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Description of a Fe/Al Electrocoagulation Method Powered by a Photovoltaic System, for the (Pre-)Treatment of Municipal Wastewater of a Small Community in Northern Greece

D. Marmanis [1], C. Emmanouil [1,2,*], J. G. Fantidis [3], A. Thysiadou [1] and K. Marmani [4]

[1] Department of Chemistry, International Hellenic University, 65404 Kavala, Greece; marmanis@chem.ihu.gr (D.M.); thysiadou@hotmail.com (A.T.)
[2] School of Spatial Planning and Development, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
[3] Department of Physics, International Hellenic University, 65404 Kavala, Greece; fantidis@physics.ihu.gr
[4] Department of Environmental Engineering, Democritus University of Thrace, 67100 Xanthi, Greece; kmarmani96@gmail.com
* Correspondence: chemmanouil@plandevel.auth.gr

Abstract: Small and insular communities are sometimes not served by an efficient Wastewater Treatment Plant, and this is a hazard for both the environment and public health. A wastewater treatment apparatus based on the electrocoagulation process (EC) was tested with municipal wastewater from a small community in Northern Greece with a maximum of 6500 population equivalents. COD decrease was assessed under various parameters: current intensity, time duration, pH and use of Fe or Al electrodes. A simulation of meeting the community's electricity needs with this apparatus was tested through RETScreen software. The results showed a satisfactory COD decrease through electrocoagulation which was affected by all the parameters mentioned; Fe electrodes could efficiently be used at 300 mA for 60 min for 55% COD removal. It was also shown that a photovoltaic panel system covers the electricity needs of the apparatus, thus no external electricity source is needed for its use. This apparatus could be used effectively by this community, so that the running costs are minimal.

Keywords: electrocoagulation; wastewater treatment; small communities; municipal wastewater; Fe-Al electrodes

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1. Introduction

Municipal Wastewater (MWW) is created after the domestic and commercial use of freshwater. This variable mixture consists of floating materials, settable solids, organic and inorganic solids, oil, dissolved gases, microorganisms and others [1–3] and it should be appropriately treated before disposal, for reasons of sanitation, public health safety and environmental protection [4]. Biological processes such as activated sludge are very effective for reducing the organic load of MWW [5] so that limited amounts of carbon, nitrogen and phosphorus are released into aquatic recipients. According to current European legislation [6], communities with capacities of equal to or more than 2000 population equivalents should be served by secondary biological treatment (activated sludge treatment) or equivalent to this from 31 December 2005 onwards. The 10th biennial EU report on the implementation of the Directive, which was published in 2020, highlights the lack of full compliance throughout EU, with 6% of the MWW collected not sufficiently treated to meet secondary treatment standards, and 8% of the MWW collected not meeting more stringent treatment standards in force [7]. This problem is more prominent in small, rural, insular or mountainous communities, where constructing and running a conventional Wastewater Treatment Plant (WWTP) is challenging and many times the latter fails to produce effluents of good quality [8–10]. In Greece, due to the mountainous terrain, quite a few communities

belong to the very small ($\leq$2000 p.e.) category and even nowadays (2022) they are not properly served by (an equivalent to) secondary treatment [11].

In the case of small and insular communities, an alternative to a large WWTP system may be appropriate; a variety of decentralized technologies exist, ranging from individual septic systems to cluster systems that serve multiple properties, to natural treatment systems that remove pollutants, among others [12]. The alternative system should be chosen after careful consideration and environmental, social and financial aspects should be taken into account.

Among physicochemical processes, electrochemical technologies have received great attention for their effectiveness in treating different types of wastewater with various electrode materials and configurations. Electrochemical technologies include electrocoagulation, electro-oxidation, and electro-flotation. Electrocoagulation (EC) is one of the processes that has indeed be used in small and decentralized systems [13,14]. Generally, iron (Fe) or aluminum (Al) electrodes are used [15]. During the EC process, organic pollutants are removed by adsorption on the electrolytically produced $Fe(OH)_3$ or $Al(OH)_3$ flocs and then by precipitation in the form of their insoluble hydroxides [1,16,17].

In brief, aluminum or iron dissolves from the metal anode of the EC apparatus into water as cations (Equations (1) and (4)), while the pollutant-adsorbing hydroxides (Equations (3) and (6)) that precipitate are pH-dependent [18].

For aluminum electrodes,

Anode:

$$Al_s \rightarrow Al_{aq}^{+3} + 3e^- \quad (1)$$

Cathode:

$$3H_2O + 3e^- \rightarrow \frac{3}{2}H_{2g} + 3OH^- \quad (2)$$

Precipitation according to

$$Al_s + 3H_2O \rightarrow Al(OH)_3 + \frac{3}{2}H_{2g} \quad (3)$$

For iron electrodes,

Anode:

$$Fe_s \rightarrow Fe_{aq}^{+2} + 2e^- \quad (4)$$

Cathode

$$2H_2O + 2e^- \rightarrow H_{2g} + 2OH^- \quad (5)$$

Precipitation according to

$$Fe_s + 2H_2O \rightarrow Fe(OH)_2 + H_{2g} \quad (6)$$

This process has been successfully used for various effluents such as dye effluents, oil liquid wastes, laundry wastewaters [19], slaughterhouse effluents [20], arsenic- or fluoride-containing waters [16,21], street food wastewaters [22] and many others. The process is simple and effective [23], and no secondary pollutants are generated during the treatment. In electrocoagulation, sludge generation is very low and it can be easily separated by sedimentation. Finally, electrocoagulation is considered a "green" technology of simple assembly, short reaction time and minimal use of chemicals [18].

The present paper deals with the application of the above-mentioned method on municipal wastewater from a small community and its optimization for this kind of liquid waste. Furthermore, its coupling with solar panel technology is assessed for achieving a completely self-sustained facility [1]. This study aids the ongoing research for treatment of MWW from small and decentralized communities and it can act as an example for similar case studies in the future.

2. Materials and Methods

2.1. Reagents

All reagents were of analytical grade unless otherwise mentioned and they were purchased from Merck (Darmstadt, Germany).

2.2. Wastewater Sample

The sample used for this study was obtained from a small community located in northern Greece (Palio; latitude: 40.9° N, longitude: 24.4°) with a minimum population equivalent of 2300 and a maximum p.e. of 6500. A 10 L sample was taken during a period of 24 h by collecting subsamples and pooling them at the end, from the main collection pipe of the community. This took place during the maximum p.e. season (July) as a worst-case scenario. The sample was kept in a plastic container in a cool, dark place until further experimentation.

2.3. Experimental Design and Apparatus

Electrocoagulation experiments were conducted at room temperature using a cylindrical electrochemical reactor (300 mL working volume) equipped with a magnetic stirrer (Nuova II S18525, Thermolyne, Boston, MA, USA), operating at 300 rpm. Two commercially available iron (St 37-2 steel) (according to German standard [24]) or aluminum plates (2024 aluminum alloy) were used as electrodes of size 8 × 5 × 0.3 cm with an effective area of 25 cm^2 each. The electrodes were placed vertically parallel to each other, with an inter-electrode distance of 1 cm. The electrodes were connected to a digital DC power supply (PHYWE System GmbH & Co, Göttingen, Germany) to provide a constant current. A multimeter (VOLTCRAFT 91, Conrad Electronic International GmbH & Co, Hirschau, Germany) was used to measure electrode potential and current.

The electrocoagulation treatment efficiency was studied for different time durations (60, 120, 180, 240 or 300 min), current densities (6, 12 or 24 mA /cm^2 corresponding to between 150, 300 and 600 mA), and type of electrodes (iron or aluminum) for the wastewater. Every 60 min of electro-processing time, liquid samples were extracted from the reactor medium and filtered through Whatman filter paper 90 mm (Merck, Darmstadt, Germany). The filtered liquid was analyzed for pH, electrical conductivity and chemical oxygen demand (COD). A pH-meter was used to measure pH (Hanna Instruments INC, USA) and electrical conductivity was measured with a conductometer (WTW GmbH & Co, Kassel, Germany). COD measurements were performed using a COD thermoreactor (Thermoreaktor TR 420, Merck KGaA, Darmstadt, Germany) and a spectrophotometer (Spectroquant Pharo100, Merck KGaA, Darmstadt, Germany) according to [25] for examination of water and wastewater.

Electrode material consumption was also calculated for the experimental runs according to [26]:

$$\text{Cmat} = (\text{I} \times \text{M}_\text{w} \times \text{t})/(\text{F} \times \text{V} \times \text{z}) \quad (7)$$

where Cmat: consumption of electrodes (kg/m^3), I: applied current (A), t: treatment time (s), V: volume of wastewater (m^3), z: no of electrons transferred, M_w: molecular mass of aluminum or iron (g/mol), and F: Faraday constant (c/mol).

Furthermore, electrical energy consumption for the experimental runs was calculated according to [26]:

$$\text{Cel} = \text{U} \times \text{I} \times \text{t} / \text{V} \quad (8)$$

where Cel: energy consumption (Wh) and U: applied voltage (V).

A second set of experiments was performed using the same sample batch (Fe electrodes only) in order to test the effect of wastewater pH on the performance of the system (COD decrease). In this case, the cylindrical reactor was attached to the Fe electrodes, NaCl (3.0 g) was added as before and a current of 300 mA was applied. Before the beginning of each experiment, wastewater (300 mL) pH was adjusted to the desirable value (3–11) with the

use of 1 M H_2SO_4 or 1 M NaOH. COD was measured as described before. Each set of the experiment was performed in triplicates.

2.4. Statistical Analysis

Pearson's correlation was performed between %COD removal and EC increase values. When triplicates of %COD removal were available, a one-way ANOVA with post-hoc Bonferonni test was performed between different pH experimental sets. All analyses were performed in SPSS27 (IBM, Armonk, New York, NY, USA).

2.5. Electricity Needs Simulation of the Apparatus in the Small Community

A simulation of running this apparatus for the wastewater treatment of the small community of Palio is possible with the aid of a photovoltaic panel power plant (Figure 1). Firstly, the electricity needs for running the upscaled apparatus were calculated based on the need of 300 mA of the experimental layout (for 300 mL) for 60 min; for a voltage of 12 V, this consumption is equal to 12 Wh (or 0.012 kWh) for 1 L of wastewater. According to [27], one population equivalent is 150 L/day for inhabitants or 300 L/day for hotels. As a worst-case scenario, the equivalent of 200 L/day was considered, because Palio is a summer-house destination. It was also postulated that for non-holiday months (October–May) the population equivalent was 2300 and for the holiday months (June–September) it was 4600.

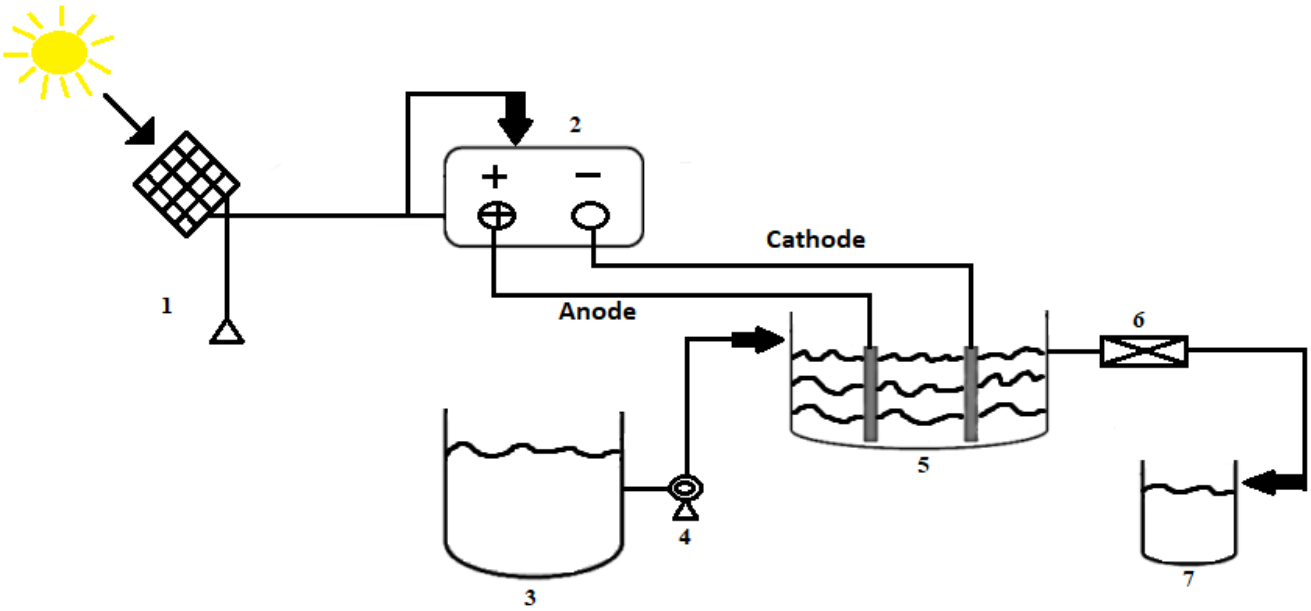


Figure 1. Graphic representation of the simulated experimental apparatus for the small community. Key: 1. PV Solar module, 2. Regulator, 3. Wastewater deposit, 4. Peristaltic pump, 5. Electrocoagulation reactor, 6. Filter, 7. Treated solution.

For calculating the renewable energy production, meteorological data for Palio community, with a mean daily horizontal solar radiation of 4.28 kWh/m^2 [28], were used as inputs for the RETScreen software (US Climate Resilience Toolkit, 2022). RETScreen, a Clean Energy Management Software system, has been used for energy efficiency, renewable energy feasibility analysis and ongoing energy performance analysis [29,30]. Based on the above data, both energy consumption by the wastewater treatment apparatus and energy production by the panel power plant may be calculated. Finally, the energy price for the photovoltaic panel plants has been assessed as equal to 650 € per MWh (value in Greece from May 2021).

3. Results

3.1. Sample Characteristics

The main characteristics of the wastewater sample used for this study are shown in Table 1.

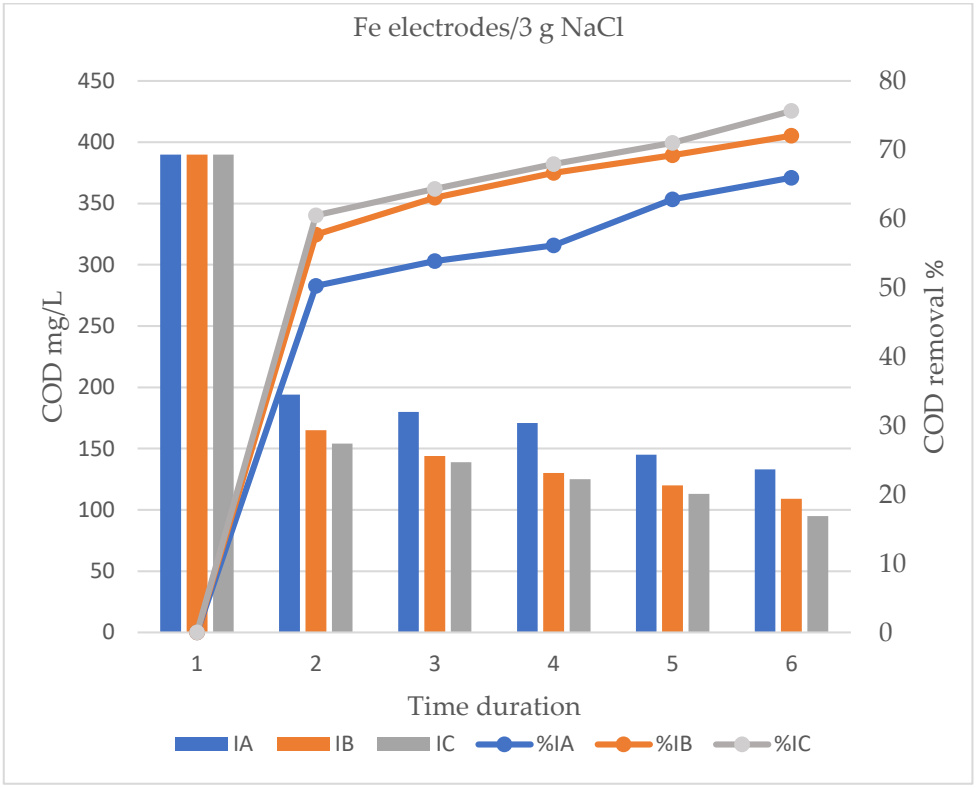
Table 1. Wastewater characteristics of 24 h sample taken during peak p.e. period, from a small community in northern Greece.

Parameter	Value
COD (mg/L)	390
Conductivity (mS/cm)	21
Temperature (°C)	24.5
pH	7.4
N-NH_3 (mg/L)	43.50
N total (mg/L)	75.60
p total (mg/L)	7.41
Suspended Solids (mg/L)	128.00
BOD (mg/L)	195

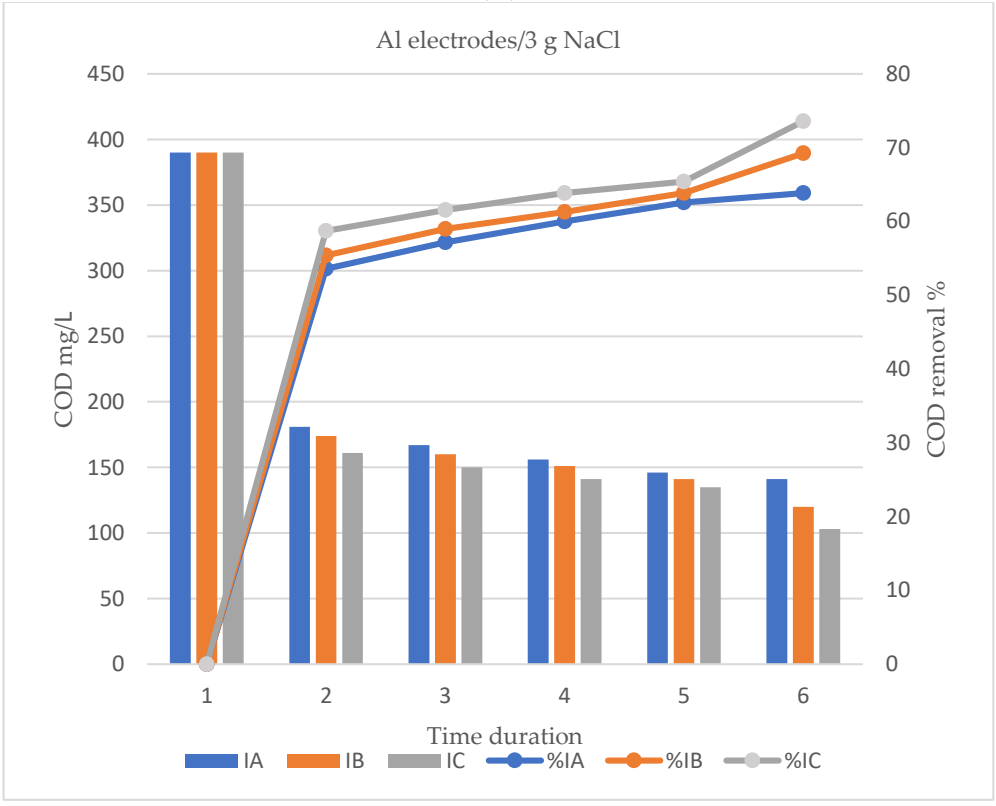
3.2. Effect of Processing Time, Current Intensity and Sample Conductivity on COD Removal

Figure 2A demonstrates the effect of processing time and of current intensity on COD removal efficiency using iron electrodes. For iron electrodes, COD removal increased when both parameters increased. According to the experimental results, it was possible to achieve around 76% COD removal efficiency within 300 min of reaction time at a maximum current intensity of 600 mA with iron electrodes. In a similar way, Figure 2B shows COD values as well as the %COD decrease when Al electrodes were used. Again, higher treatment times resulted in higher efficiency of the process. Higher current intensities also facilitated COD removal, but the differences between 150, 300 and 600 mA were less pronounced than in the case of Fe electrodes. The highest COD removal efficiency (73.6%) was achieved within 300 min of reaction time at maximum current intensity of 600 mA.

Slight increases in electric conductivity were measured as time passed for both studied systems (Fe electrodes with an addition of 3.0 g of NaCl/Al electrodes with an addition of 3.0 g of NaCl). In both cases, a higher COD reduction was measured with higher increases in conductivity of the wastewater. This relationship was highly significant for the Fe electrodes ($R^2 = 0.737$, $p < 0.01$) and even more significant for the Al electrodes ($R^2 = 0.895$, $p < 0.001$) as shown in Figure 3A,B respectively. In both experimental set-ups, NaCl (3 g) was added as an electrolyte to increase conductivity and achieve energy saving [31]. It can be assumed that Fe electrodes are more fit for COD removal than Al electrodes for the tested wastewater here. Sixty min of treatment time was efficient in removing approximately 55% of COD at 300 mA; therefore, these parameters can be chosen for pre-treatment of this municipal wastewater before biological treatment. Three-hundred min of treatment time was able to remove 70% of COD at 300 mA. As such, this apparatus can replace even biological treatment for this influent according to [6]. A further increase to 600 mA only produced a minimal additional decrease in COD, as such, for matters of energy conservation, the intensity of 300 mA was chosen.

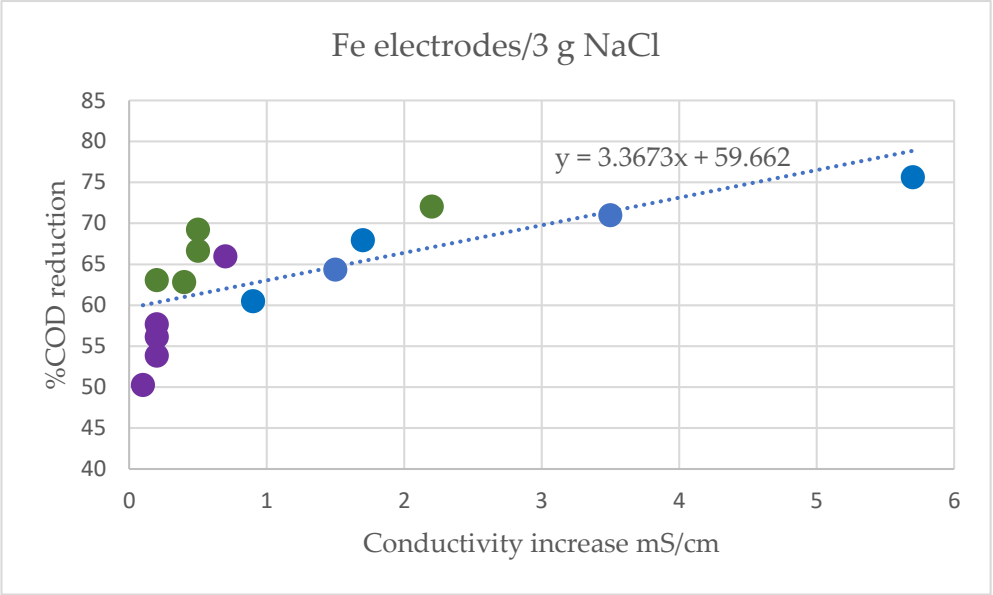


(**A**)

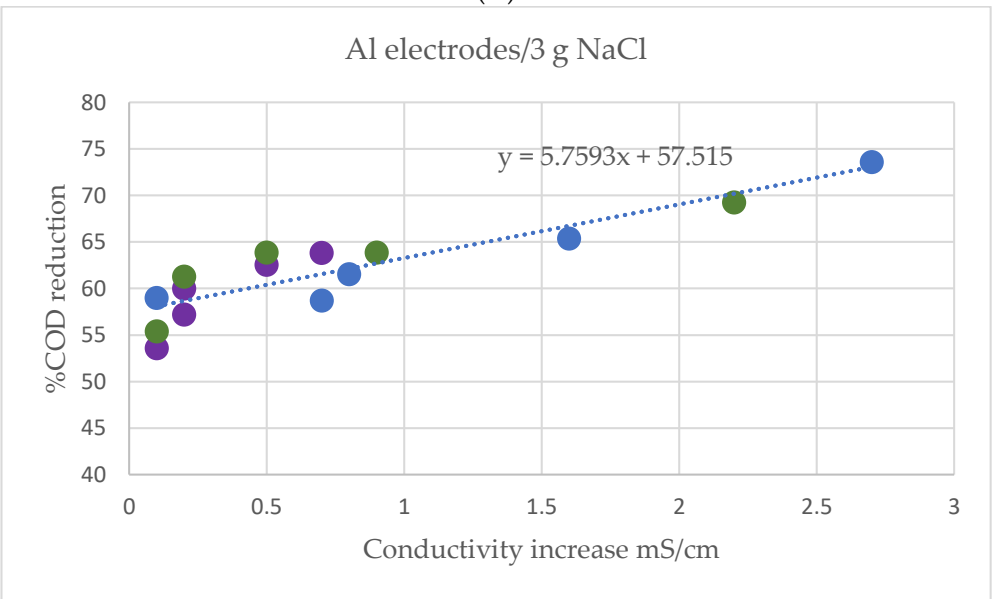


(**B**)

Figure 2. Effect of current intensity on COD values and on COD removal. (**A**) Fe electrodes; (**B**) Al electrodes. Key: 1 = 0 min, 2 = 60 min, 3 = 120 min, 4 = 180 min, 5 = 240 min, 6 = 300 min; IA = COD for 150 mA, IB = COD for 300 mA, IC = COD for 600 mA; %IA = %COD removal for 150 mA, %IB = %COD removal for 300 mA, %IC = %COD removal for 600 mA.



(**A**)



(**B**)

Figure 3. Relationship between %COD reduction values and wastewater conductivity increase. (**A**) Fe electrodes; (**B**) Al electrodes. Key: purple dots correspond to the 150-mA experiment, green dots to the 300-mA experiment and blue dots to the 600-mA experiment.

3.3. Effect of pH on COD Removal

It is known that the initial pH value of the treated solution is critical to the effectiveness of electrocoagulation. As shown in Figure 4, there is a statistically significant difference when initial wastewater pH was adjusted to quite diverse values. The highest %COD removal was found at pH 6–9, while acidic environments showed the lowest COD removal capacity.

Furthermore, as shown in Figure 5A, the pH of the reaction solution (colored bars) changed during the electrocoagulation process, as well. For the Fe electrodes in all cases (150, 300 and 600 mA), there was a modest continuous increase in pH values as time passed (from 60 to 300 min). This increase was much less pronounced for the Al electrode system, especially for the 300 and 600 mA experiments, as shown in Figure 5B.

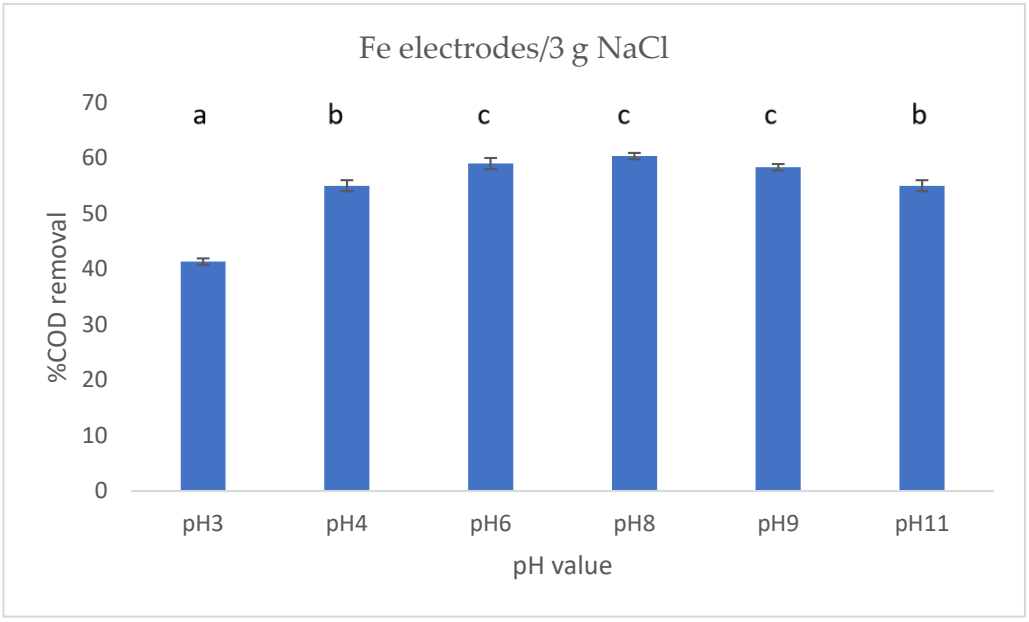
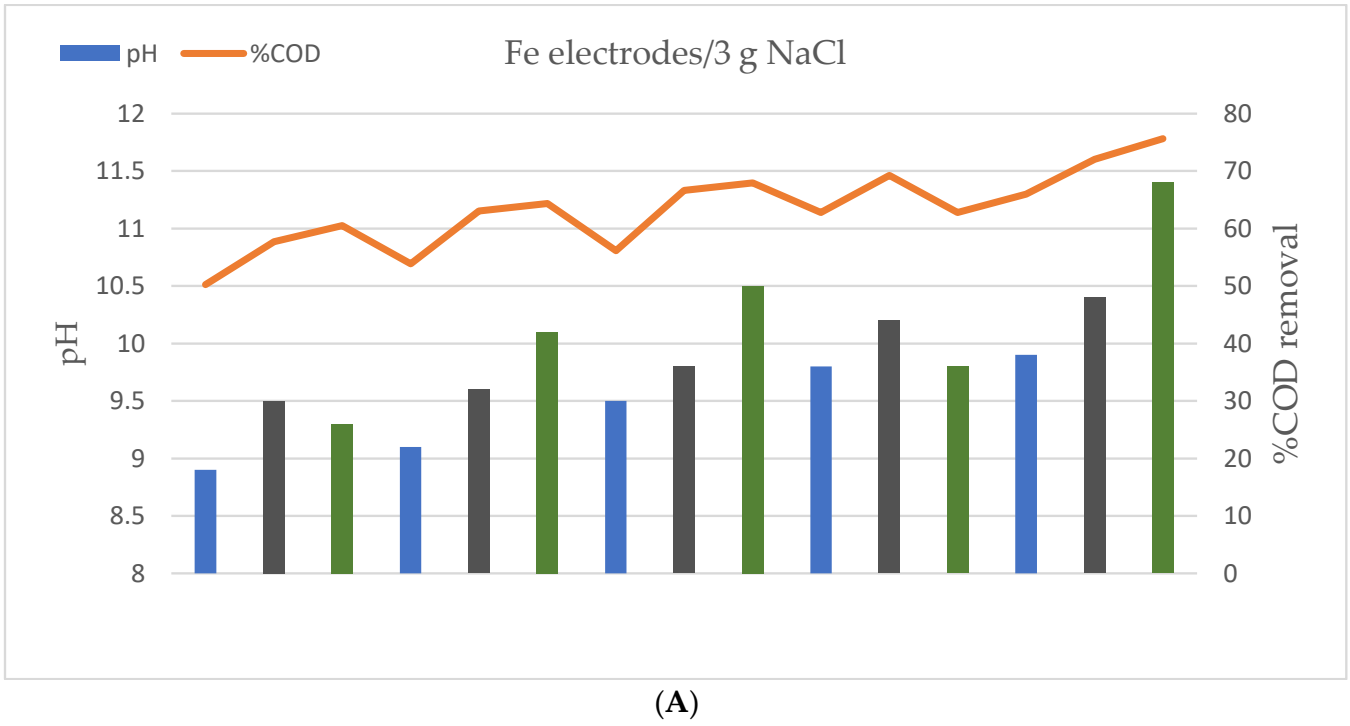
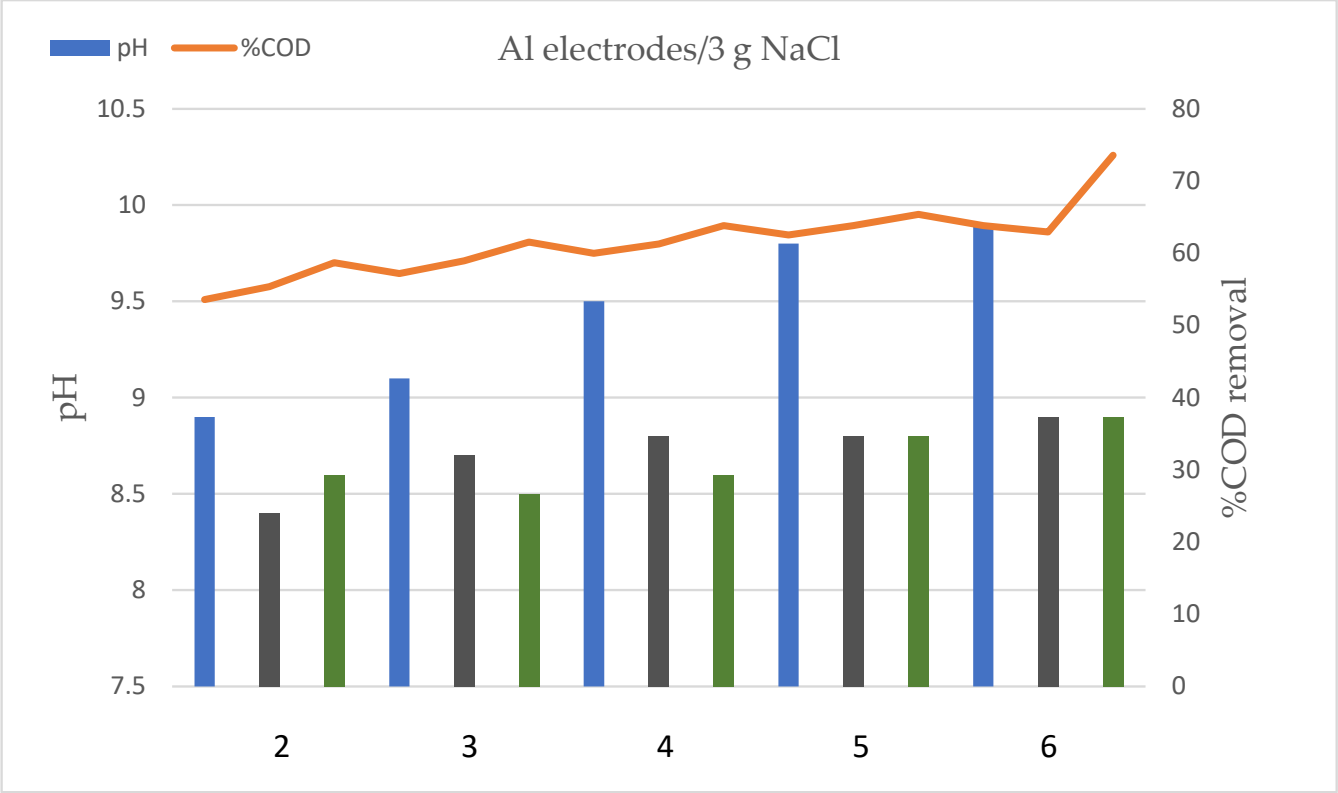


Figure 4. %COD removal (average ± SDEV values) for the Fe electrode experimental system. Different letters (a, b, c) denote statistically significant differences from one another at $p < 0.05$.



(A)

Figure 5. *Cont.*



(**B**)

Figure 5. Effect of measured solution pH on COD removal. (**A**) Fe electrodes; (**B**) Al electrodes. Key: bars correspond to pH values, line corresponds to %COD removal; time sequence: 2 = 60 min, 3 = 120 min, 4 = 180 min, 5 = 240 min, 6 = 300 min; different-color bars correspond to pH of different currents: blue to 150 mA, black to 300 mA, green to 600 mA.

3.4. Material and Energy Consumption and Electricity Needs Simulation

In Table 2, the consumption of metallic material has been calculated for Fe or Al electrodes, according to Equation (7).

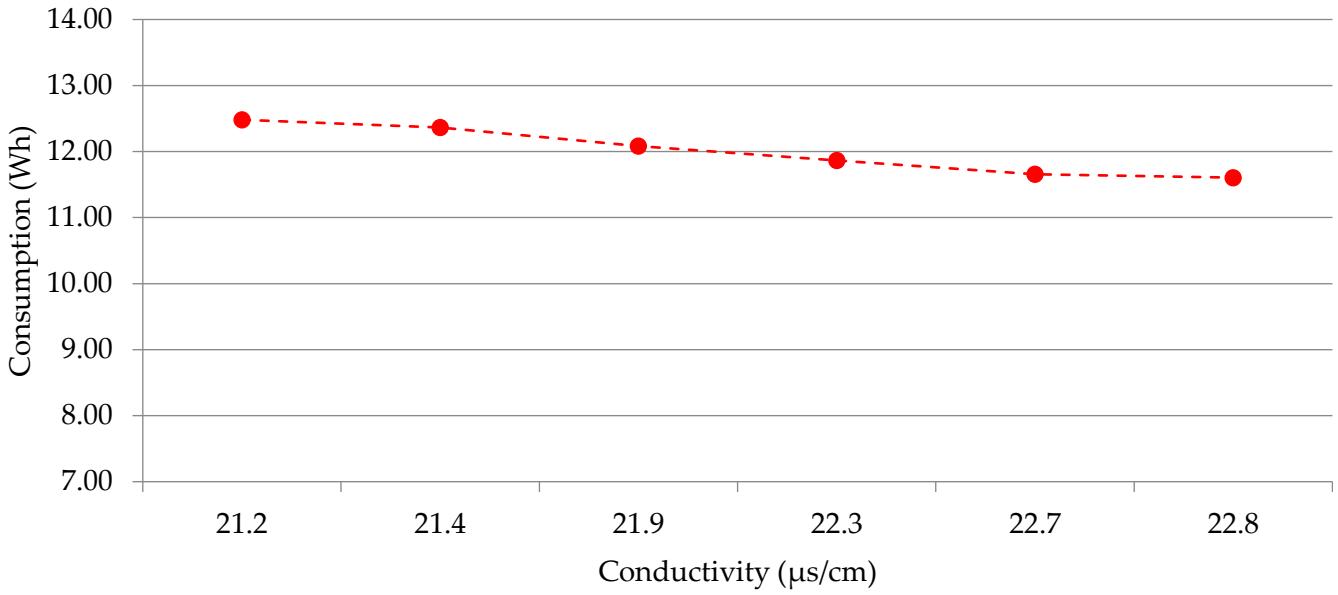
Table 2. Electrode material consumption calculation.

Electrode Consumption C	
Al	**Fe**
I = 300 mA	I = 300 mA
Mw = 26.98 g/mol	Mw = 55.85 g/mol
t = 3600 s	t = 3600 s
F = 96.487 c/mol	F = 96.487 c/mol
V = 300 mL	V = 300 mL
z = 3 e	Z = 2 e
C_{al} = 0.0932 kg/m^3	Cfe = 0.289 kg/m^3

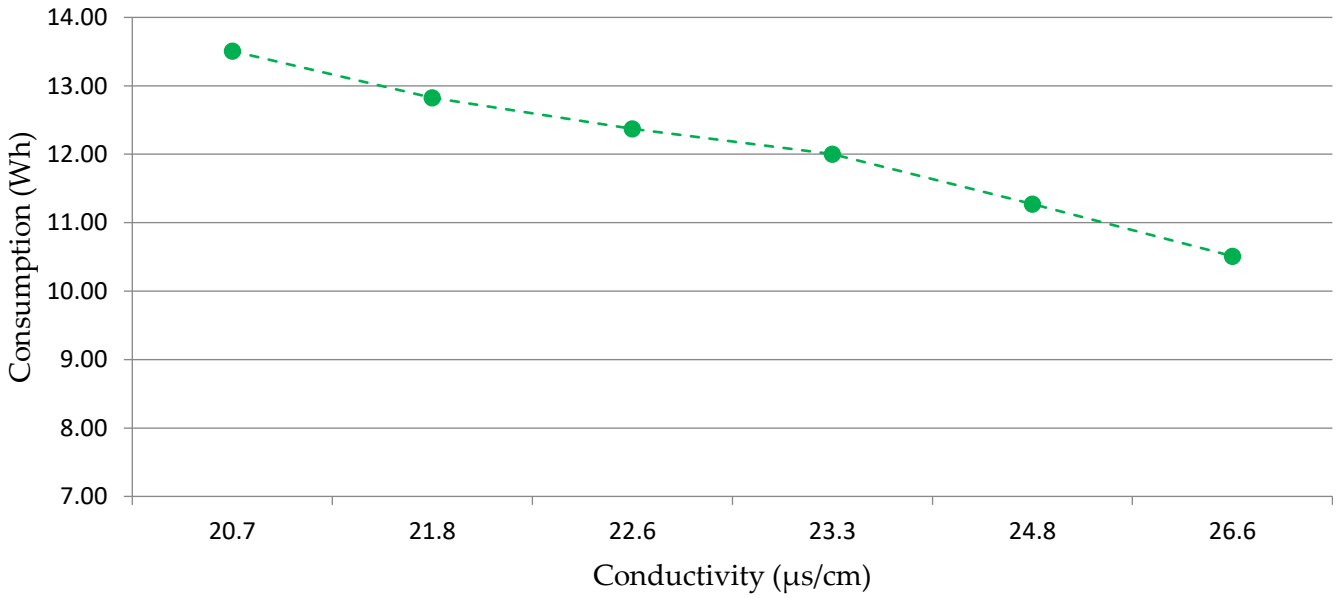
Therefore, it should be acknowledged that the electrodes have a predetermined lifetime, and they should be replaced according to treatment parameters. In Table 2, the operating parameters of 60 min and 300 mA have been chosen, since these are the parameters that will be applied in the actual Palio wastewater apparatus. Fe electrodes are quicker to be exhausted than Al electrodes, however, Fe electrodes had a better performance as shown in Figure 2. As such, the Fe electrode option was chosen for the Palio wastewater simulation calculations.

Electrical energy consumption for the system was also calculated for different current intensities (150, 300 or 600 mA) for Fe electrodes only, according to Equation (8). The results in relation to sample conductivity are shown in Figure 6.

As shown in the figure, a slight decrease was noted with increase of sample conductivity at a constant current, which was more pronounced in the case of 300 mA.

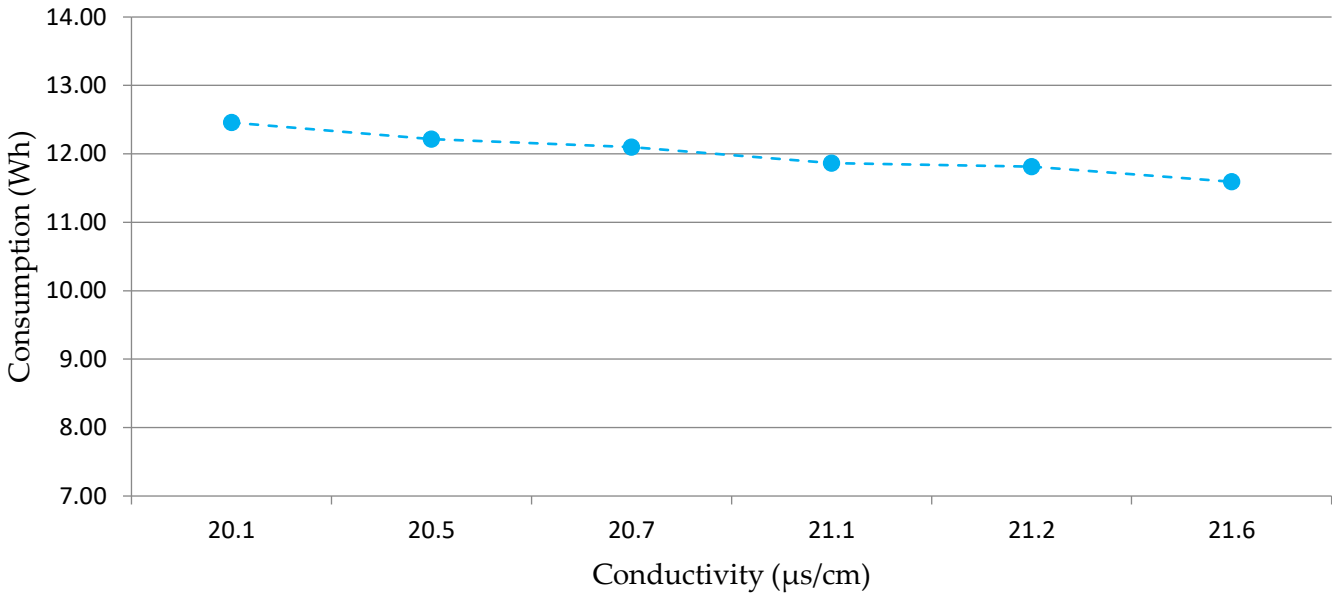


(**A**)



(**B**)

Figure 6. *Cont.*



(**C**)

Figure 6. Relationship between electricity consumption and wastewater solution conductivity for Fe electrodes. Key: (**A**) for 150 mA, (**B**) for 300 mA, (**C**) for 600 mA.

In Figure 7, a screenshot of RETScreen input data for the chosen type of photovoltaic panel plant for Palio community is shown. Based on the output of RETScreen for each calendar month and the calculated energy needs according to 2.5, the annual energy production and consumption for the simulated system can be calculated, respectively (Figure 8). It is shown that the solar energy utilized is adequate to cover the augmented needs of the treatment system in the "high season" summer months when up to 6500 p.e. are serviced. Furthermore, in the cold months, fewer people stay in the community and the wastewater treatment needs are sharply decreased. As such, the reduced solar power is more than double or triple than what the system needs.

Photovoltaic		
Type		mono-Si
Power capacity	kW	1,770
Manufacturer		
Model		
Number of units		
Efficiency	%	11.7%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m²	15,128
Bifacial cell adjustment factor	%	
Miscellaneous losses	%	1%
Inverter		
Efficiency	%	98%
Capacity	kW	100
Miscellaneous losses	%	0%

Figure 7. Technical specifications of the chosen photovoltaic power plant as shown in RETScreen software.

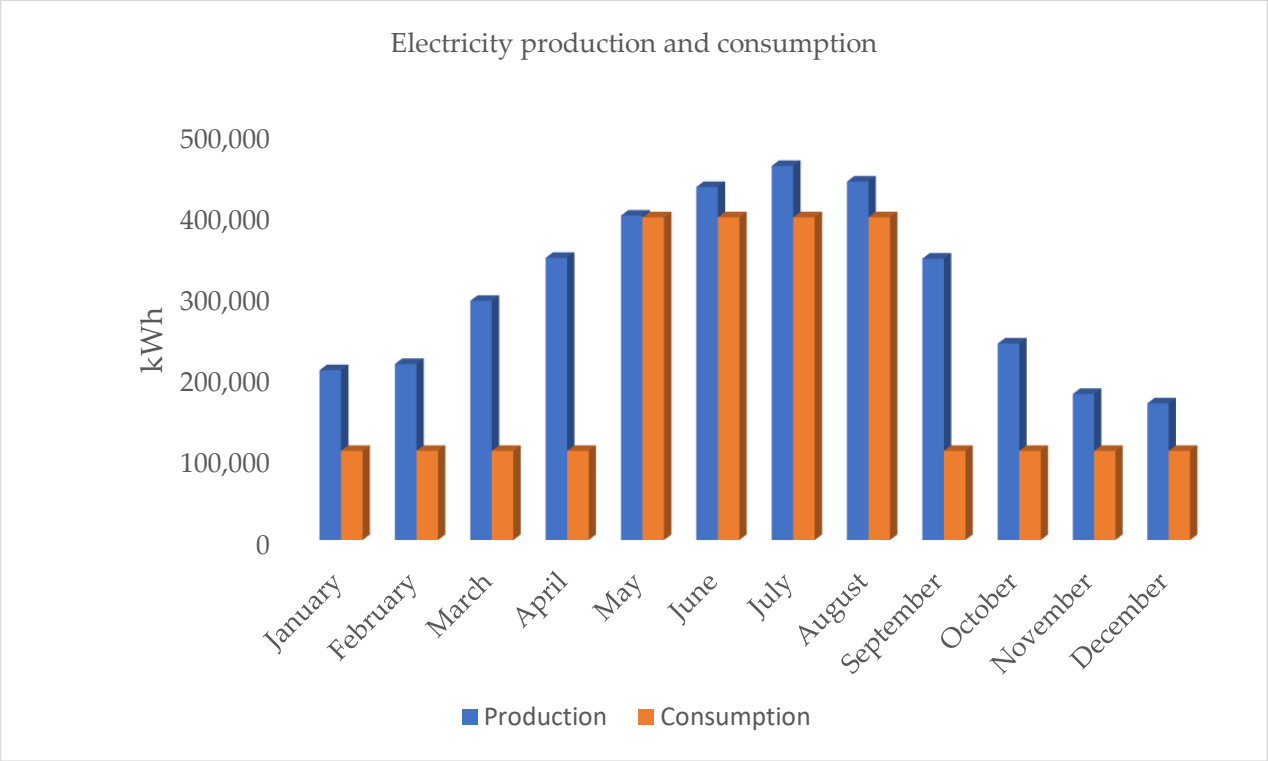


Figure 8. Monthly production and consumption of electricity for the simulated system described.

4. Discussion

4.1. Sample Characteristics

The MWW examined here derives from Palio, a small community in northern Greece with approximately 2000 p.e., which, due to its topography, cannot easily be connected to the main sewer system of Kavala city; the issue of MWW treatment becomes worse in summer when a spike in population is noted. The sample examined was taken during the peak season of summer and it was comparable (in pH, COD and conductivity) to a primary sedimentation effluent from [18], where electrocoagulation was also successfully applied. It can be considered as untreated municipal wastewater of low to medium pollution [32].

4.2. Effect of Processing Time, Current Intensity and Sample Conductivity on COD Removal

In EC, the applied current intensity affects the coagulants' release rate (by the anode) and hydrogen gas production (by the cathode) [23]. Electrical current increases the electrons' flow velocity due to ions' electrostatic attraction through the oppositely charged electrodes, increasing the coagulant ($Fe(OH)_3$ or $Al(OH)_3$) floc generation [19,33]. Increased floc generation and therefore, increased coagulant dissolution was also noted for Al or Fe electrodes, when the current was increased (from 1 to 3 A) in the experiments of [18].

The time required to achieve the desired removal efficiency is essential for the design of an electrochemical treatment technology [32]. The electrocoagulation process is separated into two phases: coagulation (destabilization of charged colloidal particles) and flocculation (aggregation of colloids); the first part is accomplished within a short time period (usually between 5 and 20 min depending on the rate of coagulant release) and the second part between 20 and 60 min depending on the mixing conditions inside the reactor [20]. The Fe^{2+}, Fe^{3+} and Al^{3+} ions released by electro-dissolution of the anodes are well known to decrease colloids' net surface charge. A short operating time results in low charge neutralization, and the produced metal ions are not enough to destabilize the colloids. Therefore, increasing processing time is generally needed for sufficient COD removal, since more iron or aluminum cations are released, which in turn act as the coagulant. Moreover,

flotation of the precipitates formed occurs by the generated hydrogen gas bubbles, resulting in additional separation of the organic pollutants [34].

In the present experiments, a slightly better %COD removal was noted with Fe electrodes. According to [35], iron electrodes were more efficient than aluminum electrodes to remove COD under the same operating conditions, which is consistent with the results of this work. However, other investigations have found considerably worse performance for Al electrodes for similar MWW influents (COD removal of 56–57% for Fe and of 12–18% for Al) [18]. Treated wastewater is nowadays under consideration for crop irrigation in Greece [36], and in this case, Al ions may create toxic effects in acidic soils and should be avoided [37]. However, it must be stressed that crop irrigation is also subject to microbiological limitations and reused wastewater should abide by these limitations, as well. Nevertheless, EC was shown to be effective for coliform removal after 30 s running time at approximately 0.6 A in an apparatus of Fe electrodes/activated carbon [32]. In any case, microbiological characteristics of the EC-treated wastewater should always be measured.

4.3. Effect of pH on COD Removal

The initial wastewater pH may affect the overall EC performance. The differences noted here may be due to the prevailing coagulants' form [$Fe(OH)_2$, $Fe(OH)_3$ and $Al(OH)_3$] between pH 6 and 8 [38]. This is within the range of typical municipal wastewater samples (see Table 2). At pH < 3 (acidic conditions) and pH > 9 (basic conditions), the corresponding cationic forms, Fe^{2+}, Fe^{3+}, Al^{3+} and a series of polymeric anionic forms, especially for aluminum, are predominant, which do not favor the coagulation process. Under these unfavorable acidic conditions, the removal efficiency of aluminum is equal to or even better than iron, due to an enhanced tendency for production of Fe^{2+}, versus Fe^{3+} ions for the latter. Indeed, ferrous ions are weaker coagulants compared to ferric ions [18,39].

Regarding the pH increase during electrocoagulation, at initial pH values lower than 7, the observed increase of the pH is due to the evolution of hydrogen and the creation of OH- ions at the cathode. In an alkaline environment (pH > 8), the final pH value does not change significantly since the OH- ions generated at the cathode are bound by the ions of Fe^{2+} and Fe^{3+} generated at the anode, forming the particles $Fe(OH)_2$ and $Fe(OH)_3$, which are necessary for the phenomenon of electrocoagulation.

The pH of the reaction solution changes during the electrocoagulation process, and the final pH of the effluent affects the overall treatment performance. It has been reported that when the initial pH value is less than 4 (acidic), the effluent pH increases [31], while it tends to decrease when the initial pH value is higher than 8 (basic), and the pH of the effluent changes only slightly when the initial pH value is in the neutral range (around 6–8). This situation indicates a pH-buffering effect during electrocoagulation which is different from traditional chemical coagulation. This pH-buffering capacity can be attributed to the balance between the production and consumption of hydroxyl ions during electrocoagulation and the need for charge neutralization before the ultimate transformation of soluble aluminum compounds into aluminum hydroxides. Thus, the formation of $Al(OH)_3$ near the anode may lead to the decrease of pH. On the other hand, it has also been reported that ultimate pH values increase rapidly during electrocoagulation such that the ultimate pH values reached at the end of electrocoagulation are always greater than 8–9 [35]. This is not surprising, since continuous hydroxyl ion production occurs at the cathode (see Equation (2)). Under alkaline conditions, the formation of $Al(OH)_4$-complexes is the major reason for a decrease in pH. Moreover, hydrogen bubbles produced at the cathode are smallest and finest at a neutral pH, providing sufficient surface area for gas–liquid–solid interfaces and mixing efficiency to favor the aggregation of tiny, destabilized particles and colloids.

4.4. Electricity Needs Simulation

Based on an extensive relevant bibliography and on the above findings, it can be verified that EC is an effective and reliable alternative to WWTP. Nevertheless, raw material

(metal) consumption and high electricity consumption are practical obstacles compared to other methods, for example, chemical coagulation–precipitation [31]. Regarding the latter (electricity consumption), coupling of EC with Renewable Energy Sources may reduce the running costs. Greece is an ideal site for solar energy exploitation, with a solar radiation peak in summer and a gradual decrease until winter. This fluctuation follows the similar fluctuation of p.e. in the examined community, with a peak in summer months and a decrease in winter months, when fewer inhabitants remain in the area. As shown in Figure 8, every year more than 1.77 GWh from this panel system can be used in order to feed the local grid. With a value of the energy from PV equal to 650 € per MWh (value in Greece from May 2021), the units for the next 20 years offer an income of more than 115,500 €. The initial cost for this power plant is approximately equal to 2,500,000 € with yearly estimated operation and maintenance costs of no more than 5000 €. This means that the whole project is capable of working without cost. Last but not least, based on the fact that natural gas now is the main fuel in Greece for electricity production purposes, the proposed system will minimize the total emission by approximately 93%; this translated to about 2105 t CO_2 less in the local area.

5. Conclusions

Wastewater taken during the highly touristic season from a small community in northern Greece was treated in an apparatus utilizing electrocoagulation. It was shown that within 60 min of treatment at a current intensity of 150, 300 or 600 mA, there was a reduction of 50% or more for Fe or Al electrodes. Performance differences were noted between the Fe and the Al electrodes, with the former showing better results; time duration was also important, with higher treatment times (up to 300 min) leading to lower final COD in the effluent that met EU effluent standards for (non-sensitive) aquatic recipients. Higher current intensities generally led to higher COD removal, however, there should be a trade-off between electrocoagulation performance and energy consumption. As expected, electrocoagulation showed the best results under near-neutral pH values of 6–8. Based on these data, a trade-off solution between %COD removal performance and energy consumption was chosen with the following characteristics: Fe electrodes, 60 min reaction time at 300 mA at pH 6–8 for effective pre-treatment of the wastewater before biological treatment or Fe electrodes, 300 min reaction time at 300 mA at pH 6–8 for total wastewater treatment.

It was also shown that electrocoagulation exerts a pH-buffering capacity when initial acidic or basic environments are present. Finally, a simulation of the electrocoagulation apparatus (Fe electrodes, 60 min reaction time at 300 mA at pH 6–8) coupled with a photovoltaic panel system highlighted that establishing this wastewater treatment system was feasible; the simulation showed that solar radiation could be sufficient to fulfill the needs for the system. As a result, cheaper alternatives to wastewater treatment plants with activated sludge should be considered and improved for use in small communities.

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