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Operating Parameters Analysis in Alkaline Water Production using Rainwater Electrolysis Methode

Nur Qudus[1,*], Harianingsih[2], Bambang Sugiyarto[1], Virgiawan Adi Kristianto[1], Indra Sakti Pangestu[2], Asti Dwi Afidah[3]

[1] Department of Civil Engineering, Universitas Negeri Semarang, Kampus Sekaran, Semarang 50229, Indonesia
[2] Department of Chemical Engineering, Universitas Negeri Semarang, Kampus Sekaran, Semarang 50229, Indonesia
[3] DSIH Administration and Finance, Universitas Negeri Semarang, Kampus Sekaran, Semarang 50229, Indonesia

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ABSTRACT

Utilization of rainwater is an alternative for the availability of drinking water. The method used is in the form of electrolysis which results in the form of alkaline water. The purpose of this research is to analyze the parameters that affect the rainwater electrolysis process in order to produce optimal alkaline water. The research stage is to make a rainwater electrolysis reactor with a volume of 1.2 liters which is connected to a power supply. Analysis was carried out for the variables used at voltages of 5, 10, 15, 20 and 25V; electrolysis process time of 10, 20, 30, 40, 50, and 60 minutes; surface area of titanium electrodes 1, 2, 3, 4 and 5 mm^2. The results of this study obtained alkaline water with a pH reaching 8.5 at a voltage of 25V, 60 minutes of electrolysis process time and a surface area of 5 mm^2 titanium electrodes. The FTIR image also shows high absorption of O-H bonds, which indicates an increase in pH.

1. Introduction

Water is an environmental component that is very important for human survival. The most important and vital use of water is as a source of drinking water [1]. Currently, the availability of water sources is increasingly limited due to changes in the condition of water bodies such as lakes, rivers, seas and groundwater caused by human activities and natural phenomena [2]. The limited availability of fresh water on alluvial plains is caused by several factors, including the influence of seawater on coastal aquifers [3]. To maintain water quality and ensure that water still meets the desired standards according to its designation, it is necessary to manage water quality [4]. The concept of the hydrologic cycle is a very important concept because water, whether in the form of surface water or groundwater, is an integral part of the hydrologic cycle. The hydrologic cycle is a continuous process that occurs in the aquatic environment, which can be explained as the passage of water from the atmosphere to the earth's surface, then back to the atmosphere, and so on [5].

* *Corresponding author.*
E-mail address: nurqudus@mail.unnes.ac.id

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Rainwater that falls as part of the hydrologic cycle is considered one of the purest water sources. The alternative solution recommended in this study is the utilization of rainwater into alkaline water using the electrolysis method [6].

Electrolysis is a chemical process that occurs in an electrolyte due to an electric current flowing through it. In this process, water molecules are broken down into positive ions (cations) and negative ions (anions) [7]. Positive ions will move towards the negative pole which is called the cathode and produce alkaline water, while negative ions will be attracted to the positive pole which is called the anode and produce acidic water [2]. The chemical reactions that occur in rainwater electrolysis are shown in Eq. (1) and Eq. (2) [8].

Anode $$2H_2O \rightarrow 4e^- + O_2 + 4H^+ \quad (1)$$

Cathode $$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (2)$$

In the process of electrolysis, chemical reactions occur at the cathode and anode. At the cathode, two water molecules react by capturing two electrons and are reduced, producing H_2 gas and hydroxide ions (OH^-) [9]. On the other hand, at the anode, two other water molecules break down into O_2, releasing 4H+ ions and passing electrons to the cathode. H^+ and OH^- ions then undergo neutralization, producing a few more water molecules [10]. The results of this electrolysis process produce two types of water with different properties. Water that has a pH greater than 8 is considered alkaline water and can be used as drinking water. While water which has acidic properties is used as an antiseptic [9]. The acidic, basic, or neutral nature of a solution depends on the concentration of H^+ (hydron) and OH^- (hydroxide) ions in the solution. A solution is considered acidic if the concentration of H^+ is more dominant than other ions, while a solution is considered basic if the concentration of OH^- is more dominant [11]. A solution is considered neutral if there are equal concentrations of H^+ and OH^- in the solution. Alkaline water is water that is alkaline or has a pH above 7 [12]. Alkaline water is often considered to have several benefits for the body due to its higher mineral content and active hydrogen ions. Active hydrogen ions in alkaline water are believed to act as natural antioxidants [13]. Antioxidants can help fight free radicals in the body. Free radicals are unstable molecules that can cause damage to body cells and contribute to aging and various health problems. Possessing antioxidant properties, alkaline water may be able to help protect the body's cells from harmful free radicals and support overall health [14].

The novelty of this study is the analysis of optimal operating parameters for the production of alkaline water from rainwater. Previous research was limited to the use of raw water as a production material for alkaline water. This study aims to analyze the effect of operating time and voltage on pH and total dissolved solids (TDS) alkaline water from rainwater.

2. Methodology

2.1 Materials

The materials used in this study were rainwater with pH=5, titanium ruthenium iridhium electrodes measuring 100 mm x 50 mm, Sodium Hydroxide Merck SAS 1310-73-2, Sulfuric Acid Merck 1.00731.2500, TDS Reagent, Aquades, Millipore Membrane Filter 0.45micron 47mm Hawp0470.

2.2 Instrumentation

The main equipment in this research is rainwater electrolysis batch reactor with a capacity of 1.2 liters. The schematic of this reactor can be seen in Figure 1. The main difference in this experiment lies in the type of charge applied to the titanium electrode, which acts as a site for exchange of positive and negative ions. When the titanium electrode is given a negative charge, the electrode will function as the cathode. Conversely, when a positive charge is applied, the titanium electrode will act as the anode. Stirring in the reactor is carried out using a magnetic stirrer with additional baffles in it. The use of baffles aims to improve mixing efficiency. In addition, this reactor is equipped with a coolant flow to maintain the temperature inside the reactor at 50°C, this is done to reduce the possibility of evaporation of the solution.

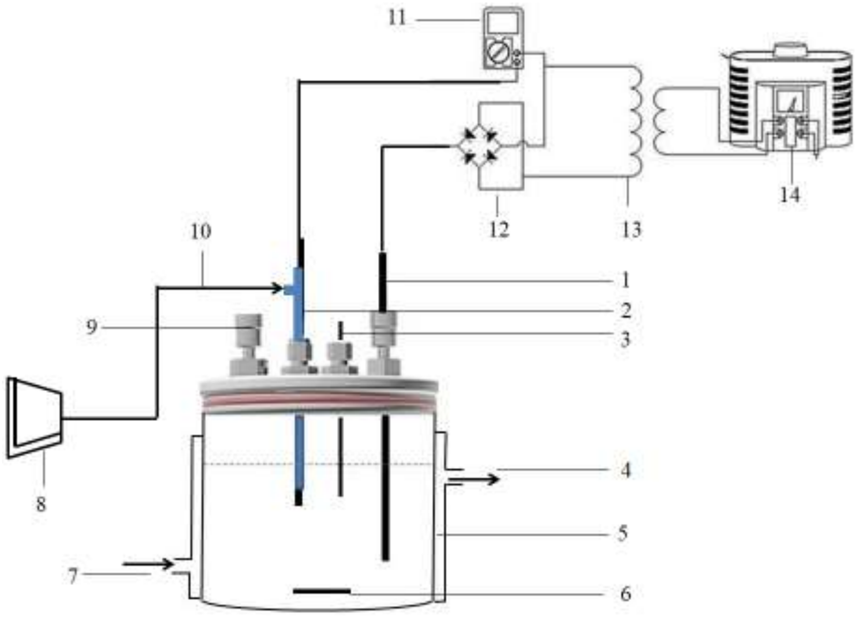

Fig. 1. Rainwater electrolysis reactor scheme: 1 and 2. Titanium electrode, 3. pH and temperature sensors, 4. Colling out, 5. Reactor, 6. Magnetic stirer, 7. Colling in, 8. Compresor, 9. Sample port, 10. Rainwater hose, 11. Multimeter, 12. Power analyzer, 13. Transformator, 14. Slide regulator

2.3 Procedure

The process of electrolysis is carried out in the following steps: prepare a vessel or tube to be used for electrolysis. The vessel or tube is filled with rainwater pH = 5. The titanium electrode is connected to a power supply. Make sure the positive pole (usually red) is connected to the first vessel or tube and the negative pole is connected to the stainless wire terminal on the second vessel. Connect the rectifier circuit (adapter) to various voltages, for example 5 V, 10 V, 15 V, 20 V and 25 V. This will determine how much electric potential will be used in the electrolysis process. Turn on the power supply and let the electrolysis process take place. You can set the electrolysis time for 10, 20, 30, 40, 50 and 60 minutes. The same treatment was carried out for the surface area of the titanium electrodes 1,2,3,4 and 5 mm^2.

3. Result

3.1 Effect of Voltage and Time on the Increase in pH

In Figure 2, it can be seen that the effect of voltage and time on the increase in pH tends to increase. This indicates that the higher the voltage used in the electrolysis process and the longer the electrolysis time, the pH of the solution tends to increase. This phenomenon can be explained by the formation of hydroxide ions (OH^-) during the electrolysis process. When water splits into ions, one of them is the hydroxide ion (OH^-), which is basic. The longer the electrolysis process lasts, the more hydroxide ions are formed in the solution. Increasing the voltage can also increase the speed of the electrolysis process and, therefore, the amount of hydroxide ions produced.

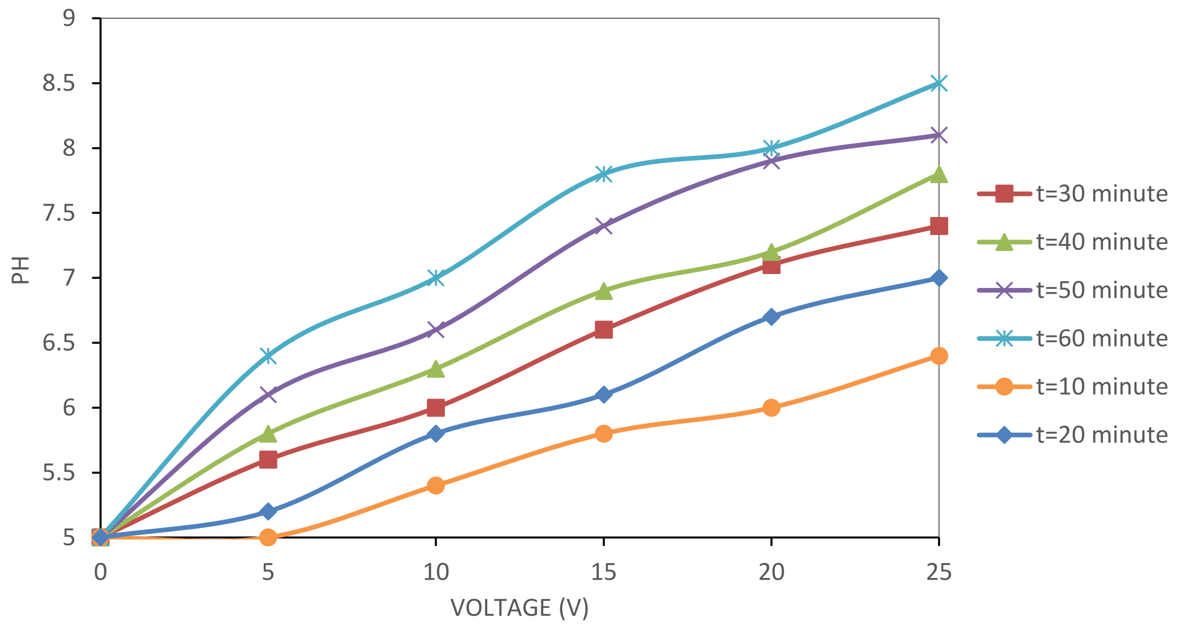

Fig. 2. Effect of voltage and time on the increase in pH

The effect of voltage on the increase in pH reached 6.4; 7; 7.4; 7.8; 8.1 and 8.5 which tend to increase at 25V for 60 minutes of rainwater electrolysis process is the expected result in electrolysis experiments. Alkaline water is achieved at a voltage of 15V, 20V and 25V. The higher the voltage used, the more hydroxide ions (OH^-) are generated, which then increases the pH of the solution, exhibiting basic characteristics. This is in accordance with the basic concept of electrolysis in which water is split into ions, including OH^-, at the cathode [12]. During electrolysis, water is split into ions, including hydroxide ions (OH-), at the cathode. The longer the electrolysis time, the more hydroxide ions are produced in solution, so the pH tends to increase (more alkaline) [5]. This corresponds to the principle that the hydroxide ion is basic. Conversely, when the electrolysis time is shorter, as in the case of electrolysis times of 5 and 10 minutes, the amount of hydroxide ions produced is less, which can result in an acidic pH in the solution.

3.2 The Effect of Voltage and Time on Decrease in Toal Dissolved Solids (TDS)

The use of the electrolysis method with titanium electrodes and variations in electric voltage and electrolysis time have a significant impact on reducing the concentration of Total Dissolved Solids (TDS) in rainwater. In Figure 3, a voltage of 25V, with a contact time of 60 minutes, the TDS concentration decreased to 98 mg L^{-1}. The decrease in TDS concentration also seems to depend on the contact time. The decrease in TDS concentration was caused by flotation events that occurred during the electrolysis process. The carbon electrode which is electrified causes the organic compounds in the wastewater to decompose, forming ions and producing gas. This gas plays a role in lowering TDS through the flotation process. The process of electrolysis involves the formation of hydroxide ions (OH^-) and hydrogen ions (H^+). H^+ ions are attracted to the negatively charged cathode pole, causing the precipitation of dissolved compounds in rainwater. During the electrolysis process, gases such as hydrogen (H_2) and oxygen (O_2) can be formed at the electrodes or in the solution as a result of the electrolysis reaction [15]. Gas bubbles will rise to the surface of the solution, and over time, more and more gas bubbles are formed. The gas bubbles act as a natural flotation agent. They attach to particles in rainwater and float them to the surface of the solution. The longer the electrolysis time, the more gas bubbles are formed, making it more effective in removing solid particles from solution. This will result in a decrease in the TDS content in rainwater [16].

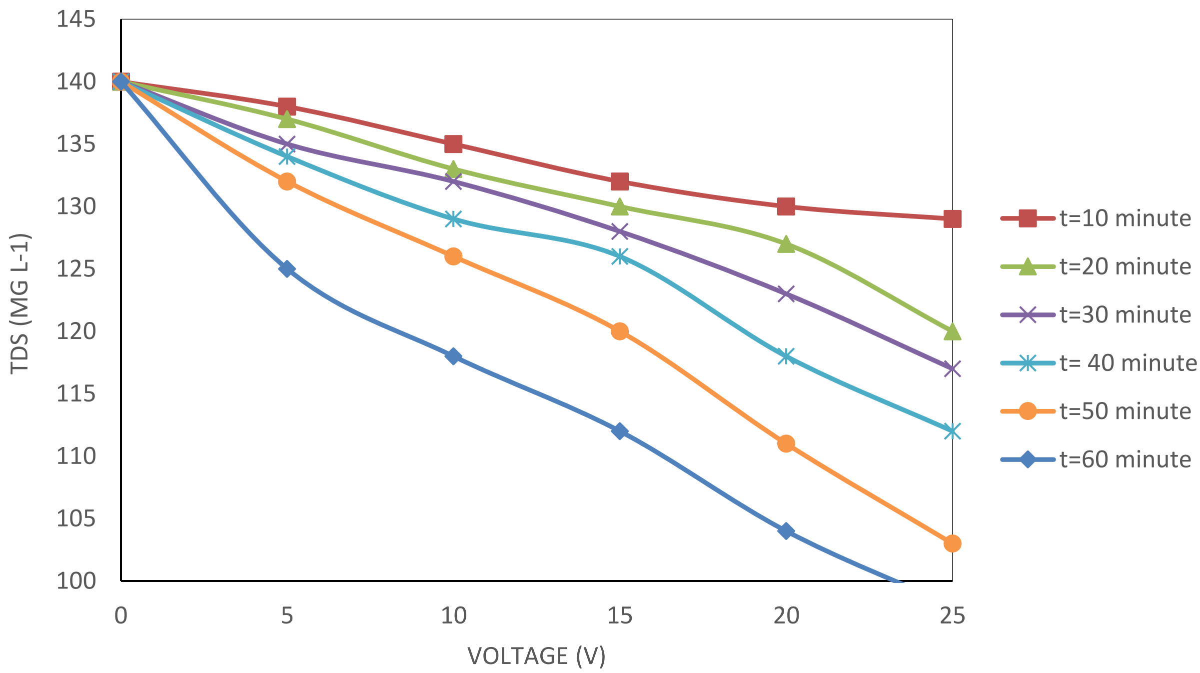

Fig. 3. The effect of voltage and time on decrease total dissolved solids (TDS)

3.3 The Effect of Electrode Surface Area and Time on the Increase in pH

The choice of titanium ruthenium iridhium titanium electrode is due to the electrolysis process has good electrical conductivity, which allows a high electric current to flow through the electrodes. This is important in electrolysis processes because a sufficiently large electric current is required to produce significant results in the separation or treatment of substances in solution. Titanium is a relatively chemically stable material [17]. This means Titanium electrodes are less likely to react chemically with substances in solution or become oxidized during the electrolysis process. This is important because a stable electrode will allow the experiment to run with good consistency. Titanium can produce a large amount of gas over a long period of time during the electrolysis process. This could be useful in a variety of applications, including the production of HHO gas or hydrogen and oxygen gases, which could have many practical applications [14,18].

In Figure 4, the increase in pH that occurs with the increase in treatment time and surface area of the electrodes in the process of electrolyzing rainwater into alkaline water. The basicity level reaches 8.5 on a surface area of 5 mm^2 during 60 minutes of electrolysis process. This is due to the accumulation of hydroxide ions (OH^-) which are produced during the electrolysis reaction of rainwater. This electrolysis reaction involves conducting an electric current in rainwater, and one of the results is an increase in the concentration of hydroxide ions in the solution. Hydroxide ions are alkaline and can increase the pH of the solution.

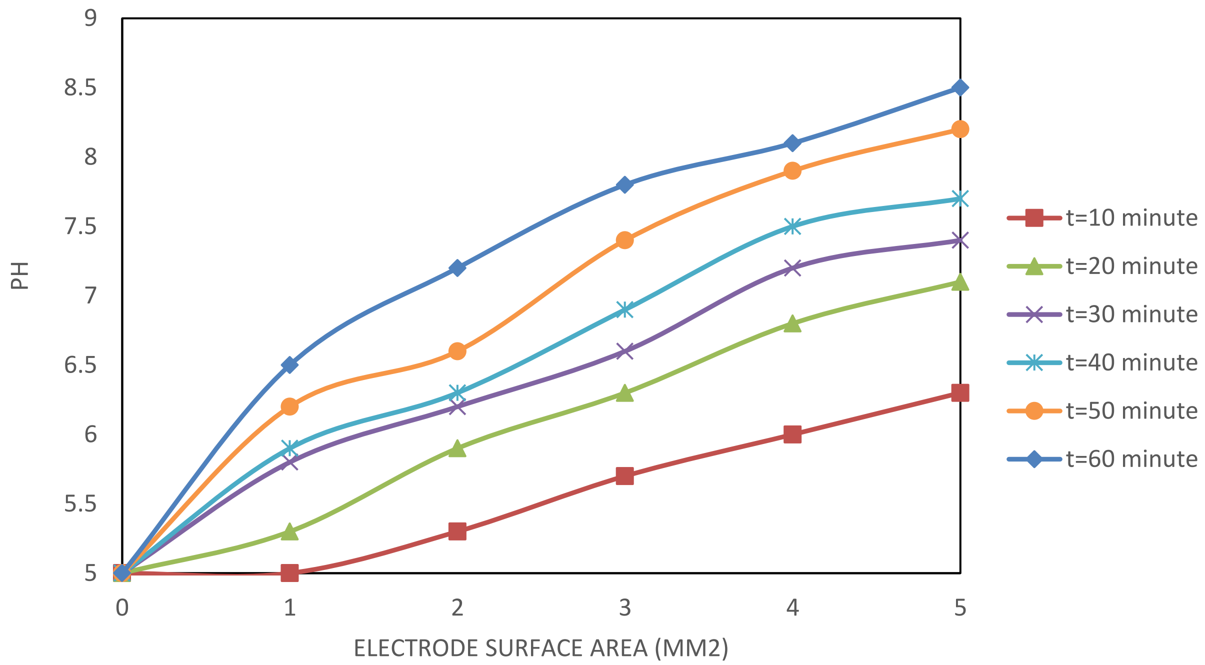

Fig. 4. The effect of electrode surface area on the increase in pH

3.4 FTIR Spectrum of Alkaline Water

The FTIR test results shown in Figure 5 provide information about the chemical composition of alkaline water resulting from rainwater electrolysis. Several identifications of functional groups can be taken from the FTIR spectrum. The absorption band at wave 3331.47 cm^{-1} identified the presence of a hydroxyl group (-OH) associated with a phenolic compound. Phenol compounds are compounds that have an aromatic ring attached to a hydroxyl group. The absorption band at wave 2099.21 cm^{-1} also identifies the presence of amine groups containing nitrogen and hydrogen (N-H). The absorption band at wave 1634.63 cm^{-1} indicates the presence of a carboxylic acid group which has a bonded hydroxyl group (O-H). This is characteristic of monomeric carboxylate compounds. The absorption band at 600-630.75 cm^{-1} indicates the presence of a double bond (C=C) which is characteristic of alkenes. The absorption band at 564.67 cm^{-1} indicates the presence of hydrogen groups attached to alkenes and aromatic rings.

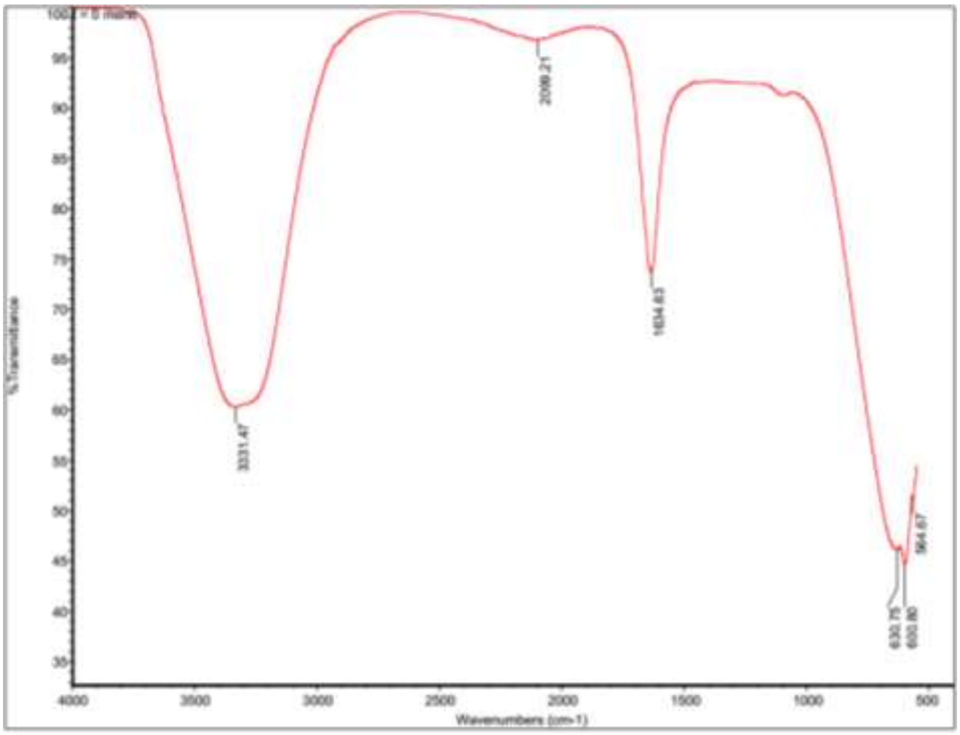

Fig. 5. FTIR spectrum of alkaline water (Voltage=25V, Time=60 minute, pH=8.5)

In Figure 5, the wide band of the infrared spectral region 3331.47 cm^{-1} is the absorption band of the hydroxyl group (-OH) in the infrared spectrum. The band width of about 3628.28 cm-1 is characteristic of the hydroxyl group (-OH) attached to the molecule in the free state, as in the compound water (H_2O). These bands reflect the O-H vibrations that occur in these molecules [19]. When there are interactions with other molecules or changes in the chemical environment, such as an addition of base or a change in pH, the absorption bands can shift or narrow. These changes in the infrared spectrum can indicate changes in chemical bonding or molecular states [20].

4. Conclusions

Rainwater electrolysis has proven to be an effective method for alkaline water production. Production of alkaline water by electrolysis of rainwater is an interesting application. Alkaline water has a higher pH than plain water and is often thought to have certain potential health benefits. The electrolysis process can increase the pH of water by producing hydroxide ions (OH^-) which are alkaline. Results reaching a pH of 7.4 to 8.5 indicate that electrolysis of rainwater can produce water with the desired alkaline properties. The ability of electrolysis to reduce the TDS of rainwater from 140 mg L^{-1} to 98 mg L^{-1} is a positive result. Total Dissolved Solids includes a variety of substances dissolved in water, including minerals and other compounds. Reducing TDS can improve water quality by reducing the content of potentially unwanted compounds in drinking water. The use of titanium electrodes in the electrolysis process has been shown to increase the pH of water. Electrodes with a wider surface can produce more hydroxide ions (OH^-), which in turn will increase the alkaline nature of water. This is an important aspect in optimizing the electrolysis process. These results indicate that electrolysis of rainwater can be an effective method for producing alkaline water and for reducing TDS in rainwater. In addition to these benefits, there may also be other considerations such as water quality, use of electrode materials, and energy efficiency that need to be considered in the development of this method.

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