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CO_2 Gas Reduction Using the Absorption Method as an Effort to Support Carbon Capture and Storage (CCS) Technology

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ABSTRACT

Significant changes in global temperature occur when CO_2 gas produced increases from industrial combustion processes that still use fossil fuels. These fuels contribute to environmental damage that will result in greenhouse gas emissions. One form of effort made by using Carbon Capture and Storage (CCS) technology is effectively able to reduce global warming. The reduction process is carried out using NaOH and KOH solutions by comparing the effectiveness of the captured gas. This study was conducted to determine the effect of solution and gas flow rates between NaOH and KOH absorbents on the removal of dissolved CO_2 gas. The chosen methods were sampling method and alkalimetric method. The method was used to determine the variation of absorbent flow rate of 2, 4 and 6 L/min. While the gas flow rate used is 10, 20 and 30 L/min. The results showed that the effective flow rate variation was obtained at a speed of 2 L/min with a gas flow rate of 30 L/min. The concentration that is removed in the absorbent is obtained 52% of CO_2 gas absorbed in NaOH solution with an electric voltage of 0.817 Volt, while KOH is obtained by 48% with an electric voltage of 0.798 Volt. The analysis results will be used as electrochemical-based electrical energy. It can be concluded that the effective absorbent solution is NaOH which can reduce CO_2 gas optimally which has a correlation to the flow rate of the solution and gas and is able to produce electrochemical-based electrical energy.

Key Words	Carbon capture storage, CO_2, absorption, electrochemistry
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INTRODUCTION

Global warming occurs when emissions from industrial combustion processes continue to increase, resulting in extreme temperature increases that occur on earth (Zubaydah et al., 2024). Based on the results of the Copernicus Climate Change Service (C3S) report on temperature changes in 2024, it is known that the global average temperature reached 1.52ºC. The increase in global temperature exceeds the threshold limit from the previous year of 1.5ºC (Okonkwo et al., 2023). This occurs because of greenhouse gas emissions. Greenhouse gases are gases found in the atmosphere or in the earth's layers that are naturally used to keep the earth's temperature stable (Nasir & Go, 2024). Stable temperatures occur when sunlight enters the earth's surface, then they will be reflected into the sky. When sunlight is reflected to the sky, some of it is absorbed by some gases in the atmosphere in the form of short waves that are received by the earth's surface and the rest will be forwarded back to space in the form of long-wave radiation or infrared radiation (Kurnia & Sudarti, 2021). Long-wave radiation emitted by greenhouse gases in the lower layers of the atmosphere will cause hot temperatures called the greenhouse effect (Habibur, 2022). An increase in global temperature that continues to increase will have a negative impact on climate damage so that it will trigger ecological and social problems (Zaky & Sari, 2024; Zahro et al., 2023).

Carbon dioxide or CO_2 emission is a type of greenhouse gas emission that is the main factor that can cause global warming. Carbon dioxide gas consists of two oxygen atoms covalently bonded to a carbon atom (Dziejarski et al., 2023; Anggraini & Sutjahja, 2023). Based on a report from the Global Carbon Project team of scientists in 2022, the amount of carbon emissions produced in Indonesia reached 700 million per year. This figure is an increase of 18.3% from the previous year. Various efforts have been made by the Indonesian government to reduce CO_2 gas emissions produced. In 2060 the government plans to reduce CO_2 gas emissions by implementing a strategy towards net zero emissions (Putri et al., 2024). The plan is to use renewable energy without fossil fuels by using CO_2 gas capture technology produced in the form of Carbon Capture and Storage (CCS) (Shu et al., 2023; Martin-Roberts et al., 2021). Technology is carried out to mitigate the release of greenhouse gas emissions from industries that use fossil fuels. This technology uses the principle of reducing the released carbon dioxide gas with the help of absorbents in liquid form (Roussanaly et al., 2021). The absorbents can be methyl diethanolamine (MDEA), monoethanolamine (MEA), potassium hydroxide (KOH) and sodium hydroxide (NaOH). These materials are commonly utilized as CO_2 capture systems (Arning et al., 2024; Yoshida, 2022). By implementing technology, it will provide an opportunity to produce emissions but not allow the emissions produced to the earth's atmosphere by engineering technology, so that the planned net zero emissions program in 2060 will be achieved (Shaw & Mukherjee, 2022; Liang et al., 2024).

Gas absorption is the process of separating and purifying gas from other gas mixtures. By using the principle of gas diffusion in contact between gas and dissolved liquid, mass transfer will occur (Dziejarski et al., 2023; Hong, 2022). These events will affect the flow rate between the solution and the injected gas during the absorption process. Absorption is used in the form of a packed column (Hanifa et al., 2023). The absorption process occurs when gas and air are mixed by being pushed at the bottom of the packed column while the absorbent solution will be injected from above which flows by gravity, so that there will be a meeting between the gas and the solution (Zhou et al., 2024). This event will affect changes in temperature, pH and EC in the solution so that the gas will be removed in the absorbent solution (Isya et al., 2021). The packed column has an elongated tube shape with packing inside. Packing is a material derived from gravel, glass, ceramic shards, copper iron or materials that are not easily corrosive when reacting with solutions with strong alkaline conditions. Packing is arranged irregularly to facilitate condensation during reduction on the surface of the packed colomn. Packed colomn occurs in a closed column so that an empirical correlation value is obtained between the absorption rate and the mass rate of liquid and gas (H. Huda et al., 2023; Putro et al., 2023).

The implementation of Carbon Capture and Storage (CCS) technology results in the output of a carbonate solution that will be utilized as electrochemical-based electrical energy. Electrochemical processes that study electro-mass transfer that occurs in a medium that has electrodes as electrical conductors (Jiang & Ashworth, 2021; Mao et al., 2023). The electrode has positive and negative caps so that when the electrode is dipped in a solution, it will produce an electrical energy source. The event will experience a redox reaction in the form of electron capture in the reduction reaction, while there is an electron release in the oxidation reaction (Chai et al., 2022). From the electrochemical process that utilizes acidic CO_2 gas emissions, the higher the reduced gas, the higher the electric current generated (Rohid et al., 2022; Salamah & Cahyonugroho, 2023). Based on this, researchers will need to analyze the effectiveness of the flow rate of the reduced gas solution on the concentration captured by comparing the types of NaOH and KOH absorbents. From the results of the absorption that occurs will form a new solution that will be used as electrochemical-based electrical energy. The process was analyzed for its effect on pH, temperature, EC and reduced gas concentration.

METHODOLOGY

In research on CO_2 gas absorption that uses a type of sampling method, alkalimteri. This type of method is needed by researchers to analyze, identify, evaluate and interpret in the form of graphs to review the concentration of CO_2 gas that is removed in the absorbent solution. Based on a scientific article from (Oktarina et al., 2023; Robiah et al., 2021) as the basis for selecting variables in the research that has been conducted. The variables in this study consisted of the influence on pH, electrical conductivity (EC), temperature and concentration of carbon dioxide gas that was removed. For the absorption process, the airflow rate used is fixed at a speed of 10 L/min and the type of absorbent used is in the form of NaOH and KOH which has a concentration of 0.01 M at the initial concentration used. We used flow rate concentration with variations of 2, 4, and 6 L/min. As for the CO_2 gas flow rate used with variations of 10, 20 and 30 L/min. The absorption process runs for 20 minutes to determine the optimum point during the process. The results of the captured output will be analyzed for the concentration of dissolved CO_2 gas and the remaining absorbent that does not form a new solution during the absorption process.

Actual sample preparation

The samples used are NaOH and KOH absorbent solutions which have a concentration of 0.01 M, which have gone through a dilution process from solid to liquid. The dilution process in addition to absorbents there is a dilution of the solution used for the alkalimetric method in the form of acid and wet titration using HCl solution as the neutralizer. HCl solution which has a concentration of 32% will be diluted to a concentration of 0.1 M. In addition, a dilution of the $BaCl_2$ solution is used to determine the remaining concentration of the solution that does not form a new solution. The concentration of $BaCl_2$ used is 0.1 M which is added to the output sample from the absorption process. Furthermore, in the electrochemical analysis, it is used as an electrolyte solution in the form of $CuSO_4$ solution which has a concentration of 0.1 M which has gone through a dilution process. In addition to preparing the absorbent and diluting the solution, the Gas Absorption Column reactor is prepared which is the process of gas absorption that occurs in the column. The reactor used uses a size with the following dimensions:

a. The gas cylinder used has a capacity of 2 m^3 which has a height of 1.2 m with a diameter of 0.14 m.
b. The reservoir used to accommodate the absorbent solution in the *inlet* and *outlet* channels has a size of 0.73 m in the length of the tub, 0.6 m in the width of the tub, and 0.46 m in the height of the tub. The tub used has a water capacity of up to 150 L which can accommodate the solution during the absorption process for 20 minutes.
c. The absorption column or called *the settling column* is made of acrylic which has a thickness of 5 mm, with a length of 1.4 m and a diameter of 2.5 inches. In the absorption column, there is *a solvent riching* that has a size of 10 x 10 mm.
d. The reactor is equipped with a centrifugal type of pump that can inject at a speed of 12 liters/minute and there is an air compressor that has a tube capacity of 25 liters/minute.
e. The reactor used has a total height of 2.17 m, with a length of 1.84 m and a width of 0.9 m.

The following reactor equipment used in reducing carbon dioxide gas is shown on Fig. 1.

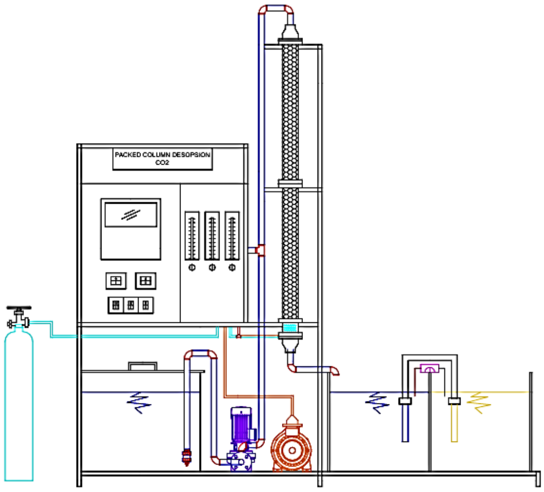

Fig. 1. Gas absorption column reactor

Work procedure in the study

The carbon dioxide gas absorption process uses NaOH and KOH absorbent types to compare the effectiveness of each absorbent used. The first step is to revive the reactor, starting with an air compressor and a water pump. Furthermore, the flow meter will be adjusted from each flow rate used which is determined according to the variables above. Then the analysis was carried out using the sampling method. The absorption process is left for 5 minutes so that the reactor runs stably. Carry out a sampling process on the outlet tube as much as 200 ml every 0 minutes, 5 minutes, 10 minutes, 15 minutes and 20 minutes. During the sampling process, the reactor is checked to see whether the flow rate of the injected is stable or not. From each sample taken, each parameter will be directly tested from pH, temperature, DHL, CO_2 gas concentration that has been removed and the rest of the solution that does not form a new solution. The test must run quickly so that the results obtained will be more accurate. Testing of dissolved CO_2 content using an alkalimetry method that uses a wet acid reaction. In this method, there are 2 stages, including the initial stage to determine the initial concentration and concentration of dissolved CO_2 gas, and the second stage is carried out to determine the remaining absorbent solution. The test in the first stage is carried out by the initial titration of an absorbent sample of 50 ml which is put into an Erlenmeyer glass which will be filled with a phenolphthalein (PP) indicator of 1-2 drops, the indicator will work in a wet reaction. From this process, it is continued by titration with HCl solution on the burette so that it will change color from pink to clear. Record the results obtained during titration as a starting point. Next, titration on the sample outlet tub is sampled every 5 minutes. The sample used is 50 ml and add 1-2 drops of the metal orange (MO) indicator, the indicator will work in an acid reaction so that the color changes to orange, then titration uses HCl on the burette until it changes color to reddish orange. Record the titration results as the concentration of trapped CO_2. In the second stage of the alkalimetry method, 50 ml samples were taken on the outlet reservoir, then the solution was added from the CO_2 concentration titration value with the initial titration of absorbent and times with 10% of the results obtained. From the results of the calculation is the value of the number of $BaCl_2$ solutions that are included. Then add the methyl orange (MO) indicator until it changes color and dilute with HCl on the burette until it turns reddish orange. Record the titration results as the result of the remaining concentration of the solution that does not form a new solution.

Parameter measurement

In the absorption process, an analysis test was carried out on the parameters of pH, temperature, and DHL which were used to determine the effect of the absorbent solution that occurred in *the settling colomn* on the concentration of dissolved CO_2. Before the analysis of the equipment used to measure parameters in the form of pH meters, thermometers, and conductivity meters, calibration was first carried out so that the tools used gave accurate and precise results, in addition, the balance or deviation from the determination value will be indicated by the tool. In addition, FTIR (Fourier Transform Infra Red) analysis was carried out which was used to identify the compounds contained in the sample by analyzing the functional groups of the compounds contained in it.

Electrochemical-based electrical stress measurement

The measurement of electrical stress was carried out on a sample resulting from the absorption process in the form of a bicarbonate solution obtained from CO_2 gas that binds to the absorbent solution. The samples taken will be analyzed with galvanized cell or volta cell groups. The voltaic cell/galvanized cell uses an oxidation reaction by using an anode as a negative electrode by using a copper plate and a cathode as a positive electrode by using a zinc plate, there is a jagarm bridge that contains positive and negative ions to neutralize the solution. So that there is a difference in tendency that will cause electrical voltage currents.

RESULT AND DISCUSSION

Effect of pH on Flow Rate Variation of Absorbent Solution and CO_2 Gas

In the absorption of CO_2 gas, there are factors that influence the absorption process, one of which is the pH concentration in the absorbent solution. The effect of pH will decrease from strong base to weak acid due to gas diffusion with the solution. The results can be shown in the table below.

Table 1. pH concentration of each absorbent to the flow rate of the solution and CO_2 gas

Type of Absorbent	Flow Rate of Absorbent (liter/min)	Flow Rate of CO_2 Gas (liter/min)	Initial pH	Final pH
Absorbent NaOH	2	10	10	7.2
		20	10	6.8
		30	10	6.4
	4	10	10	7.4
		20	10	6.8
		30	10	6.4
	6	10	10	7.8
		20	10	6.9
		30	10	6.5
Absorbent KOH	2	10	9.5	6.9
		20	9.5	6.4
		30	9.5	6.2
	4	10	9.5	6.9
		20	9.5	6.4
		30	9.5	6.3

Type of Absorbent	Flow Rate of Absorbent (liter/min)	Flow Rate of CO_2 Gas (liter/min)	Initial pH	Final pH
	6	10	9.5	7
		20	9.5	6.5
		30	9.5	6.3

The table above shows the results of the analysis of the influence of pH on the type of absorbent used. The table will be interpreted in the form of a graph to determine the elevation of each solution flow rate and CO_2 gas flow rate.

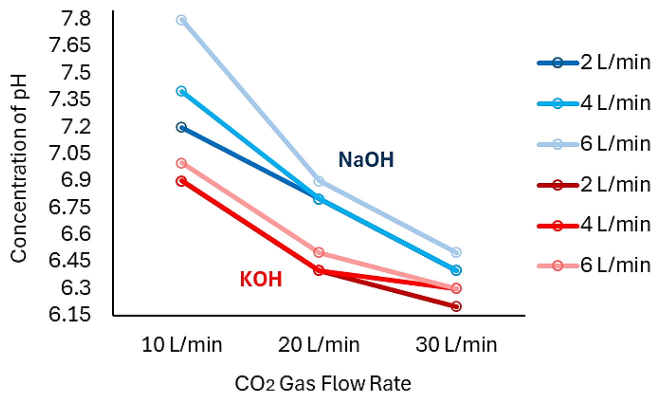

Fig. 1. Relationship between the effect of pH on the flow rate of solution and CO_2 gas from each absorbent

From **Fig. 1.** it proves that the effect on pH provides a significant change from the condition of the solution which has strong wet properties to weak acid due to the chemical reaction between CO_2 gas which has acidic properties that meet with absorbent solutions that are strong wet (F. Huda et al., 2022). From the research results obtained, the concentration of the solution flow rate has an influence on the capture of CO_2 gas. This is because the smaller the flow rate is injected, the longer the residence time of the solution in the column, so that gas capture increases. While the flow rate of the injected gas solution also affects the diffusion of CO_2 in the absorbent. The more CO_2 gas is input, the higher the concentration of CO_2 captured (Dewi et al., 2024). From the results of research on each absorbent that has been accumulated, the effective flow rate is obtained at 2 liters/minute at the solution flow rate, while the effective CO_2 gas flow rate is able to removal at a speed of 30 liters/minute. For the type of absorbent used, it will affect the effectiveness of CO_2 that is desorbed. The effect of absorbent type concentration is caused by chemical compounds that are ionized in solutions, so that they can conduct the solution well in capturing CO_2 gas. The research shows that the effective absorbent is obtained in NaOH which uses a concentration of 0.01 M. Previous research shows that the higher the concentration of absorbent used, the more CO_2 is desorbed (Yuliani et al., 2023).

Effect of Temperature on Flow Rate Variation of Absorbent Solution and CO_2 Gas

In the absorption of CO_2 gas, there are factors that affect during the absorption process, one of which is the concentration of temperature in the absorbent solution. The influence of temperature will increase due to the diffusion of gas with solution. The results can be shown on the table below.

Table 2. Temperature concentration of each absorbent against the flow rate of the solution and CO_2 gas

Type of Absorbent	Flow Rate of Absorbent (liter/min)	Flow Rate of CO_2 Gas (liter/min)	Initial Temperature	Final Temperature
Absorbent NaOH	2	10	28,8	28,9
		20	28,5	28,8
		30	28,6	28,9
	4	10	28,3	28,5
		20	28.9	29.1
		30	27.4	27.7
	6	10	28.1	28.8
		20	28.9	29.2
		30	28.1	28.5
Absorbent KOH	2	10	27.5	27.9
		20	28.5	28.5
		30	28.0	28.2
	4	10	28.5	28.7
		20	27.6	27.8
		30	28.4	28.5
	6	10	29.1	29.0
		20	29.5	29.5
		30	29.5	29.6

The table above shows the results of the analysis of the influence of temperature on the type of absorbent used. The table will be interpreted in the form of a graph to determine the elevation of each solution flow rate and CO_2 gas flow rate.

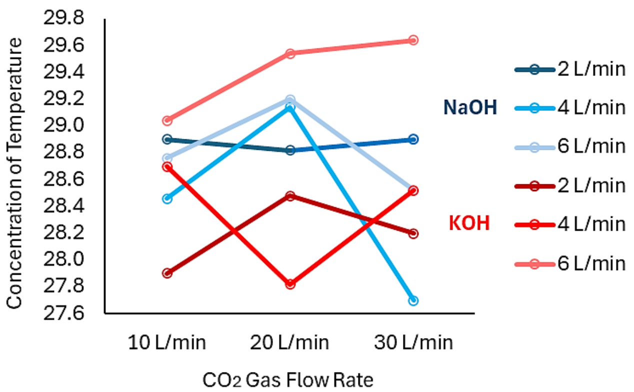

Fig. 2. Relationship between the effect of temperature on the flow rate of solution and CO_2 gas from each absorbent

Fig. 2. shows that the temperature parameter has an influence on the concentration of CO_2 captured. The graph shows an increase from the initial temperature to the final temperature, so the greater the CO_2 gas injected, the higher the temperature produced, while the smaller the CO_2 gas injected, the lower the temperature obtained. This is due to the amount of CO_2 gas added from the reaction that occurs in rich solvent. Based on scientific articles, the effect of temperature will correlate

to the empirical equation that has been developed, explaining that an increase in temperature can increase the value of cosntanta during the process of gas diffusion with solution (Parningotan & Dewi, 2021). The increase in the cosntantant value in the gas diffusion process will cause mass transfer between gas and liquid. From the research obtained, there are other factors that affect the temperature in the solution in the form of the influence of room temperature which can provide changes in temperature in the solution so that the temperature obtained during the research process will experience the instability obtained (Ihsanpuro et al., 2023).

Effect of EC on flow rate variation of absorbent solution and CO_2 gas

In the absorption of CO_2 gas, there are factors that affect during the absorption process, one of which is the concentration of EC in the absorbent solution. EC's influence will increase due to the diffusion of gas with solution. The results can be shown in the table below.

Table 3. DHL concentration of each absorbent to the flow rate of the solution and CO_2 gas

Type of Absorbent	Flow Rate of Absorbent (liter/min)	Flow Rate of CO_2 Gas (liter/min)	Initial DHL	Final DHL
Absorbent NaOH	2	10	0.206	0.225
		20	0.219	0.241
		30	0.213	0.239
	4	10	0.216	0.231
		20	0.208	0.228
		30	0.223	0.247
	6	10	0.222	0.234
		20	0.227	0.245
		30	0.228	0.248
Absorbent KOH	2	10	0.200	0.214
		20	0.211	0.227
		30	0.213	0.230
	4	10	0.214	0.225
		20	0.214	0.227
		30	0.213	0.228
	6	10	0.202	0.213
		20	0.202	0.214
		30	0.202	0.216

The table above shows the results of the analysis of DHL influence on the type of absorbent used. The table will be interpreted in the form of a graph to determine the elevation of each solution flow rate and CO_2 gas flow rate.

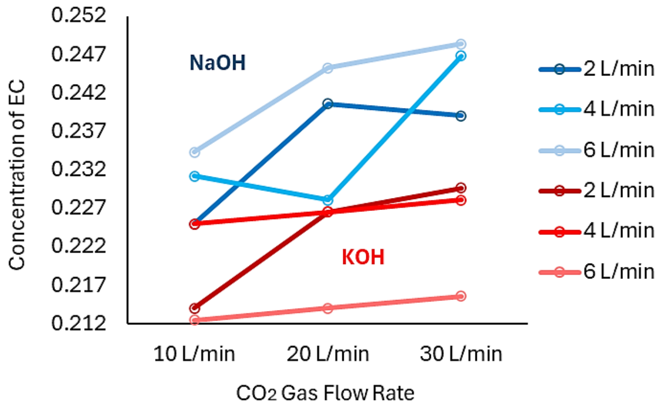

Fig. 3. Relationship between the effect of EC on the flow rate of solution and CO_2 gas from each absorbent

Based on the research results obtained, it shows that the effect on electrical conductivity or EC gives a significant increase in desorbed CO_2 gas. During the CO_2 gas absorption process, there will be an increase from the absorpben solution in the initial reservoir to the final reservoir. If the higher the EC obtained, the more dissolved gas, while if the lower the EC obtained, the less gas will be captured. This occurs due to the presence of absorbent material in the liquid phase that will react with CO_2 gas and will produce high electrical conductivity. The effect of electrical conductivity or called EC depends on the total concentration produced in solutes that have been ionized into solution form (Ramadhanti, 2023). The mobility of the ions that have been dissolved will correlate with the value of valence so that it can increase the value of the electrical conductivity obtained. Solutions containing ions that can conduct electricity with high concentrations due to the movement of electrodes from the negative pole to the positive pole (Arisukma et al., 2021). From the research obtained, the highest concentration of electrical conductivity was obtained by a solution flow rate of 2 liters/minute with a CO_2 gas flow rate of 30 liters/minute. The determination of the optimum flow rate is seen from the difference obtained from the initial concentration minus the final, so that it has a difference of 0.027 µmhos/cm in NaOH solution, while in KOH it has a difference of 0.017 µmhos/cm.

Effect of dissolved CO_2 concentration on flow rate variation of absorbent solution and CO_2 gas

Based on the results of the analysis that has been carried out in the laboratory, it shows that the type of absorbent affects the concentration of dissolved CO_2 gas. Before the analysis is carried out, the initial concentration of each absorbent is determined as a starting point in determining the concentration of CO_2 gas captured. The following reaction equations used include:

$$2\ NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

$$2\ KOH + CO_2 \rightarrow K_2CO_3 + H_2O$$

From the results of the initial concentration value, the dissolved CO_2 gas analysis is then carried out on the type of absorbent used. The following is the reaction equation that occurs during titration including:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$KOH + HCl \rightarrow KCl + H_2O$$

In the second stage of titration, the analysis of the remaining absorbent that does not form a new solution during the absorption process is carried out by adding $BaCl_2$ solution so that the reaction will form as follows.

$$Na_2CO_3 + BaCl_2 \rightarrow BaCO_3 + 2\ NaCl$$

$$K_2CO_3 + BaCl_2 \rightarrow 2\ KCl + BaCO_3$$

During the research process carried out, the results of the analysis were obtained during the titration process. In addition, an analysis test of influence parameters on pH, temperature, and EC was carried out as supporting data in the research conducted (Nugroho et al., 2023; Adhi et al., 2022). The following are the results of the analysis that has been carried out on the flow rate of solution and gas to the concentration of dissolved CO_2.

Table 4. Concentration of dissolved CO_2 gas from each absorbent

Type of Absorbent	Flow Rate of Absorbent (liter/min)	Flow Rate of CO_2 Gas (liter/min)	% CO_2 Absorbent
Absorbent NaOH	2 L/min	10 L/min	44%
		20 L/min	48%
		30 L/min	52%
	4 L/min	10 L/min	40%
		20 L/min	44%
		30 L/min	50%
	6 L/min	10 L/min	40%
		20 L/min	44%
		30 L/min	48%
Absorbent KOH	2 L/min	10 L/min	40%
		20 L/min	44%
		30 L/min	48%
	4 L/min	10 L/min	36%
		20 L/min	40%
		30 L/min	44%
	6 L/min	10 L/min	36%
		20 L/min	40%
		30 L/min	43%

The table above shows the results of the analysis on the effect on the concentration of dissolved CO_2. in the table will be interpreted in a graph to show the elevation value resulting from the CO_2 concentration removed.

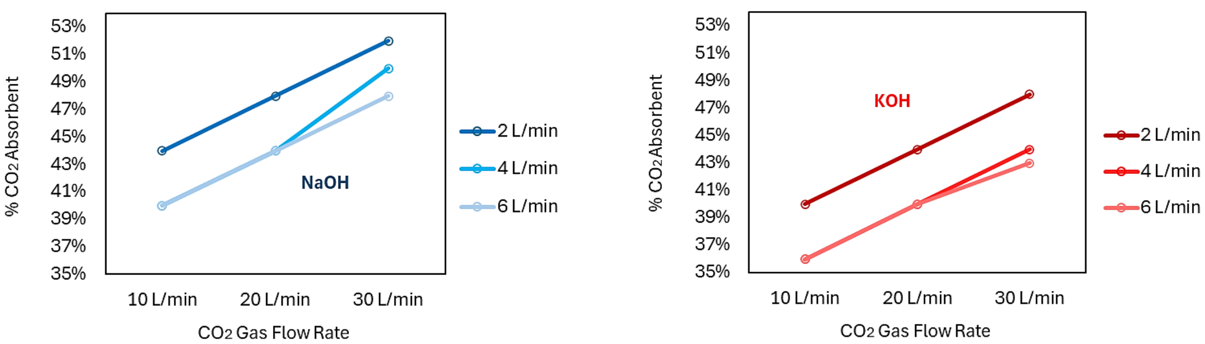

Fig. 4. Relationship between dissolved CO_2 gas from each absorbent

Based on the graph above, it shows that the effect of the solution flow rate and CO_2 gas will have an impact on the concentration of dissolved CO_2, so that flooding will occur. The flooding process occurs due to the collection of liquid in the absorption column that passes from the inlet column to the outlet column. The flooding process if it gets higher will cause liquid hold-up so that the liquid bound in the room will increase (Fadlih & Megawati, 2020). In addition, in the absorption process there will be a mass transfer of substances from gaseous to liquid. This process uses counter current flow. Counter current flow is the opposite flow direction so that there is a large fraction of contact or fluid friction. Counter current flow events occur when an increasingly large absorbent load that has reached saturation point will experience an increase in CO_2 absorption, so that the resulting solution will have a high CO_2 concentration (Saputra et al., 2023). There are supporting factors during the absorption process in columns that are influenced by the contact area in the column and the packing used. The effect of the contact area in the column will be able to increase the diffusion of gas into a solution. If the flow rate of the solution in a small fluid will cause the contact time with the gas against the solvent will be longer. Thus, if the contact time will experience a difference in concentration that can cause a driving force in the diffusion process that occurs in the fluid (Daiyan et al., 2020). The diffusion process of carbon dioxide gas which has a high fraction with an absorbent solution that has low levels of carbon dioxide, so that gas contact with the solution will cause a flow rate in the solution. In the absorption process, the flow used is turbulent or exceeds the Reynold number so that the greater the substance that will collide with the gas can increase the absorption of gas in the solute. While packing gives influence in the contact area. Packing is used in a random position so that it will have a low pressure on the gas used for the chemicals used (Maulizar et al., 2023; Gantina, 2021).

Based on the type of absorbent used in the form of NaOH and KOH, it shows the difference in desorbed concentration. This is evidenced from the results of the study above showing NaOH compounds can remove 52% compared to KOH by 48%, because chemical compounds that have been fully ionized into hydroside ions (OH^-) in liquid form. The process where the release of hydroxide ions in solution. The proton compound that has been received depends on the concentration of the solution used, by reviewing the covalent value of the bond. Meanwhile, based on each absorbent used, it shows that the highest or effective concentration in NaOH>KOH solution. This proves that the concentration of NaOH can trap CO_2 gas better than KOH because chemical compounds are fully dissociated or ionize into hydroside ions (OH^-) in solution. This means that all molecules have a very good ability to release hydroxide ions to increase the concentration of OH^- in solutions. The strength in solution is determined by whether it is easy for a compound to accept protons, release OH^- ions or contribute free electron pairs (Anggraini & Sutjahja, 2023). In terms of freedom, compounds based on ionization ability are influenced by covalent or ionic characters in their bonds (Haryanti et al., 2024). The covalent or ionic character of the bond is discussed in the Fajas rule. Fajas suggests that the smaller the size and the greater the strength of a cation, the greater the ability of the cation to cause anoin to polarize. The easier the anion is polarized, the more covalent character of a bond increases. If the bond is more covalent, the compound is more difficult to ionize (Chotimah et al., 2022). In addition, the selection of NaOH and KOH absorbent types because they have compounds in the form of high amines compared to other materials. Amine type materials, namely high reactivity with CO_2 molecules, high thermal stability, and high absorption capacity so that they can absorb more CO_2 gas, and the materials used are easy to find and more affordable (Anggraini & Sutjahja, 2023).

Effect of dissolved CO_2 concentration on electrochemical-based electric current voltage

In the absorption of CO_2 gas, there are factors that affect the absorption process, one of which is the concentration of CO_2 gas in the absorbent solution. The effect of CO_2 gas concentration will increase if the higher the concentration received, the higher the electrical voltage produced due to the diffusion of the gas with the solution. The results can be shown on the table below.

Table 5. Electrical Voltage of each absorbent to the flow rate of solution and CO_2 gas

Type of Absorbent	Effective Flow Rate of Absorbent L/min	Effective Flow Rate of CO_2 Gas L/min	Electrical Voltage Volt
Absorbent Na_2CO_3	2	30	0,817
Absorbent K_2CO_3	2	30	0,798

The table above shows the results of the analysis of the influence of CO_2 gas that can produce electrochemical-based electrical voltage on the type of absorbent used. The table will be interpreted in the form of a graph to determine the elevation of each solution flow rate and CO_2 gas flow rate.

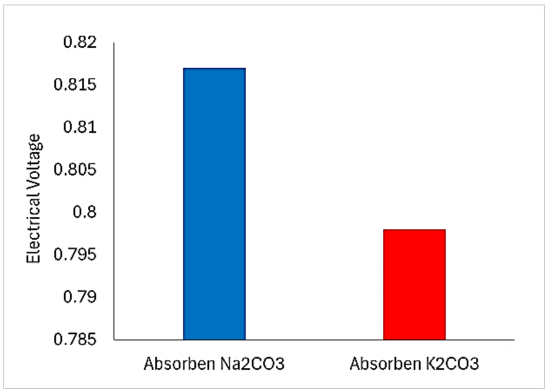

Fig. 5. The relationship between electrical voltage to the flow rate of solution and CO_2 gas from each absorbent

Based on the results of the graph above, it proves that the solution resulting from the absorption process can produce an electric voltage of 0.817 volts in NaOH absorbent while for an electric voltage of 0.798 volts from KOH absorbent. The voltage produced comes from the CO_2 that is absorbed in the solution. The higher the dissolved CO_2, the higher the electric voltage produced, and if the lower the desorbed CO_2, the lower the electric voltage produced (Erans et al., 2022). The results of the research that has been carried out show that in the process of emitting acidic CO_2 gas can be applied to electrical energy using electrochemical methods. The method utilizes two types of electrodes in the form of tembanga plates as anodes (-) by using an electrolyte solution in the form of $CuSO_4$ solution and for zinc plates as a cathode (+) by using a solution resulting from the absorption process in the form of K_2CO_3 solution. The conversion process begins with the capture of CO_2 gas from the Coloumn Gas Absorption *reactor*, then the CO_2 gas acid content that spreads will occur a chemical process between the compounds that produce carbonate compounds. The higher the acidity level of a solution, the greater the number of protons produced. This will have an impact of mutual attraction between the electrons in the cathode and the protons in the latode, so that electrical energy is formed during the process. $CuSO_4$ solution which is an electrolyte solution that will undergo oxidation (release electrons). The difference in the tendency to oxidize which produces artificial fruiting which will result in a potential difference (electron driver) called the cell potential measured using a voltmeter (Ramadhanti, 2023).

Based on the research results, technology is very promising as a solution in optimizing the use of available resources. Through the results of the production process in the oil and gas industry sector which has the potential to produce high CO_2 emissions. The results of emissions will be captured with this technology which is converted into electrochemical-based electrical energy. The form of implementation in accordance with CCS technology has been carried out by the Indonesian government through the Minister of Energy and Mineral Resources Regulation Number 2 of the Year concerning Determination of Carbon Emissions and Storage, as well as Determination, Storage, and Utilization of Carbon in the Production Process of Hydrocarbons and Gas. Currently, there are 15 CCS projects in Indonesia spread across Sumatra, Java, Kalimantan and Papua. This technology will have an impact on the environment and economy because it reduces climate change due to the greenhouse effect and can increase economic value for industries obtained from electrical energy. However, there are challenges faced in the form of high investment costs in building infrastructure and the lack of public awareness of Carbon Capture and Storage (CCS) in Indonesia is still relatively low. To overcome the limitations of the research, there needs to be support from the government, both financially and non-financially, as well as technological advances that can reduce the cost of CCS. In addition, to increase public awareness, wider socialization of the CCS concept is needed so that there is increased interest in CCS research in Indonesia, which is reflected in the new regulatory measures that have been issued to regulate short-term Research and Development (R&D) plans related to CCS. These regulations not only emphasize the technical aspects but also underline the importance of developing non-technical regulations as part of CCS development in Indonesia. (Putri et al., 2024).

The results of the analysis using an infrared spectrophotometer

Sample testing from the results of the CO_2 gas absorption process will be analyzed by infrared spectrophotometer to determine the functional group of the molecular structure in the sample. The identification of the functional group will be interpreted in a graph that will be shown in the absorption ranges in the figure below.

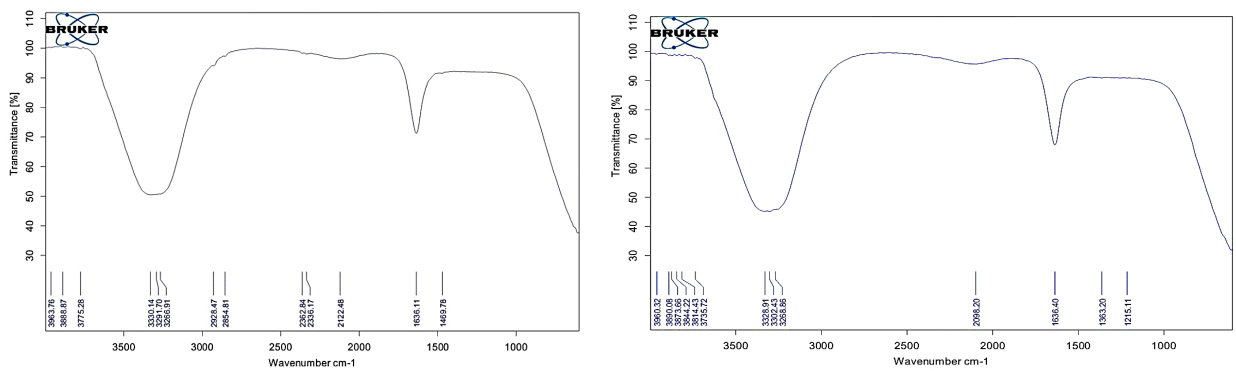

Fig. 6. Spectrogram results in (a) Na_2CO_3 solution, and (b) K_2CO_3 solution

The graph above shows the results of the analysis of the value of the functional group on the type of absorbent used. The graph will be interpreted in the form of a table to determine the absorption of each absorbent.

Table 6. Absorption results on the FTIR spectrogram in each absorbent

Uptake of Na_2CO_3	Function group absorption (cm^{-1})	Bonding	Intensity
3330,14	3200 – 3600	O-H	Strong
1636,11	1690 – 1760	C=O	Strong

Uptake of K_2CO_3	Function group absorption (cm^{-1})	Bonding	Intensity
3328,91	3200 – 3600	O-H	Strong
1636,40	1690 – 1760	C=O	Strong

From the results of qualitative analysis obtained on the graph shows the absorption of functional groups (cm^{-1}) between 3200 to 3600 with a sloping elevation form showing the bond of the functional group in the form of O-H which is the name for alcohols that bind to hydrogen, from the functional groups obtained including the compound of 1-pentanol. Whereas in the absorption of functional groups (cm^{-1}) between 1690 to 1760 with a sharp and narrow elevation shape shows the bond of the functional group in the form of C=O containing ketone groups (alkanones) which are isomeric functions with aldehydes (alkanals) so that the functional group isomers obtained are included in the compound of 2-pentanone (Haryanti et al., 2024).

CONCLUSIONS

Based on the results of the study, it is concluded that CO_2 gas reduction with different types of absorbents has a significant effect on CO_2 concentration. The results showed that the optimum type of absorbent was obtained in NaOH which had an effective solution flow rate of 2 liters/minute with a CO_2 gas flow rate of 30 liters/minute which was able to reduce by 52%. This is evidenced by changes in the effect on pH concentration, temperature and EC. From the absorption results, it is then utilized as electrochemical-based electrical energy so that the optimum electrical voltage of 0.817 Volts is obtained. Based on the research results obtained, it shows that the research has great potential in reducing CO_2 gas produced in the fossil energy sector. In addition, the Indonesian government has taken significant steps to reduce greenhouse gas emissions. With a commitment to achieve zero emission clean energy by 2060, Indonesia introduced strategies such as Clean Coal Technology (CCT) with the use of Carbon Capture Storage (CCS). This is in line with the global paradigm that supports energy conservation energy conservation and zero carbon emissions to combat global warming.

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