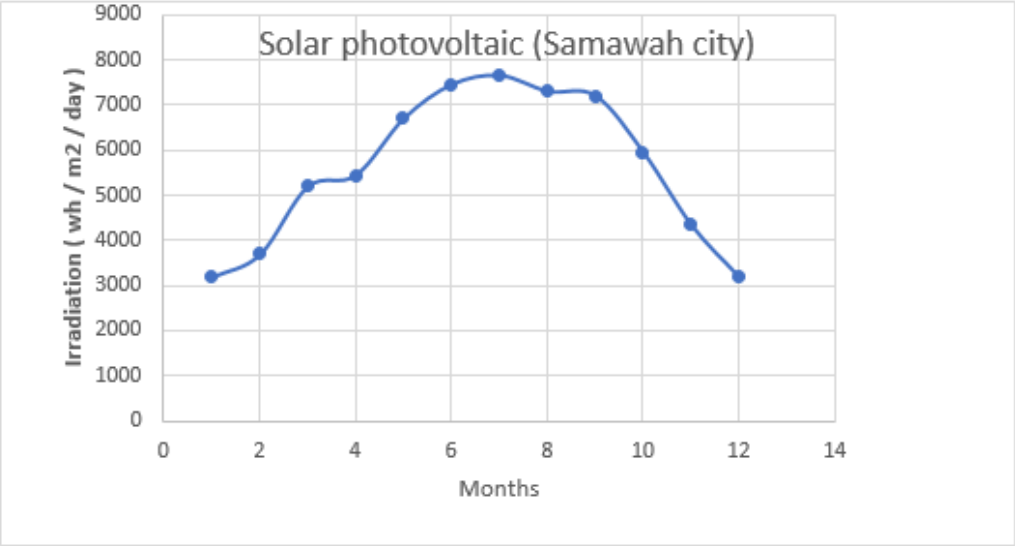

Figure 7: The monthly radioactivity with time on flat plane

Renewable energy is becoming increasingly popular all over the world. Solar energy-based electricity generation has become a viable and acceptable option all over the world [12]. Solar energy is the finest and most rational alternative toward burning fossil fuels in Iraq. If used properly, the solar energy that falls to the ground in one hour is enough to power the entire planet for a full year. There is no denying that energy availability is critical to societal progress and development. It also addresses issues for instance water, nourishment, the environment, well-being, teaching, weather defense, information, communication, and mobility. One of the most pressing issues confronting the world today is a sufficient supply of environmentally friendly energy that reduces high air pollution and greenhouse gas emissions. Solar energy, rather than fossil fuels, can be used in a variety of applications [27], [28].

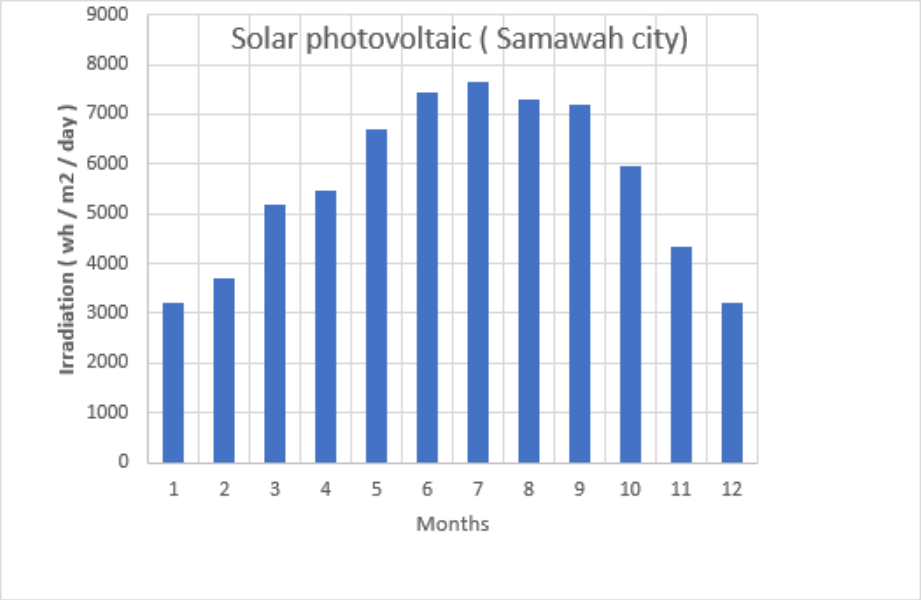

Figure 8: The monthly radioactivity with time on flat plane

3.2 The effect mechanical impeller

A mixer's mechanical design that prioritizes the forces exerted on the impellers by the fluids flowing through the mixing vessel. Intermittent fluid flow anomalies acting on the blending impeller are the forces that create them, according to the research. Axial flow impellers that are designed for high efficiency employ no separated flow. When it comes to coagulation and flocculation treatments, the oil removal rate goes up in direct proportion to the impeller blade size. The two variables that influence the impeller, mixing time and rpm, are used to examine the outcomes.

3.2.1 Effect of mixing time:

Understanding the two impellers' respective flow patterns is the first and foremost need. In Figures 9 and 10, we can see the mixing times of the main wastewater treatment systems with one and two impellers, respectively. The oily waste is mixed more quickly in axial flow impellers, exposing the impeller zone to high intensity shear more often than the bulk zone, where turbulent energy dissipation rates are much lower [29]. The following figures show photos of flocs at different phases of flocculation. Large flocs are developing after 15 minutes of flocculation, while tiny clusters are still common. This results in a bimodal distribution of floc size. The bigger the floc, the more irregular its structure becomes due to the increased porosity that comes with increasing floc size. In twenty minutes, the majority of the smaller clusters have been "swept out" and integrated into the bigger flocs' structure, but a few are still there. According to flocculation figures, the floc structure is due to collisions between aggregates; the floc picture reveals that the floc is composed of several smaller flocs that are packed together in an arbitrary pattern [30].

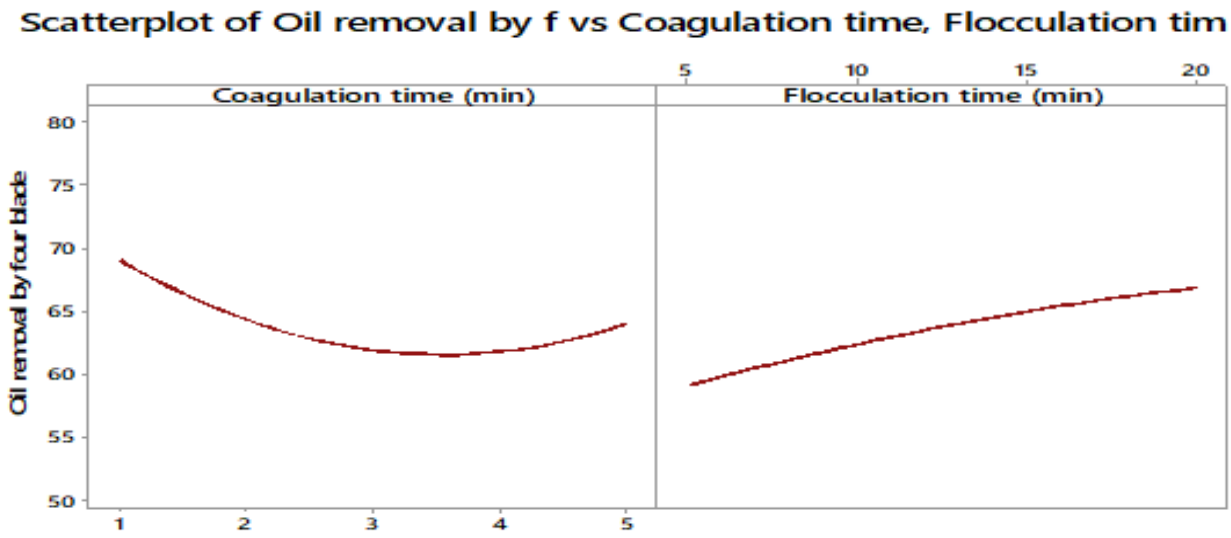

Figure 9: The effect of mixing time on coagulation and flocculation treatment for one impeller with four blades

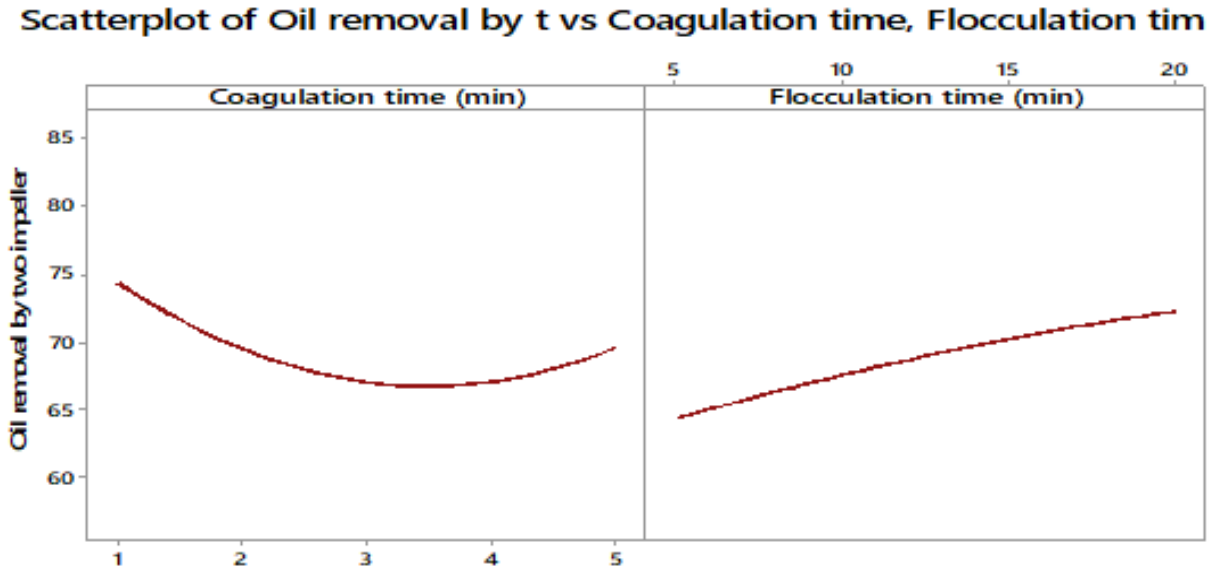

Figure 10: The effect of mixing time on coagulation and flocculation treatment for two impellers with four blades.

3.2.2 Effect of speed impeller

Typically, the degree to which the liquid is homogenized in the agitated vessel is affected by the speed of the impeller. On the other hand, the geometry of the agitated vessel and the kind of impeller both has an impact on the mixing time [31]. This effect is shown in Figures (11 for one impeller) and (12 for two impellers). The experimental results reveal that the efficiency of essential oil removal was time- and speed-dependent, with shorter mixing durations requiring faster speeds for coagulation. Both Figures 11 and 12 demonstrate this for a rapid mixing period of 60 seconds. Slow impeller speeds and extended mixing durations remove the most oil in the flocculation process, as seen in Figure 12. At low impeller speeds and high time mixing, the flocculation treatment yields the best oil removal results (Figure 12). Additionally, using two impellers results in significant oil removal from a single impeller in oily wastewater [7].

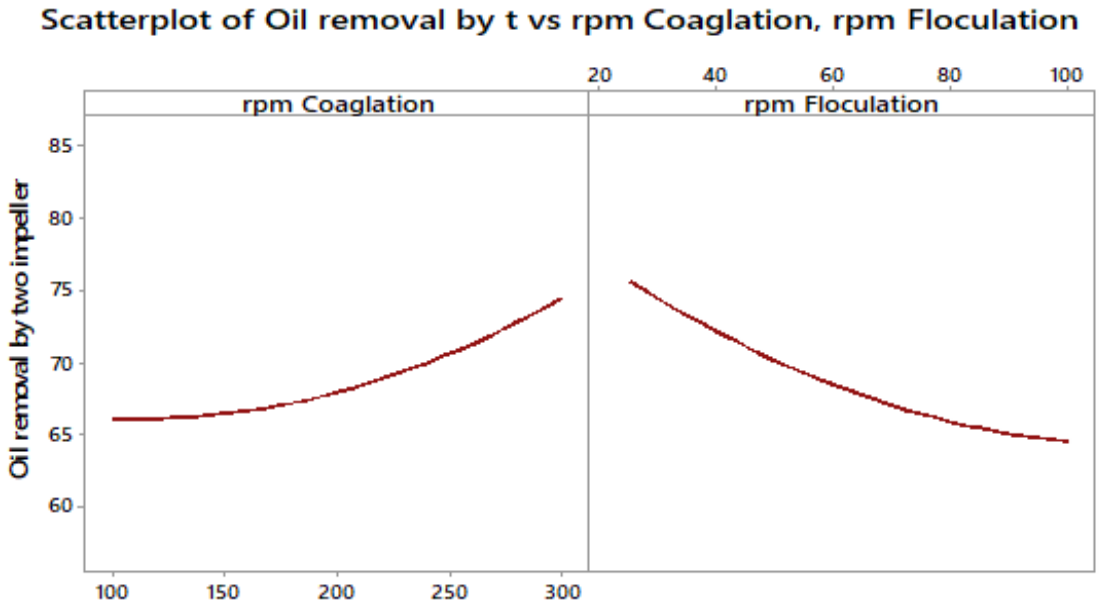

Figure 11: The effect of speed impeller on coagulation and flocculation treatment for one impeller with four blades

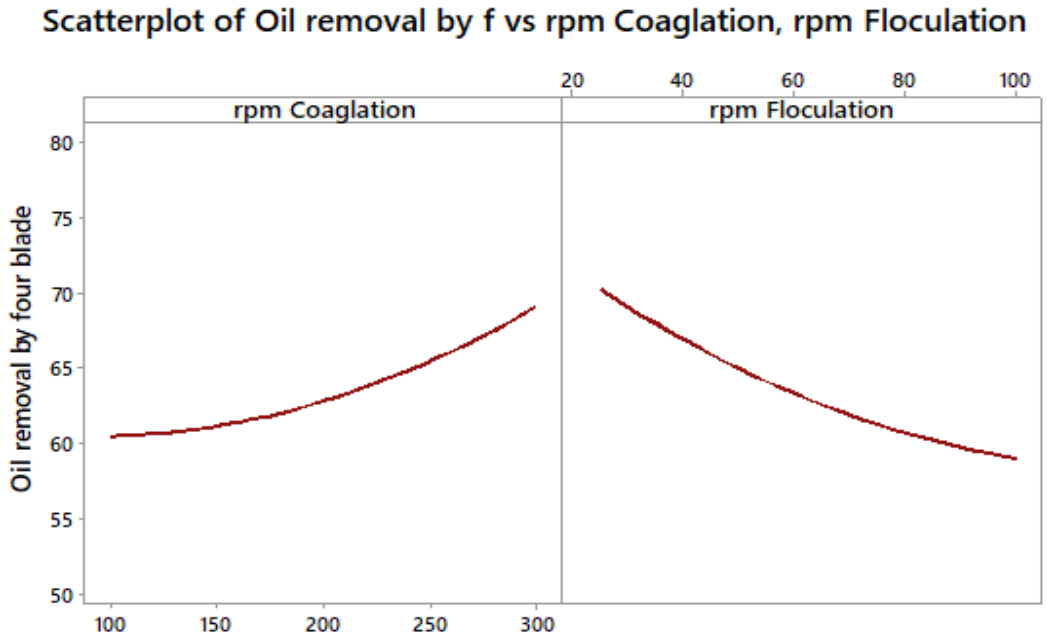

Figure 12: The effect of speed impeller on coagulation and flocculation treatment for two impellers with four blades

3.2.3 Comparison between one and two impellers

This thesis aims to describe the impact of different types of impellers on the growth of average floc size and shape during stirred tank flocculation of poly acrylamide particles with iron sulfate. Using image analysis, the size and structure of the floc are tracked throughout time, allowing us to understand the structural processes leading up to steady state [32]. It continues to be demonstrated that the average floc size at steady state is influenced by the recirculation incidence to the impeller zone and the characteristic velocity gradient of that zone. The outcomes of comparing the use of one impeller compared to two impellers for coagulation, as well treatment is depicted in Figures 13 and 14, which indicate that employing two impellers increases, oil removal.

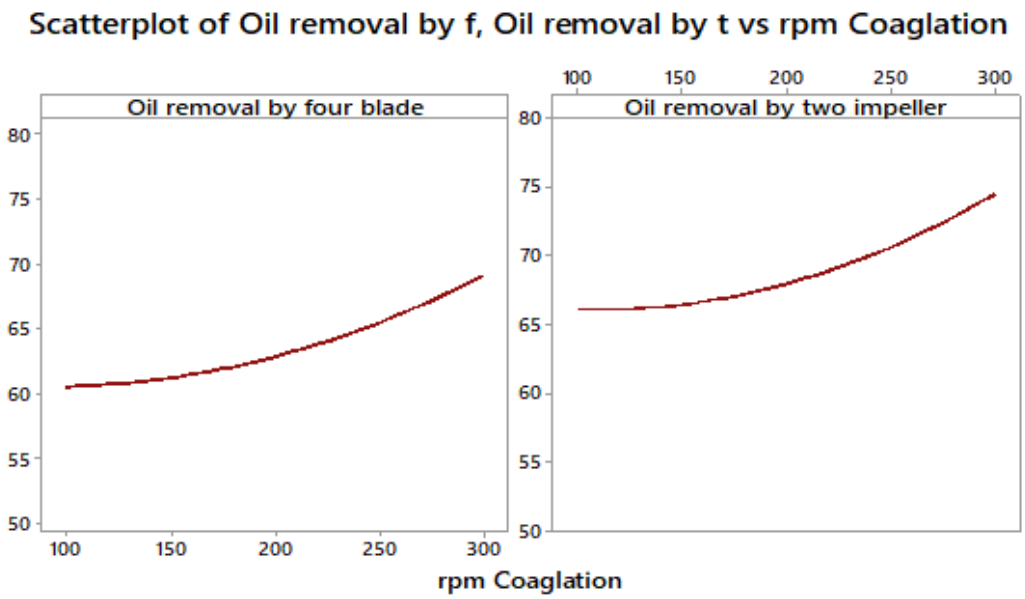

Figure 13: The effect of speed impeller on coagulation for one and two impellers

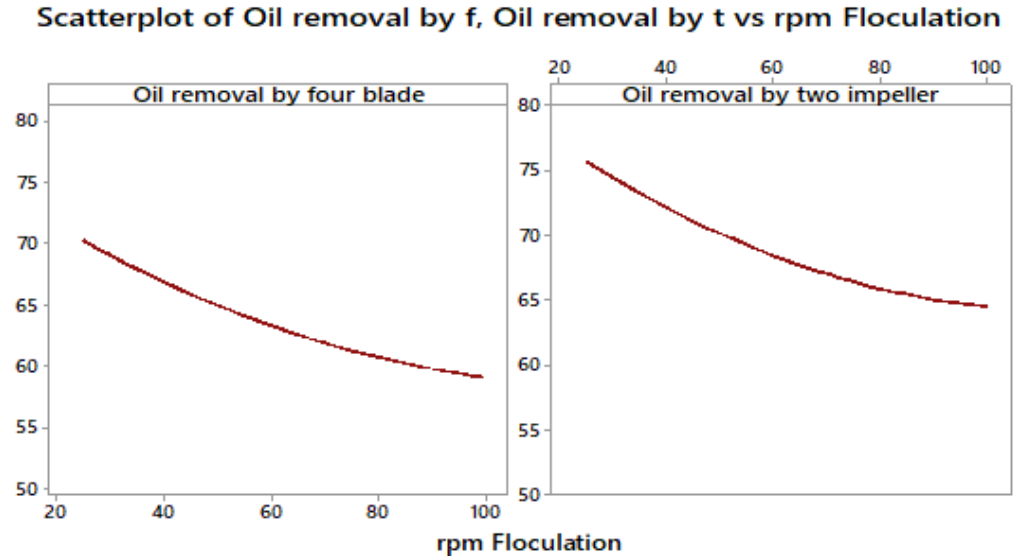

Figure 14: The effect of speed impeller on flocculation for one and two impellers

4. Conclusions

1. Dust storms significantly reduce solar radiation rates in Iraq, negatively impacting the solar energy potential. Further research on mitigating dust storm effects on photovoltaics is warranted.
2. Solar energy demonstrates potential as the second largest energy source in Iraq after oil reserves if dust storm effects can be addressed. Additional renewable sources may further offset electricity shortages.
3. The fluid forces imposed on impellers govern mechanical mixer design and performance, originating from asymmetries in the vessel-impeller-fluid interaction.
4. Optimal mixer configuration, informed by computational fluid dynamics, enhances oil removal efficiency from wastewater via dual four-bladed impeller coagulation-flocculation treatment.

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