Lime Characterisation Manual

(Project SMaRT)

User Guidance

This illustrative manual was produced as part of Project SMaRT (Safer Management and Reliable Treatment of faecal sludge in humanitarian setting) and focusses on a simple, portable field-based approach for establishing the quality of lime supplies. Enhanced understanding of the quality of lime supplies (percentage of available lime) following characterisation is important as it can improve confidence in lime dosing. What's more it can help reduce reliance on costly imported supplies during humanitarian emergencies, such as armed conflicts and/or waterborne disease outbreaks.

The manual is principally designed for practitioners including non-governmental and public implementing organisations operating in low-resource settings, such as at field laboratories located at faecal sludge treatment facilities.

Project SMaRT partners from the University of Brighton, Médecins Sans Frontières and BRAC, Bangladesh would like to thank the funder Elrha for their support and guidance, the Mineral Products Association (formally the British Lime Association) for provision of characterised lime supplies and the not-for-profit design company Roots and Wings C.I.C for their creative input. This manual is one of a series of three funded and supported by Elrha's Humanitarian Innovation Fund (HIF) programme, a grant making facility which improves outcomes for people affected by humanitarian crises by identifying, nurturing and sharing more effective, innovative and scalable solutions. Elrha's HIF is funded by aid from the UK Foreign, Commonwealth and Development Office (FCDO). Elrha is a global charity that finds solutions to complex humanitarian problems through research and innovation. Visit www.elrha.org to find out more.

This manual has been developed to assist those working in emergency humanitarian settings where resources, including time, may be limited due to the urgent nature of the response. The manual is intended to support decision making and should complement, rather than substitute, sound professional judgement. The authors and publishers do not guarantee or accept legal liability of whatever nature arising from or connected to the content of this manual.

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Introduction

Lime Quality: The primary factor determining lime quality is the percentage of available lime, either as calcium oxide (CaO), or calcium hydroxide ($Ca(OH)_2$), though it is typically quoted in terms of the equivalent CaO content (Practical Action, 1997). Therefore, pure calcium oxide (or quick lime) will have 100% available CaO, whilst pure calcium hydroxide, or slaked (hydrated) lime will contain approximately 75.56% available CaO. The less lime that there is 'available', then the greater the quantity of lime that would need to be used and transported to site.

Project SMaRT sought to identify a simple, novel, portable field-based approach with which to test the 'percentage of available lime' and hence establish the quality of lime sources. This in turn should help to reduce current uncertainties surrounding lime dosing*

Improvements in our understanding of lime quality can also facilitate the downstream production of **simplified dosing protocols**, based quantities of available lime needed to achieve a particular pH. Lime testing can not only help determine if it is possible to reduce overall lime consumption at Faecal Sludge Treatment Plants (FSTPs) but can help ensure the maintenance of treatment efficacy. Importantly, the **field-based characterisation** of lime may also help to improve confidence in the use of less well-characterised, locally sourced, lime supplies. Thereby reducing reliance on more costly, imported lime stocks.

A review was undertaken of the available scientific and commercial literature (Mineral Products Association (MPA)) as part of an Elrha-funded initiative (Project SMaRT), in order to identify potential methods for the field-based characterisation of lime. The literature revealed that it is easier to test the quality of 'lime' when it is in the form of calcium oxide (quick lime) and this would be the case if the lime were sourced direct from a kiln before the kiln operator had started to hydrate it (Practical Action, 1997). However, given that quicklime (CaO) will deteriorate if left exposed to the elements (and because it reacts violently with water, releasing a large amount of heat that can ignite combustible material, and cause thermal and chemical burns), it has been suggested as a last resort in some guidelines (UNHCR, 2024)). Fortunately hydrated lime ($Ca(OH)_2$) tends to be more readily available.

Two methods potentially suitable for the field-based assessment and characterisation of available lime were explored and compared during laboratory trials at the University of Brighton (April – May 2023) and supported by the Mineral Products Association (MPA – formally the British Lime Association). The first method, (A) involved Heat of Hydration testing and the second, (B) involved an ASTM Rapid Sugar Test – which is relatively simple to perform, portable, relying on laboratory glassware and common lab reagents and according to Practical Action (1997), 'can be performed wherever there is a small bench or tabletop to work on, preferably in a quiet place'. There are two slightly different procedures for method B, depending on whether hydrochloric acid (HCl), or sulphuric acid (H_2SO_4) happens to be available in the field (Table 1).

*Note: This a problem faced by Médecins Sans Frontières (MSF) at Cholera Treatment Centres in NE Syria

(A) Heat of hydration Test Method

This method uses simple field-based laboratory items to measure the maximum temperature generated (and rate of temperature increase) during the heat-producing (exothermic) reaction of lime with water and is a good indicator of the quality of the lime (in terms of available CaO). However, it is primarily suitable for comparing the reactivity of different quality quicklimes (Practical Action, 1997) and therefore, Method B was deemed more appropriate for the needs of Project SMaRT as it could also be applied to hydrated lime.

Table 1. Summary of potential field-based lime characterisation methods and their advantages and disadvantages

Method	Advantage	Disadvantage
(A) Heat of hydration Test Method*	Uses simple field-based laboratory items; rapid; suitable for testing calcium oxide 'quick lime' (CaO)	Unsuitable for use with Hydrated Lime ($Ca(OH)_2$)
(Bi) ASTM Rapid Sugar Test Method** (using hydrochloric acid HCl)	Uses simple field-based laboratory items (can be performed wherever there is a small bench or tabletop to work on); Suitable for use with Hydrated Lime (Ca(OH)2); more accurate than H_2SO_4 method	Slightly more complex than Heat of hydration method
(Bii) ASTM Rapid Sugar Test Method*** (using sulphuric acid H_2SO_4)	Uses simple field-based laboratory items can be performed wherever there is a small bench or tabletop to work on); Suitable for use with Hydrated Lime ($Ca(OH)_2$); Sulphuric acid (battery acid) is easier to source than HCl in certain settings	Slightly more complex than Heat of hydration method; Less accurate (with results up to 3% higher than HCl method)

*Method in accordance with *Practical Action Publishing, 1997; **Boynton (1966); and
*** Geological Survey Department (the analytical chemistry lab) in Zomba, Malawi

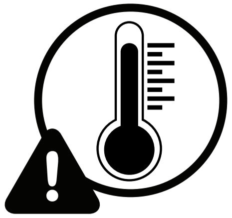
Reasons for poor quality lime - It has been suggested by the authors of Practical Action, (1997) that hydrated lime can be of poor quality for the following reasons: (i) that the original limestone had a relatively low level of calcium carbonate ($CaCO_3$) and there were other components containing magnesia (MgO), silica (SiO_2), iron, alumina, etc; (ii) that the limestone was poorly burned so that the lime still contains some of the original limestone as calcium carbonate ($CaCO_3$); and (iii) that the lime has been left exposed to the atmosphere so that carbon dioxide (CO_2) has converted some of the calcium hydroxide ($Ca(OH)_2$), back to calcium carbonate ($CaCO_3$). Where the lime has become carbonated, there may be no apparent change in appearance. What tends to happen is the lime is no longer fine, light and soft but bags of lime become harder and the lime lumpy. Good quality lime should have not more than 6% calcium carbonate. A simple test is to see if there is a reaction with dilute hydrochloric acid (HCl). There should be no obvious effect if some dilute, 10%, hydrochloric acid is dropped onto a little of the lime in a watch glass or saucer, apart from some dissolution of the lime. If there is 'fizzing' and bubbles of CO_2, then it suggests that the quality of the lime has deteriorated due to exposure, possibly due to inadequate storage conditions over a period of time (Practical Action, 1997).

Note: It has been suggested that the maximum shelf life of hydrated lime is 6-months (UNHCR, 2024). However, our characterisation of historical lime supplies stored out of the sun and in the dry at MSF's FSTP at Cox's Bazar showed that it can potentially retain its quality over a far greater periods of time and should certainly be tested, prior to disposal (even if past the recommended shelf life).

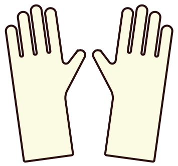
(B) Safety – Personal Protective Equipment (PPE)

SAFETY – PERSONAL PROTECTIVE EQUIPMENT (PPE)

Safety glasses, gloves and facemask should be used when handling lime and HCl solutions



Particular care must be taken when heating lime solutions



Thermally insulated gloves should be used when handling heated glassware

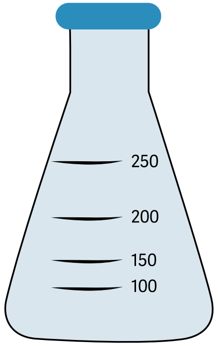
Shoes must be closed toe (no sandals) and hair tied back

The hazards of working with lime include severe chemical burns when in contact with skin, eyes or lungs.

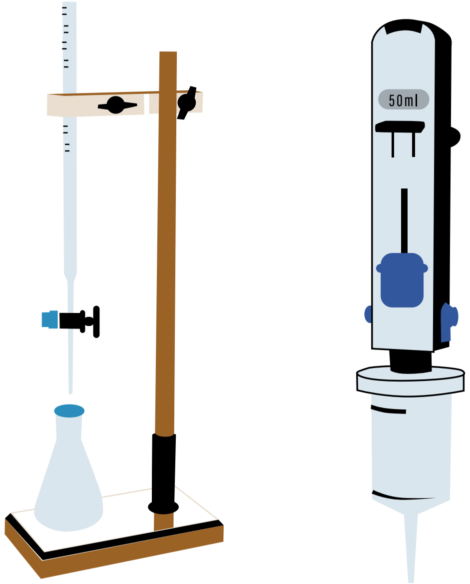
Note: Lime contact with faecal sludge can release potentially harmful Ammonia (NH_3)

Apparatus

- 250-300 mL Erlenmeyer, or conical flask having approx. volumes marked at intervals

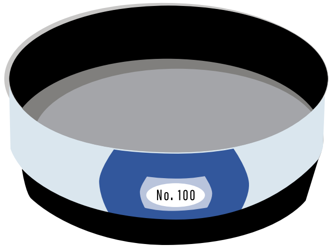


- 50-100 mL burette, with stand or multi-stepper pipette (e.g. 50mL Eppendorf)



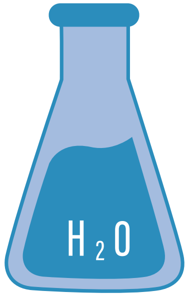
- Balance capable of weighing 0.85 g and 0.5 g to an accuracy of 2%, (i.e. to 0.01 g)

- No.100 mesh-sieve (if lime supplies are coarse)

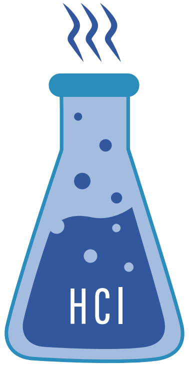


Materials

- Distilled H_2O (CO_2 free if available)

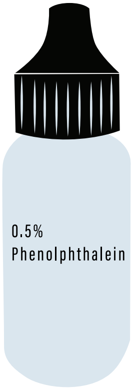


- Hydrochloric acid (HCl) 15.7 mL per litre of distilled H_2O

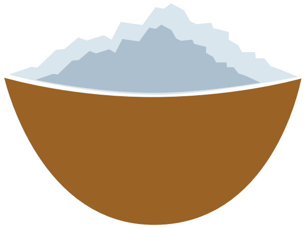


Note: Remember if handling concentrated acids do so in a fume hood and always add the acid to the H2O and not the other way around!

- 0.5% Phenolphthalein indicator

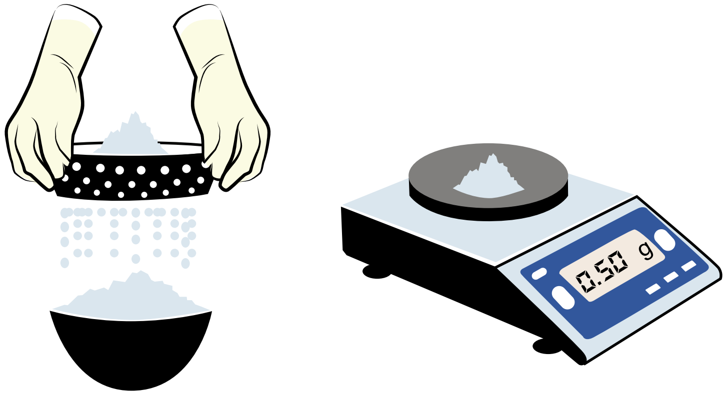


- Sucrose – granulated sugar is satisfactory – 15 g

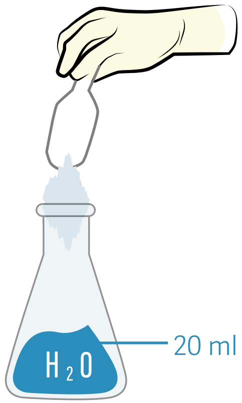


Method

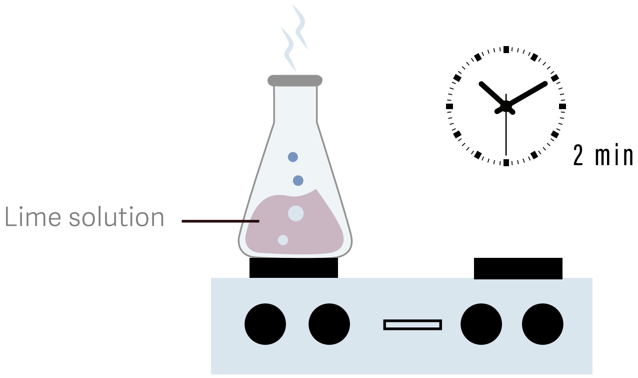
Step 1. Weigh out 0.5 grams of lime sample (No.100 mesh-sieved if coarse)



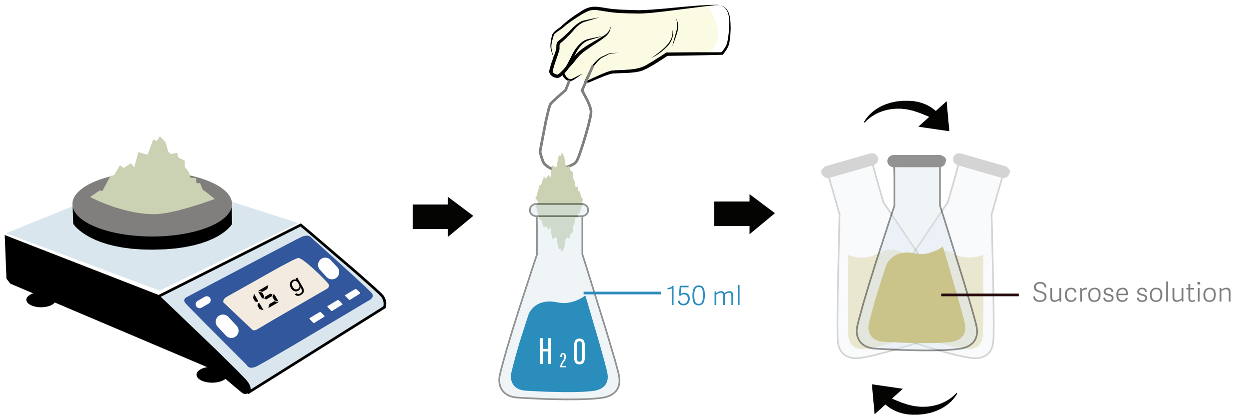
Step 2. Add the lime to a conical flask (or Erlenmeyer flask) containing 20 mL of distilled H_2O



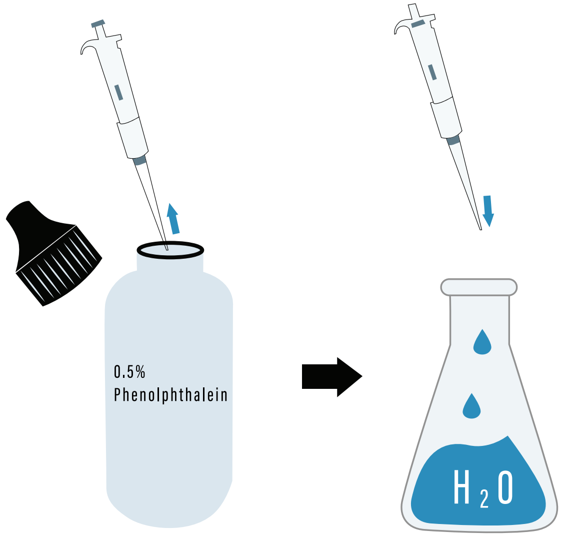
Step 3. Cover the flask. Swirl and heat to boiling for 2 mins. Remove from heat



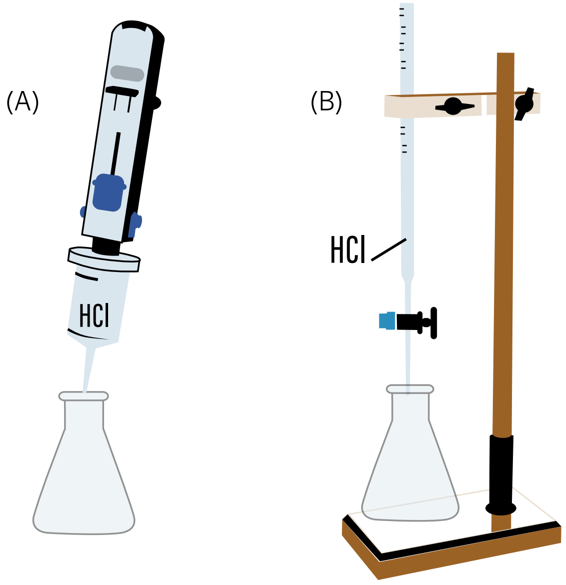
Step 4. Add 150 mL of H_2O to 15 g of sucrose. Stopper the flask, gently swirl at intervals (30 sec-1min) for 5 minutes and allow to stand for 30-60 minutes



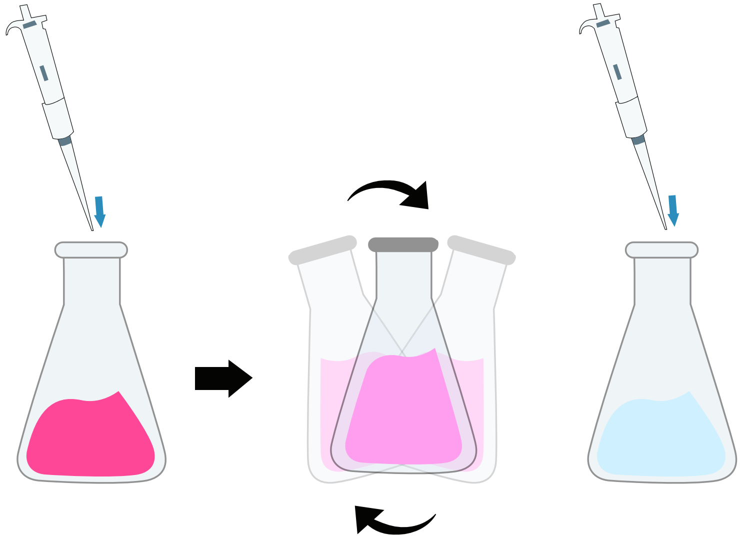
Step 5. Add 2 drops phenolphthalein indicator, wash down stopper and sides of flask with distilled H_2O.



Step 6. The HCl (acid) solution can be added using a multistep pipette (A) or alternatively a burette secured using a retort stand and clamp (B), whichever is convenient.



Step 7. Start by adding 10mL volumes of acid, while gently swirling the flask and reduce this to 1mL volumes once you start approaching the estimated amount needed to change the colour from pink to white



*** Note:** The reading as 1 mL of the acid solution is equivalent to 1% available lime expressed as CaO.

*** Note:** Standard HCl solution: 15.7 mL of HCl (specific gravity 1.18) per litre of H_2O. The solution can be standardised against 0.85 g of anhydrous Na_2CO_3 with methyl orange as indicator, so that this amount will neutralise exactly 90 mL of standard HCl solution. In adjusting for this, add more H_2O if it is too strong, or more acid if too weak.

Alternative ASTM Rapid Sugar Test Method

(using sulphuric acid H_2SO_4) in accordance with the analytical chemistry lab of the Geological Survey Department in Zomba, Malawi.

Apparatus

- As per above, but this variation on the ASTM approach uses sulphuric acid (instead of HCl) and gives values for the available CaO which are up to 3% more than those obtained when HCl is used.

Materials

- As above, but exchange HCl for '0.357N sulphuric acid'.

Directions:

Put 2.5g of lime into a 250 mL Erlenmeyer flask, add 35–45 mL of distilled H_2O and boil for 3 mins. Cool to room temperature. Mix 20 g of sucrose (sugar) in 20 mL of H_2O (= 50% solution). Add this solution to the lime in the flask and swirl for 30 mins. Add more H_2O up to the 250 mL mark. Filter through a No.1 Whatman paper. Discard the first 15–30 mL of filtrate. Pipette 25 mL into a flask. Add 5 drops of phenolphthalein. Titrate with 0.357N sulphuric acid.

Calculation:

The available lime, as CaO = mL of 0.357N acid, on the burette, x 4.

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