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THE EFFECT OF VOLTAGE ON HDPE MICROPLASTIC REMOVAL BY ELECTROCOAGULATION PROCESS USING STAINLESS STEEL ELECTRODE

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ABSTRACT

Plastic pollution, especially high-density polyethylene (HDPE), is highly concerned with human health and ecosystems. This study investigates the potential of the electrocoagulation process on the removal of HDPE microplastics from water, evaluating the best operating conditions, including the voltage (4, 8, and 12 V), time (40, 80, and 120 minutes), and pH (3, 5, 7, and 9) to achieve the maximum removal efficiency. Coagulation experiments were conducted in the electrolytic cell, using stainless steel and aluminum electrodes, while Na_2SO_4 served as the electrolyte. Because loss of surface area and change in structure was more evident in fragmented flake and granular microplastics (FTIR and SEM analyses), those microplastics were more retained in the swollen coagulant. The alkaline condition also supports the highest removal efficiency of 96.60% when the pH, voltage, and duration were 9, 8V, and 120 minutes, respectively, as experienced in addition to 0.1g of carbon CTO5 in the study. Conclusions Our findings show that electrocoagulation works best at a medium voltage and in alkaline pH conditions. Under low pH conditions, the removal is not notably influenced by the applied voltage, whereas under neutral and alkaline conditions, removal is significantly enhanced with increased voltage. Moreover, the stainless steel electrodes were more corrosion-resistant than aluminum, thus making the process more sustainable. The results indicate that electrocoagulation represents an environmentally friendly, effective microplastic removal method under the right voltage, time, and pH conditions. Such techniques are an effective strategy that helps reduce water contamination and conserve ecosystems.

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INTRODUCTION

Microplastic pollution represents a serious global environmental issue, especially because of its potential effects on health and ecosystems [1]. Worldwide production of plastics totaled 350 million tons in 2017. The generation and release of microplastics into the environment reached 11 million tons [2]. Statistical data in 2020 showed that Indonesian plastic waste reached 66 million tons per year [3]. The distribution of microplastics is 66.67% on the island of Java. The form of microplastics are mostly found in fiber compared to other forms found in freshwater, sea, and the body of organisms [4]. Microplastics: 1-5000 μm

according to size and nano (<1 μm). The blobs can be fibers/filaments (thin or fibrous, straight), pellets (hard, round particles), fragments (hard plastic particles, jagged), foam (light, spongy), or film (thin sheet). Split into blue, black, yellow, transparent, white, and red [5].

High-density polyethylene (HDPE) microplastics in Figure 1 were discovered in marine and freshwater [6]. HDPE is pervasive because it becomes attached to disposable plastic products ubiquitous in everyday life. [7], [8] Microplastic contamination in the environment continues to rise, with microplastics present in different air, water, and soil regions. Effects on Health, Biota, and Ecology [2]: oxidative stress resulting from high intracellular concentrations of reactive oxygen species (ROS), promoting inflammatory activity, and derangement of energy homeostasis and metabolism, which can lead to cytotoxicity, genotoxicity, metabolic disorders, and potentially carcinogenesis [9]. Thus, its handling is important, and one of these is chemical electrolysis.

Figure 1. HDPE plastic (high-density polyethylene)

Foam presence in aquatic ecosystems is an environmental problem as foam is resilient and non-biodegradable. Thanks to its durability, high-density polyethylene (HDPE) is a versatile plastic used in everything from packaging to industrial products. Still, it represents a long-term threat when disposed of improperly, potentially leaching into water bodies and harming aquatic biodiversity. This bioaccumulation travels up the food chain, and ingestion by aquatic organisms disrupts food chains, harming human health. Conventional remediation approaches, including filtering and bioremediation, have inherent drawbacks. These methods often prove prohibitively expensive and impractical for large-scale deployment and struggle to effectively capture microplastics, which are typically microscopic and chemically resisted 10. Therefore, there is a pressing need for innovative, cost-effective, and scalable solutions to help reduce microplastic emissions and their wide-ranging effects.

Electrocoagulation is a promising alternative and exhibits a practical, eco-sustainable solution for microplastic removal. This technique uses electric current to cause coagulation, allowing for the clumping and removal of microplastics from the water. This rapid, energy-efficient, and flexible water treatment technology provides significant advantages over conventional techniques for contaminated microplastic water treatment. It can maximize the fundamental parameters (voltage, time, pH, etc.) for better removal efficiencies. In addition, replacing electrodes with stainless steel promotes more durability and cost-effectiveness as the commonly used materials, such as aluminum and iron, are limited in their application 12. Through a rigorous variation of even partially factoring in the variation of these parameters, we not only gain a better understanding of microplastic remediation processes but also can further

the development of scalable and practical water treatment technologies, which are key to sustainable environmental management.

One key novelty of this study is that it employs stainless steel electrodes having significantly higher corrosion resistance and durability during operation than Al and Fe electrodes commonly used for electrocoagulation [14]. Unlike polymeric materials, which can degrade over time, and metals that corrode, stainless steel retains its integrity throughout service life, making it a low-maintenance and sustainable solution for long-term processes [16]. Flocs are then formed more quickly, resulting in increased removal rates of microplastics owing to their efficient electrical conductivity. Such results affirm the suitability of the material for the advancement of electrocoagulation technology, as in previous studies, the limitations were enhanced durability of the electrodes with reasonable efficiency [17].

Fewer studies focused on operational parameters such as voltage, duration, and pH, which were emphasized to maximize the removal efficiency and minimize energy consumption. It was revealed that high voltages exhibited rapid flocking, while alkaline pH conditions induced the coagulation process with 96.6% removal efficiency [11]. Not only does this nuanced understanding of the interplay of parameters pave the way for enhanced electrocoagulation of HDPE microplastics, but it also lays a foundation for modifying electrocoagulation to target other pollutants. These results represent an important advance towards the design of efficient and adaptable systems for water treatment.

This study aids early sustainability research on water treatment techniques by combining optimized electrocoagulation conditions with a long-term stable stainless steel water pollutant scavenger. The findings pave the way for an efficient, energy-easily applicable means of combating HDPE microplastic pollution in various environmental settings [14]. In addition to addressing a vital gap in the literature, this study offers theoretical contributions and pragmatic recommendations that complement the global goals of combating plastic waste and advancing sustainability [18].

This work develops the electrocoagulation method for the removal of plastic waste by modeling the interactions of three independent variables: voltage, duration, and pH, in the removal of high-density polyethylene (HDPE) microplastics from water. The study overcomes the drawbacks of conventional electrode materials (like aluminum and iron) to a great extent by adopting the electrochemical performance of stainless steel electrodes with excellent corrosion resistance and low cost. In short, this research's major advantage is presenting a more practical and environmentally friendly solution to removing microplastics, enhancing scalability and efficiency. Electrocoagulation is suitable for large-scale water treatment due to its quick processing, low energy consumption, and flexible approach to different water conditions compared to conventional filtration and bioremediation methods. This study contributes to a deeper understanding of electrocoagulation mechanisms and

catalyzes the development of novel and sustainable water purification processes that cater to the increasing need for efficacious environmental stewardship.

METHODS

1. Material and Equipment

In this study, the materials used include High-density polyethylene (HDPE) plastic as a source of microplastics, anhydrous Sulfuric Acid (H_2SO_4) (98%) for acidification, Sodium Hydroxide (NaOH) for pH adjustment, surfactants to increase solubility, and distilled water as a solvent. Stainless steel and aluminum (Al) electrodes were also used, which were chosen specifically for their durability and conductivity in the electrolysis process. Additional materials were filter paper (Whatman No. 42 and Semi Millipore 0.45 Micron), label paper, and tissue for filtration procedures and data recording.

The equipment used included a set of standard glassware, a set of chemical electrolysis apparatus with a DC power supply (Power Supply Model: MPD-3305C MY WAVE) for voltage regulation, connecting cables, and plastic cups as containers. For mass measurement, an analytical balance (Fujitsu) was used. Other tools included scissors, a digital multimeter (A830L) for measuring current and voltage, aluminum foil, a hot plate (Cimaric & Faithfull), a magnetic stirrer for heating and stirring, and an electrode cover or clamp. In addition, glass and plastic stirrers, thermometer, 60 mesh sieve, spatula, watch glass, grinding machine (HUJIAtool), sandpaper (Grit 120), insulation/duct tape (NACHI TAPE), hammer, pliers, screwdriver, pH meter (EZ9908), basket, oven (Memmert), Buchner funnel, vacuum pump, and bottles were used. For result analysis, analytical instruments such as Fourier Transform Infrared Spectroscopy (FTIR) (Shimadzu Ir-Spirit) for chemical analysis, Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX) (JEOL JCM-7000) for microstructure observation, and microscope (Olympus) for visual observation were used.

2. Sample Preparation

In this look, high-density polyethylene (HDPE) microplastic resolution was achieved with a focus of 0.5 g/L. HDPE was lowered into micro-sized particles with dimensions lower than 0.3 mm (250 µm) to maximize the contact space within the subsequent course. They were then evenly dispersed into water. Thereafter, 20 mg/L of surfactant was added to the solution.

The surfactant's inclusion was intended to resemble the average surfactant concentration in domestic wastewater more closely, hindering microplastics from agglomerating and promoting an even and stable microplastic suspension. Pre-treatment is performed in filtration before the electrocoagulation stage to remove unwanted impurities or particles from the water and the microplastics. This procedure keeps the resulting nomadic microplastic technology solution particle size distribution homogeneous and clean to facilitate the best research outcome.

3. Electrocoagulation of Microplastics

This experiment took one liter of microplastic suspension with uniform concentration. To prepare an anodized aluminum plate and control the electrolysis process, we use an electrolytic cell with Stainless Steel electrodes, Aluminum electrodes (4 cm × 10 cm) with a thickness of 0.1 cm, and separate the distance between electrodes (2 cm). Anhydrous Na_2SO_4 0.05 M was used as the electrolyte to test the current density's influence on microplastic removal, and the voltage was varied at 4V, 8V, and 12V. A Digital Multimeter (A830L) was used to control the voltage. The time of electrocoagulation was also varied for energy efficiency computation against the most effective energy expenditure, which was found to be 40 minutes, 80 minutes, and 120 minutes. The pH of the wastewater was adjusted at 3, 5, 7, and 9 with H_2SO_4 or NaOH solutions that were monitored using a pH meter (EZ9908).

The SOL was agitated at 150 rpm at ambient temperature during the experiment. The solutions were allowed to settle for 16 hours after the electrocoagulation; as we kindly remember in Figure 2 [19], the supernatant was filtered through a 0.45 µm microporous membrane. The membrane was then dried for 24h at 40°C [11], [20], and the mass of microplastics was calculated from the mass difference before and after filtration. Then, the microplastic efficiency was calculated:

FTIR, microscopy, and SEM-EDX were performed on the microplastics post-electrocoagulation to determine their removal mechanism and the efficacy of the electrocoagulation process.

4. Microplastic Analysis

a. Fourier Transform Infrared Spectroscopy (FTIR)

The FTIR analysis was performed to identify functional groups in coagulated microplastics, with a wave number ranging from 400 to 4000 cm^{-1} [21]. Transmittance band peaks in FTIR spectra exhibit typical functional group characteristics. Origin software was used to process FTIR data to identify microplastic functional groups.

b. Microscope

Microscopy observed the structural and morphological changes of microplastics after electrocoagulation treatment. Microplastic particles >100 µm were visible under a low magnification (40x, 100x) light microscope. In contrast, high magnification (400x, 1000x) was used to observe microplastics in the 1-100 µm size range, while stereoscopic microscopes (up to 50x) were used to observe larger microplastics.

c. Scanning Electron Microscope (SEM)

Microplastics were analyzed morphologically using a Scanning Electron Microscope (SEM) to evaluate surface change and particle size. Elemental analysis was performed through the Energy Dispersive X-ray (EDX) mapping technique in which the SEM magnification was adapted to the size and shape of the investigated microplastics [21],

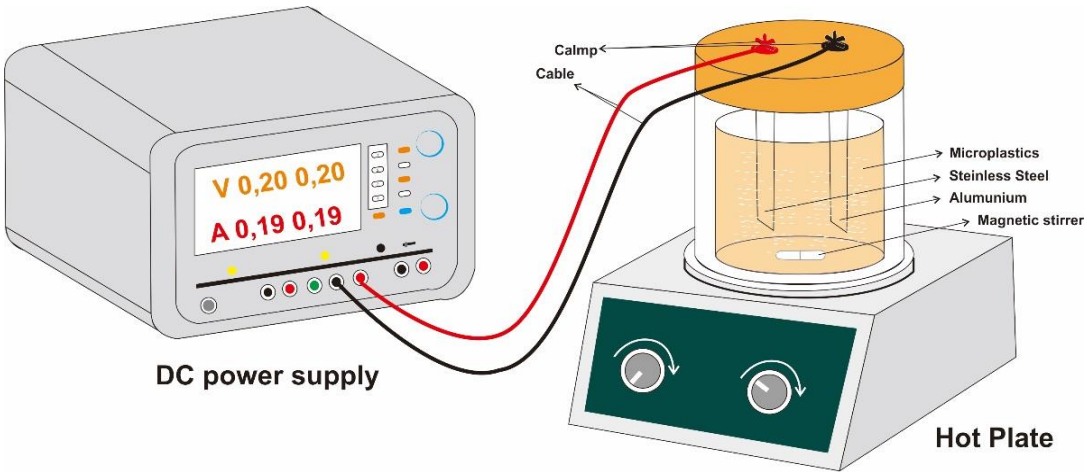

Figure 2. Electrolysis Apparatus Setup

RESULTS AND DISCUSSION

1. Microplastic

Microplastics, defined as plastic particles with a size of no more than 0.3 mm (250 μm) [23], have become an environmental issue of great local and global concern. In 2017, worldwide plastic production amounted to over 348 million tons, of which around 80 percent of Europe's production comprised six main polymers: polypropylene (PP), high- and low density polyethylene (HDPE and LDPE), polyvinyl chloride (PVC), polyurethane (PUR), polyethylene terephthalate (PET), and polystyrene (PS) [6], [7]. Of these, HDPE is used to manufacture different products such as shopping bags, milk & juice containers, shampoo bottles, medicine bottles, Tupperware, water gallons, and folding chairs [22], [25], [26]. This characteristic is explained by the polymer's low-branched linear structure and high crystallinity, which improve its resistance and durability [21]. However, HDPE can also be detrimental to health since its estrogenic effects can upset hormonal systems and have long-term health consequences.

Microplastics, including HDPE particles, accumulate in the higher food chain organisms, including humans, fish, and marine mammals, dramatically affecting the marine food chain and human health. These particles potentially threaten ecosystems, as they can interfere with biodiversity and disrupt the ecological balance [11], [27]. The vast production of plastics contributes to environmental degradation, evidenced by worrying pollution levels and the risk of harmful effects on health and the environment [7]. Microplastics have presented themselves as a most persistent and ubiquitous pollution, emphasizing the importance of effective mitigation strategies to combat this growing global concern.

2. FTIR Analysis of HDPE Microplastics

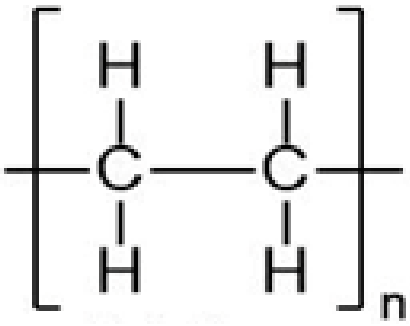

Figure 3. HDPE structure

The chemical structure and functional groups of type microplastic HDPE and electrocoagulated microplastic coagulant were detected by performing Fourier Transform Infrared (FTIR) analysis as illustrated in Figure 3 and Figure 4. Understanding the formation process, the characteristic structure of HDPE is primarily composed of aliphatic hydrocarbon chains, including alkanes and olefins [28], [29], which are further identified with FTIR.

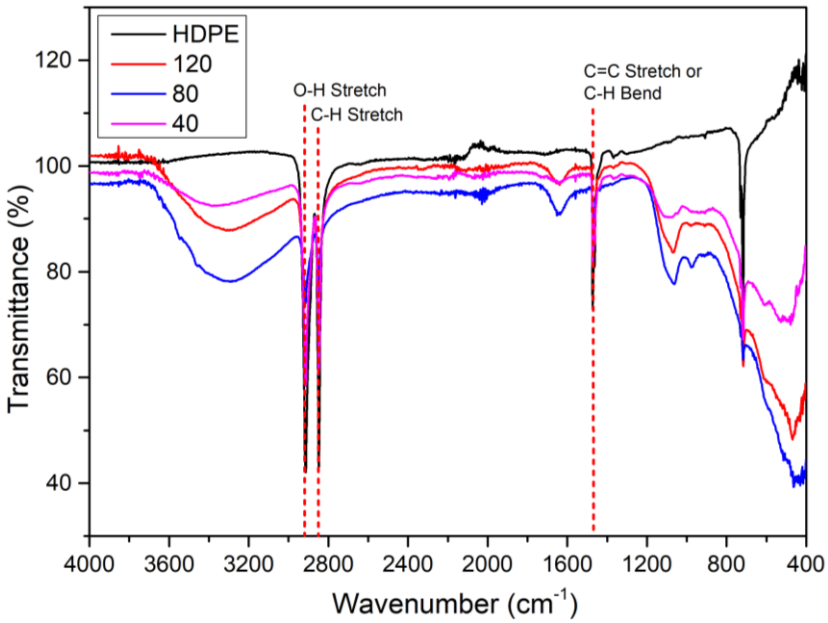

Figure 4. HDPE Microplastic Spectrum

Figure 4 shows the FTIR spectrum of HDPE microplastics, in which the main peaks can be seen around the wave numbers of 2925-2968 cm-1 which reflected the asymmetric and symmetric stretching of C-H bonds of alkane chains and O-H bonds of carboxylic acid chains. This is my usual aliphatic structure in HDPE [30]. Another maximum at 1458 cm-1 is associated with C-H deformation, consistent with standard behavior for alkane chains. So, this peak is well correlated with the attributes of pure HDPE [31]. The sharp peak at 1458 cm-1 corresponds to the vibration of the C-C stretch of the aromatic ring and the C-H bond of the alkane.

The FTIR spectra of HDPE once the electrocoagulation process was performed, represented by the pink (40 min), blue (80 min), syllable (120 min), and black (HDPE) lines in Figure 4, indicates that most presented were intact, containing most of the functional groups characteristic of the HDPE. These results show that the base structure of HDPE is not significantly altered, even in terms of oxidation at certain stress levels. This result is consistent with other studies showing that the electrocoagulation process can effectively bind microplastics without radically altering the fundamental properties of the material [32]. Hence, the resultant

coagulant can successfully adsorb and flocculate the microplastics from the solution.

3. Microplastic Electrocoagulation

Electrocoagulation is an innovative water treatment method that separates contaminants by liberating metal cations from electrodes in an electric field. This is considered an energy-efficient, cost-effective, environmentally friendly, and low-sludge-generating method for working on the water quality and at the same time solving the environmental pollution problems [14], [17], [18]. Moreover, its demonstrated capability in treating various water contaminants, including microplastics, highlights its potential contribution to improving environmental sustainability [11].

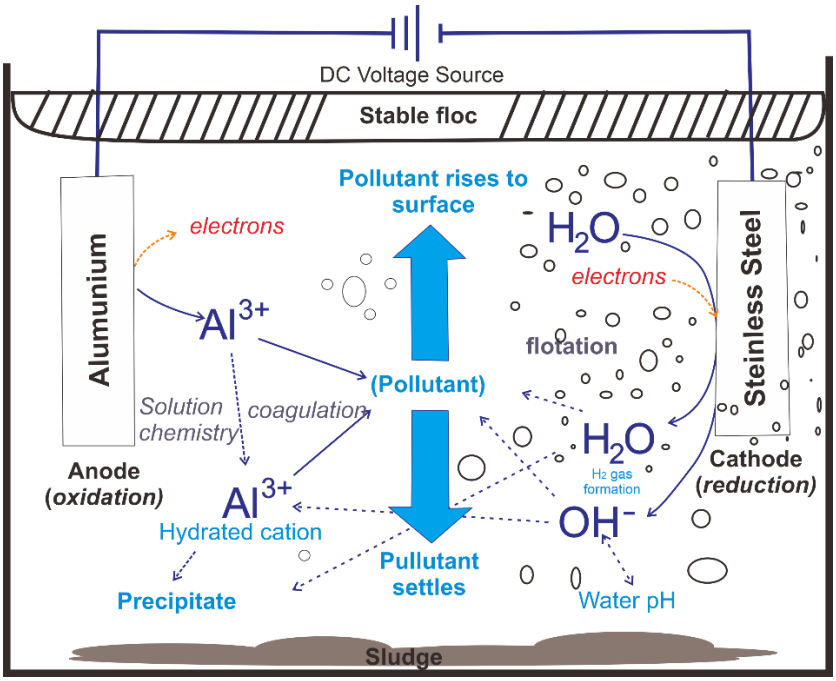

Figure 5. The Electrocoagulation Process

Electrocoagulation was performed using different voltages (4V, 8V, and 12V), pH levels (3, 5, 7, and 9), and times (40, 80, and 120 minutes) in this study. It was found that the enhancement was closely relevant to the voltage value mainly used in high voltages like 12V that speeded up the releasing of metal ions in electrodes and flocculant formation, so improvement caused by flocculant was a dominant mechanism to macroplastic removal efficiency. In contrast, lower voltages produced slower coagulation processes and were less efficient because of the low ion yield. Optimal pH promoted flocculation activity and colloidal stability, thus driving removal rates, while prolonged times effectively enabled microplastic collectibility and deposition [10].

The electrocoagulation mechanisms include three main steps that operate at the same time. In the first stage, an electric current causes metal ions to be released from electrodes, such as from stainless steel or aluminum. Stage II: Electrooxidation (in this step, metal ions dissolve in water after anodic reactions, the whole anodic process). Lastly, during the electroflotation process, the formation of froth assists in raising

microplastics to the surface for effective separation. Such cooperative endeavor guarantees an ever-evolving and thorough strategy to tackle water contamination problems [10].

In this process, Aluminum as an anode and stainless steel as a cathode occur reactions:

Anode:

$$Al \longrightarrow Al3^{+} + 3e^{-} \quad (1)$$

Cathode:

$$3H_2O + 3e^{-} \longrightarrow \frac{3}{2}H_2 \uparrow + 3OH^{-} \quad (2)$$

Floc Formation Reaction:

$$Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^{+} \quad (3)$$

Al loses 3 electrons and forms aluminum ions Al^{3+} tends to remain in solution because it has a higher reduction potential. Al^{3+} reacts with water to form $Al(OH)_3$, which can bind microplastics in the coagulant.

$Al(OH)^{2+}$, $Al(OH)_2^{+}$, $Al(OH)_3$, and $Al_3(OH)_4^{5+}$ ions formed in the reaction process are positively charged, which can adsorb microplastics. The addition of surfactants can increase the negative charge on the surface of microplastics in the solution suspension. It can precipitate microplastics with $Al(OH)_3$—electrostatic adsorption process with the following mechanism [16].

$$\mathrm{AlOH}^{2+} + 2\mathrm{Mikroplastik}^{-} \longrightarrow \mathrm{AlOH}^{2+} - 2\mathrm{Mikroplastik}^{-} \quad (4)$$

$$Al(OH)_2^{+} + \mathrm{Mikroplastik}^{-} \longrightarrow Al(OH)_2^{+} - \mathrm{Mikroplastik}^{-} \quad (5)$$

$$Al_3(OH)_4^{5+} + 5\mathrm{Mikroplastik}^{-} \longrightarrow Al_3(OH)_4^{5+} - 5\mathrm{Mikroplastik}^{-} \quad (6)$$

Electrocoagulation is affected by the pH, strength, and time of the current and the electrode. The electrodes are stainless steel, corrosion-resistant, and stable in acidic and alkaline solutions. Such electrodes can combine more stable flocculants, making them vital in binding and settling microplastics. The floc formed through aluminum anodes is flaky and known to have high polymerization, allowing it to capture microplastic particles, in contrast to iron, which provides a fluffy granular floc. Sorption of microplastics onto aluminum flocs demonstrated that the aluminum electrode has better microplastic binding and higher removal efficiency than iron electrodes.

Similar to previous studies that reported a higher voltage enhanced the dissolved metal ions, promoting microplastic coagulation and flotation [32]. Furthermore, the choice of electrodes and the optimization of voltage, pH, and time parameters can enhance the effectiveness of electrocoagulation, thereby facilitating the efficient removal of microplastics from water [11].

4. Microplastic Morphology

The microscope observations revealed that the increase in voltage applied in the electrocoagulation process led to a marked change in the morphology of the HDPE microplastics. Microplastics of HDPE in the control sample, in the absence of voltage, are small, non-cohesive, and stable particles. The initial clumping occurred with enlarged and non-uniform particle sizes, which are shown in Figure 6 at 4V voltage. At the 8V point, flocculation is more evident with the formation of much bigger and denser particles that are also darker due to oxidation. 12V agglomeration is intense, with dense, large flocs almost filling the entire microscope field of view. Because of the strong oxidation at a higher voltage applied, we see that the highest voltage has the darkest color, indicating the optimal binding of microplastic to the carnallite. In summary, the higher the applied voltage, the better the electrodeposition of HDPE microplastics due to electrocoagulation.

5. SEM of Microplastics

Based on Figure 7, the result of the scanning electron microscope (SEM) shows changes in the morphology of HDPE microplastics at various magnification levels (1000x and 5000x) of electrolysis results using Stainless Steel and Aluminum (Al) after the electrocoagulation process. Figure 7a is a floc of microplastic electrocoagulation products with stainless steel and aluminum electrodes at 1000 x magnification. Strong flocs formed microplastic particles broken at the surface and particle size. The surface morphology of flakes and granular observed in assumed microplastic particles was observed under 5000x magnification Figure 7b.

Table 1 reveals a fairly characteristic elemental composition in analyzed samples, based upon the EDX test results. The mass percentage of carbon (C) is high (41.68±1.06%). All formulas are given on an atomic percentage basis: 51.55±1.30%. The atomic and mass percentages for oxygen (O) were 40.64±1.66% and 43.86±1.79%.

That indicates a more favored production of carbon and oxygen. The atomic percentage for sodium (Na) is 0.46±0.11%, and the mass percentage is 0.72±0.17%. Al: Atomic % = 6.96±0.30% / wt% = 12.67±0.5%. Sulfur (S) at an atomic percentage of 0.50±0.08% and a mass percentage of 1.07±0.7%. In short, the EDX results indicate that the most abundant element is carbon, followed by oxygen and aluminum. Sodium and sulfur are also included.

Table 1. EDX Test Results of Microplastics

Element	*Atomic* (%)	*Massa* (%)
C	51,44±1,30	41,68±1,06
O	40,64±1,66	43,86±1,79
Na	0,46±0,11	0,72±0,17
Al	6,96±0,30	12,67±0,55
S	0,50±0,08	1,07±0,17

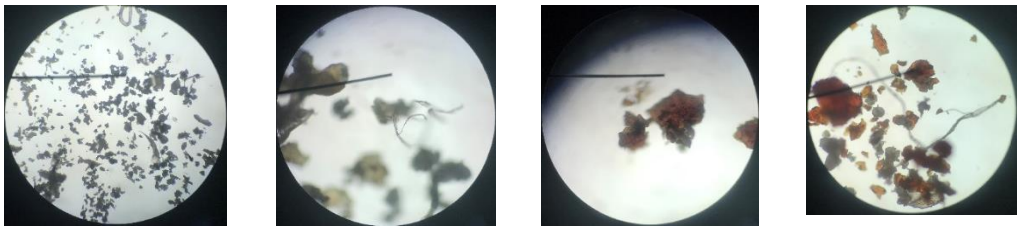

Figure 6. Microplastic shapes observed under a microscope

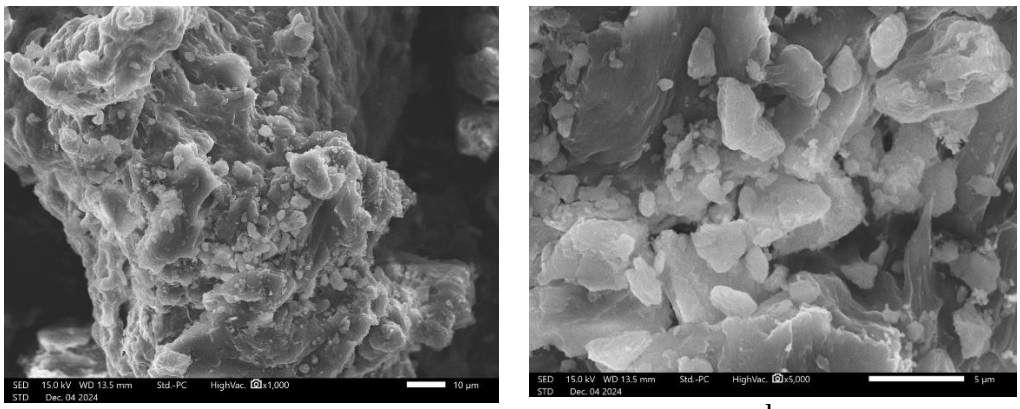

Figure 7. SEM of Microplastic

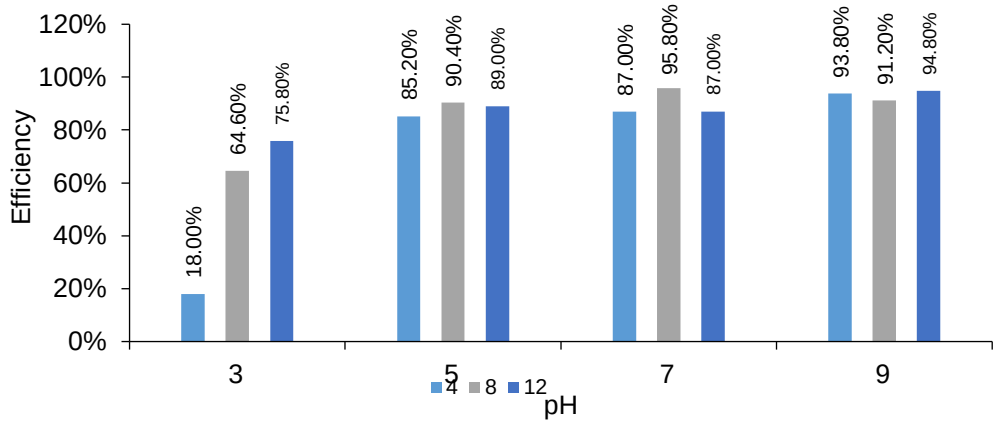

Figure 8. Microplastic Efficiency at 40 Minutes

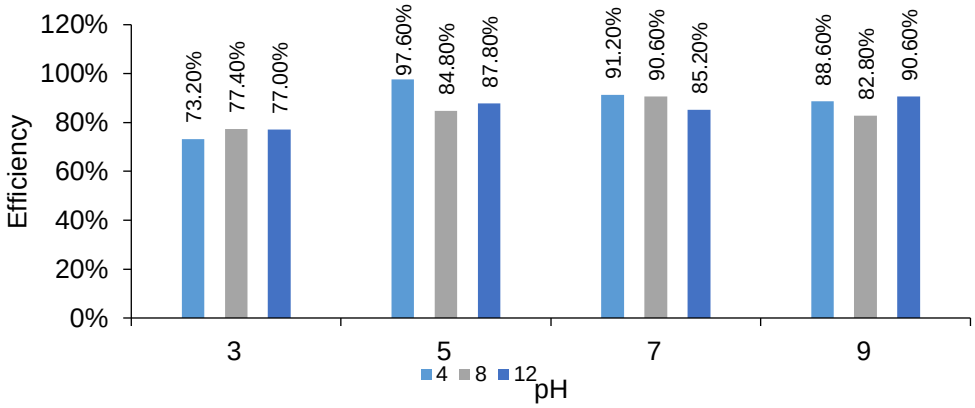

Figure 9. Microplastic Efficiency at 80 Minutes

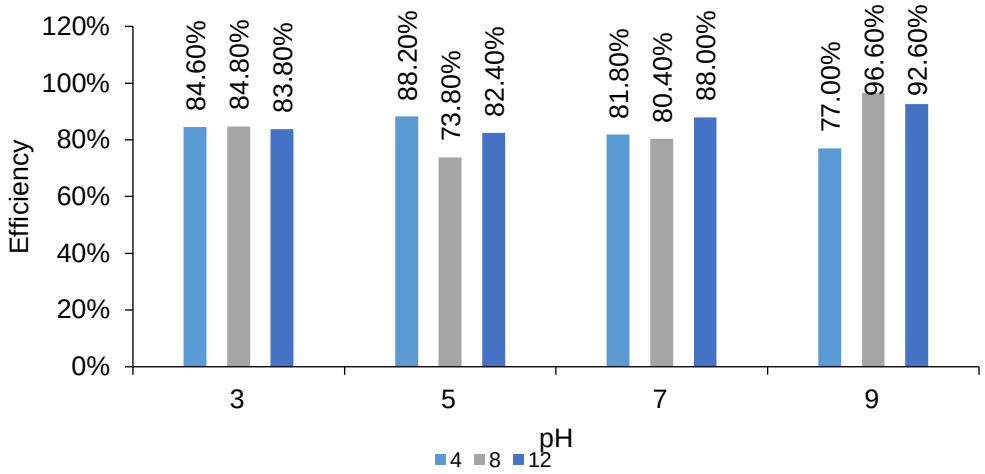

Figure 10. Microplastic Efficiency at 120 Minutes

6. Microplastic Removal Efficiency Concerning pH, Voltage, and Time

a. 40 Minute Duration

At 40-minute duration: The analysis on the microplastic removal efficiency in dependence on the pH (3, 5, 7, and 9) combined with three voltages (4V, 8V, and 12V), which is significant by the combined parameters on removal efficiency of microplastic during the electrocoagulation processes. Results reveal that microplastic removal under strongly acidic (pH 3) conditions is remarkably low at 4V (18.00%) with considerable improvement at higher voltages (8V: 64.60% and 12V: 75.80%), indicating that significantly low microplastic removal is achieved under low pH but high voltage effectively alters the removal profile as represented in (Figure 8). Efficiency, however, is much higher at pH 5, registering at 85.20% at 4V, then rising to 90.40% at 8V and slightly dropping to 89.00% at 12V, showing much less influence of voltage variation on the removal efficiency at this pH level.

At neutral pH (7), the removal efficiency is the best at 8V (95.80%), but the result is reduced to 87.00% when the voltage increases to 12V; at pH 9, the microplastic removal efficiency is up to 93.80% under 4V, while at 8V becomes a bit worse (91.20%) but 12V has an increase (94.80%), indicating that microplastic results at higher pH are relatively better especially alkaline pH. Under high voltage (12V), the complete results have higher efficiency (94.80%) under 40 minutes. pH nine and high voltage were the most efficient conditions for removing microplastics.

b. 80 Minute Duration

Based on Figure 9 shows microplastic removal efficiency over an 80-minute electrocoagulation process with varying pH (3, 5, 7, and 9) and voltages (4V, 8V, and 12V), demonstrating that these conditions have varied impacts on removal effectiveness. At pH 3, acidic microplastic removal efficiency shows minimal differences across voltages, with results ranging from 73.20% to 77.40%, indicating that increased

voltage has little impact on efficiency at this pH. Conversely, at pH 5, removal efficiency reaches a peak of 97.60% at 4V but decreases at 8V and 12V to 84.80% and 87.80%, respectively, indicating that 4V at pH 5 is optimal for the highest efficiency at an 80-minute duration.

At pH 7, microplastic removal efficiency remains stable across voltages, with results of 91.20% at 4V, 90.60% at 8V, and a slight decrease to 85.20% at 12V, showing that low and medium voltages are equally effective at neutral pH. At pH 9, removal efficiency is quite high, with a value of 88.60% at 4V, decreasing to 82.80% at 8V and increasing again to 90.60% at 12V. This shows that the highest voltage (12V) in alkaline pH provides the best removal efficiency over 80 minutes. These results show that the optimal combination of pH and voltage depends on conditions, with pH five and 4V yielding the highest removal efficiency (97.60%). In contrast, at higher pH, higher voltage gives better results.

c. 120 Minute Duration

The microplastic removal efficiency over 120 minutes under various pH levels (3, 5, 7, and 9) and applied voltages (4V, 8V, and 12V) presented in Figure 10 indicates that the combination of pH and voltage significantly affects removal efficiency. At pH 3, the removal efficiency of microplastics is not affected by voltage changes; at about 84.60%~84.80%, efficiency is not dependent on increased voltage as before at this pH. Results for 20 ppm initial concentration of Cr (VI) using pulsed (4, 8, 12) voltage (Hurst, Drechsel, & EST, 2018). During treatment at pH 5, the removal efficiency substantially increases at 8V to 88.20, but this then falls at both low (73.80% at 4V) and high voltage (82.40% at 12V), suggesting this introduction of medium voltage (8V) is optimal under these conditions.

Microplastic removal efficiency is relatively stable at neutral pH 7 for all voltage variations, although an increase occurs at 12V, yielding the final highest efficiency of 88.00% at neutral pH. At alkaline pH 9, the microplastic removal efficiency was at an optimal value of 96.60% at 8V and maintained a high level of 92.60% at 12V. These results indicate that the best alkaline values of the medium pH (9) and voltage (8V) for the 120 minutes of treatment give a high removal of microplastic. In general, the highest removal efficiency of microplastics was achieved by optimizing pH and voltage for removal, reaching superior removal rates at pH nine and 8V.

CONCLUSION

This study demonstrates that the microplastic electrocoagulation process is a suitable treatment for the adsorption of HDPE from water, with removal efficiency depending on the electrocoagulation process variables such as voltage, pH, and reaction time. Stainless steel and aluminum electrodes are the best option for this procedure due to their cost and resistance to corrosion. At 40 min, optimum efficiencies were expressed at the same voltage at pH 9; at 80 min, the highest efficiencies were shown for pH five hexavalent chromium solution at 4V; nevertheless, larger voltages were given better results under higher pH

conditions. The best efficiency of microplastic removal, 96.60%, occurred in 120 minutes at pH nine and voltage 8V. The combination of higher pH with longer duration and medium voltage conditions resulted in the best removal of HDPE microplastics. Microplastic morphological investigation using Macroscopy and Scanning Electron Microscope (SEM) indicated that the coagulant presented flakes and was fragmented granularly. The obtained findings would be beneficial in optimizing electrocoagulation parameters for sustainable and efficient water treatment.

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