Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

Black Sea Science International Competition of Student Scientific Works by Odesa National University of Technology

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Proceedings

Odesa, ONUT 2022

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

The author of the work is responsible for the accuracy of the information.

Odesa National University of Technology, 2022.

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INTRODUCTION

International Competition of Student Scientific Works "Black Sea Science" has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

5. ECOLOGY AND ENVIRONMENTAL PROTECTION

AIR-LIQUID MICROTUBE CARBON DIOXIDE CAPTURE SYSTEM

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Abstract. *Our approach lies in using an already effective and performant mechanism of the human respiratory system repurposed to filter and transform carbon dioxide instead of oxygen.*

This concept effectively divides posed problem into three separate tasks: capturing of CO2 (taking analogy from alveoli to increase contact area), transportation of CO2 through-out the system (optimized substance analogous to blood to provide minimum losses of gas), and utilization system (inspired by cells functionality we combine CO2 with industrial waste to produce carbonates).

What is unique in our approach is the choice of materials and substances that enable us to create efficient and performant system.

Keywords: *sequestration, carbon dioxide, sorbent, superamphiphobic, capture.*

I. INTRODUCTION

Our approach lies in using an already effective and performant mechanism of the human respiratory system repurposed to filter and transform carbon dioxide instead of oxygen. This concept effectively divides posed problem into three separate tasks performed by biological constructs: capturing of CO2 performed by alveoli, transportation of CO2 through-out the system – blood, and utilization subsystem that transforms CO2 into useful product - cells.

We deconstructed underlying mechanism of each of these parts to optimize it as much as possible: refining geometry of the filtering component to maximize contact area for capturing CO2 and efficiency of diffusion, using regenerative sorbent as a transport to improve lifetime of the system and increase amount of gas processed, applying electro-chemical method to combine CO2 from previous phases and industrial waste of thermal power stations to produce carbonates making system even more ecological – all these methods and ideas combined to deliver effective and relatively cheap system for removal of carbon dioxide.

The scientific or engineering phenomena that your concept relies on:

1) gas diffusion under the action of a concentration gradient. In our case, CO2 will diffuse from the air into the sorbent where its concentration in the ideal case is 0;

2)increasing diffusion surface area due to the use of superamphiphobic porous monoliths material and special geometry ;

3)Using of special chemical properties of the KOH that make it a good sorbent for CO2 ;

4)electrochemical method of sorbent regeneration based on K2CO3 electrolysis with the formation of H2;

5)The mineral carbonation technologies which based on the spontaneous reaction between CO2 and metal oxide bearing minerals to form insoluble carbonates.Mineral carbonates such as CaCO3 or MgCO3 are the thermodynamically most stable form of carbon, long-term storage of CO2 can be achieved once it is transformed to carbonates;

6) possibility of transformation products, such as CaCO3, to value-added materials that can be utilized in various applications such as adhesives, sealants, food and pharmaceuticals, paints, coatings, paper, cements, and construction materials.

The simple illustration of working of the system that we proposed is shown on the Fig. 1.

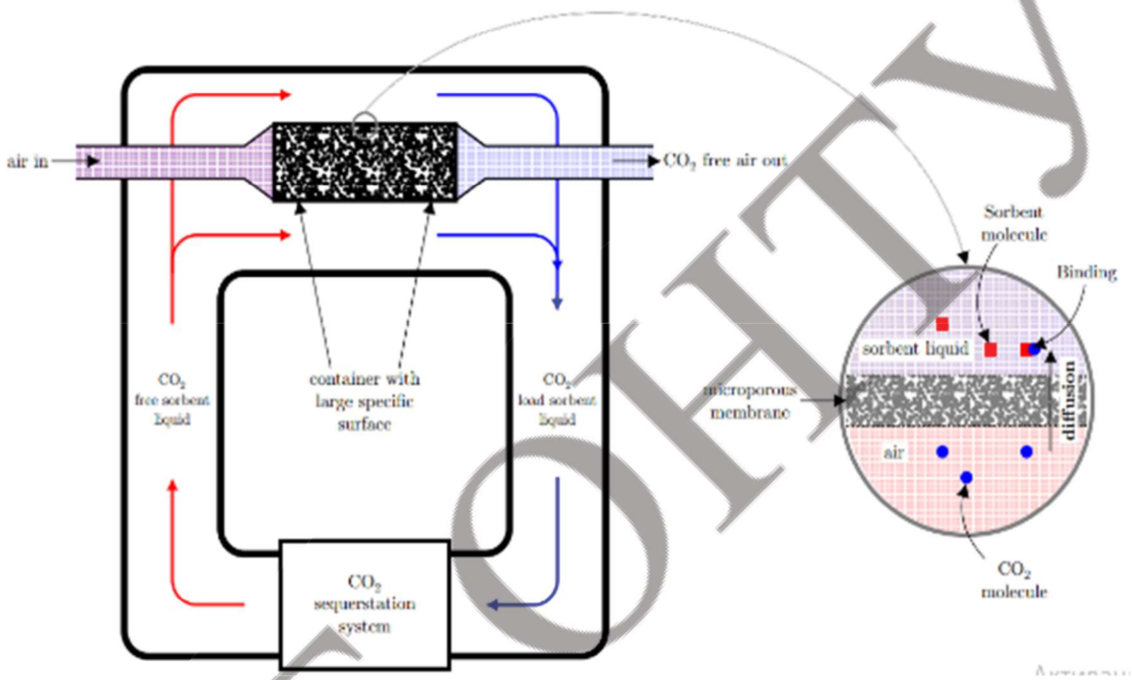

Fig. 1. Basic sheme

II. LITERATURE ANALYSIS

Our work is based on a big massive of information from science literature. The information was taken from articles from the lead science journals like “Nature”, “ScienceDirect”, “Springer” etc.

Because in our work there were used principles from different areas of physics we broke our literature analysis on subsections which contain information about such area.

2.1. Human respiratory system

Book [1] describes the structure of human respiratory system using a mathematical apparatus, and gives many interesting examples of the application of different sciences to the study of the respiratory system

2.2. Modern methods of carbon dioxide capture

[2] this book describes well the modern industrial methods of CO2 capture.

Article [3] describes the main technologies for CO2 direct air capture. Articles [4], [5] provide a qualitative description of various electrochemical methods for the regeneration of liquid sorbents.

In the article [6] is shown a method for the synthesis of superamphiphobic porous monoliths and also shows an experimental analysis of their properties. Article [7] demonstrates the practical implementation of a CO2 capture system using electrochemical sorbent regeneration. The experimental data are also compared with the simulation results.

In article [8] is demonstrated the practical implementation of a CO2 capture system using a KOH as a sorbent and also demonstrates its electrochemical regeneration using electrolysis with hydrogen evolution.

Article [9] reviews and justifies the use of the ex situ mineral carbonation route as a way to efficiently utilize CO2.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The proposed device is a combination of common design and novel materials. In the multiple studies [10–13] for adsorption of gas to the liquid, used, so called, hollow fiber membrane pipes made from polymeric materials with high specific surface. Recent publication [14] claims about manufacturing a highly permeable porous (70%) superamphiphobic material based on Low-temperature expandable graphite and polyvinylidenefluoride with good operation stability (fig.1), which is planning to use in our device.

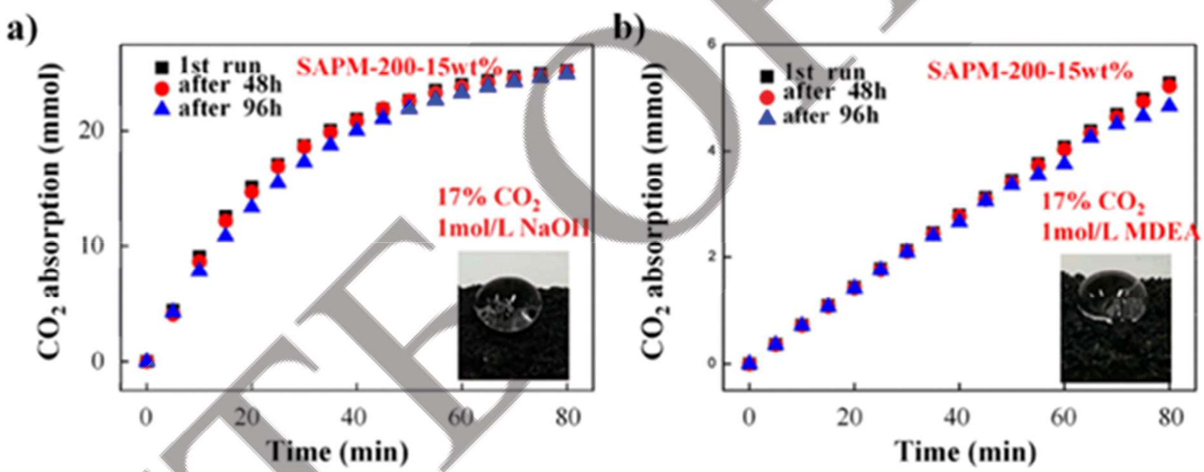

Figure 1: Operation stability of considered membrane

The device is represented as cylinder tube with diameter around 0.5-1 m and length up to 1m filled with hollow fiber tubes with diameter 10-20mm. Inner cut of device's model with some number of pipes in the center depicted on the Figure 2.

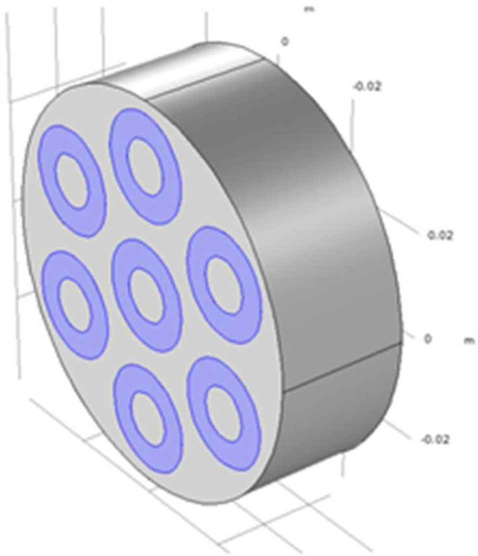

Figure 2: Inner cut of device

Gas flows in the pipes and liquid with diluted adsorption solution washed the outer shell around the pipe. Researchers conduct various studies to obtain removing rate of CO2 from concentrated mixtures of gases depending on velocity of gas and liquid flows and further adsorption with NaOH [10; 11]. From this results seems that convection transfer can significantly affect the diffusion of CO2 through membrane.

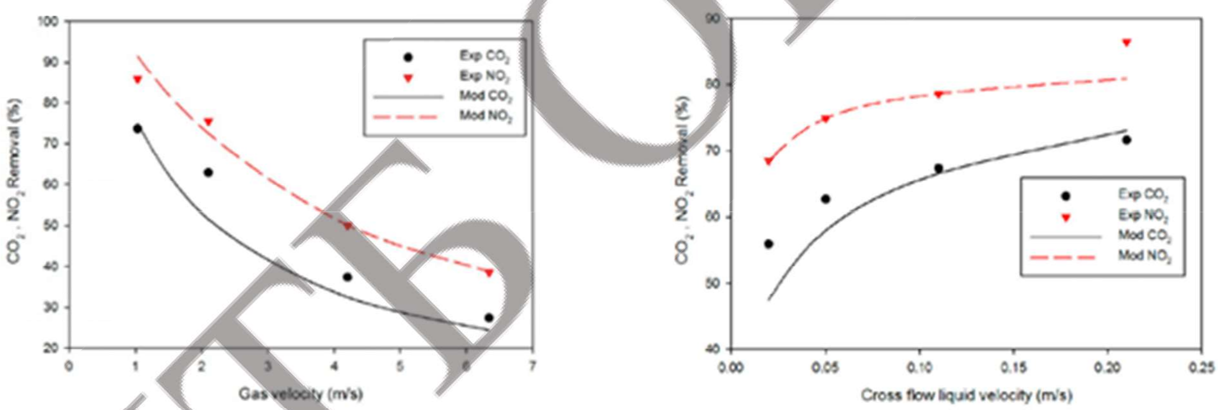

Figure 3: Percent removal of CO2 and NO2 as dependency of gas and liquid velocity [13]

We instead, tried to conduct a small research on the dependency of diffusion flow through the pipes and volume of adsorbed gas based on configuration inside the device and distance between fibers assuming constant shapes of device. Total amount of gas adsorbed through membrane will be proportional to the total outer surface area of fibers so to the numbers of fibers in the device. Changing the distance between fibers inside we can achieve better concentration gradient (so diffusion flux) but in the same time decreasing number of fibers which can be located inside device. The idea was to check whether there is an optimal distance between membranes which corresponds to maximum amount of diffused gas. For this reason in COMSOL Multiphysics was simulated (fig.4) pure diffusion (without convective flow) of CO2 concentration of 300-400ppm (average concentration in air) for model depicted on figure 2 and distance between membranes in range from 5 to 15mm.

IV. RESULTS

This section can be split into several subsections (if necessary). Tables and figures must be referenced in the text and formatted as follows:

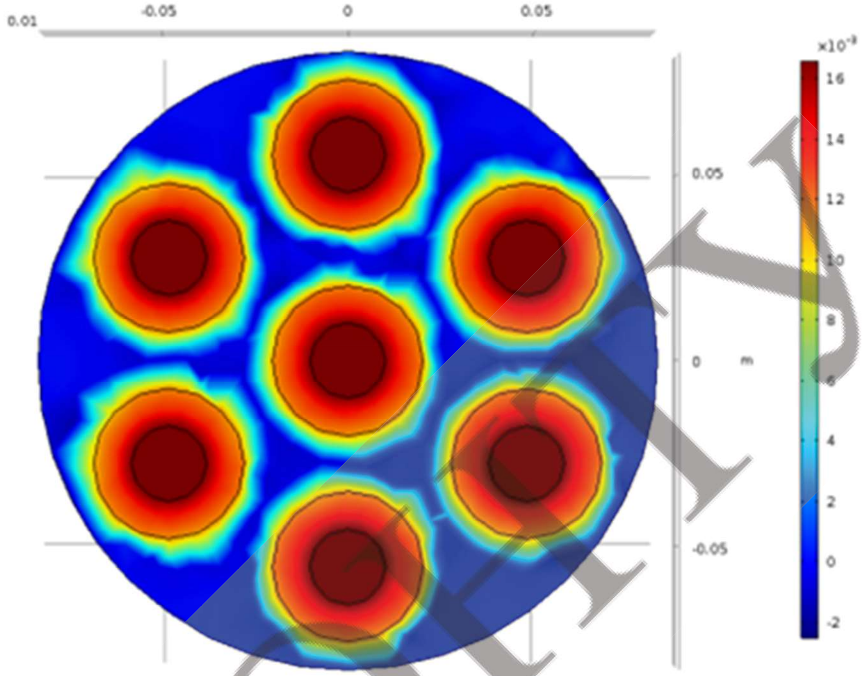

Figure 4: Simulated concentration distribution of CO_2 diffused from air to water.

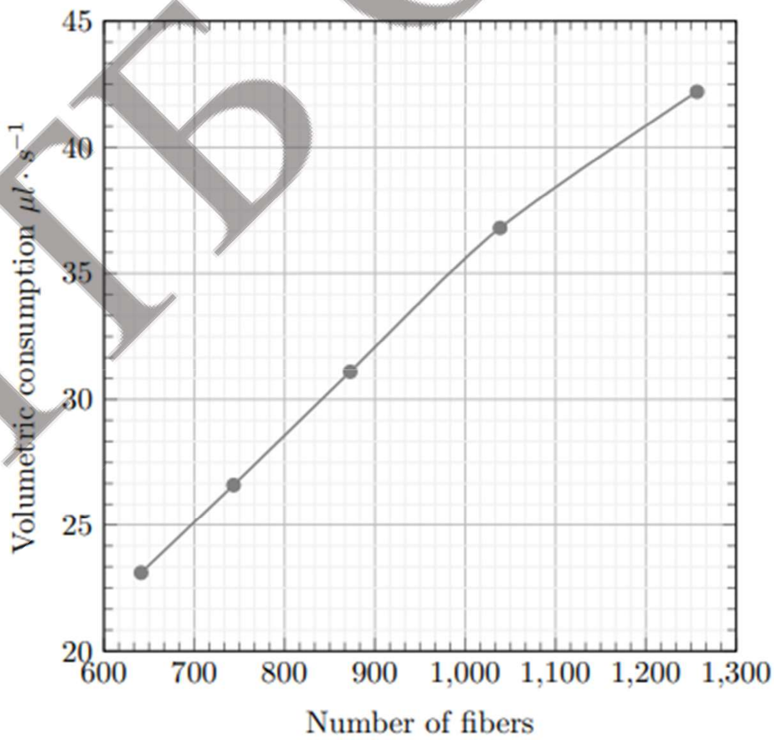

Figure 5: Dependency of volume of CO_2 , that can be adsorbed for 1 second, from number of fibers required for device

Also initial results of feed pressure, pressure which is required to push gas through pipe and allow diffusion through membrane, was obtained. To pump gas with a velocity of 1 m/s through pipe with diameter of 10mm for 2 cm require 0.5 atm of pressure. From the estimation for all device will be necessary to get pressure of 20 atm. But exact requirements can be obtained only after further simulation of coupled fluid flow/diffusion/reacting task.

The effect of increasing diffusion flux due to increasing space between membranes appeared not to make significant difference to the total volume of diffused gas, so it is almost linearly proportional to the numbers of fibers. The graph on the figure 5 can be helpful when building device with the known capacity of gas that can diffused per time unit. Using this data it's clear that for current design and maximum number of fibers (≈ 1250) device will collect almost 3 liters of pure CO2 per day.

V. CONCLUSIONS

This article proposes a method of pumping carbon dioxide using a system of microtubes. Theoretical estimates of the scheme are carried out. And also the part of microtubes is modeled. With the help of this, was calculated the number of fibers required for the construction of the device and efficient pumping of CO2.

The detailed scheme of the proposed microtube system is shown on Fig.6

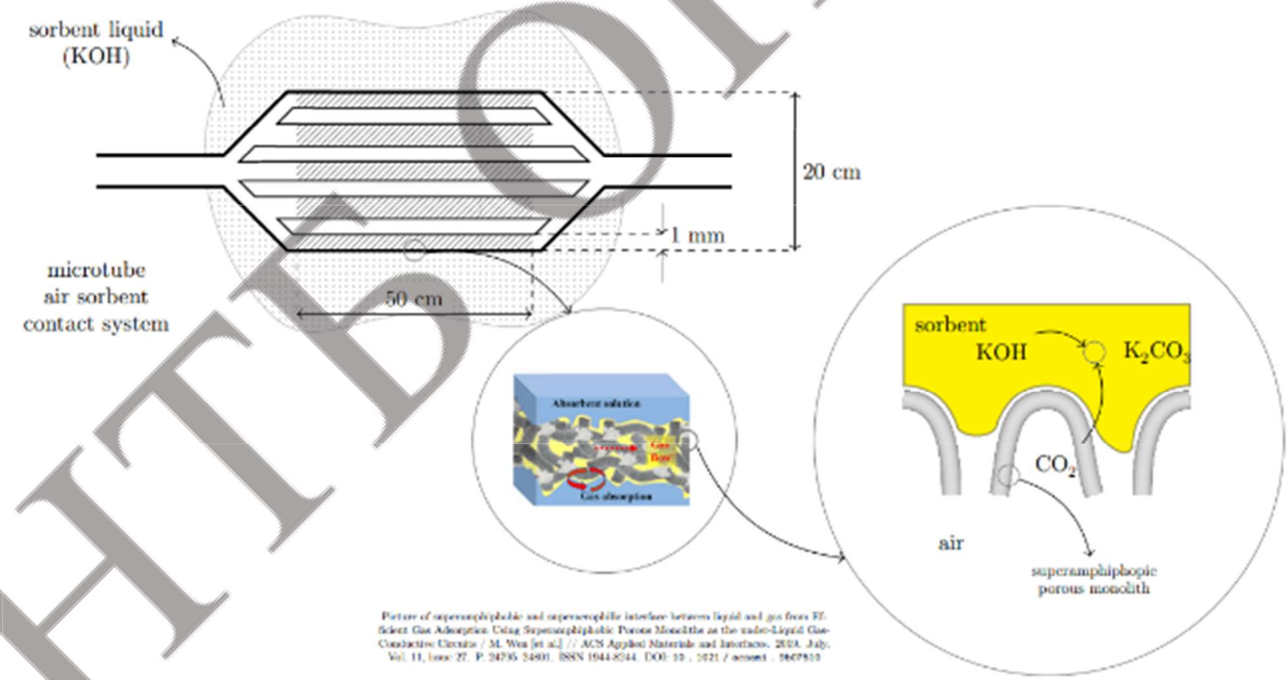

Fig.6 Detailed scheme of microtube system

The process-flow diagram of the whole carbon dioxide capture system with approximate values of energy density is shown on Fig. 7.

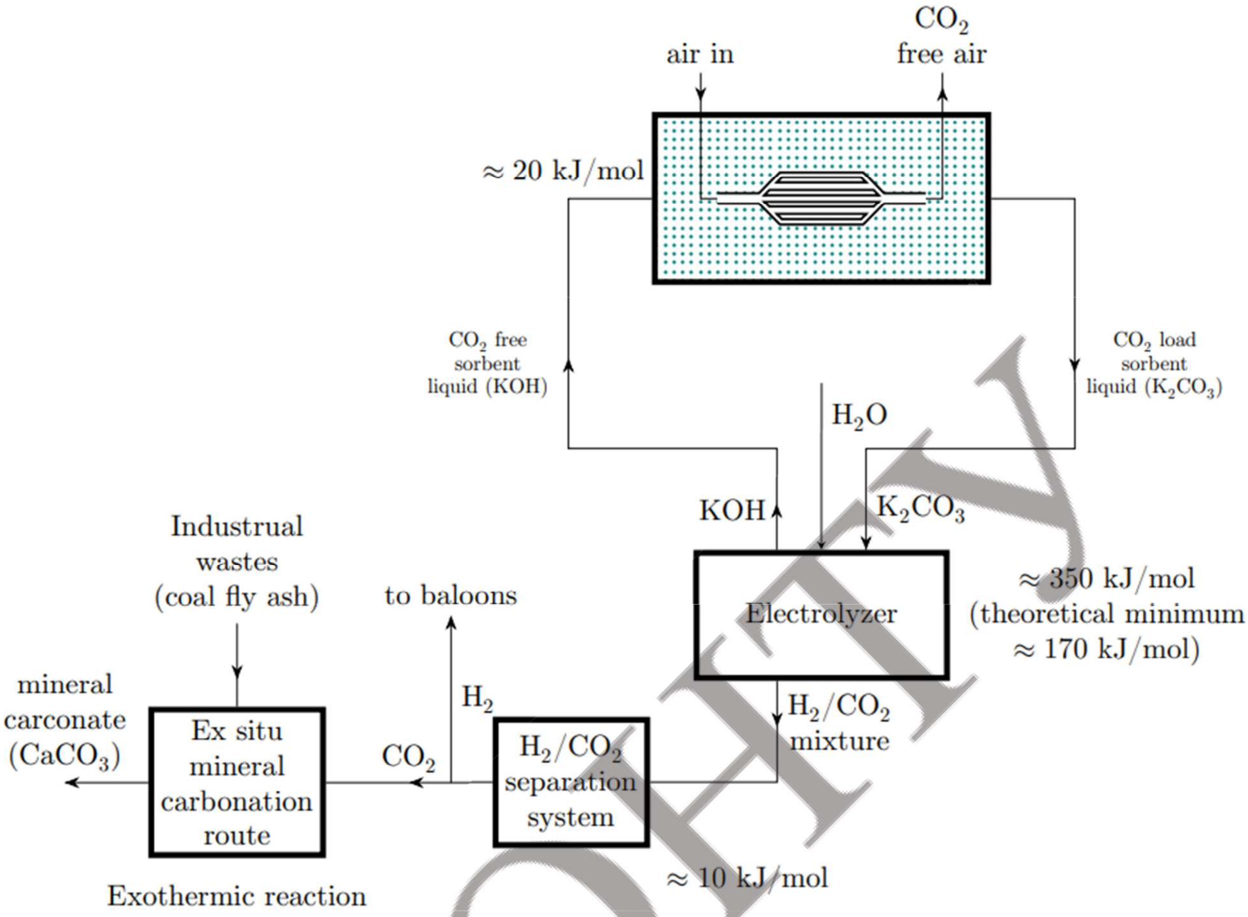

Fig. 7 Process-Flow Diagram

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