# Investigating Direct Air Capture of $CO_2$ using a TORBED Reactor

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## 1. Introduction

Carbon capture technology is going to play a vital part of combating the climate crisis we face, and large-scale carbon sequestration is the only way to reverse the damage already done to the planet. The project studied the intensified TORBED reactor configuration based on swirling gas motion for direct air capture using solid powder adsorbents.

The aim of the research was to prove the concept that the reactor was capable of capturing CO2 at atmospheric concentrations, this aim was found to be successful as a proof of concept. However, the amount of carbon adsorbed was found to be lower than expected because the powder adsorbent was unsuitable for the conditions of the experiment.

## 2. Aims

- Experimentally determine the breakthrough capacity of the sold particulate adsorbent for current atmospheric levels of $CO_2$.
- Evaluate optimum reactor conditions to maximize adsorption of $CO_2$.

## 3. Methods

The powder was weighed out on an analytical balance and then deposited into the reactor. This was then sealed and hooked up to two inlet and two outlet tubes; one for pure nitrogen and one for mixed gas and $CO_2$ at 0.04% as seen in figure 1.

Once the gas had been through the reactor it passed through a filter to ensure no powder got in the sensor and disturbed the measurements.

The rotameter was used to ensure the flow rate into the sensor did not exceed the upper limit it could take.

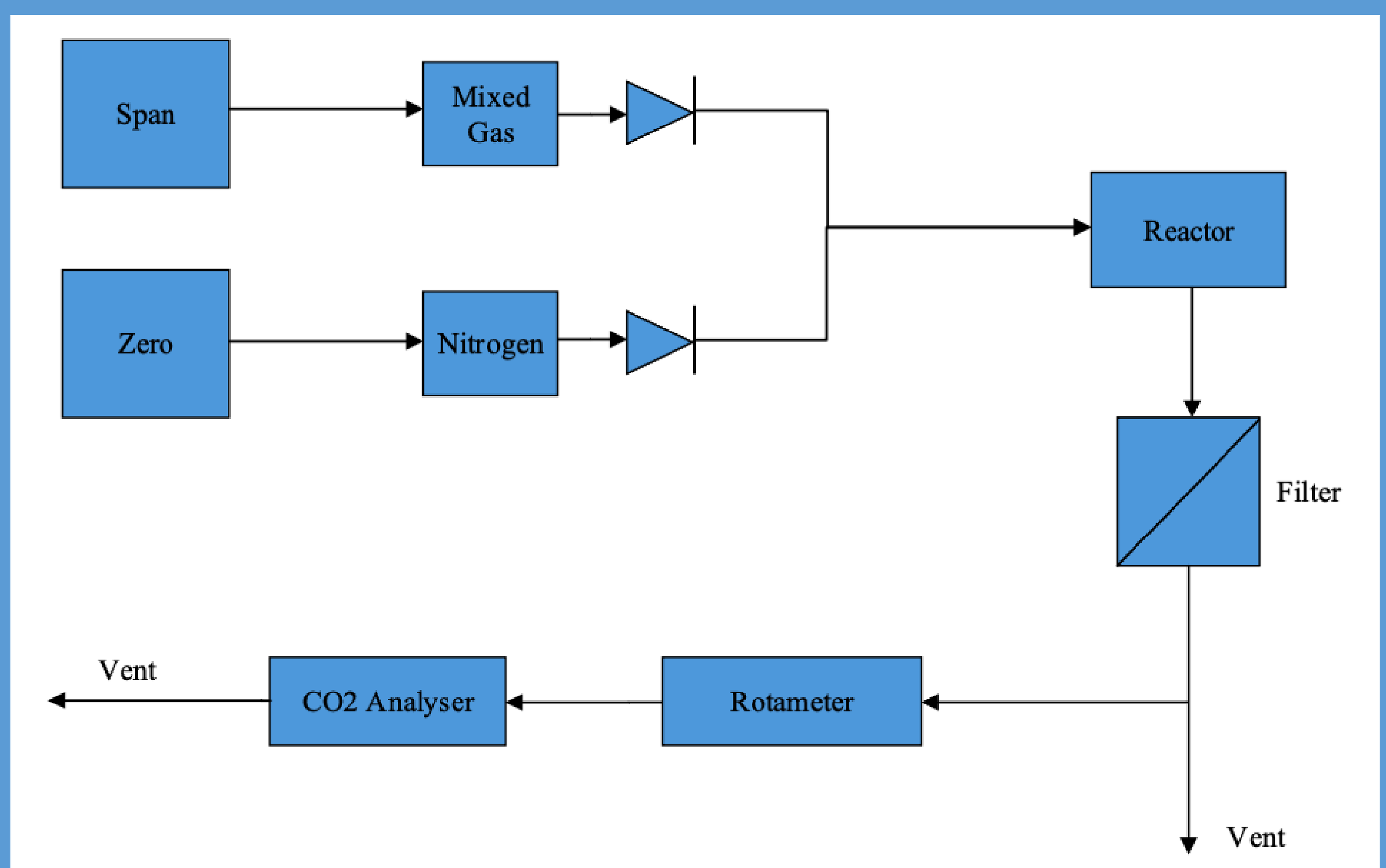


*Figure 1: Flow diagram of experimental setup*

## 4. Results

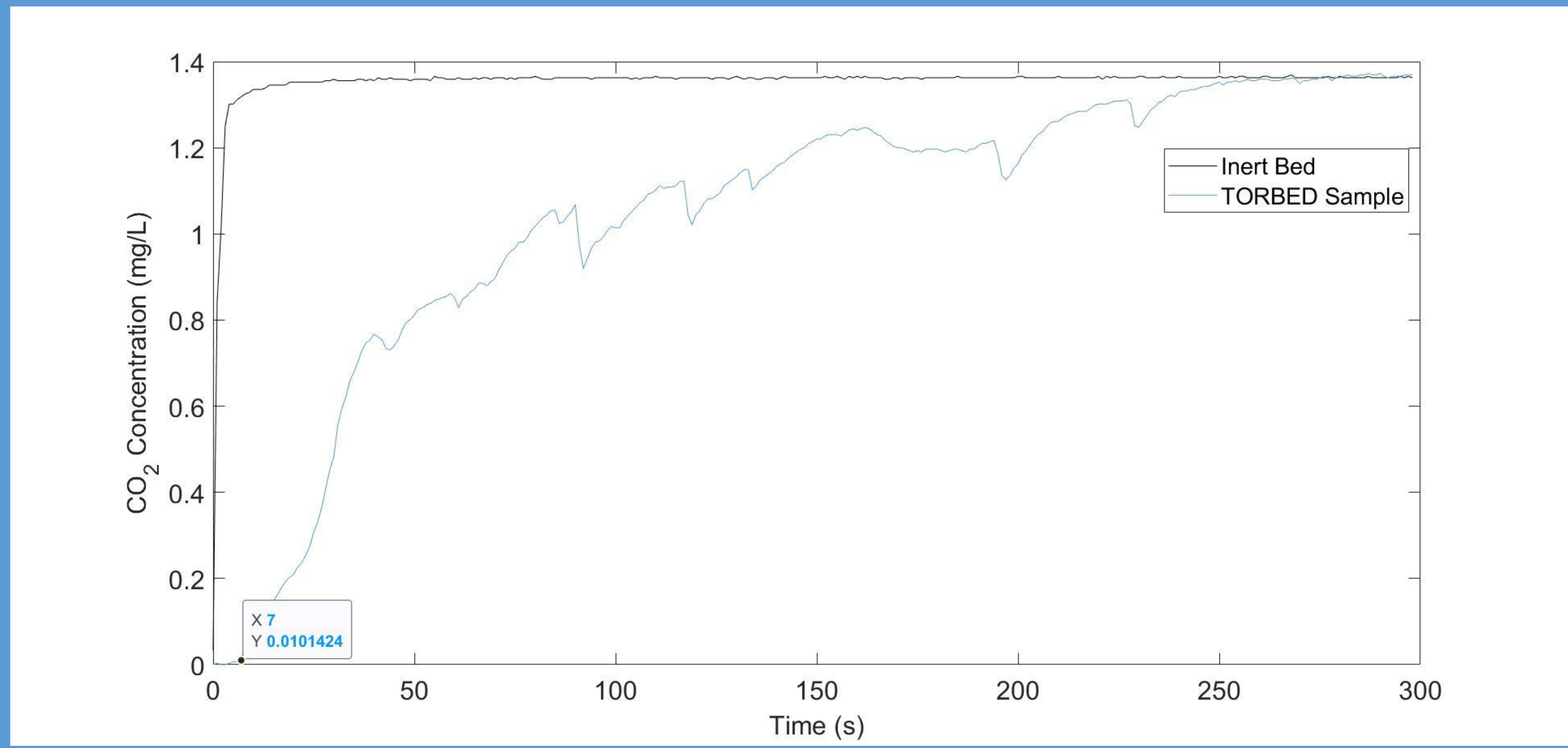


*Figure 2: Breakthrough profile for $CO_2$ adsorption with 2 g adsorbent at 20 ˚C*

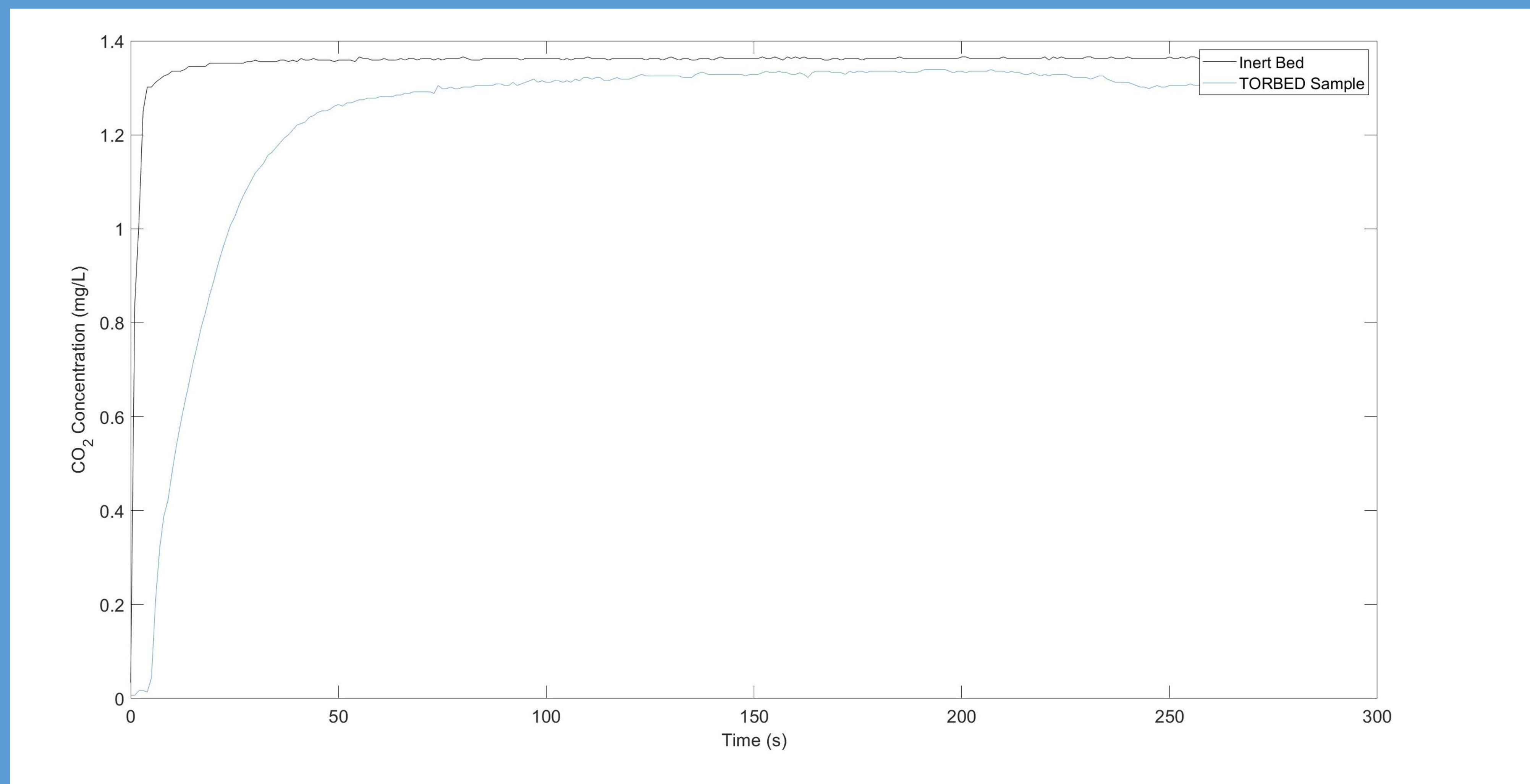


*Figure 3: Breakthrough profile for $CO_2$ adsorption with 2 g adsorbent at 40 ˚C*

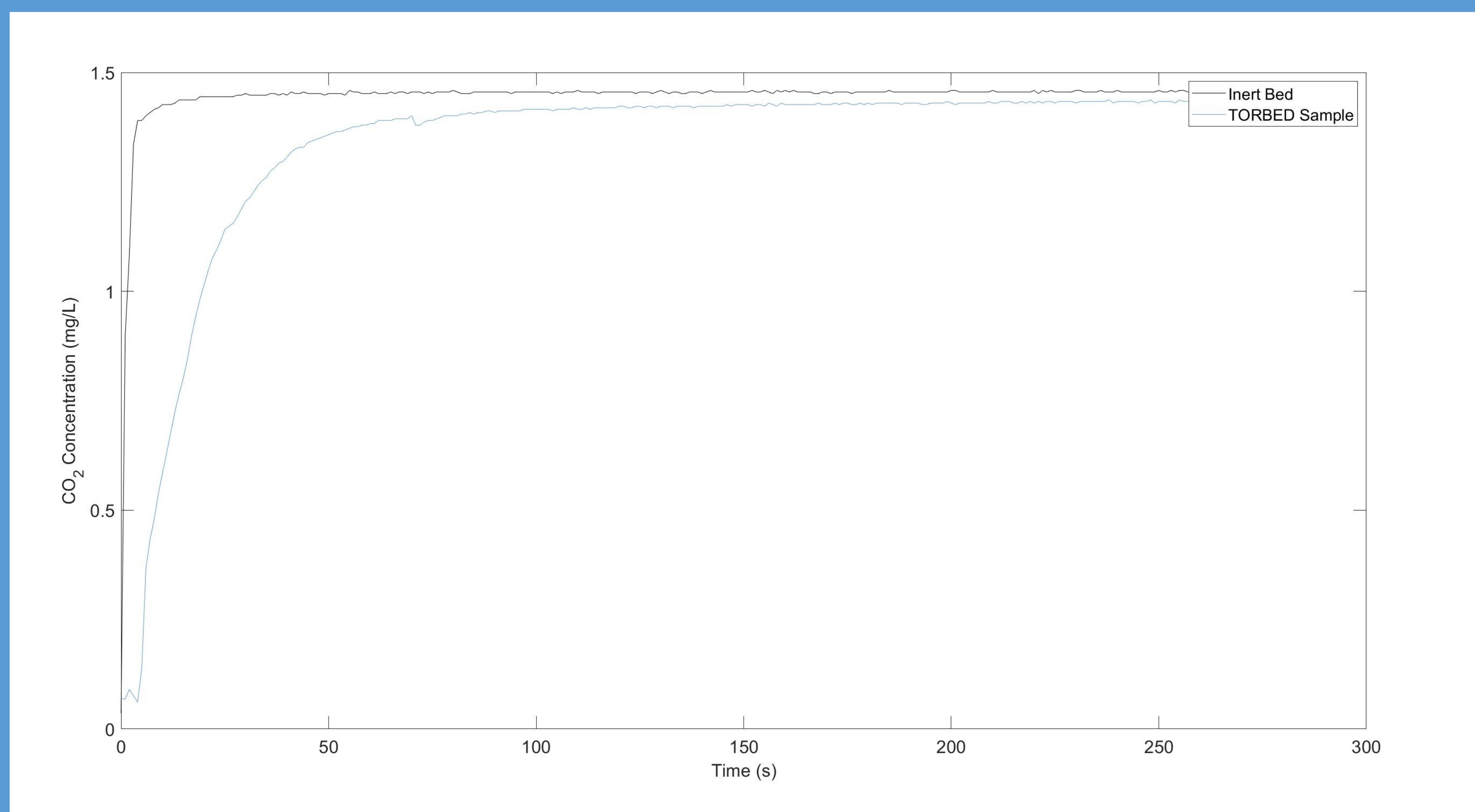


*Figure 4: Breakthrough profile for $CO_2$ adsorption with 3 g adsorbent at 20 ˚C*

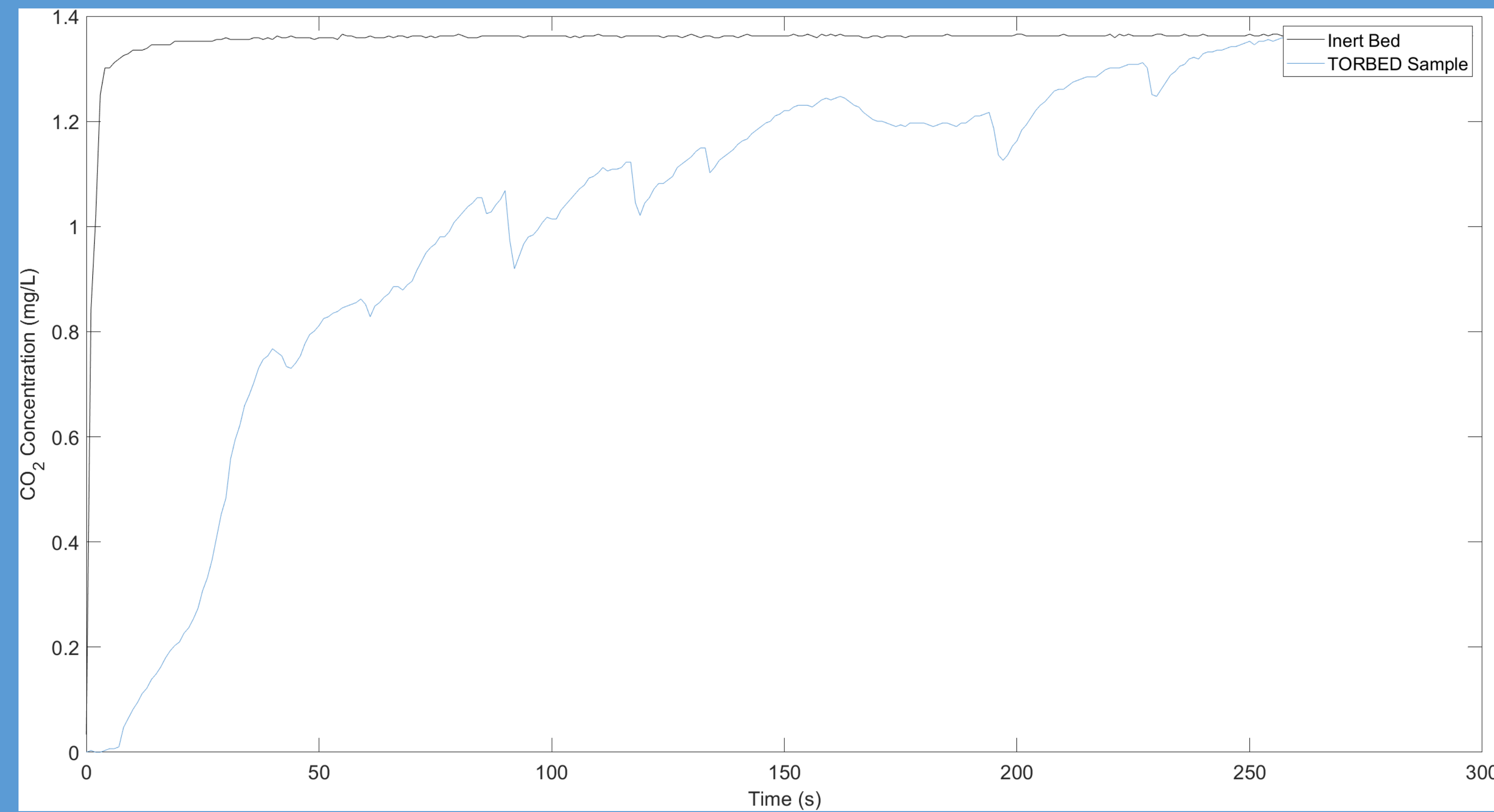


*Figure 5: Breakthrough profile for $CO_2$ adsorption with 3 g adsorbent at 40˚C*

The figures show the carbon concentration compared to readings made by an inert empty bed containing none of the sorbent powder.

The recorded data was run through a program that calculated the $CO_2$ uptake by measuring the area between the inert bed and the sample being run.

*Table 1: The amount of $CO_2$ captured per gram of adsorbent in the reactor.*

| Temperature<br>Mass of adsorbent | 20 °C | 40 °C |
|---|---|---|
| 2 g | 0.2236 mmol/g | 0.1184 mmol/g |
| 3 g | 0.0732 mmol/g | 0. 3352 mmol/g |

## 5. Conclusion

- The reactor successfully adsorbed $CO_2$ from the gas being passed through it proving its capable of carbon capture in atmospheric conditions.
- From table 1 above it is seen that the setup with a greater mass of adsorbent at a higher temperature was best for capturing $CO_2$.
- In future iterations of the experiment, in order to improve the adsorption capacity of the reactor; the adsorbent must be changed for one that is less kinetically limited for atmospheric concentrations of carbon dioxide. [1] [2] [3] [4].

## 6. References


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[2] Hanusch, J.M., Kerschgens, I.P., Huber, F., Neuburger, M. & Gademann, K. (2019) Pyrrolizidines for direct air capture and CO 2 conversion †. *Chem. Commun.* 55949.

[3] Nikulshina, V., Gebald, C. & Steinfeld, A. (2009) CO 2 capture from atmospheric air via consecutive CaO-carbonation and CaCO 3-calcination cycles in a fluidized-bed solar reactor. *Chemical Engineering Journal*. 146244–248.

[4] Veselovskaya, J. V, Derevschikov, V.S., Kardash, T.Y., Stonkus, O.A., Trubitsina, T.A. & Okunev, A.G. (2013) Direct CO 2 capture from ambient air using K 2 CO 3 /Al 2 O 3 composite sorbent. *International Journal of Greenhouse Gas Control*. 17332–340.