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Optimization of Alkaline Water Production from Rainwater through Electrolysis Method: Effect of Voltage and Time on pH and TDS

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Abstract

Alkaline water is known to have health benefits due to its higher pH than ordinary water. In this study, the production of alkaline water from rainwater using electrolysis method was optimized, with variations in voltage and time to evaluate its effect on pH and Total Dissolved Solids (TDS). The experiment involved three voltage levels (12 Volt, 24 Volt, and 36 Volt) and three time intervals (10 minutes, 20 minutes, and 30 minutes). The results showed that increasing the voltage and electrolysis time contributed significantly to the increase in water pH, which reached the highest value at 36 Volt for 30 minutes. However, increasing the voltage and time also increased the TDS value linearly, which can affect the water quality if it exceeds a certain limit. This study concludes that the optimal voltage for producing alkaline water with suitable pH and TDS is 24 Volt with an electrolysis time of 20 minutes. Thus, this method offers an efficient and simple solution to produce alkaline water from rainwater, which could potentially benefit public health in areas with limited access to high-quality drinking water.

Keywords : alkaline water, rainwater, electrolysis, ph, tds, voltage, time

INTRODUCTION

Water is essential for the survival of humans and other creatures. Fulfillment of water worthy of consumption is of course inevitable. Water in the human body is 74% in the brain, 75.6% in the muscles, 83% in the blood, 82.7% in the kidneys and 22% in the bones. So that the need for water in the human body is approximately 10 liters every day (Sa'idi, 2020). Various water sources have been developed in fulfilling clean water and healthy water needs for the body. Clean water can be developed from rainwater harvesting. Abundant rainwater is often not utilized, only thrown away because rainwater will be suitable for human consumption if it uses special processing (Welch *et al.*, 2014). This is evidenced by the presence of Escherichia coli and other coliforms detected in rainwater but can be overcome by ultraviolet light (UV) sterilization (Lee *et al.*, 2017). One form of rainwater treatment is to make it as ionized alkaline water. Alkaline water is water with a higher pH level than normal drinking water. This type of water can be produced at the cathode in the electrolysis process which is also known as electrolyzed reduced water (Weidman *et al.*, 2016). The event of decomposition compound H_2O commonly known as electrolysis can change H_2O into oxygen and hydrogen. This process of course requires the flow of electric current and electrodes. Electrodes with two poles cathode and anode (Brauns and Turek, 2020). The event that occurs at the cathode is the reaction of two water molecules capturing two electrons so that they are reduced to hydrogen in the gas phase and hydroxide. +Events that occur at the anode in the form of two water molecules that break down into oxygen and release H ions then flow electrons at the cathode. The potential difference arising from the electric current between the anode and cathode will cause ionization of water molecules into positive ions and negative ions (Kusuma, 2020). At the cathode, positive ions absorb electrons, forming H_2 ion molecules, while negative ions move towards the anode to release electrons and form O_2 ion molecules (Sa'idi, 2020). From the above description, the basic ions that form alkaline water are determined by the cathode and anode, so the electrode material will affect the result of alkaline water production. The higher pH is due to the enrichment of basic minerals and the removal of acidic minerals. In addition, alkaline water has smaller water molecules compared to ordinary water (Masuda *et al*., 2017). Alkaline water is proven to have the ability to scavenge radicals, which is recognized as effective in treating gastric hyperacidity, dyspepsia, diarrhea, and normalizing intestinal microflora in Japan and Korea (Pasiga and Akbar, 2019). In recent research on water electrolysis, several studies have suggested voltage variation as a critical factor in optimizing alkaline water production (Kurniawan *et al*., 2022) (Tan and Liu, 2021). Previous studies highlighted that manipulation of this parameter can affect pH and total dissolved solids (TDS) (Yildiz *et al*., 2008) (Erabee *et al*., 2017), strengthening our understanding of the response of rainwater electrochemical systems to electrical stimuli. Correspondingly, the use of different types of electrodes became the focus of research to observe their respective roles in shaping the alkaline nature of electrolyzed water (Dahlan, 2009) (Muchrar and Rustana, 2020) (Fajrin *et al.,* 2022). Previous research also resulted in effective drinking water purification methods using adsorption and ultraviolet methods (Gusain *et al*., 2020) (Reizaie *et al*., 2020).

METHODS

Research Materials

The materials needed in this study include water, all chemicals used in this study were purchased from MERCK, Germany. In addition, the electrodes in the form of stainless-steel plates were cut into 127 mm long, 13 mm wide and the thickness was maintained at exactly 1.2 mm, polished with a grinder polisher and washed thoroughly with distilled water to remove any adhering dust or dirt and then dried in the open air.

Tool Design

The tools that will be used during the experimental process are arranged by combining several components, including an acrylic tank with a volume of 25 liters, a cathode and anode measuring 127 mm x 13 mm x 1.2 mm attached to the tank wall, a ultraviolet C (UVC) with type ultraviolet tube with a volume of 1 liter, a water hyacinth adsorbent filter tube, accompanied by a voltage adapter, a food grade pump, a pH sensor, and a hardness sensor

Electrolysis Procedure

In this study, the research procedure was carried out through experimental methods carried out for different sample types. The electrodes used were stainless steel and 220 volt voltage difference. The water sample used was prepared in the tank. Then the electrode is powered by DC electric current with the appropriate voltage on the experimental sample. The electrolysis process will run for 15 minutes and produce alkaline products in the main tank in the form of water with high basicity in the cathode tank and acidic products in the anode tank.

Analysis

Tests will be carried out on physical parameters including TDS (total dissolve solid), turbidity measured by the Water Quality Criteria (WQC) tool direct method [19]. The next analysis is organoleptic analysis which includes the color, smell, and taste of the alkaline water produced. Chemical parameter analysis is also carried out, which includes pH, and the distribution of bacteria can be tested through total plate number testing. The test results will be compared with the quality standards regarding drinking water quality requirements in accordance with PERMENKES Number 492 of 2010 and Indonesian National Standard 3553: 2015 [20, 21]. The purpose of the three analyses is to determine pH and TDS.

RESULT AND DISCUSSION

Acid and alkaline water formation zone

The mechanism of formation of H^+ and OH^- ions mapped through the phase state of the solution can be shown from the graph of the relationship of voltage to pH and the limits can be taken from the reduction and oxidation potential of water. At standard temperature and pressure, the acidic water region is limited by voltage $E^o = 0$ Volt and $E^o = 1.23$ Volt at pH = 0. The alkaline region is limited by the voltage $E^o = 0.41$ Volt and $E^o = -0.83$ Volt at pH = 14. After the electrolysis process will be formed H_2, O_2, acidic water and alkaline water in the standard state. The voltage after electrolysis becomes E = 1.23 Volt at pH = 0.0591.

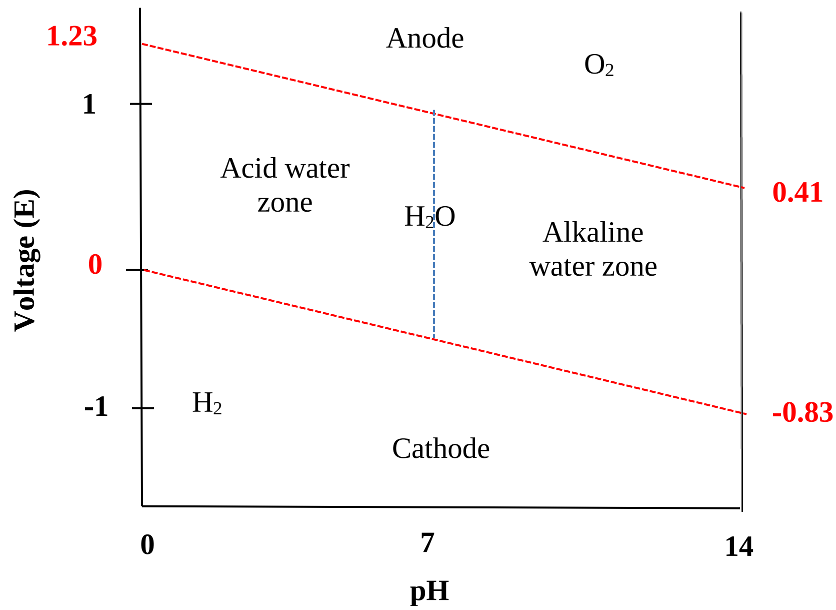

Figure 1. Acidic and basic water formation zones

Figure 1 shows the electrochemical stability of hydrogen, oxygen and electrons due to the effect of voltage on pH. Changes in liquid, gaseous phases, hydrogen and oxygen ion activity as well as acidic and basic water zones are indicated by the separation line between the cathode and anode as well as acidic and basic pH (Mousa, 2016). The reaction mechanism that occurs at the cathode anode of each voltage includes:

Anode

$E^o = 0.41$ Volt: $4OH^-_{(aq)} \rightarrow O_{2(g)} + 2H_2O_{(l)} + 4e^-$

$E^o = 1.23$ Volt: $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$

Cathode

$E^o = 0.0591$ Volt: $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

$E^o = -0.83$ Volt: $2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

The level of acidity and alkalinity produced from the electrolysis of rainwater depends on the ions that bind to it. The greater the number of binding ions, the greater the ion concentration and the greater the pH and pOH values (Sutapa *et al.*, 2022). To produce strong acids and bases, enhancers are added that work like catalysts and are made from sodium hypochlorite. Sodium hypochlorite can be used to make alkaline water with a pH of up to 11.5 and strong acid with a pH of up to 2.5.

Effect of Voltage on electrolysis time

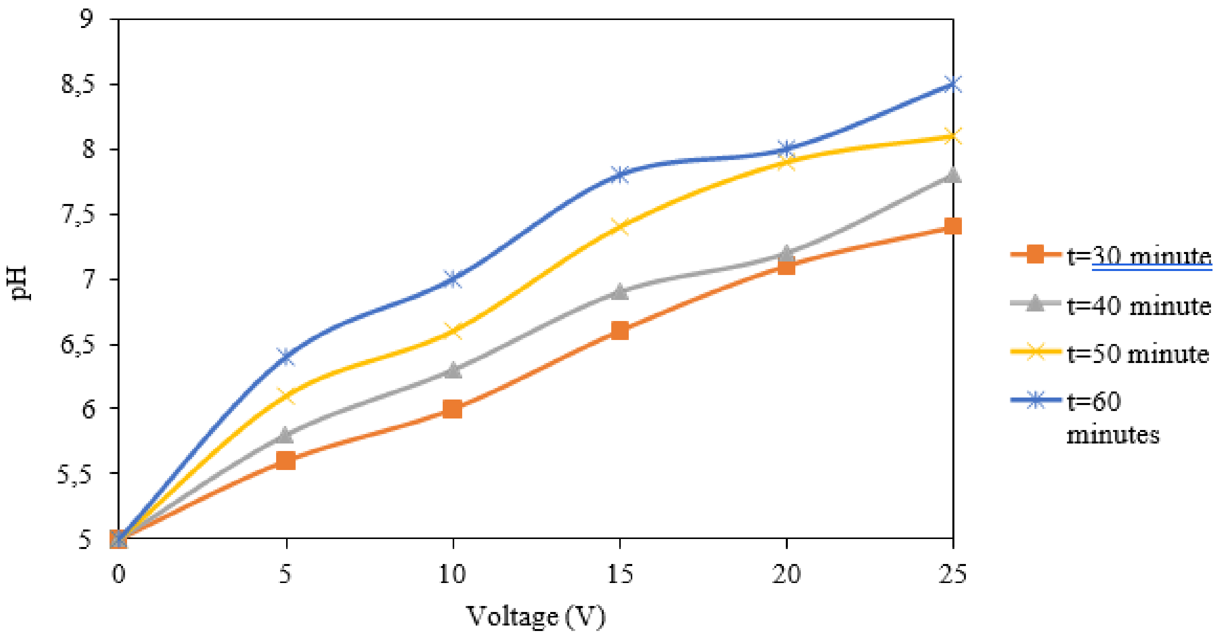

Figure 2. Graph of voltage and time relationship to pH

Figure 2 shows that the higher the voltage used in the electrolysis process and the longer the electrolysis time, the higher the pH of the solution. This phenomenon can be explained by the formation of hydroxide ions (OH^-) during the electrolysis process. When water is broken down into ions, one of them is hydroxide base ion (OH^-) (Lestari and Fuady, 2022). The longer the electrolysis process lasts, the more hydroxide ions are formed in the solution. Increasing the voltage also increases the rate of the electrolysis process and the amount of hydroxide ions produced.

The effect of voltage on the increase of pH to 7.4; 7.8; 8.1 and 8.5, which tends to increase at 25 Volt for 60 minutes of rainwater electrolysis process, is the expected result in the electrolysis experiment. Alkaline water is available at voltages of 15Volt, 20Volt, and 25Volt. The higher the voltage used, the more hydroxide ions (OH^-) are produced and the pH of the solution increases, indicating its alkaline nature. This is in accordance with the basic concept of electrolysis, where water is broken down into OH^- containing ions at the cathode. During electrolysis, water is broken down into ions including hydroxide ions (OH^-) at the cathode. The longer the electrolysis lasts, the more hydroxide ions are produced in the solution, so the pH tends to increase (become more alkaline). This is in accordance with the principle that hydroxide ions are alkaline.

Effect of voltage and time on total solid demand (TDS)

The use of electrolysis method using titanium electrodes, variations in voltage and electrolysis time have a significant effect on reducing the concentration of total dissolved solids (TDS) in rainwater.

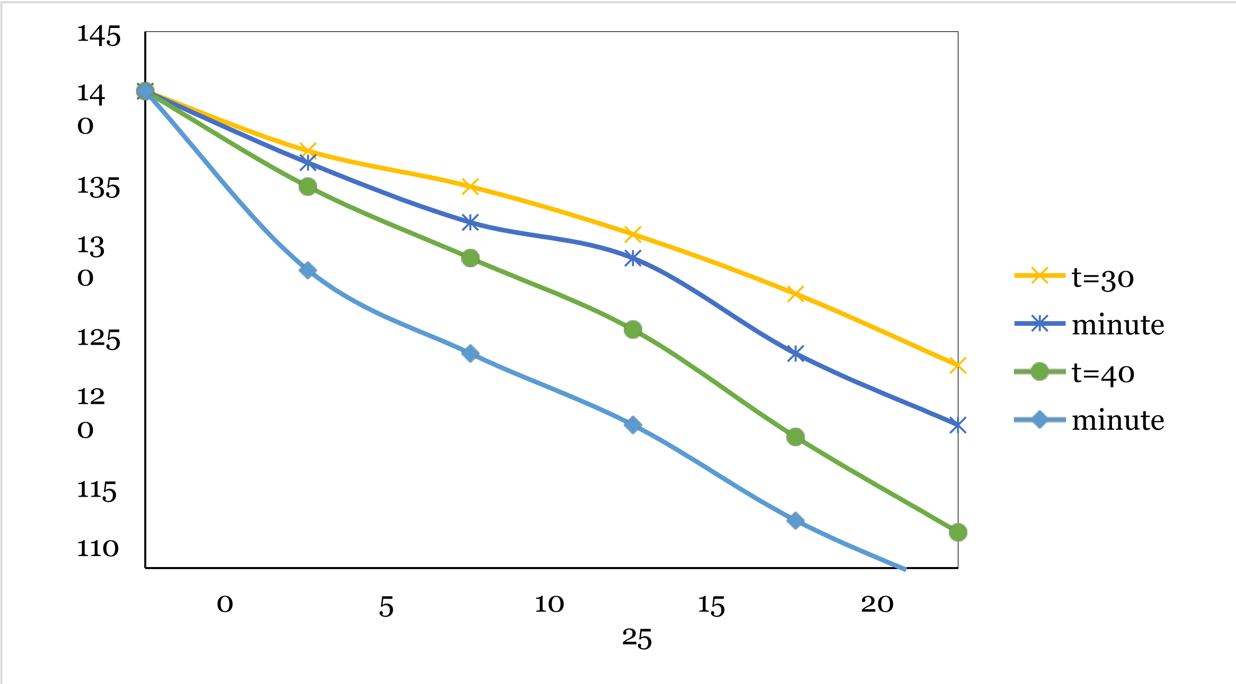

Figure 3. Graph of voltage and time relationship to TDS

At a voltage of 25 Volt and 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 value is due to the flotation phenomenon that occurs in the electrolysis process. The energized carbon electrode decomposes organic compounds in wastewater, generating ions and producing gas. This gas serves to reduce TDS through the flotation process. The electrolysis process produces hydroxide ions (OH^-) and hydrogen ions (H^+). H^+ ions are attracted to the negatively charged cathode pole, causing precipitation of dissolved compounds in rainwater (Lestari *et al*., 2023). During the electrolysis process, gases such as hydrogen (H_2) and oxygen (O_2) may form on the electrodes or solution as a result of the electrolysis reaction. The bubbles rise to the surface of the solution and over time more and more bubbles are formed. Air bubbles act as a natural flotation agent. It attaches to particles in the rainwater and transfer it to the surface of the solution. A longer electrolysis time means more bubbles are formed and solid particles can be released from the solution more effectively. This leads to lower TDS levels in the rainwater.

CONCLUSIONS

Rainwater electrolysis has proven to be an effective method for producing alkaline water. An interesting application is the production of alkaline water by rainwater electrolysis. Alkaline water has a higher pH than regular water and is considered to have certain potential health benefits. The electrolysis process produces alkaline hydroxide (OH^-) ions that increase the pH of the water. Results reaching pH 7.4-8.5 indicate that rainwater electrolysis can produce water with the desired alkaline properties. The ability of electrolysis to reduce rainwater TDS from 140 mg.L^{-1} to 98 mg.L^{-1} is a positive result. Total dissolved solids include various dissolved substances in water, such as minerals and other compounds. Reducing TDS can improve water quality by reducing the levels of potentially undesirable compounds in drinking water.

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