

# Utilization of Nickel Nanoparticles as Catalytic Additive in Acceleration of the Mineral Carbonation Process

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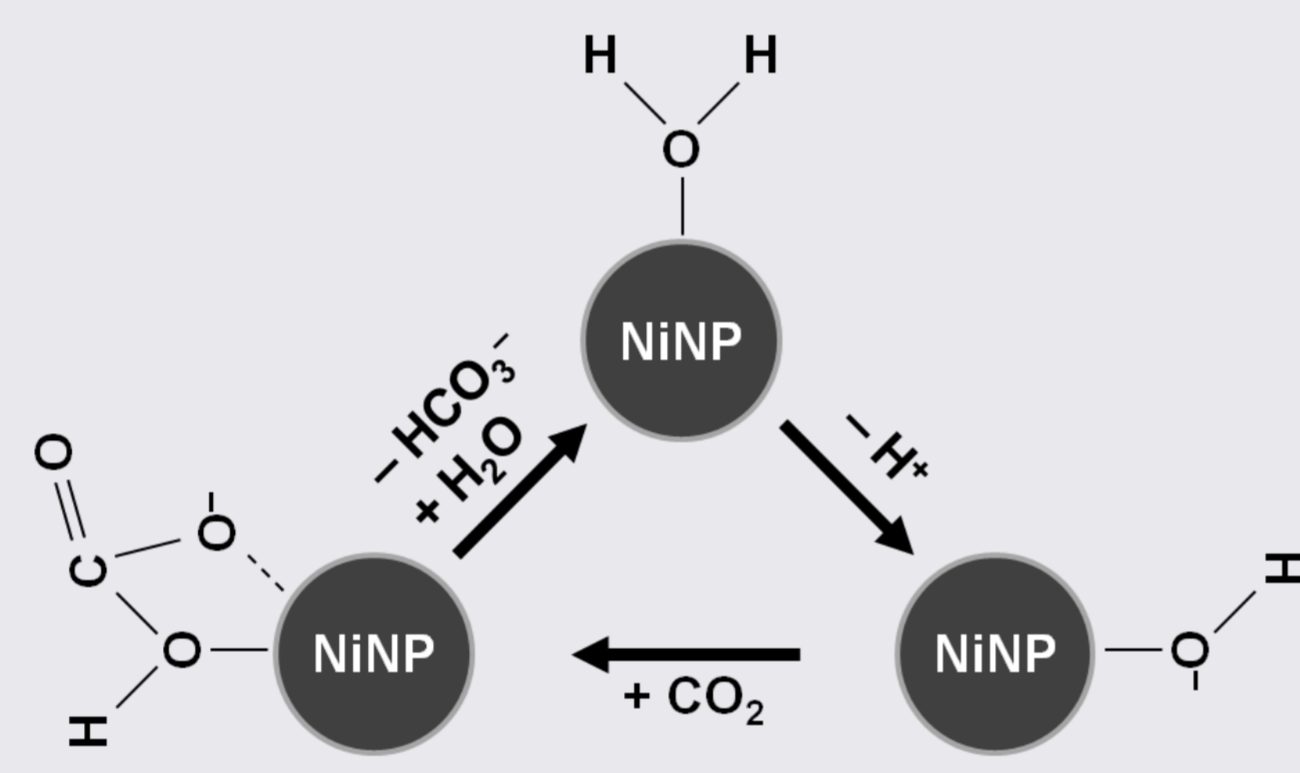
## Introduction

Carbon dioxide mitigation through mineral carbonation is still economically inefficient, despite the mounting knowledge pool on the subject. This inefficiency is due to high energy demand, slow reaction kinetics and low conversion degrees (and implicitly limited CO<sub>2</sub> sequestration). Additive usage remains an interesting choice to accelerate CO<sub>2</sub> absorption, especially if mild process conditions can be maintained. Most research conducted to date has sought additives to increase mineral dissolution and carbonate precipitation. This work presents a different approach regarding the use of pure nickel nanoparticles (NiNP) as a mineral carbonation additive.

The mechanism of NiNP, of catalytic nature, is based on increasing the quantities of dissolved CO<sub>2</sub> and dissociated carbonic acid in the process water, thus increasing the concentration of bicarbonate ions available to react with solubilised alkaline earth metals. This effect has the potential to reduce the time needed to reach a certain level of conversion through mineral carbonation. This study presents results and discussions regarding the effect of NiNP on the CO<sub>2</sub> mineralization by four alkaline materials (pure CaO and MgO, and AOD and CC steelmaking slags), on the product mineralogy, on the particle size distribution, and on the morphology of resulting materials.

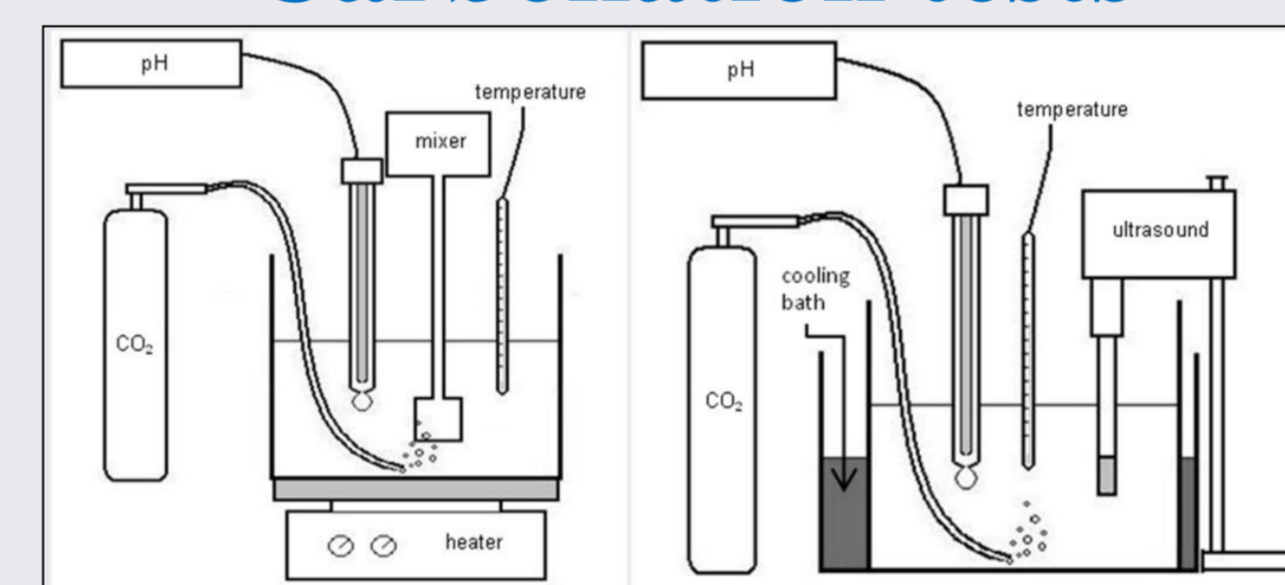
## Materials and concept

- CaO;
- MgO;
- AOD slag;
- CC slag.



Schematic of the reaction mechanism of hydrogenation of CO<sub>2</sub> by NiNP, adapted from Bhaduri and Šiller

## Carbonation tests

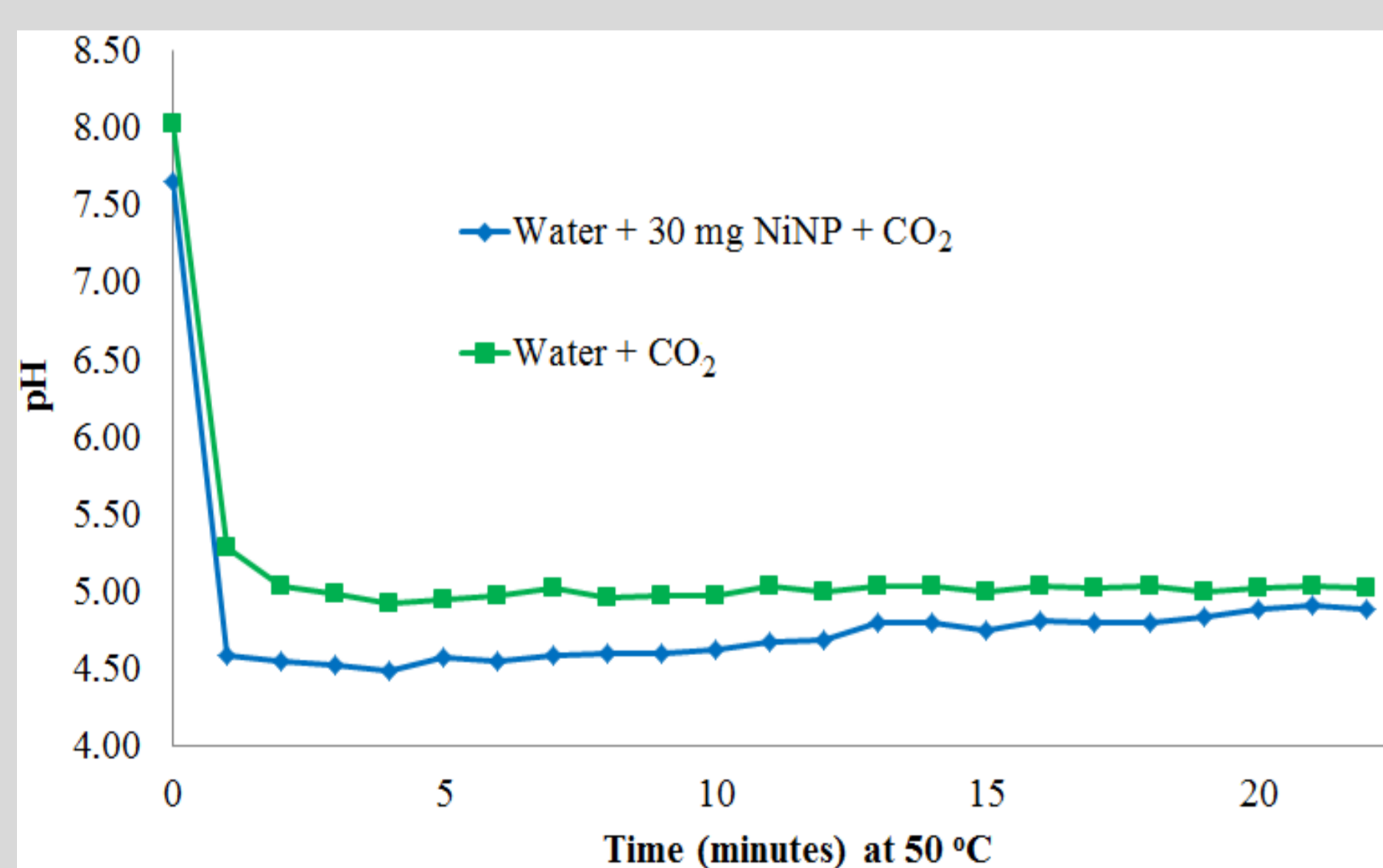


- CO<sub>2</sub> flow rate: 0.72 NL/min.
- Temperature: 50 °C.
- Time: 30 min to 240 min.
- Solids loading: 50 g/L.
- NiNP addition: 30 ppm.

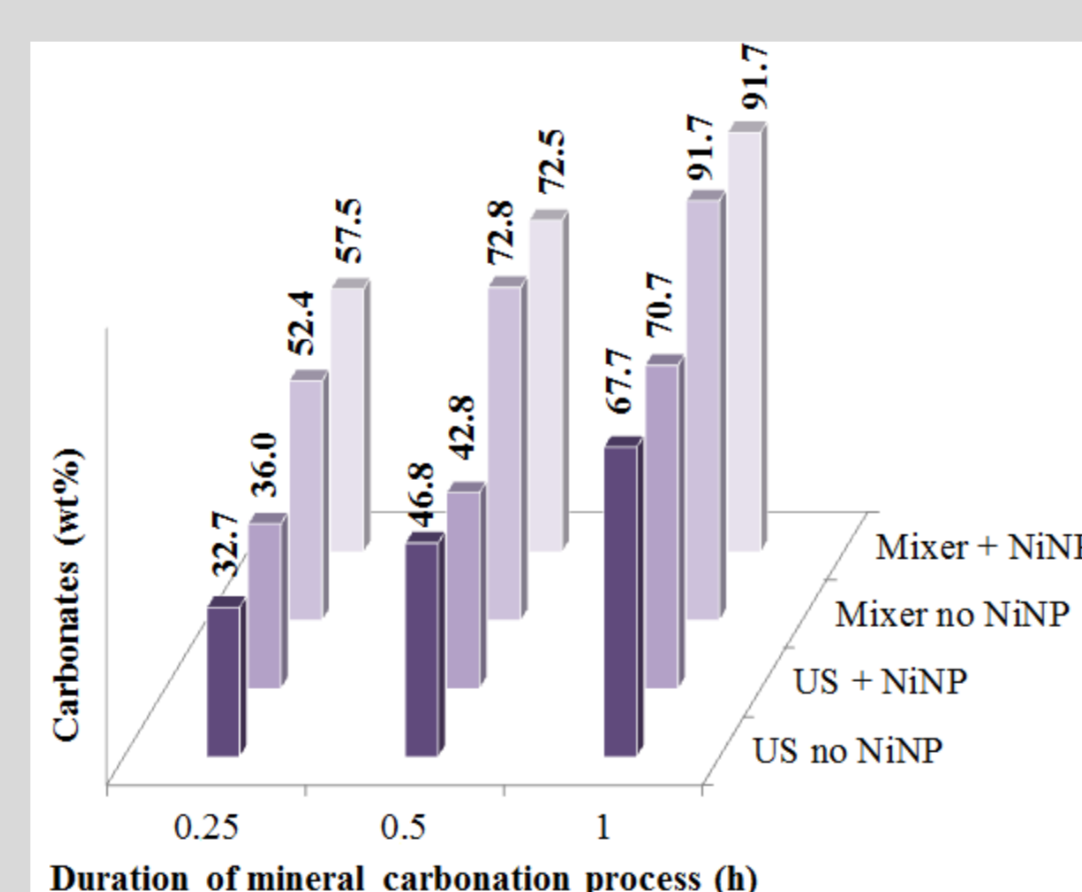
## Analytical methods

- XRF;
- QXRD;
- TGA;
- SEM;
- PSD;
- pH.

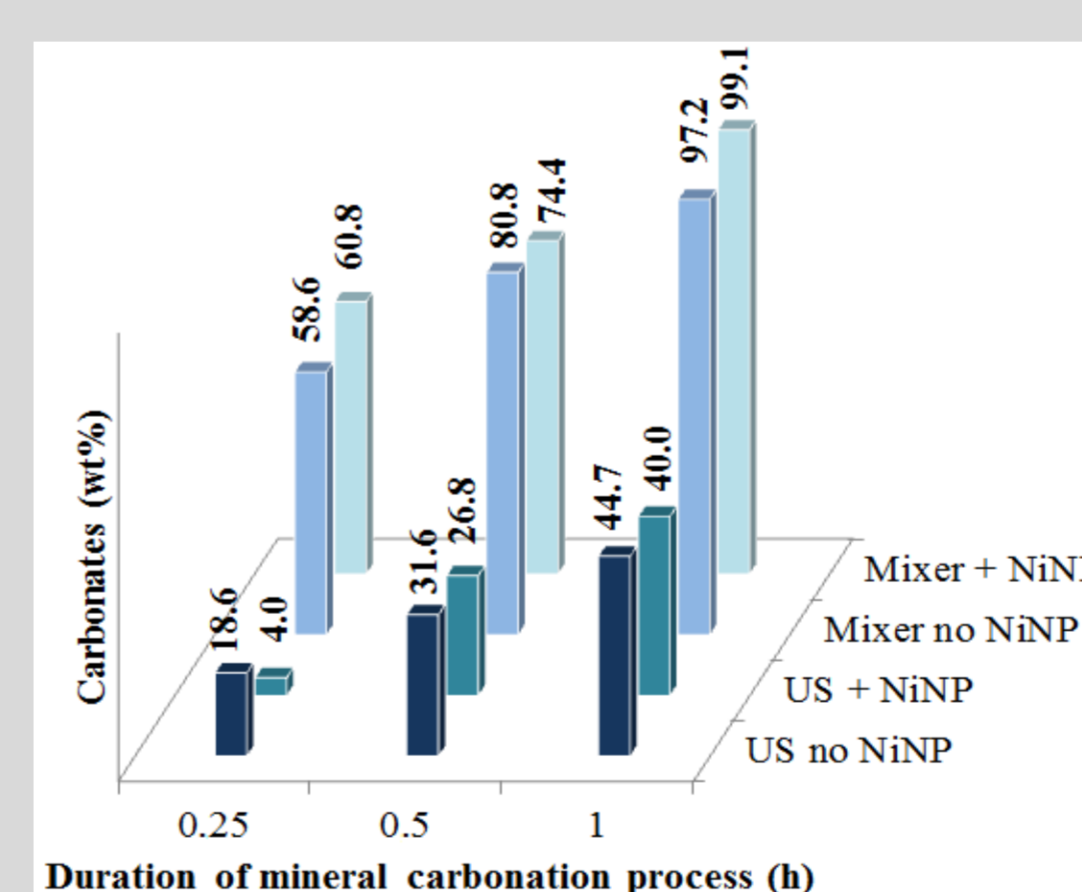
## Results



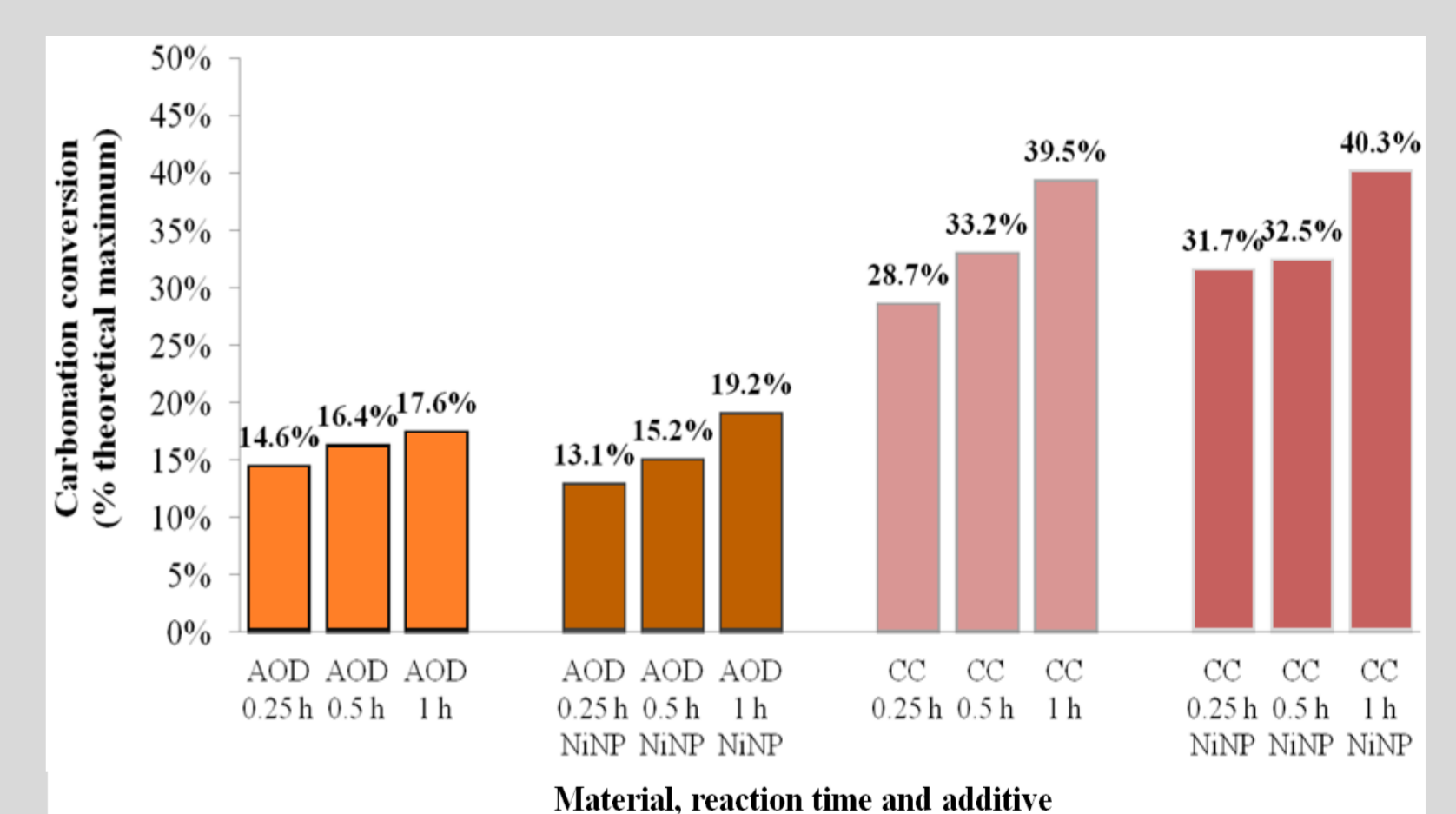
Evolution of pH value for ultra-pure water with/without NiNP addition, after commencement of CO<sub>2</sub> bubbling at 50 °C



Carbonate content after CaO mineral carbonation, using S/L ratio of 50 g/1000 ml, determined by QXRD



Carbonate content after MgO mineral carbonation, using S/L ratio of 35.95 g/1000 ml, determined by QXRD



Carbonation conversion of AOD and CC slags after mineral carbonation, using S/L ratio of 50 g/1000 ml, determined by TGA

## Conclusions

- The confirmation of dissolving a higher quantity of CO<sub>2</sub> in the NiNP-containing solution was done by studying the evolution of solution's pH value; more acidic values obtained in the presence of NiNP suggest an increased presence of dissociated carbonic acid;
- This higher quantity of dissolved CO<sub>2</sub> resulted in acceleration of the mineral carbonation process in the first fifteen minutes of reaction time when NiNP was present. This was demonstrated by the results regarding the obtained carbonate quantities, determined by QXRD and TGA;
- Increasing solids content decreased the benefit of NiNP even in the early stages, since the fraction of extra dissolved CO<sub>2</sub> to the required amount of CO<sub>2</sub> for carbonation decreases with higher solids loading;
- The presence of NiNP did not result in significant differences regarding carbonate mineral composition nor particle and crystal morphologies;
- Further accelerating the NiNP-assisted process by reducing the loading of materials or carbonation of solutions containing dissolved alkaline earth metals, such as brines and brackish waters, may benefit more from NiNP addition.

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