



Study of carbon capture and sequestration techniques-modelling

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ABSTRACT

Carbon dioxide is the primary anthropogenic greenhouse gas. India's CO₂ emissions are expected to extend 70% by 2025. Geologic carbon storage (GCS) offers a way to reduce CO₂ emission. Global climate change results in an urgent need for countries governments to reduce their carbon footprints by adopting sustainable development methods. To mitigate this devastating effect of global warming, the CO₂ is captured from industrial utility and compressed either in supercritical form or sub-cooled liquid form for underground storage. We have adopted an air contactor design model with some modifications. Air capture plant is fabricated using heat resistance glass. Based on the experimental studies, chemical solutions are used to capture the CO₂. The basic reaction of these solutions with the CO₂ present in the air is discussed in our study. The reaction of hydrated oxide with air captures the CO₂ as carbonate resolution by scouring techniques. Then the combined reaction of hydrated oxide and slaked lime leaves precipitates of carbonate. NaOH is redirected to air-contactor for any production of carbonate resolution. The comparative efficiency of CO₂ capture will be analyzed using primarily based chemicals like sodium hydroxide (NaOH), calcium hydroxide (CaOH₂).

Keywords— Carbon dioxide, Global warming, CO₂ emission, Geological carbon storage, Design model, Removal efficiencies

1. INTRODUCTION

Industry and manufacturing units are the main source of carbon dioxide emission in worldwide. The release of carbon dioxide to atmosphere liable to greenhouse gas, ecology and ecosystem changes, global climate changes, etc. The CCS has the potential to recycle back overall mitigation value and increase flexibility in achieving greenhouse gas emission reductions. To assess the potential of CCS as a choice for reducing international CO₂ emissions, the current global geographical relationship between large stationary CO₂ emission sources and their proximity to potential storage sites has been examined. CO₂ emissions in the residential, commercial and transportation sectors have not been considered in this analysis because these emission sources are individually small and often mobile, and therefore unsuitable for capture and storage. The discussion here conjointly includes Associate in nursing analysis efficiency, capture supported many situations.

1.1 Capture of Carbondioxide

The purpose of greenhouse gas capture is to supply a focused stream of greenhouse gas at a high that may promptly be transported to a storage website. Although, in essence, the whole gas stream containing low concentrations of greenhouse gas may well be transported and injected underground, energy prices and different associated prices typically create this approach impractically. It's thus necessary to supply an almost pure greenhouse gas stream for transport and storage. Applications are separated greenhouse gas in massive industrial plants, as well as fossil fuel treatment plants and ammonia production facilities, are already operative these days. Currently, greenhouse gas is often removed to purify different industrial gas streams. Removal has been used for storage functions in mere many cases; in most cases, the greenhouse gas is emitted to the atmosphere. Capture processes; even have been wanting to acquire commercially helpful amounts of greenhouse gas from flue gas streams generated by the combustion of coal or fossil fuel.

1.2 Standing of CCS technology

There are different sorts of CO₂ captive systems: post-combustion, Pre-combustion and oxyfuel combustion. The immersion of greenhouse gas within the energy stream, the compression of the energy stream and the fuel type (solid or gas) are consequential factors in the choice of the capture system.

1.3 Storage of CO₂

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Pipelines are committing for transporting a broad quantity of CO₂ a distant up to around 1,000 km. CO₂ could leak to the atmosphere during transport, although leakage losses from pipelines are very small.

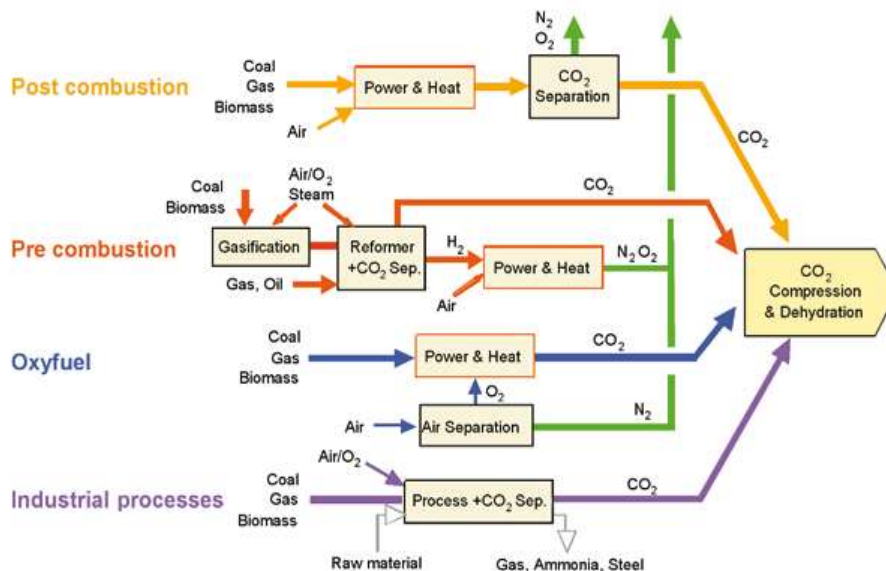


Fig. 1: Summary of CO₂ capture, processes and systems

If CO₂ is interposed into the suitable saline configuration or oil or gas ground, at deep below 800 m, different material and geochemical trapping mechanisms desired help it fare migrating to the globe face. The coal layer depository shall take place at superficial deepness and depend on the immersion of CO₂ on the coal, but the specialized viable mostly dependent on the penetrability of the burn stratum. The synthesis of CO₂ depository with Enhanced Oil Recovery or, possible, Enhanced Coal Bed Methane recovery could deceive to further profit from the oil or gas recapture. Well-drilling technical, interpolate application, computer simulation of depository inventory performance and monitoring systems from the existing operation are presently developed moreover for utilization in the pattern and assigning of the geological storage scheme.

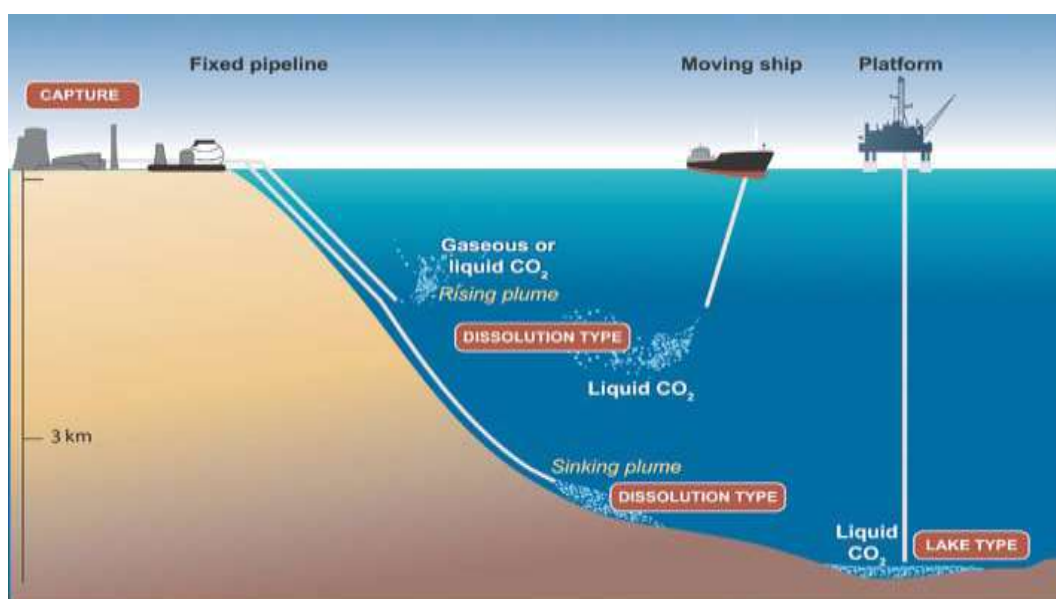


Fig. 2: Overview of ocean storage concepts. In “dissolution type” ocean storage

Although capturing carbon dioxide in geological storage is a vast and long process to carry out. To overcome this CO₂ is captured as a direct gas by several methods and technologies like ccs technology.

Here using the air capture method to capture the atmospheric and industrial releases of carbon dioxide effectively with a natural heat source and also an energy efficient way of capturing process by adopting chemical solutions to trap the large amount of CO₂. The CE’s air capture method is known as “wet scrubbing” because it uses a water-based solution to absorb CO₂ out of air passed through a contactor device.

This technique has been used for other industrial applications also. Thus the methodology for carbon capture using the air captured method is discussed here

2. MATERIALS AND METHODS

2.1 Air capture method (Wet Scrubbing)

CE’s air capture methodology is thought as “wet scrubbing” as a result of it uses a water-based answer to soak up carbon dioxide out of air undergone a contactor device. We have chosen the wet scrubbing method from several possible techniques through the following advantage:

Air contactors for atmospheric CO₂ capture must be huge in order to capture meaningful amounts of CO₂. A liquid-based system allows the CO₂ captured throughout the huge structure to be collected in a single location with simple and inexpensive pumps and pipes.

Atmospheric air contains contaminants such as particulates, trace gases and larger debris of all types. A wet-scrubbing system is able to out-perform solid membranes and micro-pores because its absorbing surface is continually replenished. Also, a system with flowing liquids is less prone to small scale fouling and clogging from atmospheric dust particles than solid-based systems, which expose specialized and expensive solid materials to the relatively dirty atmospheric environment.

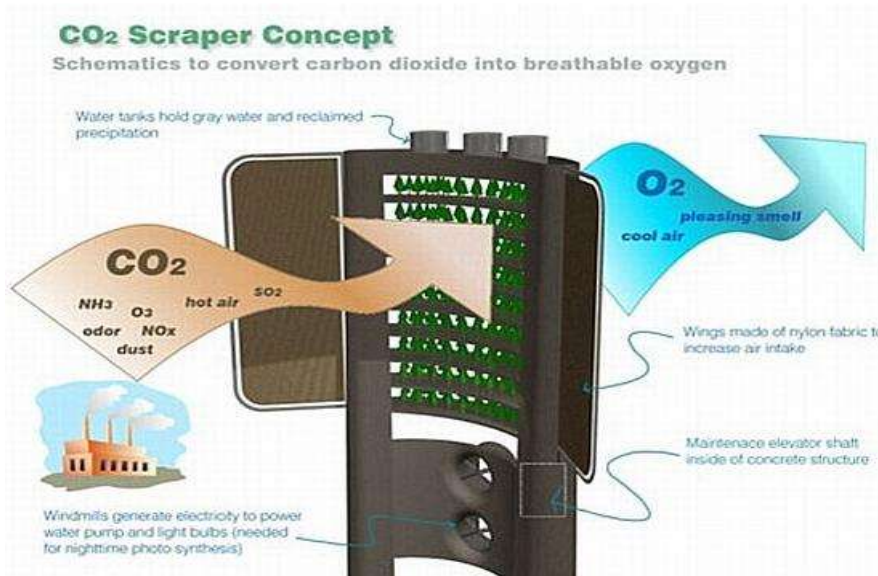


Fig. 3: Wet Scrubbing

2.2 Air capturing process

CE's patented technology integrates two processes: an air contactor, and a regeneration cycle, for continuous capture of atmospheric carbon dioxide and production of pure CO₂.

These two processes work together to enable continuous capture of CO₂ from atmospheric air, with energy (and small amounts of make-up chemicals) as an input, and pure CO₂ as an output. The stream of pure CO₂ can be sold and used in industrial applications and/or permanently sequestered (geologically stored) deep underground.

Air contactor absorbs part of atmospheric CO₂ into our capture solution to provide a liquid solution that is rich in carbon dioxide. The regeneration method, involving many processing steps, produces a refined stream of CO₂ and re-makes the initial capture chemical.

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2.3 Air contactor

Our capture system brings part air containing CO₂ into contact with a chemical solution that naturally absorbs CO₂, in a device called a contractor. Air contactor design captures carbon dioxide with a strong alkaline hydroxide solution. This solution optimized to quickly absorb CO₂ by careful selection of concentrations and additives.

We have developed a unique contactor design that maximizes CO₂ absorption by utilizing a large solution surface area, optimize air turbulence and mixing and solution-refresh rates. Our contractor design enables us to capture industrial- scales of CO₂ using a cost-effective device with a slow solution pumping and fan energy inputs and with minimal land use requirements. Both the sodium hydroxide (reactant) used by our contractor and produced sodium carbonate is non-toxic.

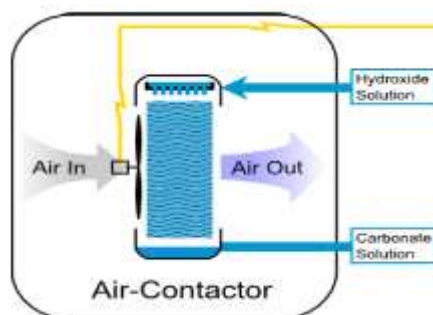


Fig. 4: Air-Contactor

2.4 Regeneration cycle

In the regeneration cycle, the CO₂ rich solution from the air contactor is processed to unleash pure compressed CO₂ and additionally regenerate the initial capture solution for further use.

- After CO₂ is captured in the air contactor it forms a chemical known as sodium carbonate (Na₂CO₃) which is carried to the regeneration cycle dissolved in solution. This solution is fed into a device called pellet reactor, which simultaneously react it's with calcium hydroxide(CaOH₂) to regenerate the sodium hydroxide (NaOH)for reuse in the contractor and precipitate the CO₂ out of solution as solid calcium carbonate (CaCO₃).
- Once the solid calcium carbonate (CaCO₃) has been separated from the solution, it is sent to a device called calciner. It operates at 900°C which decomposes the calcium carbonate into calcium oxide (CaO) during which pure carbon dioxide(CO₂) is released. The calciner burns fuel like gas, in an oxygen environment to supply the heat needed to perform this reaction. The calciner also generates the heat that is used to supply electricity for the rest of air capture plant The CO₂ produced by burning the fuel mixes with the captured atmospheric CO₂ and all the CO₂ is sent to the final compression and clean-up stage to produce clean CO₂.
- After the solids have released their CO₂, they are sent to calcium hydroxide mixing tank where they react with water to reform (CaOH₂). This calcium hydroxide is recycled to a pellet reactor for reuse.

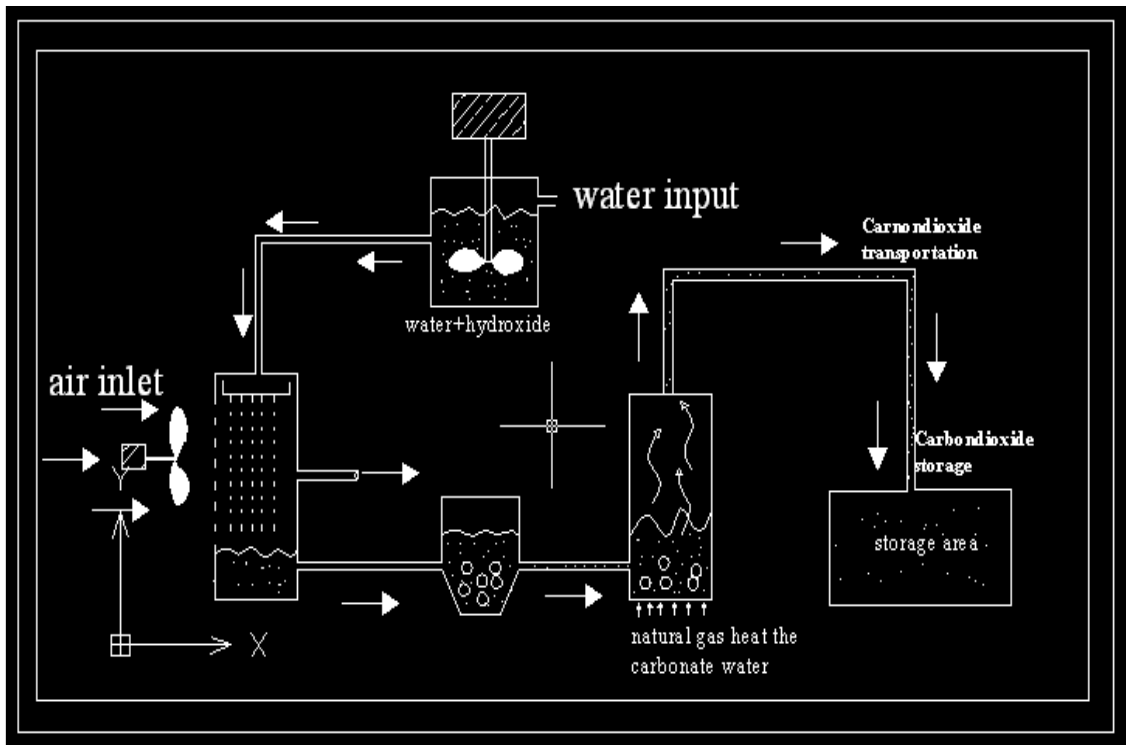


Fig. 5: Design the air-capture plant using AUTOCADD Software (Plan for fabrication)

2.5 Experimental setup



Fig. 6: Location- Environmental lab, (carbon-capture plant after completing the fabrication)

3. CHEMICAL REACTION

3.1 CO₂ production cycle

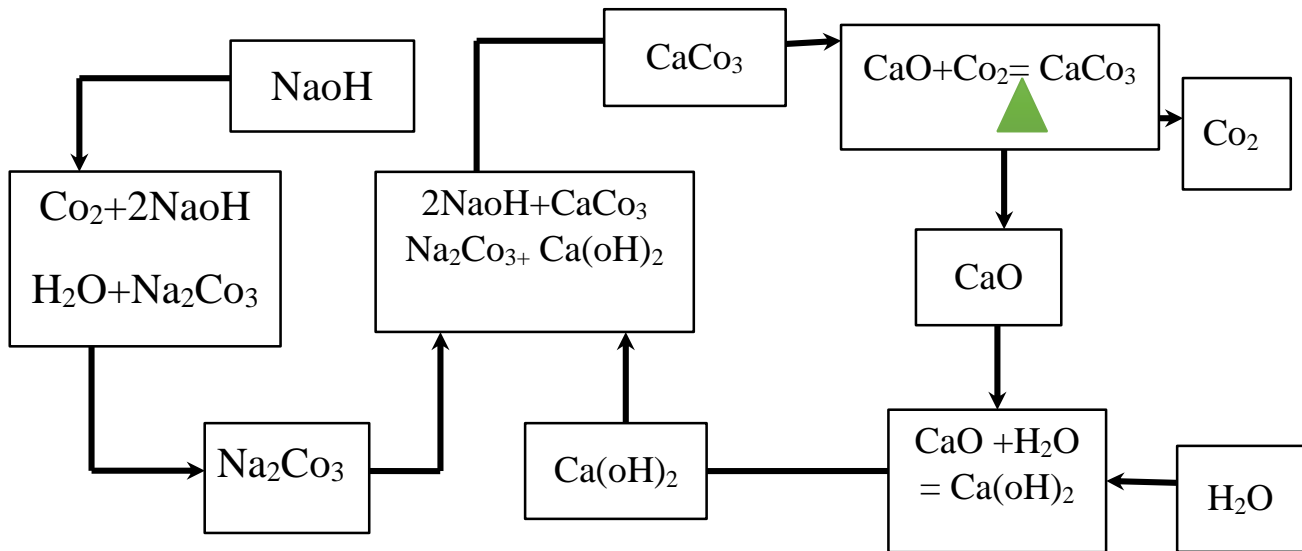
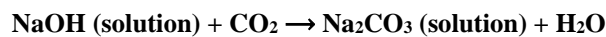
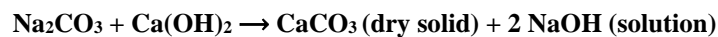


Fig. 7: Chemical reaction

The reaction of Sodium hydroxide with air captures the CO₂ as carbonate solution by scrubbing techniques is



The combined reaction of sodium hydroxide and calcium hydroxide leaves a precipitate of calcium carbonate is



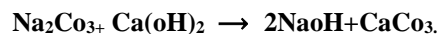
Here, NaOH is redirected to air-contactor for further production of carbonate solution.

The calcium carbonate is further heated above 800°C to decompose the calcium oxide and carbon dioxide (CO₂). Thus,



Here, the carbon dioxide is captured and compressed to storage and other requirements.

The dry precipitate on calcium oxide is further reacting against water to decompose a calcium hydroxide (Ca(OH)₂) and this solution is redirected to regeneration cycle for the reproduction of calcium carbonate(CaCO₃) on reaction with sodium carbonate.



4. EXPERIMENTAL TESTS

After the arrangement of the experimental setup in the desired location for the efficient capture of CO₂. The trail tests are performed initially to rectify the common errors. Thus the supply of sodium hydroxide solution to the scrubbing chamber is quite difficult for spraying the nozzle devices to direct contact with the inlet air because of low pressure flow and also the length of the pipe connection is the risk found during trial tests. These errors are rectified by raising the height of the sodium hydroxide storage tank to obtain the high-pressure flow in the nozzle sprayer and also air bubbles are removed in pipe conduits, as well as increase the pipe length for the efficient flow.

After these complete arrangements, CO₂ is captured using the different normalities of the SODIUM HYDROXIDE solution. Here, sodium hydroxide with five different normalities is chosen to the compared efficiency, thus 0.1N, 0.2N, 0.3N, 0.4N and 0.5N.

4.1 Determination of CO₂ level by titration

A titration includes the incremental extension of a titration solution to a solution known as analysis. The titrant in titration has a known absorption, whereas the analysis has an unknown absorption of some compound. In arranging to discover CO₂ honest in a solution, you can titrate through with sodium hydroxide. The CO₂ in the solution will respond with the sodium hydroxide (NaOH) to form sodium bicarbonate (NaHCO₃). By applying an indicator such as phenolphthalein, you can judge when all of the CO₂ in the water has been desolate.

4.2 Procedure

Fill the graduated cylinder with an exactly known volume of water you wish to test. Pour this into the beakers. Append two to five drops of phenolphthalein in the water using the dropper. The phenolphthalein will change into pink if the solution is basic. CO₂ lends a slight acidity to water, hence the water should stay clear when you add phenolphthalein. Multiply the No.of litres of sodium hydroxide you used by the molarity of the sodium hydroxide solution. The molarity should be listed on the container. This

will give you the number of moles of sodium hydroxide used in the titration. If your titration reached the endpoint and did not go beyond it, this also equals the number of moles of carbon dioxide consumed.

The NaOH solution comes out the pink colour on the extension of phenolphthalein indicator and then it will respond with sodium hydroxide to form light pink colour as an endpoint.

4.3 Calculation Of CO₂ PPM

$$\text{No of moles of NaOH in Solution} = \text{Volume of burette solution} \times \text{Normality of NaOH}$$

$$\text{Molarity of Co2 in Titrant} = \frac{\text{Volume of burette solution} * \text{Normality of NaOH}}{\text{Volume of titrant}}$$

5. RESULT AND DISCUSSION

The comparative efficiency of carbon dioxide is verified by graphic variation of different concentration level. The amount of carbon dioxide captured by different normality's of NaOH solution, heating time, settling time and inlet air level. Thus the capture efficiency of CO₂ is compared with 0.1, 0.2, 0.3, 0.4, 0.5 N of the NaOH solution.

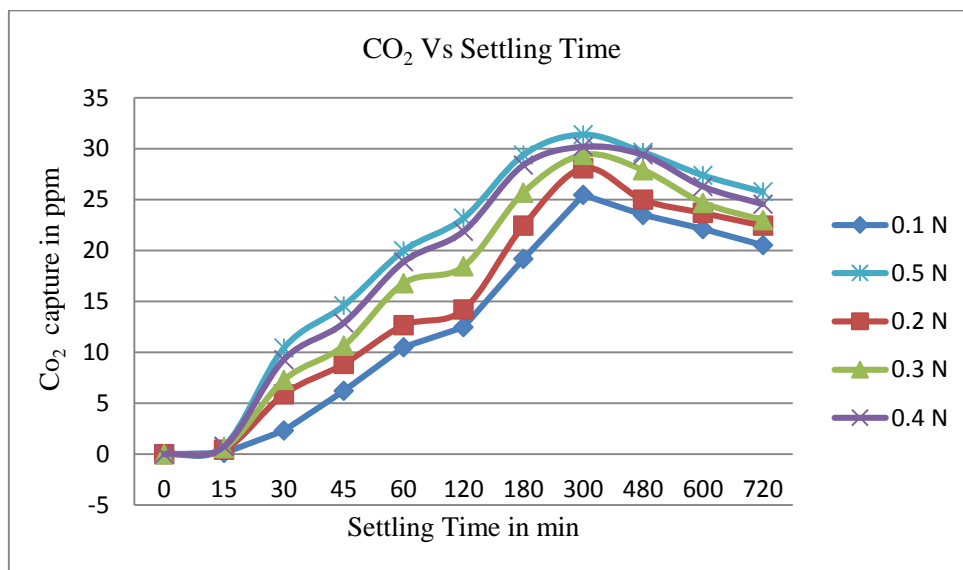


Fig. 8: CO₂ Vs Settling Time

The optimum level of CO₂ captivate at the different normality on Sodium hydroxide is 25.45 to 31.67 ppm at the settling time of 300 mins. The results are similar to observation mode, and decreasing after 300 mins.

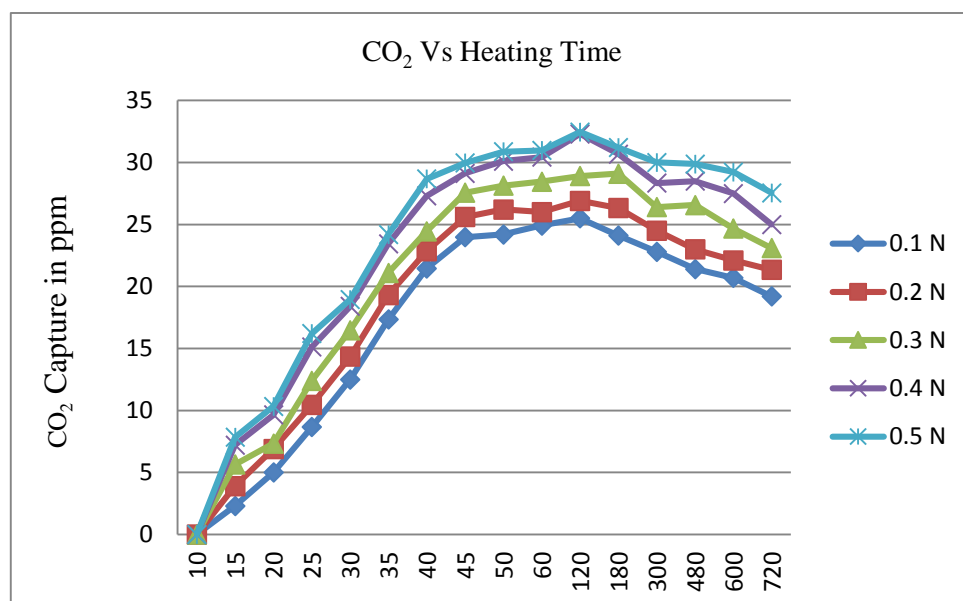


Fig. 9: CO₂ Vs Heating Time

The optimum level of CO₂ captivate at the different normality on Sodium hydroxide is 25.5 to 32.45 ppm at the settling time of 120 mins. The resolutions are similar to observation mode, and decreasing after 120 minutes.

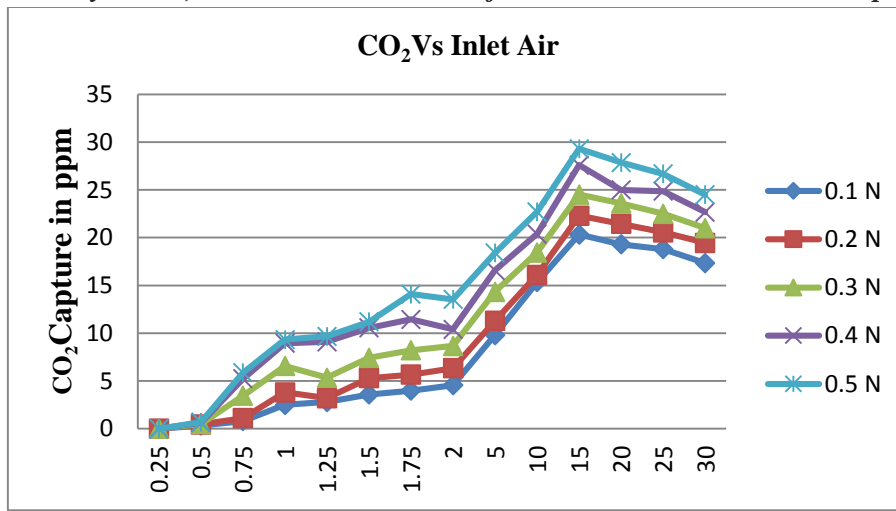


Fig. 10: CO₂ Vs Inlet Air

The optimum level of CO₂ capture at the different normality on Sodium hydroxide is 20.32 to 29.3 ppm at the settling time of 15 mins. The resolutions are similar to observation mode, and decreasing after 15 minutes.

Test samplings of CO₂ capture were performed and analyzed the amount of CO₂ capture.

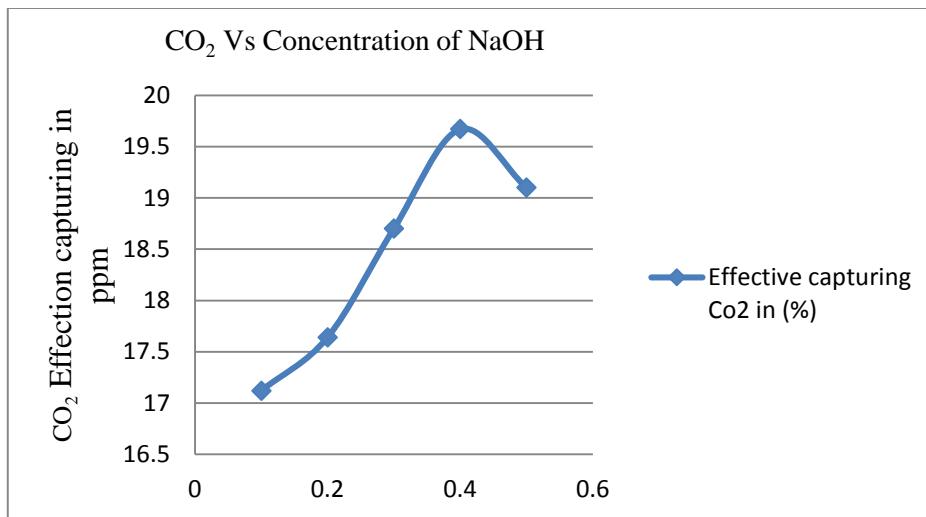


Fig. 11: CO₂ vs Concentration of NaOH

Next, the comparative efficiency of CO₂ capture was analyzed using the water-based chemicals like sodium hydroxide (NaOH). The all-over the efficacy of CO₂ capture from experimental setup.

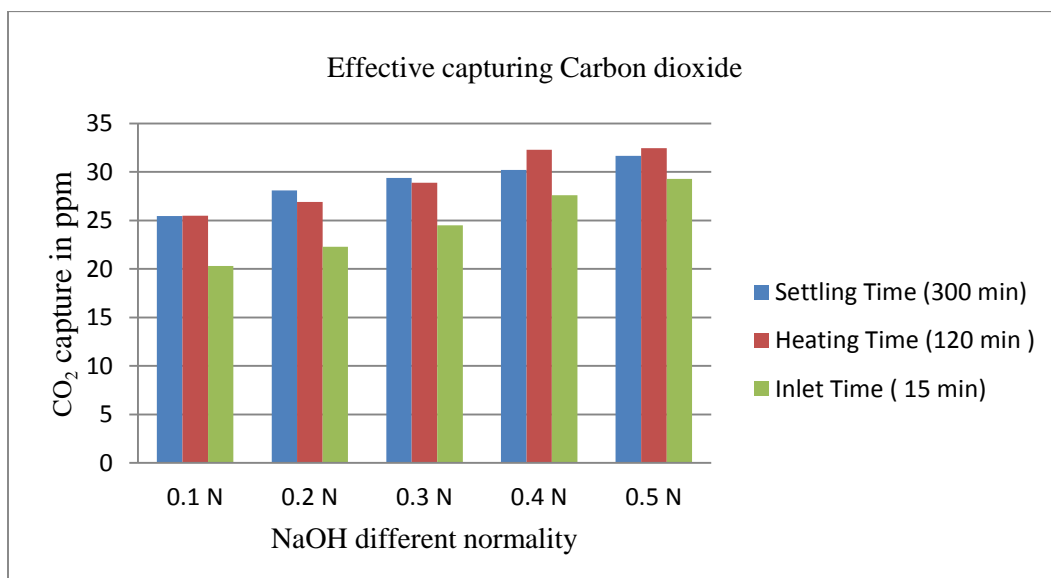


Fig. 12: Effective capturing of Carbon dioxide

6. CONCLUSION

The planning of industrial, experimental setup is proceeding by adopting the capturing techniques to retard the major effects of CO₂ from these sources. This is an effective technology majorly adopting to denigrate the greenhouse effects and make our surroundings as an eco-friendly environment. Also, we adopting the CCS technology to the three main applications of industrial and residential source such as a chimney, cooling tower and housing.

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