

The influence of various common ions on the slaking of some South African limes

JH Potgieter¹, SS Potgieter^{2*}, CA Strydom³ and O Gheeverhese⁴

¹Department of Chemical & Metallurgical Engineering, Technikon Pretoria, Private Bag X680, Pretoria 0001, South Africa

²Department of Chemistry & Physics, Technikon Pretoria, Private Bag X680, Pretoria 0001, South Africa

³Department of Chemistry, University of Pretoria, Pretoria 0001, South Africa

⁴Department of Chemistry, Medunsa, Pretoria 0204, South Africa

Abstract

The rate of transformation from CaO to Ca(OH)₂ during the slaking process is influenced by a number of factors. In this investigation the effects of common ions normally encountered in the slaking water were investigated. It was found that chloride and nitrate ions enhanced the slaking rate, while carbonate, sulphate and phosphate ions retarded the hydration of various limes used in the investigation. The increases and decreases in the degree of hydration correlate with the solubilities of the anions forming more soluble compounds than Ca(OH)₂, as well as the solubility constants of the anions that formed less soluble compounds than the hydrated lime. The geological origin of the lime also influenced the slaking of the limes.

Keywords: lime, slaking, geological origin, accelerating anions, decelerating anions

Introduction

Lime is one of the most important industrial chemicals and its slaking from the quicklime (CaO) form to the hydrated lime (Ca(OH)₂) species is of importance in a number of practical applications, such as potable water treatment, neutralisation of acidic effluents and flue gas desulphurisation, to name but a few. The rate of transformation from CaO to Ca(OH)₂ during the slaking process is influenced by a number of factors, for example the production and storage conditions of the lime (Potgieter et al., 2002) the water and material composition (Gheeverhese et al., 2002; Potgieter et al., 2003a) and calcination temperature (Moropoulou et al., 2001).

Recently the authors described the effect of different agitation methods on the hydration rate of lime (Potgieter et al., 2003b) and concluded that this, together with the geological origin of the lime, greatly affects the amount of slaking occurring in each particular case.

This investigation further explores the influence of common ions, which can be encountered in water used for slaking quicklime, on the hydration rate of various limes. An ultrasonic agitation procedure was employed, as it is a faster way of slaking lime than the mechanical method used in the previous investigations by the group.

Experimental procedure

The experimental detail and set-up have been described comprehensively in previous papers dealing with this topic (Gheeverhese et al., 2002; Potgieter et al., 2003b). In this investigation ultrasonic agitation was used to induce hydration of the various lime samples in the different solutions of interests. The chemical compositions of the various lime samples are given in Table 1. A description of

TABLE 1
Chemical composition of the various limestones investigated

Element expressed as relevant oxide	Pienaars-river limestone % (m/m)	Lime Acres limestone % (m/m)	Beeste-kraal limestone % (m/m)
SiO ₂	18.95	0.54	4.42
Al ₂ O ₃	2.40	0.26	0.80
Fe ₂ O ₃	1.12	0.05	0.28
MnO	0.08	0.54	0.86
TiO ₂	0.13	0.01	0.02
CaO	42.37	55.34	49.47
MgO	1.23	0.80	3.30
P ₂ O ₅	<0.01	<0.01	<0.01
K ₂ O	0.30	0.04	0.40
Na ₂ O	0.17	0.14	0.05
LOI	34.09	42.99	40.93
TOTAL	100.84	100.71	100.53

their sources of origin can be found in previous work described in the literature (Gheeverhese et al., 2002). All slaking percentages were normalised to the total amount of available lime contained in each limestone after calcining.

Results and discussion

The effect of a 1 M NaCl and a 1 M NaNO₃ addition to the slaking water on the hydration rate of pure lime and three other different natural limes is shown schematically in Figs. 1 to 4. It can clearly be seen from all the curves in Figs. 1 to 4 that the nitrate enhanced the slaking rate in the initial stage of the hydration reaction.

* To whom all correspondence should be addressed.

☎ +2712 318 6368; fax: +2712 318 6286; e-mail: potgieters@techpta.ac.za

Received 2 May 2003; accepted in revised form 25 June 2003.

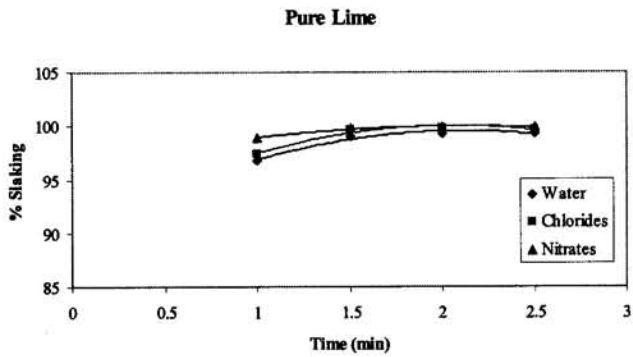


Figure 1
The effect of chloride and nitrate ions on the hydration rate of pure calcium oxide

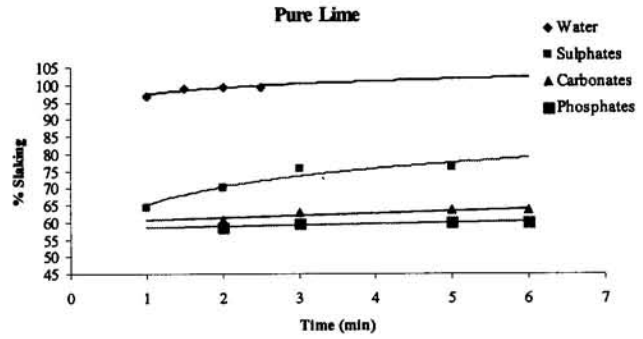


Figure 5
The effect of sulphate, carbonate and phosphate ions on the hydration rate of pure calcium oxide

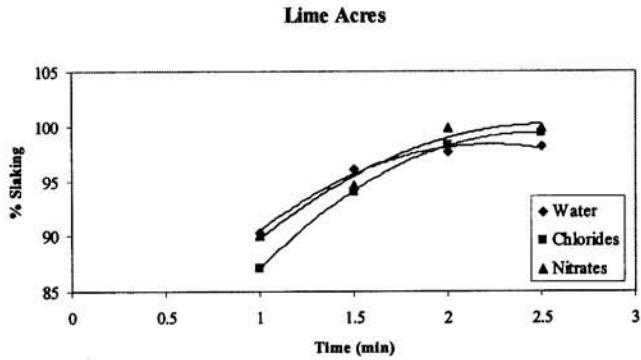


Figure 2
The effect of chloride and nitrate ions on the hydration rate of Lime Acres lime

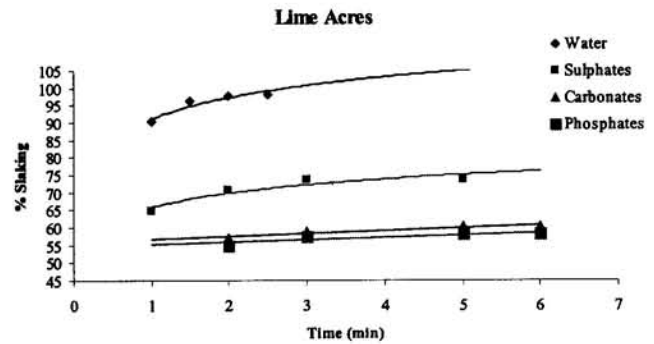


Figure 6
The effect of sulphate, carbonate and phosphate ions on the hydration rate of Lime Acres lime

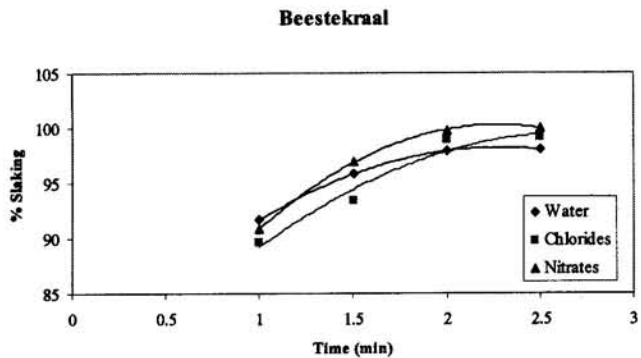


Figure 3
The effect of chloride and nitrate ions on the hydration rate of Beestekraal lime

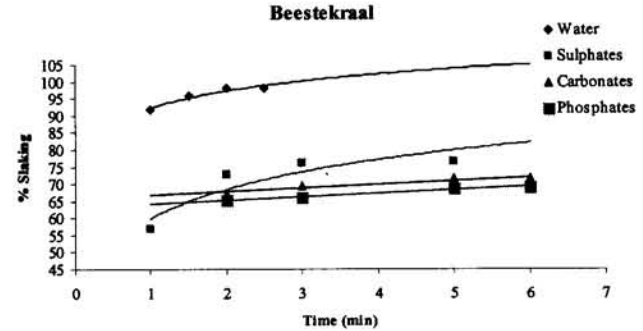


Figure 7
The effect of sulphate, carbonate and phosphate ions on the hydration rate of Beestekraal lime

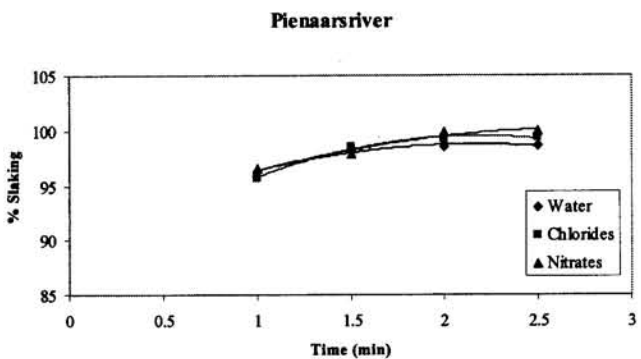


Figure 4
The effect of chloride and nitrate ions on the hydration rate of Pienaarsriver lime

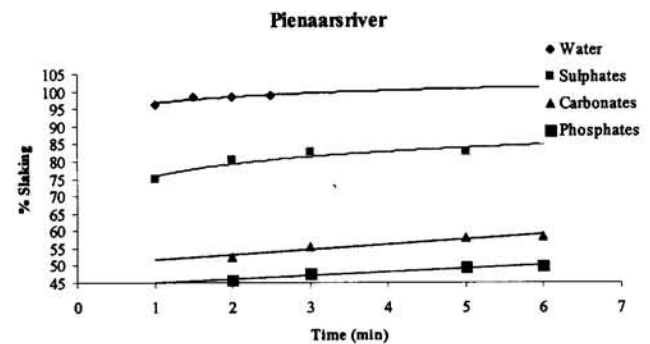


Figure 8
The effect of sulphate, carbonate and phosphate ions on the hydration rate of Pienaarsriver lime

Figure 9
The effect of nitrate ions on the hydration rate of various limes

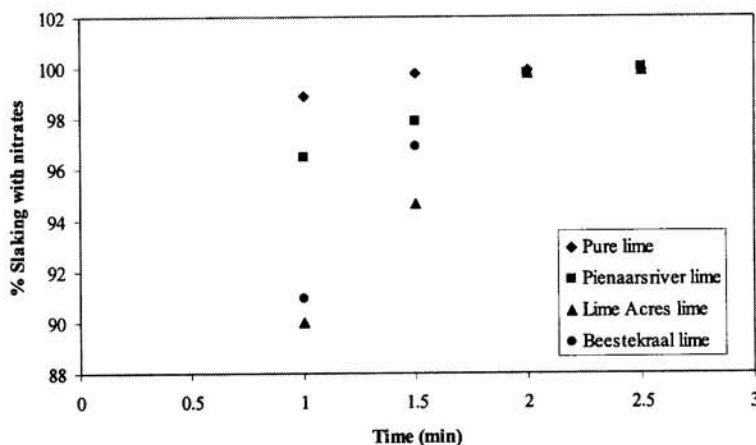
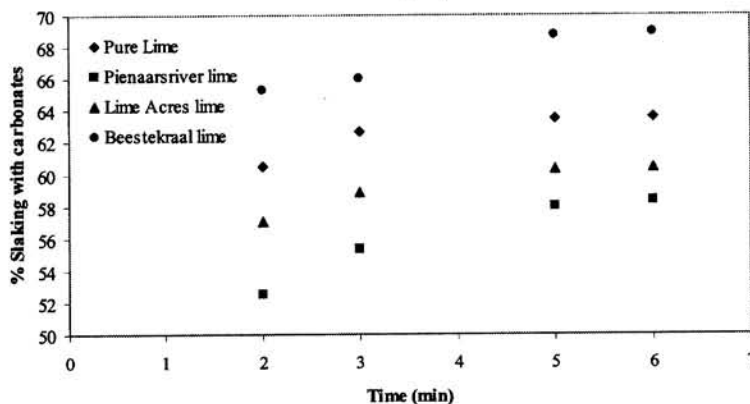


Figure 10
The effect of carbonate ions on the hydration rate of various limes



However, the degree of hydration becomes practically the same from about 1.5 min onwards. If one compares the solubility of CaCl_2 and $\text{Ca}(\text{NO}_3)_2$ in standard tables (CRC, 1980), it is evident that calcium nitrate is more soluble than calcium chloride in both cold and hot water. This is in agreement with the trends observed in Figs. 1 to 4.

The effect of additions of solutions containing anions which form sparingly soluble compounds with calcium ions, on the slaking rate of the various limes, is graphically shown in Figs. 5 to 8. In all the cases the additions of Na_2CO_3 , Na_2SO_4 and Na_3PO_4 had a retarding influence on the hydration rate of all the limes evaluated. The curves depicted in Figs. 5 to 8 clearly indicate that the retarding effect of the various anions increased in the order $\text{SO}_4^{2-} < \text{CO}_3^{2-} < \text{PO}_4^{3-}$ regardless of the lime evaluated. If one compares this with the solubility products of the different calcium compounds that are formed in each case with the anions present in the slaking water (CRC, 1980; Zoltek, 1974), it can be seen that the sequence of retardation correlates with the solubility of the various compounds, with sulphate having the smallest effect of the three ions investigated, and phosphate having the largest effect on the hydration rate of the different limes.

The effect of the geological origin and chemical composition of the lime also play a role in the observed slaking behaviour. This is illustrated in Figs. 9 and 10 for one anion enhancing the slaking rate (NO_3^-) and one anion (CO_3^{2-}) retarding the slaking rate of each lime. This is in agreement with previous observations by the same authors (Gheeverhese et al., 2002; Potgieter et al., 2003b) that the geological origin and chemical composition of the lime also play a role in the observed slaking behaviour. In this investigation, it was found that the hydration occurred to a greater degree in the sequence:

Pure lime > Pienaarsriver > Lime Acres / Beestekraal

wherever an anion that enhances the solubility of the lime was added to the solution. In cases where the added anion decreased the solubility of the lime, the sequence was generally:

Beestekraal > Pure lime > Lime Acres / Pienaarsriver

Conclusions

The following conclusions can be drawn from this investigation:

- The hydration rate of lime is enhanced upon the addition of anions that form more soluble calcium compounds than lime to the slaking water.
- The initial enhancement of the slaking rate of lime is greater for nitrate than for chloride, which is in agreement with the fact that calcium nitrate has a higher solubility in water than calcium chloride.
- The hydration rate of lime is decreased upon the addition of anions that form less soluble calcium compounds than lime to the slaking water.
- The decrease in the degree of hydration increases in the order of $\text{SO}_4^{2-} < \text{CO}_3^{2-} < \text{PO}_4^{3-}$, which is in agreement with the decrease in the solubilities of the corresponding calcium compounds with these anions.
- The increase in lime slaking by Cl^- and NO_3^- , as well as the decrease caused by SO_4^{2-} , CO_3^{2-} and PO_4^{3-} ions have been quantified and this could assist in practical applications of lime in industry.

Acknowledgements

The National Research Foundation (NRF), the Technikon of Pretoria, the University of Pretoria and the Medical University of South Africa (Medunsa) are gratefully acknowledged for financial assistance.

References

- CRC HANDBOOK OF CHEMISTRY & PHYSICS (1980) CRC Press Inc. Boca Raton, Florida, USA. B220: B64-67.
- GHEEVARHESE O, STRYDOM CA, POTGIETER JH and POTGIETER SS (2002) The influence of chloride and sulphate ions on the slaking rate of lime derived from different limestone deposits in South Africa. *Water SA* **28** (1) 45-48.
- MOROPOULOU A, BAKOLAS A and AGGELAKOPOULOU E (2001) The effects of limestone characteristics and calcination temperature to the reactivity of the quicklime. *Cem. & Concr. Res.* **31** 633-639.
- POTGIETER JH, POTGIETER SS, MOJA SJ and MULABABAFUBIANDI AF (2002) An empirical study of factors influencing lime slaking: Part I. Production and storage conditions. *Min. Eng.* **15** 201-203.
- POTGIETER JH, POTGIETER SS and DE WAALD (2003a) An empirical study of factors influencing lime slaking: Part II. Influence of material and water composition. *Water SA* **29** (2) 157-160.
- POTGIETER SS, GHEEVARHESE O and STRYDOM CA (2003b) The effect of ultrasonic energy on the slaking of lime. *Min. Eng.* **16** (8) 767-770.
- ZOLTEK J (Jr) (1974) Phosphorus removal by orthophosphate nucleation. *J. Water Pollut. Control Fed.* **46** (11) 2498-2519.
-