

Use of MgO by-products as a magnesium source for ammoniacal-nitrogen removal and struvite precipitation in pig manure

M.S. Romero-Güiza^{a,b}, S. Astals^{b,c}, R. del Valle-Zermeño^a, M. Martínez^a, J. Mata-Alvarez^b, J.M. Chimenos^a

^a Department of Materials Science and Metallurgical Engineering, University of Barcelona, C/ Martí i Franquès, no. 1, 7th floor, 08028 Barcelona, Spain.

^b Department of Chemical Engineering, University of Barcelona, C/ Martí i Franquès, no. 1, 6th floor, 08028 Barcelona, Spain.

^c Advanced Water Management Centre, The University of Queensland, 4072 Brisbane, QLD, Australia



Objectives

Evaluate the N-NH₄⁺ removal and struvite formation capacity at different magnesium by-products from the calcination of magnesite. Compare the N-NH₄⁺ removal efficiency of magnesium by-products and stabilizing agent (SA) formulated in advance with the industrial by-product and phosphoric acid.

Introducció

Nitrogen and phosphorus recovery from wastewaters has become an important topic due to the environmental problems caused by these compounds (e.g. eutrophication or land nutrient overload). In the case of pig manure, which main application is as direct fertilizer on agricultural land, most of ammoniacal-nitrogen (N-NH₄⁺) is readily oxidized to nitrate, which is poorly absorbed by soil, thus facilitating its transfer to surface or groundwater. Hence, sustainable solutions for pig manure treatment regarding nitrogen removal need to be implemented with respect to environmental and agricultural benefits. In this regard, struvite precipitation has been attracting an increased interest, since struvite has a high nutrient value per unit weight (low transport cost) and is highly effective as a slow-release fertilizer.

Materials and methods

Magnesium by-products and stabilizing agent formulation

Four MgO industrial sources were classified as one high-grade MgO (HGMgO) supplied by PremierMagnesia, LLC (Kansas City, USA) and three low-grade MgO (LGMgO) samples were labelled as PC8, PCC and Caustic P (CP) and were provided by Magnesitas Navarras, S.A. (Navarra, Spain) (Table 1). The stabilizing agent (SA) of each magnesium source was obtained after treating each product of MgO with phosphoric acid (Table 2). Specifically, phosphoric acid was slowly added to aqueous slurry of each magnesium source at a high solid-to-liquid ratio [1].

Precipitation batch experiments

The N-NH₄⁺ removal efficiency was performed in a jar-test device according with a Mg:P:N expressed in the table 3. The Struvite precipitation (N-NH₄⁺ recovery) efficiency from pig manure was evaluated through N-NH₄⁺, phosphates, magnesium and pH evolution in the course time.

Table 1. N:P:Mg ratio in the batch test

	N:P:Mg
PC8	1:1:1.5
PCC	1:1:1.5
CP	1:1:1.5
HGMgO	1:1:1.5
SA-PC8	1:1:1.6
SA-PCC	1:1:1.7
SA-CP	1:1:1.3
SA-HGMgO	1:1:1.3

Table 2. Semi-quantitative characterisation of each magnesium oxide by-product

		PC8	PCC	CP	HGMgO
MgO	%	68.6	61.1	79.4	89.8
CaO	%	9.0	9.8	9.9	1.51
SO ₃	%	8.1	4.7	0.0	0.0
Fe ₂ O ₃	%	2.7	2.3	2.9	0.0
SiO ₂	%	2.5	2.3	3.8	0.0
LOI (1100°C)	%	8.7	19.5	8.7	8.7
Reactivity*	s	445	2725	2655	90

*Acid citric test

Table 3. Semi-quantitative characterisation of each stabilizing agent

		SA-PC8	SA-PCC	SA-CP	SA-HGMgO
MgO	%	25.3	25.9	25.8	27.4
P ₂ O ₅	%	28.8	27.0	36.5	39.7
CaO	%	3.0	3.6	2.3	0.4
SO ₃	%	0.0	0.0	0.0	0.0
Fe ₂ O ₃	%	0.9	0.9	0.9	0.0
SiO ₂	%	1.2	2.0	1.3	0.0
LOI (1100°C)	%	40.0	40.2	33.0	32.4

Results and discussion

The use of low-cost magnesium sources present an N-NH₄⁺ reduction range between 30 and 43%, using a P:Mg ratio of 1:1.5. In comparison with the results present by the SAs with a maximum N-NH₄⁺ reduction range between 40-79%, where the best efficiency was SA-CP with an N-NH₄⁺ fixation of 79% with a P:Mg range of 1:1.3.

The lower struvite precipitation capacity obtained by the LGMgO by-products compared to the HGMgO is attributed to the fact that part of the Mg²⁺ supplied by the LGMgOs is to some extent in the form of dolomite and magnesite (Fig. 2). These compounds are insoluble at the pH values obtained during the experiments [2,3]. In the case of SAs the presence of newberyite or bobierrite determine the N-NH₄⁺ reduction capacity. The stabilizing agents rich in newberyite present better N-NH₄⁺ fixation performance than those rich in bobierrite.

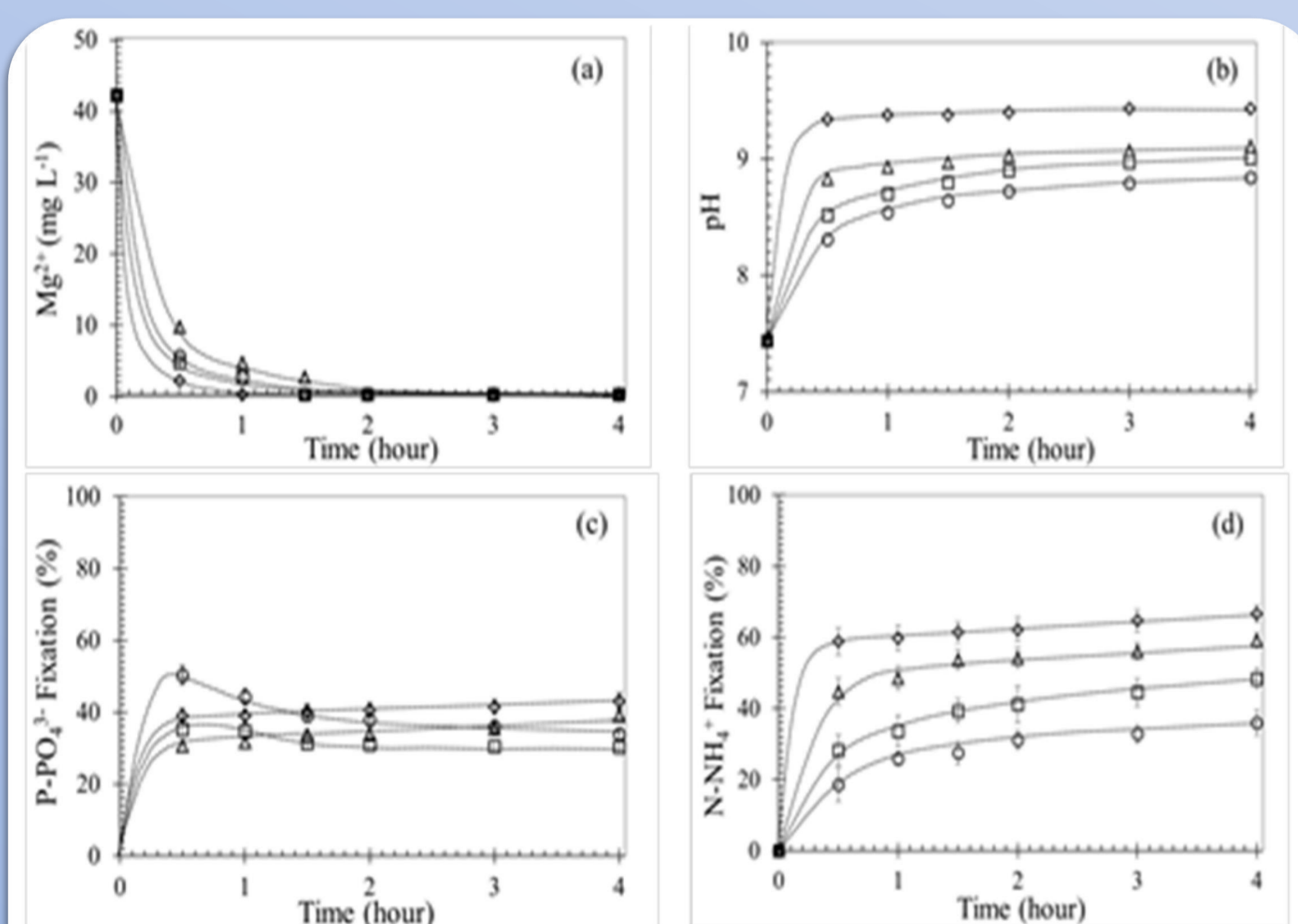


Fig. 1. (a) Concentration of Mg²⁺, (b) pH, (c) % P-PO₄³⁻ Fixation and (d) % N-NH₄⁺ Fixation in time for the different LG-MgO's and HG-MgO (PC8 (?), PCC (?), CP (?)) and HGMgO (?) additions.

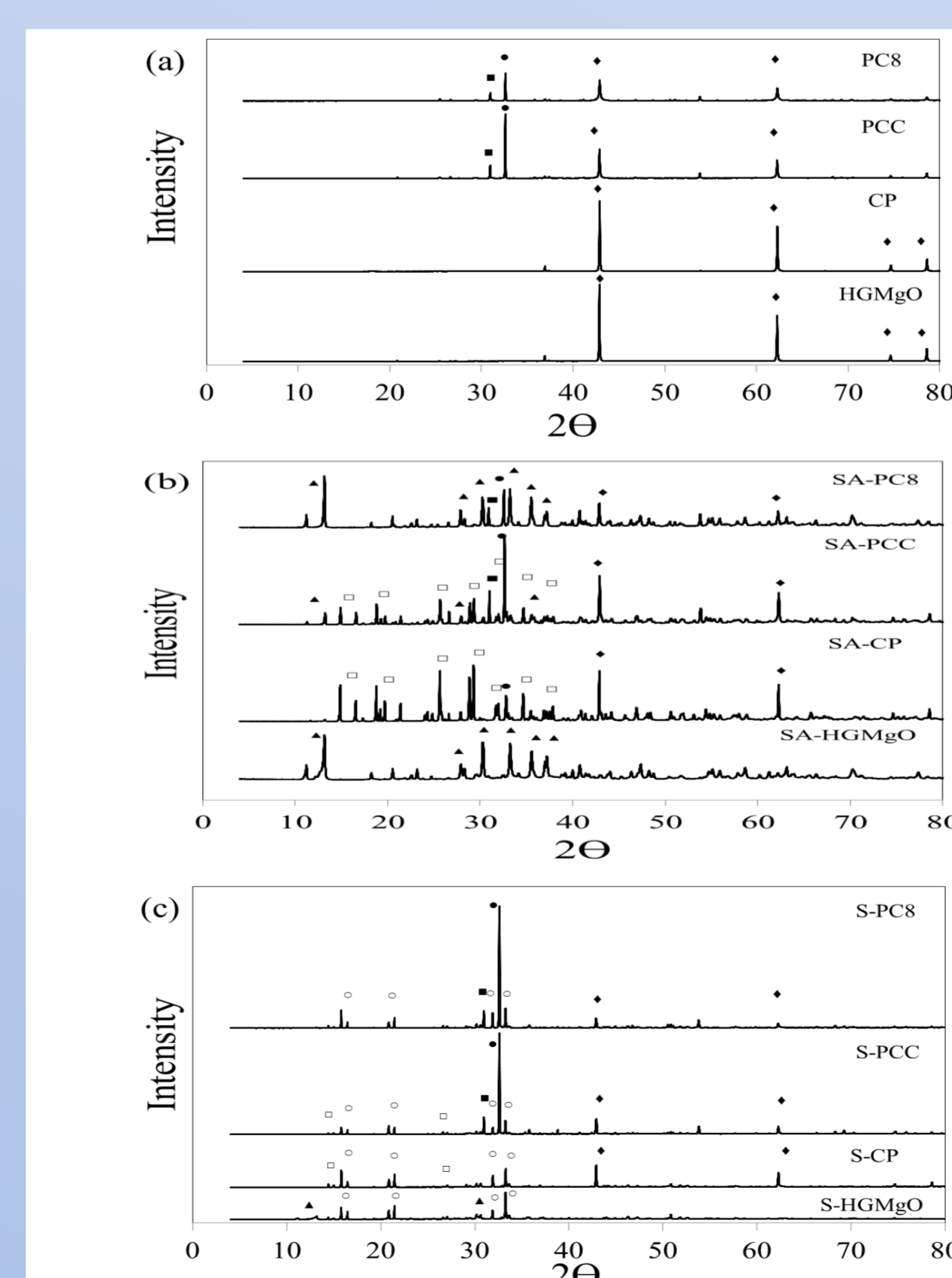


Fig. 2. XRD analysis for the (a) MgO, LG-MgO's, (b) SA's and (c) the struvite products S-SA's; signals correspond periclase (●), magnesite (●), dolomite (●), bobierrite (▲), newberyite (□) and struvite (○).

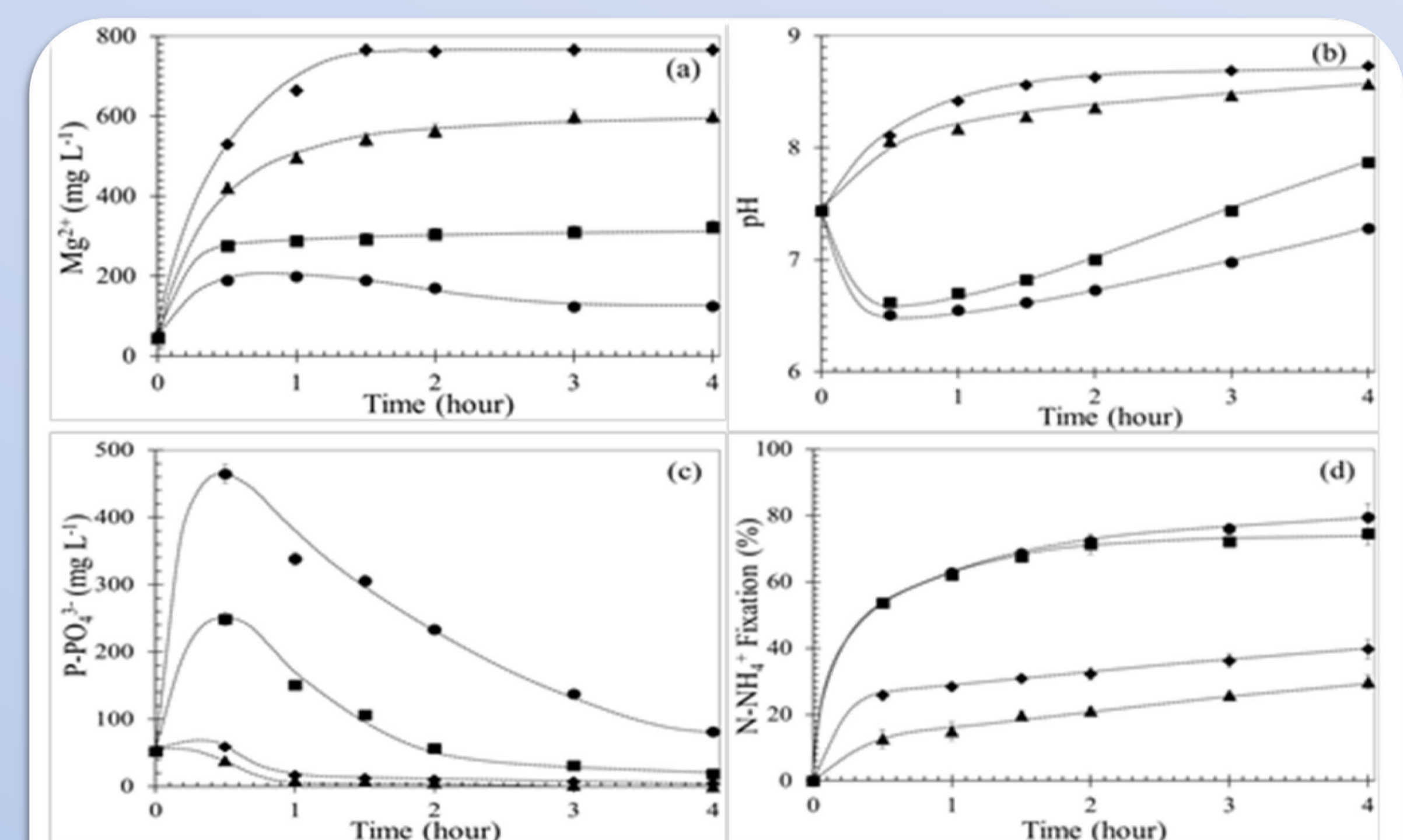


Fig. 3. (a) Concentration of Mg²⁺, (b) pH, (c) Concentration of P-PO₄³⁻ and (d) % N-NH₄⁺ Fixation in time for the different SA's (SA-PC8 (▲); SA-PCC (■); SA-CP (●) and SA-HGMgO (◆)) additions.

Conclusions

It has been established that the phosphate magnesium compounds obtained in the stabilizing agents formation present an important influence in the N-NH₄⁺ fixation or struvite precipitation capacity. The stabilizing agents rich in newberyite present better N-NH₄⁺ fixation performance than those rich in bobierrite.

References

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