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Turbidity, dissolved Oxygen and pH measurement system for grey water treatment process by electrocoagulation

Sistema de medición de turbidez, oxígeno disuelto y pH para el proceso de tratamiento de aguas grises por electrocoagulación

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Abstract

Electrocoagulation is an electrochemical process used to treat wastewater and water contaminated with heavy metals. This method destabilizes contaminants that are suspended, emulsified or dissolved in wastewater by applying electrical current through electrodes and then removing them by filtration. In this work we present a turbidity, dissolved oxygen and pH measurement system for the influent and effluent of the gray water treatment process by the electrocoagulation method. The treatment process is carried out via batch and the measurement system allows to know the initial and final levels of the variables through a human machine interface (HMI) designed in LabVIEW. Twelve experimental tests were performed varying the treatment time and applied voltage in the electrocoagulation process to analyze the rate of change of the measured variables and its behavior regarding time and voltage. The applied direct current voltages were 10 V, 15 V and 20 V during 30 min, 60 min, 90 min and 120 min.

Electrocoagulation, Grey Water Treatment, Measurement System

Resumen

La electrocoagulación es un proceso electroquímico utilizado para tratar aguas residuales y agua contaminada con metales pesados. Este método desestabiliza los contaminantes que están suspendidos, emulsionados o disueltos en las aguas residuales aplicando corriente eléctrica a través de electrodos y luego eliminándolos por filtración. En este trabajo se presenta un sistema de medición de turbidez, oxígeno disuelto y pH para el afluente y efluente del proceso de tratamiento de aguas grises por el método de electrocoagulación. El proceso de tratamiento se realiza vía batch y el sistema de medición permite conocer los niveles inicial y final de las variables a través de una interfaz hombre-máquina (HMI) diseñada en LabVIEW. Se realizaron doce pruebas experimentales variando el tiempo de tratamiento y la tensión aplicada en el proceso de electrocoagulación para analizar la tasa de cambio de las variables medidas y su comportamiento en cuanto a tiempo y tensión. Los voltajes de corriente continua aplicados fueron 10 V, 15 V y 20 V durante 30 min, 60 min, 90 min y 120 min.

Electrocoagulación, Tratamiento de aguas grises, Sistema de medición

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Introduction

According to United Nations (UN) information [1], due to the water scarcity and poor water quality by 2050 at least one in four people is likely to live in a country affected by chronic or recurring shortages of freshwater. A sustainable development goal for UN is clean water and sanitation to ensure availability and sustainable management of water and sanitation for all and also halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally [1]. In this sense, the electrocoagulation (EC) for wastewater treatment is a choice. Different studies and applications have demonstrated its effectiveness [2, 3, 4, 5, 6, 7, 16]. On the other hand, a very important part for any wastewater treatment process is the knowledge of the degree of pollution that water presents.

The degree of water pollution is determined by the permissible levels of its physical, chemical and biological characteristics established in national and international standards, for example [8, 9]. Some of this characteristics are turbidity, temperature, conductivity, pH, alkalinity and colloids, dissolved oxygen (DO), biochemical and chemical oxygen demand, and its knowledge will allow to establish a quality control of the treated water and to detect alterations in the treatment process. Most of the studies that use EC for water treatment show the analysis of the following variables: current and voltage applied, size and material used on the electrodes, distance between electrodes, pH, temperature and conductivity of water and operating costs [4, 16].

However, the physical, chemical and biological characteristics of water have not been studied enough [4]. Hence we design a turbidity, dissolved oxygen and pH measurement system for the influent and effluent. For the gray water treatment process using the EC method to analyze its behavior for different treatment times and applied voltages through a human machine interface (HMI) designed in LabVIEW. As far as the authors know, this is the first time that a measurement system of analytic variables is applied to the gray water treatment by electrocoagulation.

The structure of this work is as follows: Section 2 describes the basic equipment to carry out the EC and the treatment process designed. Section 3 describes the measurement system equipment used, the HMI and its sequential operation. Finally, section 4 shows the turbidity, dissolved oxygen and pH measurement data from twelve experimental test and then concluding remarks.

Methodology of Wastewater Treatment Process by EC

Several studies such as [2, 6, 7] define the different reactions and mechanisms involved during the EC but the main reaction involves a continuously dissolving anode due to the passage of electricity, releasing cations into the wastewater. On the other hand, considering several applications such as [10, 11, 12, 13, 14] the basic equipment to carry out the EC are 1) electrochemical reactor, 2) sacrificial electrodes and 3) direct current electrical power supply as shown in Figure 1.

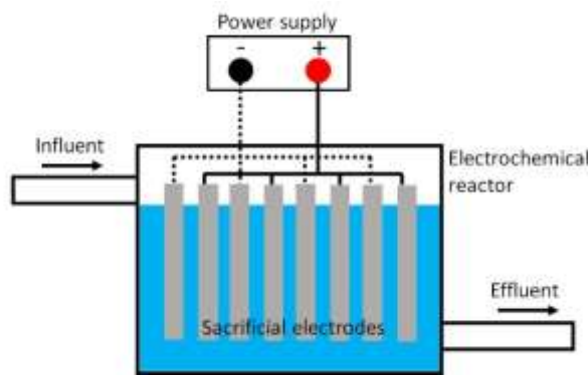

Figure 1 Basic equipment for EC.
Source: Own Elaboration

The proposed gray water treatment process using EC is carried out via batch and we design the treatment process shown in Figure 2 which adds two storage tanks where the turbidity, dissolved oxygen and pH measurements will be made.

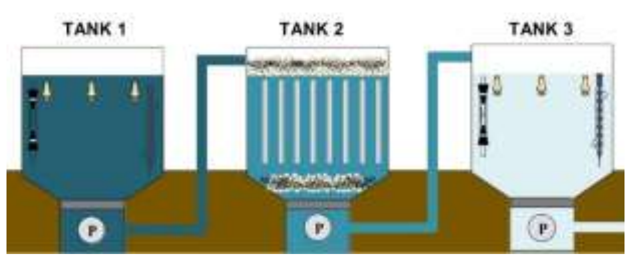

Figure 2 Treatment process
Source: Own Elaboration

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The process has three stages, each of them carried out in each tank of the Figure 2 and sequentially. In the first stage (tank 1) the pH, dissolved oxygen and turbidity measurement is carried out on the gray water, later the EC is carried out in the second stage (tank 2) finally in the third stage (tank 3) the pH, dissolved oxygen and turbidity measurement is carried out on the treated water. The electrochemical reactor used in this process has a maximum treatment capacity of 9 L, its components are shown in Figure 3.

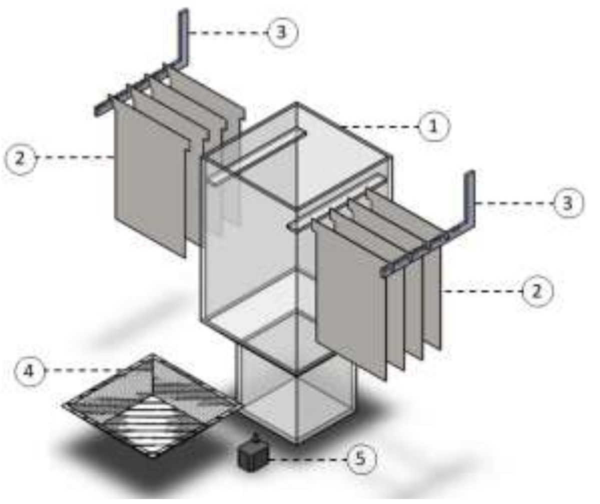

Figure 3 Electrocoagulation equipment. 1) Electrochemical reactor, 2) Sacrificial electrodes, 3) Power terminals, 4) Strainer filter, 5) Pump.
Source: Own Elaboration

Development

The measurement stages are carried out in tanks 1 and 3, each of them with the components shown in Figure 4. Each measurement stage has 3 turbidity sensors, 1 dissolved oxygen sensor and 1 pH sensor, a brief description the sensors used is shown below.

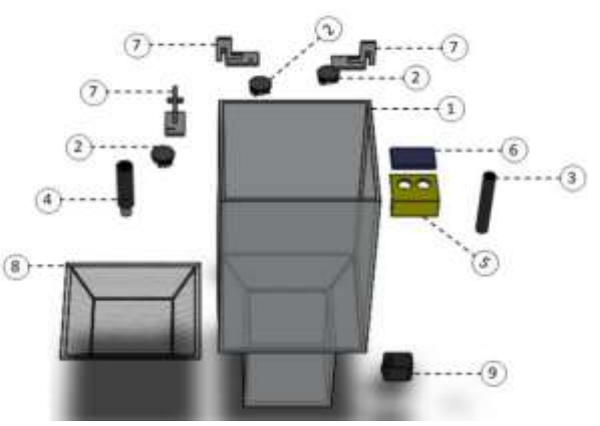

Figure 4 Measurement stage. 1) Tank, 2) Turbidity sensor, 3) Dissolved oxygen sensor, 4) pH sensor, 5) Level sensor support, 6) Level sensor, 7) Turbidity sensor support, 8) Strainer filter, 9) Pump
Source: Own elaboration

3.1 Turbidity Sensor

Some particles such as clays, inorganic matter, salts, soluble color compounds and microorganisms affect water clarity. Turbidity is a transparency degree measurement in a liquid and it is an indicator of water pollution [8, 9]. It is measured in Nephelometric Turbidity Units (NTU) by a nephelometer or turbidimeter, which measures the intensity of light scattered as a beam of light passes through a water sample. The turbidity sensor used in this work is Gravity arduino turbidity sensor and its documentation can be found in [17].

3.2 Dissolved Oxygen Sensor

DO is an indicator of pollution [8, 9], generally a higher level of dissolved oxygen that indicates better water quality [5] to support plant and animal life. The OD sensor is a galvanic probe, which measure the oxygen content of water in mg/L using an electrochemical method [21]. In this work the sensor used is Gravity analog that dissolved oxygen sensor and its documentation can be found in [18].

3.3 pH Sensor

The pH is an index of the hydrogen ion concentration H+ in water and it is an important variable in water quality [22]. It is a measure of acidity and alkalinity of a solution, which is based on logarithmic transformation of the hydrogen ion concentration. It has a scale ranging from 0-14, where the value 7 represents neutrality. Solutions with a pH above 7 are alkaline, while below 7 are acidic. The pH sensor used is Gravity analog and documentation for pH sensor can be found in [19].

The principal technical characteristics of the sensors are shown in Table. On the other hand, the signal acquisition of all sensors is carried out by a microcontroller ATMEGA 2560 its documentation can be found in [20].

3.4 Human Machine Interface

The sensors signals processing and operation of the process is carried out by a human machine interface (HMI) designed in LabVIEW [23]. Due to LabVIEW graphical programming language, it is easy to create flexible interfaces to changes and needs. The HMI is divided in three sections: tanks, measurement and control.

Variable	Sensor	Technical characteristics
DO	Gravity analog dissolved oxygen sensor DFRobot	Measuring Range: 0-20 mg/L Analog Signal Output: 0-3 V Membrane Cap Replacement Period: 1-2 months in muddy water
pH	Gravity pH sensor DFRobot	Measuring Range: 0-14pH Measuring Precision: ≤0.02pH Drift: ≤0.02pH/24hours
Turbidity	Gravity arduino turbidity sensor DFRobot	Measuring Range: 0-3000 NTU Analog output: 0-4.5 V Turbidity-Voltage relationship: -1120.4V2+5742.3V-4352.9

Table 1 Sensors technical characteristics
Source: Own Elaboration

In Figure 5, red line indicates the tanks section, when the treatment process is running, the HMI has visual indicators of the current status of tank levels and pump activation. Blue and green lines indicate the measurement section for the measurement stages 1 and 2 respectively, at each measurement stages, turbidity is measured first, then pH and finally dissolved oxygen. The yellow line indicates the control section, it has a start selector for automatic mode, an emergency stop button, a button to select manual mode and another to exit, it also has a selector to take measurements when the process is in manual mode.

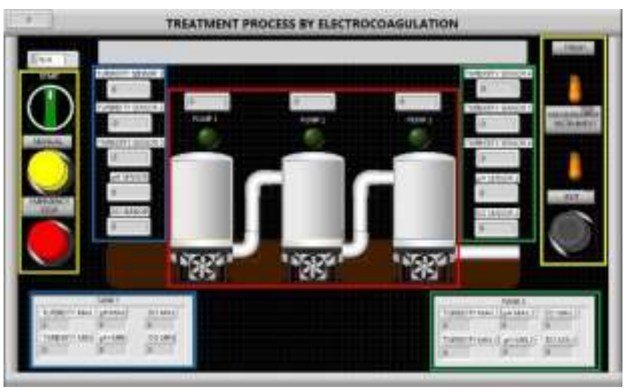

Figure 5 Treatment process interface
Source: Own Elaboration

4 Experiments and Results

Experimental tests were performed under the following considerations: The electrodes used were aluminum with dimensions of 220 mm length, 170 mm width and 1 mm thickness, eight electrodes were used in parallel monopolar connection (see Figure 1) and they were separated by a space of 10 mm. More details about electrode connections consult [2].

The wastewater used was grey water from a laundry. The applied voltages were 10 V, 15 V and 20 V during 30 min, 60 min, 90 min, and 120 min. During the experiment tests the electrodes and the strainer filter in the electrochemical reactor were cleaned after each experiment. Also, before carried out experiments 5, 8 y 12 the electrochemical reactor was cleaned and before experiment 8, four central electrodes were replaced. The sensors and the treatment process setup are shown in Figures 6 and 7 respectively.

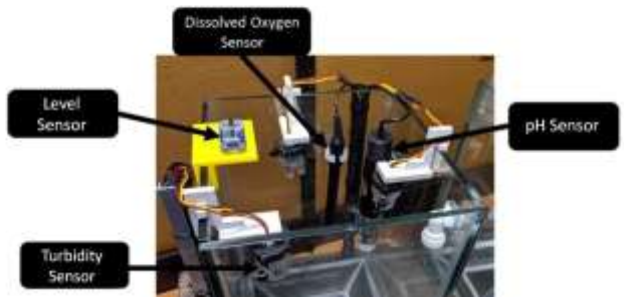

Figure 6 Sensors setup.
Source: Own Elaboration

Figure 7 Treatment process setup.
Source: Own Elaboration

Table 2 shown the DO and pH experimental measurements, in Tables 3 and 4 are shown the influent and effluent turbidity experimental measurement in NTU, respectively.

	Time [min]	Voltage [V]	Influent [mg/L]	Effluent [mg/L]	Influent [pH	Effluent [pH]
1	30	10 V	0.135	0.480	7.709	7.635
2	60	10 V	0.128	0.487	7.757	8.852
3	90	10 V	0.122	0.507	7.823	9.288
4	120	10 V	0.115	0.520	7.786	8.730
5	30	15 V	0.460	0.890	7.280	7.650
6	60	15 V	0.450	1.080	8.010	8.100
7	90	15 V	0.330	0.820	7.980	9.130
8	120	15 V	0.350	0.910	7.970	9.150
9	30	20 V	0.480	0.950	7.900	7.990
10	60	20 V	0.550	1.100	8.010	8.840
11	90	20 V	0.600	1.150	8.200	9.470
12	120	20 V	0.520	1.200	8.200	9.600

Table 2 Sensors technical characteristics.
Source: Own Elaboration

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	Sensor 1	Sensor 2	Sensor 3	Average
1	1686.000	1613.000	1412.000	1570.333
2	1709.000	1802.000	1440.000	1650.333
3	1686.000	1850.000	1450.000	1662.000
4	1700.000	1800.000	1500.000	1666.667
5	1730.000	1613.000	1498.000	1613.667
6	1500.000	1600.000	1300.000	1466.667
7	1600.000	1700.000	1400.000	1566.667
8	1630.000	1710.000	1450.000	1596.667
9	1660.000	1800.000	1500.000	1653.333
10	1686.000	1810.000	1800.000	1765.333
11	1700.000	1700.000	1800.000	1733.333
12	2200.000	1959.000	2080.000	2079.667

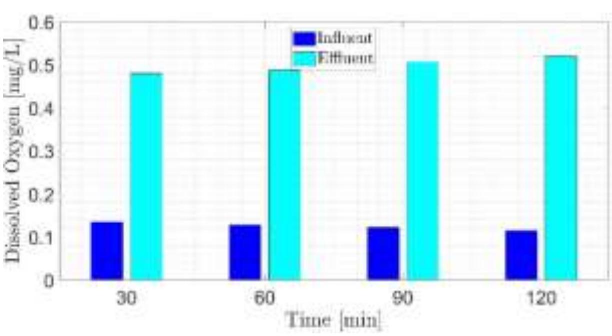
Table 3 Sensors technical characteristics.
Source: Own Elaboration

	Sensor 1	Sensor 2	Sensor 3	Average
1	1563.000	1654.000	1352.000	1523.000
2	1577.000	1600.000	1377.000	1518.000
3	1425.000	1529.730	1450.000	1468.243
4	1289.264	1477.860	1344.271	1370.465
5	950.000	850.000	1062.000	954.000
6	800.000	1000.000	950.000	916.667
7	1110.000	1097.000	924.000	1043.667
8	950.000	1000.000	1050.000	1000.000
9	786.000	850.000	926.000	854.000
10	922.000	930.000	1020.000	957.333
11	1250.000	1300.000	1200.000	1250.000
12	832.000	862.000	850.000	848.000

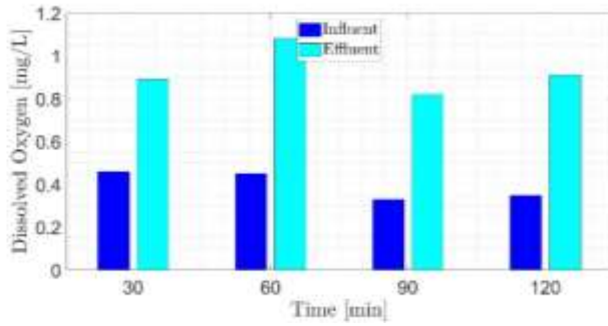
Table 4 Sensors technical characteristics.
Source: Own Elaboration

According with the experimental measurements tables, next figures show the behavior of DO, pH and turbidity.

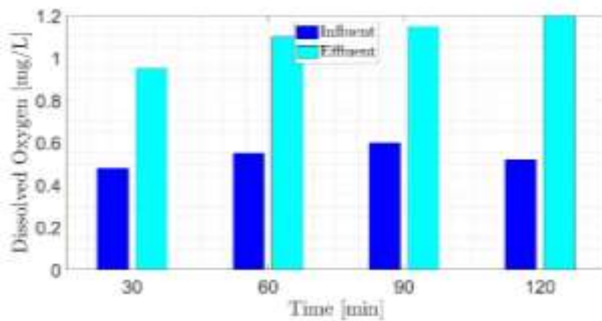
Graphics 1-3 show the comparative values of initial and final DO for 10 V, 15 V and 20 V respectively during 30 min, 60 min, 90 min, and 120 min, and Graphics 4 shows the DO rate of change.



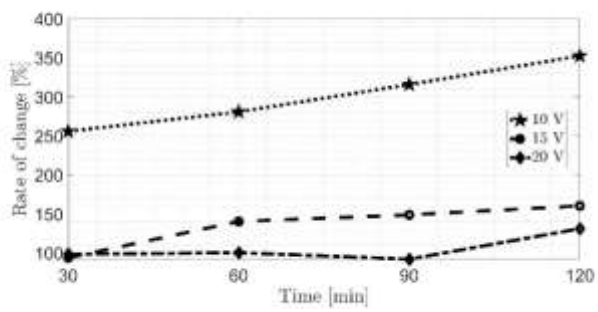
Graphic 1 Initial and final DO levels for 10 V.
Source: Own Elaboration



Graphic 2 Initial and final DO levels for 15 V.
Source: Own Elaboration

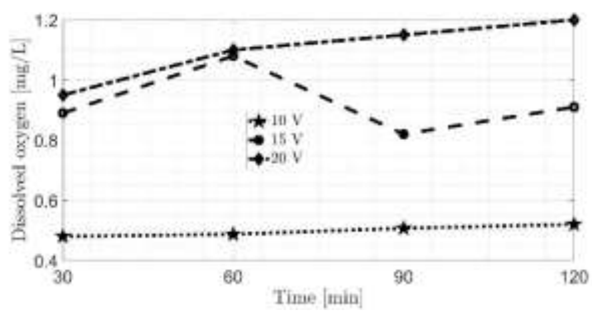


Graphic 3 Initial and final DO levels for 20 V.
Source: Own Elaboration



Graphic 4 DO rate of change
Source: Own Elaboration

From DO levels graphs, Graphics 5 and 6 show the behavior of dissolved oxygen in the effluent regarding to treatment time and applied voltage respectively.



Graphic 5 DO variation in the effluent with respect to treatment time
Source: Own Elaboration

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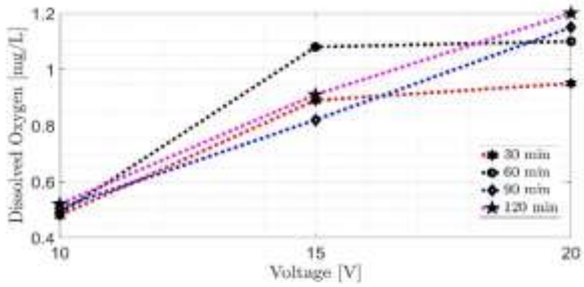
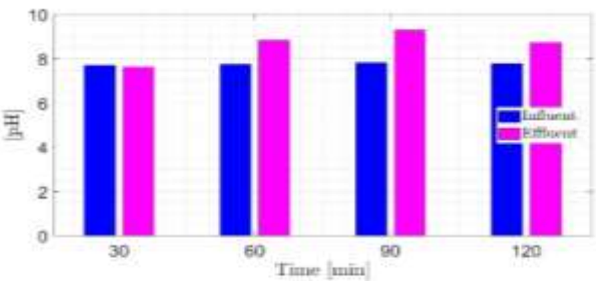
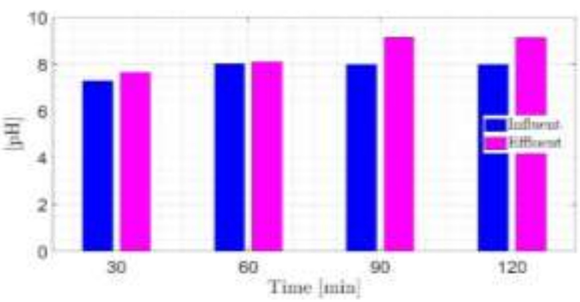


Graphic 6 DO variation in the effluent with respect to applied voltage
Source: Own Elaboration

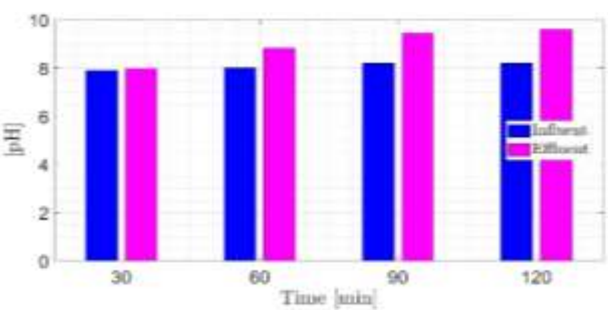
Graphics 7-9 show the comparative values of initial and final pH for 10 V, 15 V and 20 V respectively during 30 min, 60 min, 90 min, and 120 min and Graphic 10 shows the pH rate of change. From the pH levels graphs, Graphics 11 and 12 show the behavior of pH in the effluent with respect to treatment time and applied voltage respectively.



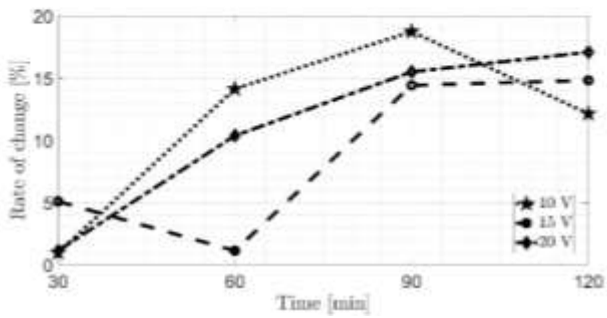
Graphic 7 Initial and final pH levels for 10 V
Source: Own Elaboration



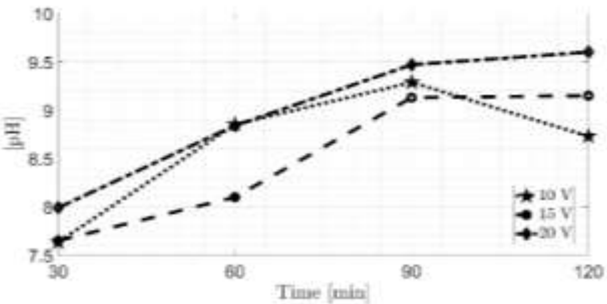
Graphic 8 Initial and final pH levels for 15 V.
Source: Own Elaboration



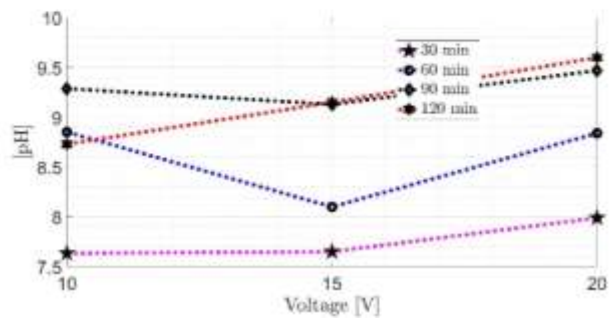
Graphic 9 Initial and final pH levels for 20 V.
Source: Own Elaboration



Graphic 10 pH rate of change
Source: Own Elaboration



Grphic 11 pH variation in the effluent with respect to treatment time.
Source: Own Elaboration



Graphic 12 pH variation in the effluent with respect to applied voltage
Source: Own Elaboration

Graphics 13-15 show the comparative values of initial and final turbidity for 10 V, 15 V and 20 V respectively during 30 min, 60 min, 90 min and 120 min, these graphs show the measurements of the three turbidity sensors and the average of them.

Also from the averages of the effluents, Figures 16, 17 and 18 show the turbidity rate of change, the behavior of turbidity in the effluent with respect to treatment time and applied voltage, respectively.

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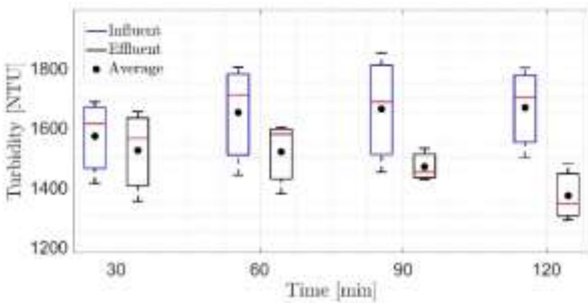
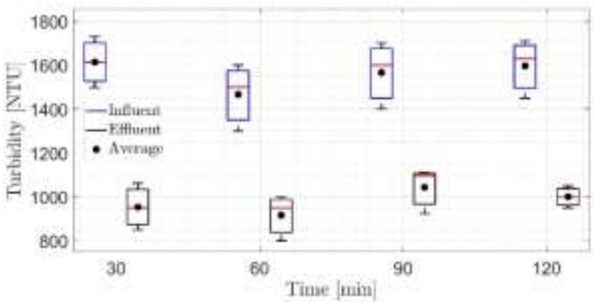
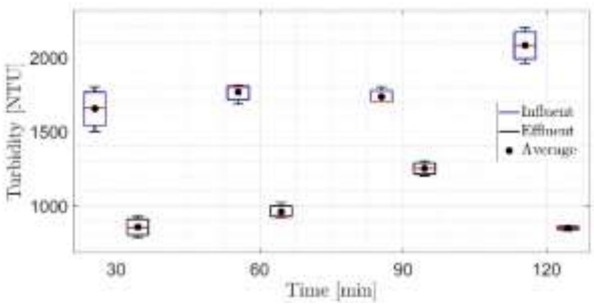


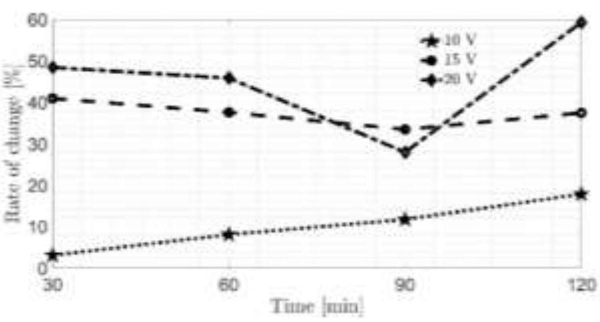
Graphic 13 Initial and final turbidity levels for 10 V
Source: Own Elaboration



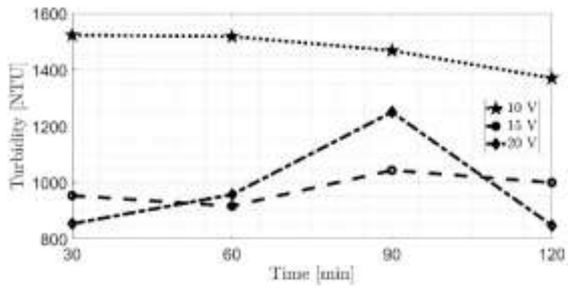
Graphic 14 Initial and final turbidity levels for 15 V.
Source: Own Elaboration



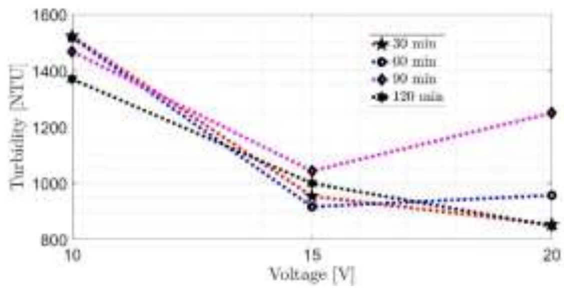
Graphic 15 Initial and final turbidity levels for 20 V.
Source: Own Elaboration



Graphic 16 Turbidity rate of change
Source: Own Elaboration



Graphic 17 Turbidity variation in the effluent with respect to treatment time
Source: Own Elaboration



Graphic 18 Turbidity variation in the effluent with respect to applied voltage
Source: Own Elaboration

5 Conclusions

The measurement system allows online monitoring through the HMI of the variables dissolved oxygen, pH and turbidity in the influent and effluents of the grey water treatment process and determining changes of them quickly. Experimental tests of the treatment process were performed varying the applied voltage and duration of the EC process. The dissolve oxygen variable shows an increase when the applied voltage and treatment time are increased, and the pH variable also shows an increase when the applied voltage and treatment time are increased.

On the other hand the average turbidity measurements show a decrease when the applied voltage and treatment time are increased. Although the DO, pH and turbidity measurements in the influents show different values in all experiments, the highest percentage increase in DO was 352.20% in the experiment 4 with 10 V and 120 min of treatment, the pH had a maximum increase of 18.73% in the experiment 3 with 10 V and 90 min of treatment and the turbidity variable had a maximum decrease of 59.22% in the experiment 12 with 20 V and 120 min of treatment.

Acknowledgements

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Referencias

[1] U. Nations, Water and sanitation - united nations sustainable, https://www.un.org/ sustainabledevelopment/water-and-sanitation/.

[2] M. Y. A. Mollah, R. Schennach, J. R. Parga, D. L. Cocke, Journal of hazardous materials 2001, 84, 1 29.

[3] G. Chen, Separation and purification Technology 2004, 38, 1 11.

[4] S. Piña, M. Dominguez, G. Ramirez, Revista Mexicana de Ingenier´ıa Qu´ımica 2011, 10, 2.

[5] C. E. B. Díaz, Aplicaciones electroqu´ımicas al tratamiento de aguas residuales, Reverte, 2014.

[6] S. Garcia-Segura, M. M. S. Eiband, J. V. de Melo, C. A. Martínez-Huitle, Journal of Electroanalytical Chemistry 2017, 801 267.

[7] S. Mondal, M. K. Purkait, S. De, Advances in dye removal technologies, Springer, 2018.

[8] R. Bastian, D. Murray, Guidelines for water reuse. us epa office of research and development, washington, dc, Technical report, EPA/600/R-12/618, 2012.

[9] N. O. Mexicana, Diario Oficial de la Federaci´on: Mexico City, Mexico 1997.

[10] P. K. Holt, G. W. Barton, C. A. Mitchell, Chemosphere 2005, 59, 3 355.

[11] S. Zhang, J. Zhang, W. Wang, F. Li, X. Cheng, Solar Energy Materials and Solar Cells 2013, 117 73.

[12] G. Sharma, J. Choi, H. Shon, S. Phuntsho, Desalination and water treatment 2011, 32, 1-3 381.

[13] D. Marmanis, K. Dermentzis, A. Christoforidis, K. Ouzounis, A. Moumtzakis, Desalination and Water Treatment 2015, 56, 11 2988.

[14] C. Nawarkar, V. Salkar, Fuel 2019, 237 222.

[15] M. M. Emamjomeh, M. Sivakumar, Journal of Environmental Management 2009, 90, 2 1204.

[16] M. M. Emamjomeh, M. Sivakumar, Journal of Environmental Management 2009, 90, 5 1663.

[17] DFRobot, Turbidity sensor sku sen0189, https://wiki.dfrobot.com/Turbidity_sensor_SKU_ _SEN0189#target_4.

[18] DFRobot, Gravity analog dissolved oxygen sensor sku sen0237, https://wiki.dfrobot.com/ Gravity__Analog_Dissolved_Oxygen_Sensor_ SKU_SEN0237.

[19] DFRobot, Industrial ph electrode sku fit0348, https://wiki.dfrobot.com/Industrial_pH_ electrode_SKU_FIT0348_.

[20] Arduino, Arduino mega 2560 rev3, https://store.arduino.cc/usa/mega-2560-r3.

[21] Y. Wei, Y. Jiao, D. An, D. Li, W. Li, Q. Wei, Sensors 2019, 19, 18 3995.

[22] C. E. Boyd, C. S. Tucker, R. Viriyatum, North American Journal of Aquaculture 2011, 73, 4 403.

[23] J. Essick, Hands-on introduction to LabVIEW for scientists and engineers, Oxford University Press, 2018.

[24] M. Michael, USA, O'Relly 2012.