In the last decades, the valorization of the solid organic waste has received growing interest. The waste treatment has increased the attention towards a new renewable energy carrier: the biogas. The biogas has different composition depending on the solid waste (i.e., CH₄=65%, CO₂=30%, H₂O=1.9%, N₂=1.8%, H₂S=0.6%, O₂=0.5%, mercaptans=0.2%). Since the CO₂ amount is not negligible, it must be captured because it is one of the significant contributors to the greenhouse effect (Hijazi, Munro, Zerhusen, & Effenberger, 2016).

Over the years, several technologies were developed to abate CO₂. However, the actual capture systems are not low-cost, and the research is focusing on other possible technologies (Khraisheh et al., 2020). In this scenario, zeolites could be an interesting solution. These materials are characterized by [SiO₄] and [AlO₃] with three-dimensional structure. Thanks to this structural conformation, the zeolite can create cavities with different pores dimensions: micropores (d < 2 nm), mesopores (2 nm < d < 50 nm) or macropores (d > 50 nm). A material with these physico-chemical properties could have application for several environmental applications, like water, soil and air decontamination (Colella, 2007).

Among the zeolites, the natural ones have received interest in academia and industry because of their potential applications and low-cost compared with the commercial (synthetic) zeolites. In particular, the clinoptilolite is the most used natural zeolite. This material can adsorb CO₂ by Van der Waals forces, and the modification of the chemical composition (i.e., by means ion exchange method) may increase the CO₂ adsorption capacity. It was demonstrated that the capacity of CO₂ removal by clinoptilolite follows the following orders: Cs⁺ > Rb⁺ > K⁺ > Na⁺ > Li⁺ and Ba²⁺ > Sr²⁺ > Ca²⁺ > Mg²⁺ (Siriwardane, Shen, & Fisher, 2003).

In this study, the clinoptilolite (powder, provided by Zeolado, Greece) was used for the CO₂ capture at different temperatures, in the range 25 – 150 °C. The CO₂ adsorption tests were performed at 10 vol.% CO₂ and W/F = 7.5 g min⁻¹. Before the tests, the clinoptilolite was pretreated at 400 °C for 2 h with N₂ flow. The results are reported in Figure 1 and Table 1. As a whole, the CO₂ adsorption capacity decreases as the temperature increases (Figure 1A). The clinoptilolite presents good adsorption capacity at low temperature (2.2 mmol CO₂ adsorbed g⁻¹ clin). Moreover, the clinoptilolite is stable for two consecutive runs (Figure 1B).

![Figure 1. A) CO₂ capture over the time at different temperatures and B) stability tests (at 25 °C) for two consecutive runs on clinoptilolite powder.](image)

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>25</th>
<th>60</th>
<th>90</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ adsorbed (mmol CO₂ adsorbed g⁻¹ clin)</td>
<td>2.2</td>
<td>1.8</td>
<td>1.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Table 1. CO₂ absorbed (mmol CO₂ adsorbed) over the clinoptilolite mass at 25, 60, 90 and 150 °C.
Also, the clinoptilolite was compared with other CO\textsubscript{2} capture materials, as the hydrocalcite and the Linde Type A (LTA) zeolites. The LTA was ion-exchanged with Na and Ca in order to have better performances. The results are shown in Figure 2 at 25, 60, 90 and 150 °C. With the increase of the temperature, the adsorption capacity for all the samples decreases. At 25 °C, the most performing catalysts are Na- Cal.LTA samples, respectively, 3.1 and 3.3 mmol\textsubscript{CO2}_adsorbed g\textsuperscript{-1}_adsorbent. However, at a higher temperature (150 °C), the most interesting catalyst is clinoptilolite (0.7 mmol\textsubscript{CO2}_adsorbed g\textsuperscript{-1}_adsorbent), and the worst performances are represented by the hydrocalcite (0.4 mmol\textsubscript{CO2}_adsorbed g\textsuperscript{-1}_adsorbent).

In conclusion, the clinoptilolite is an interesting (sustainable) material that can be used for the CO\textsubscript{2} capture at relatively high temperature since it is less affected by the variation of the temperature, compared to LTA-type zeolite and hydrocalcite.

Figure 2. A) CO\textsubscript{2} capture at 25 °C, B) 60 °C, C) 90 °C and D) 150 °C over the time.

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