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Overseas Geology Series

LOCAL DEVELOPMENT OF AFFORDABLE LIME IN SOUTHERN AFRICA: PROJECT SUMMARY REPORT

CJ Mitchell¹, SDJ Inglethorpe¹, P Tawodzera², S Bradwell³ & EJ Evans¹

with contributions from

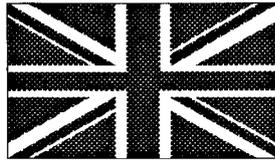
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Summary

Lime is an important and versatile chemical used in a wide range of industrial and other applications. The term lime, which strictly refers to calcium oxide (CaO), is applied to a range of products arising from the grinding, calcination and hydration of limestone and dolomite. Many less developed countries do not have adequate lime production and this leads to problems associated with under-utilisation of lime. In particular, insufficient application of agricultural lime can lead to soil acidification, with associated aluminium / manganese toxicity and poor crop yields.

As part of the UK Government's commitment to provide technical assistance to developing countries, a project was initiated to help solve this problem. The BGS/DFID project "Local development of affordable lime in Southern Africa" (R6492) carried out under the DFID Knowledge and Research (formerly the Technology Development and Research) programme aimed to encourage the development of low-cost lime for agriculture and water treatment. As part of the project, carbonate resources were matched with appropriate lime production technology to provide a methodology for the establishment of local production units.

The project was undertaken in collaboration with the Zambian Geological Survey Department (GSD), who carried out field sampling and laboratory evaluation of carbonates, and Intermediate Technology Zimbabwe (ITZ), who reviewed existing small-scale lime production practices in Zimbabwe. The project focused on agricultural lime production in Zambia, following the recommendations of a recent survey of the lime industry of the Southern African Development Community (SADC) region (AUSTROPLAN, 1990). The project was sub-divided into three main activities:

- 1) Lime evaluation programme
- 2) Small-scale lime production research
- 3) Dissemination

The aim of the lime evaluation programme was to identify carbonate resources suitable for use as lime close to the point of need. A 'market survey' was carried out to determine the demand for lime, its quality, quantity and where it is most needed. The findings indicated that Zambia has a suppressed demand for agricultural lime, especially in the Northern provinces and those provinces more heavily cultivated. Agricultural lime consumption is held back by its poor availability and relatively high cost.

A review of the carbonate resources of Zambia identified numerous dolomitic carbonates that are potentially suitable for the production of agricultural lime. Most of the carbonates occur in the Basement Complex and the Katanga Supergroup, along the line of rail from Livingstone up to the Copperbelt and North-Western provinces, as well as smaller deposits in Luapula, Northern and Eastern provinces.

Appropriate laboratory evaluation test methods were identified to determine the properties that are critical for the effective use of limestone and dolomite as agricultural lime, as follows:

- i) Plant nutrient content, especially calcium & magnesium oxide content
- ii) Neutralising ability, important for amelioration of soil acidity
- iii) Particle-size distribution, a principal factor in controlling the effectiveness of agricultural lime
- iv) Agronomic effectiveness, the rate at which agricultural lime reacts to neutralise soil acidity
- v) Ease of pulverisation (or grindability), an important factor in the production of ground limestone & dolomite

A carbonate-sampling programme resulted in the collection of 35 samples from approximately 20 sites across Zambia. All the samples were evaluated, firstly for their mineralogy and major element chemistry at the BGS, and secondly for their plant nutrient content, neutralising ability, agronomic effectiveness and ease of pulverisation at the GSD. The test results were used to “screen” the samples, those with Neutralisation Values higher than 80% calcium carbonate equivalent (CCE) and more than 6% magnesium oxide were considered to be suitable for use as agricultural lime.

The aim of the small-scale lime production research was to identify a low-cost method for the small-scale production of lime. A review of small-scale lime production practices in Zimbabwe was carried out by ITZ. The most appropriate small-scale method for the production of aglime would probably involve contract extraction, manual crushing and dressing, mechanical milling and manual bagging. The cost of producing aglime using a small-scale method would be approximately US\$29 per tonne (1997 prices). Also, the Technology Development and Advisory Unit (TDAU) at the University of Zambia (UNZA) carried out a small-scale lime production trial. A bulk sample of dolomitic carbonate from Mkushi was milled using the TD hammer mill and the resulting product was sufficiently fine grained to be used as agricultural lime.

As part of the dissemination process, a workshop was held at the Pamodzi Hotel, Lusaka in February 1998. At this meeting representatives of Government Ministries & research institutes, as well as UNZA and the farming community, met to learn of the project findings and also to discuss the ‘way forward’ for small-scale lime production and use.

Recommendations for the evaluation and production of lime are summarised below:

- i) A survey of the lime market and a review of the carbonate resources is recommended in order to identify appropriate local production sites.
- ii) Identification of suitable laboratory test procedures and a lime evaluation programme is recommended in order to identify those limestone & dolomite samples that are suitable for use as lime.
- iii) Identification and testing of production methods is recommended in order to develop the most appropriate procedure for the small-scale production of lime.

1. INTRODUCTION

This document represents the summary report of the BGS/DFID project “Local development of affordable lime in Southern Africa “ (R6492). It accompanies the project technical report (WC/97/20), which is referred to throughout this report.

Lime is an important and versatile chemical that is used in a wide range of industrial and other applications. Strictly, lime is calcium oxide (CaO or calcitic lime) and is produced by the calcination of limestone, which is formed of calcium carbonate (CaCO₃). However, the term lime has been used to denote a wide variety of different commercial products including ground limestone, calcined limestone and hydrated lime (calcium hydroxide, Ca(OH)₂). Calcitic lime, also known as burnt lime or quick lime, is normally consumed as hydrated (or slaked) lime. Dolomite, which is formed of calcium magnesium carbonate (CaMg(CO₃)₂), may also be processed to form dolomitic lime (a mixture of calcium oxide and magnesium oxide, MgO). Other forms of calcareous material may also be referred to as lime.

Lime is used as a source of calcium in the manufacture of chemicals, as a metallurgical flux, as a means of controlling the pH of industrial processes, as part of waste and water treatment, in sugar refining, in environmental applications (such as flue gas desulphurisation), in construction (mortars, plasters, limewash, as a pozzolanic additive and in soil stabilisation) and in agriculture (for soil conditioning and contribution of nutrients).

Industrial nations have either developed their own indigenous lime production or have arranged ready access to lime. In less developed countries the availability of lime can be limited, either due to a lack of limestone resources or inefficient lime production / distribution. In Southern Africa (excluding South Africa), lime production is centralised which means that, the lime produced is either too expensive or not readily available to those consumers remote from the immediate vicinity of the plant. This shortage of locally available, low cost lime is a constraint on development. Limited access to lime has serious implications. Lime is used to condition agricultural land; which if unlimed could become acidified and result in a reduction in food and cash crop yields. It is also used to purify drinking water, and to treat industrial effluent and wastewater; which if untreated could contaminate surface and ground water and pose a direct threat to human health.

As part of the UK Government’s commitment to provide technical assistance to developing countries a project was initiated to help tackle this problem. The project “Local development of affordable lime in Southern Africa” (R6492) was funded as part of the Knowledge and Research (KAR, previously the Technology Development Research (TDR)) programme of the Department for International Development (DFID). The objectives of this project were to encourage the development of low-cost lime for agriculture and water treatment. As part of the project, carbonate resources were matched with appropriate lime production technology to provide a methodology for the establishment of local production units.

This methodology was developed using Zambia as the focal point. A recent survey (AUSTROPLAN, 1990) of the SADC (Southern African Development Community) region highlighted the priorities for future development of the lime industries of the individual countries. The survey report concluded that Zambia has a need to increase its production of agricultural lime (aglime) but Zimbabwe, in contrast, has a need to develop production of high-quality burnt lime. It was decided to focus the project on the development of aglime because there is a strong need for locally available low cost aglime in many SADC countries. The methodologies developed in Zambia could easily be translated to many of the other countries in the SADC region whether their priorities are for the development of agricultural or burnt lime production.

2. PROJECT METHODOLOGIES

The objective of the project, i.e. to encourage the development of locally available, low cost aglime, could be achieved by firstly identifying suitable resources of carbonate rocks close to the point of use and secondly by investigating appropriate low cost means of production. To this end the project was sub-divided into three main activities:

1) Lime evaluation programme

The aim of the lime evaluation programme was to identify carbonate resources suitable for use as lime close to the point of need. This involved a 'market survey' of lime use and a review of the carbonate resources of Zambia. It also involved the development of appropriate laboratory test methods which were applied to the evaluation of carbonate rocks, collected across Zambia, at the Zambian Geological Survey Department.

2) Small-scale lime production research

The aim of this research was to identify a low-cost method for the small-scale production of lime. This involved a review (conducted by Intermediate Technology Zimbabwe (ITZ)) of the methods used by small-scale lime producers in Zimbabwe. It also involved small-scale lime production trials (carried out by the Technology Development and Advisory Unit at the University of Zambia (TDAU, UNZA)) using a Zambian-produced hammer mill.

3) Dissemination

The aim of the dissemination was to publicise the findings of the project, especially the methods of producing locally available, affordable lime. This involved a one-day workshop that was held in Lusaka and was attended by staff from Government Ministries and research institutes, lime producers, the farming community and the media.

3. LIME EVALUATION PROGRAMME

3.1. Lime market survey

A survey of the state of the aglime market in Zambia was undertaken as a first step in addressing the need to produce low cost lime at, or as close as possible, to the point of use (Section A of the project technical report). This survey aimed to determine the demand for lime, its quality, quantity and where it is most needed. These aims were largely met by reviewing data and information contained in existing literature. In addition, a 'questionnaire mailshot' was initiated to determine the actual usage of aglime, its cost and availability. Approximately 800 questionnaires were despatched, of which 1 in 10 were returned from 7 out of the 9 Zambian provinces.

The demand for aglime in Zambia has been estimated at approximately 37,000 tonnes a year. However, the potential demand for aglime is estimated to be much greater, somewhere in the region of 140,000 tonnes per year. This is based on the amount of aglime that would be required to neutralise natural soil acidity and to counteract the acidifying effect of nitrogen-based fertilisers (Shitumbanuma & Simukanga, 1995).

Aglime can be defined as material having "the necessary qualities to neutralise acidic soils and provide essential nutrients to promote plant growth". Ground limestone is the most common form of aglime. The effectiveness of aglime depends upon its neutralising value and its fineness of grinding. Dolomite is preferable as not only does it have a higher neutralising value than limestone, but also it contributes both calcium and magnesium to the soil. The ideal aglime is a dolomitic carbonate that has been ground to a particle-size 100% finer than 2 mm, of which 60% is finer than 400 microns and 40% finer than 150 microns. The quality requirements of lime used in agriculture can be defined using the following criteria:

i) Plant nutrient content

Typically expressed as the weight percentages of calcium oxide (CaO) and magnesium (MgO) oxide contents.

ii) Neutralisation ability

This is a measure of the amount of carbonate available for the neutralisation of hydrogen ions (H^+) present in the soil. Expressed as the weight percentage of Calcium Carbonate Equivalent (CCE).

iii) Agronomic effectiveness.

Typically expressed as the percentage reactivity. This is a measure of the ability of the liming material to neutralise a fixed volume of acid. Expressed as the percentage of neutralisation achieved (100% being complete).

iv) Ease of pulverisation, or grindability.

This indicates the relative ease of grinding of a carbonate rock. Expressed as the weight percentage of material finer than 75 microns after milling under standard conditions.

The quantity of aglime currently produced in Zambia is equivalent to the estimated demand, approximately 37,000 tonnes per year. The known quantity of carbonate resources potentially available for use as aglime in Zambia exceeds 500 million tonnes.

Carbonates are used to condition soils where fertilisers are used. Continued use of nitrogen-based fertilisers has an acidifying effect on soil. Fertiliser is extensively used by the medium to large scale commercial farmers who mainly work along the line of rail from Livingstone to the Copperbelt. Soil acidity is associated with aluminium and manganese toxicity and reduced crop yields. Liming can prevent acidification, reduce aluminium and manganese toxicity, and increase calcium and magnesium availability to plants. High soil acidity (<4.5 pH) occurs in those parts of Zambia, generally the Northern provinces, where average annual rainfall exceeds 1000 mm per year. Downward movement of water through soil leaches out the bases, such as calcium and magnesium. This has the consequence of concentrating hydrogen and aluminium ions and increasing soil acidity. Also soil acidification has become exacerbated by the increased frequency between cycles of the traditional *Chitemene* (slash-and-burn) cultivation method. Increasing population has put pressure on this method, with a consequent reduction in the fallow periods between burning & cultivation, which has helped increase soil acidity. Therefore, there is a need for aglime in the northern provinces of Zambia and also along the line of rail down to Livingstone.

The questionnaire mailshot provided some interesting information, which is summarised in Table 1. Respondents indicated that they apply aglime every 2 to 3 years, before ploughing (as shown in Plate 1), as a means of controlling soil pH. The majority of respondents follow the Government guideline by applying 1 to 2 tonnes of aglime per hectare. The price of using aglime (product plus transport costs) varies from less than 64US\$ to over 160US\$ per tonne. Most respondents travel over 100 km (over 800 km in one extreme example) to collect their aglime from lime producers (such as from Lilyvale Farm, shown in Plate 2 and Mindeco Small Mines Ltd, as shown in Plate 3) and identify the transport costs as one of the main problems associated with its use.

Table 1. A summary of the findings from the questionnaire survey of lime users

57% of respondents use aglime every 2-3 years
81% of respondents use aglime to prevent soil acidity
53% of respondents use aglime before ploughing
63% of respondents use 1 – 2 tonnes of aglime per hectare
53% of respondents pay more than 64US\$ per tonne of aglime (1997)
83% of respondents buy aglime from a lime producer
59% of respondents travel more than 100 km to buy aglime
50% of respondents identify transport costs as the main problem associated with the use of aglime

The market survey found that there is a relatively large latent demand for aglime in Zambia. The discrepancy between latent and actual demand for aglime is probably due mainly to its cost but also to a lack of awareness of its need, especially amongst emergent



Plate 1. Farmland after application of agricultural lime (Mr Mwandira, Ndola, Zambia)



Plate 2. Opencast limestone quarry, Lilyvale Farm, Kabwe, Zambia

and subsistence farmers. This is supported by anecdotal evidence, which indicates that the larger scale commercial farmers, who have ready access to transport and finance, actively benefit from the use of aglime. Whereas, poor availability, high transport costs and ignorance of its benefits impedes the use of aglime by the smaller scale farmers.

The recommendations of the studies carried out over the last 15 years would be to place aglime plants throughout Zambia to serve the provinces e.g. Chivuna (Southern Province), Mkushi (Central Province), Nyimba (Eastern Province), Isoka (Northern Province), Matanda (Luapula Province) and Solwezi (North Western Province). Recent efforts to establish a lime plant at Chivuna failed. This was partly due to the excessive cost of the plant (>US\$750,000), overly ambitious scale and the reliance on centralisation. Cost of transportation is acknowledged as a problem, however the closest these studies come to solving this problem is to suggest subsidies on aglime (generally politically unacceptable) or infrastructural investment (expensive and slow). The perceived lack of demand limits the designs and cost projections for aglime plants. Most plants are designed to operate at high throughput capacities, which gives relatively low production costs per tonne. Reducing throughput capacity will therefore result in a relatively high production cost per tonne. A small-scale plant using appropriate technology and local labour would keep production costs low. Farming co-operatives could manage these plants and co-ordinate lime production to suit the needs of members.

3.2. Review of the carbonate resources of Zambia

A review of the carbonate resources of Zambia was undertaken to identify carbonate rocks potentially suitable for use as aglime, especially in those areas with a need for liming (Section B of the project technical report).

Information regarding the carbonate resources of Zambia is patchy and comes mainly from two sources, the Geological Survey Department and the former MINEX (Mining Exploration) Department. Minor sources include reports from UNZA, UNDP/UNIDO (United Nations Development Programme / United Nations Industrial Development Organisation), NORAD (Norwegian Agency for International Development), SADC (Southern African Development Community) and BGR (the German Federal Institute for Geosciences and Natural Resources).

Carbonate rocks are known to occur throughout Zambia, especially along the line of rail from Livingstone to North-Western Province, with some carbonates occurring in Luapula, Northern and Eastern provinces (Plates 4 and 5). Western Province apparently has no carbonates. Most of the carbonates occur in the clastic sequences of the Katanga Supergroup, with a smaller proportion in the older underlying Basement Complex.

The chemistry of selected dolomitic carbonates is given in Table 2. The Basement Complex consists of the Lufubu and the Muva Supergroup. The carbonates occur as calcitic and dolomitic marbles, occasionally banded and often associated with calc-silicate rocks.



Plate 3. Small-scale ground lime production, Mindeco Small mines Ltd, Lusaka, Zambia



Plate 4. Exposure of dolomitic marble, Chivuna, Zambia

Table 2. Chemistry of selected dolomitic carbonates, Zambia

Stratigraphy	CaO (wt %)	MgO (wt %)
Basement Complex Sasare Group	38.1*	12.6*
Lower Katanga Supergroup Mujimbeji Marble, Monze Group, Mampompo Limestone, Broken Hill Group Upper Roan Formation, Mine Series Group	29.4 33.0* 28.62 – 55.86*	18.2 20.0* 0.4 – 27.72*
Upper Katanga Supergroup Kakontwe Limestone, Kundelungu Group Muchinda Limestone, Kundelungu Group Luapula Beds, Kundelungu Group! “Mkushi Dolomite”, Kundelungu Group	30.7 30.1* 28.6 28.2	20.8 16.0* 17.8 20.6
Undifferentiated Katanga Supergroup Mapanza Carbonate Formation Mvuvye Marble, Mvuvye Group	28.8* 28.1	17.0* 27.5
Nkombwa Hill Dolomitic Carbonatite	24.0	19.0

NB Values are averages unless marked with *

Carbonates younger than the Katanga are restricted to argillaceous limestones (Madumbisa Formation) in Southern Province and impure calcretes in Western Province. Carbonatites (igneous carbonates) occur in Northern and Eastern provinces. The most significant of these occurs at Nkombwa Hill, near Isoka in Northern Province and consists of white, fine to coarse-grained banded to massive dolomitic carbonatite.

Carbonates potentially suitable for use as aglime were identified from this review and incorporated into a sample collection programme. A magnesium oxide (MgO) content greater than 6% was used as the selection criterion.

3.3. The laboratory analysis of limestone and dolomite for use as agricultural lime

As part of the lime evaluation programme appropriate laboratory methods for the evaluation of limestone and dolomite for use as aglime were reviewed and tested (section C of the project technical report). The key technical properties of limestone and dolomite in relation to their effectiveness for use as aglime were identified as the following:

Calcium and magnesium are essential plant nutrients, and their levels within limestone and dolomite used as aglime needs to be quantified. American (ASTM) and British (BS) methods (wet chemical analysis) exist for the determination of the CaO and MgO content of limestone and dolomite. UK recommendations indicate that 15% MgO is a minimum for dolomitic limestone sold as aglime, whereas in Zambia >6% MgO is recommended (Tether & Money, 1986).

Particle-size is a principal factor in controlling the effectiveness of aglime. Aglime should contain at least 80% <2.36 mm (Barber, 1984). Commercial products contain up to 55% <0.15 mm. The proportion <0.25 mm can be related to the “effectiveness” of aglime i.e. the degree of dissolution within the soil after 3 months. Particles coarser than 0.85 mm have comparatively little agronomic value, whereas those finer than 0.25 mm completely dissolve within a year and those finer than 0.15 mm react very quickly upon contact with soil. The effect of particle-size is moderated to some extent by other factors such as the degree of spreading and soil moisture.

Amelioration of soil acidity is a prime function of aglime. Nutrient availability and plant growth are maximised at neutral pH. The neutralising capacity of aglime is expressed in terms of the calcium carbonate equivalent (CCE) i.e. the acid neutralising ability expressed as the weight percent of calcium carbonate (% CaCO₃). Pure limestone has a CCE of 100% whereas dolomite has a CCE of 108%. An ASTM method exists for the measurement of CCE. In the UK neutralising ability is expressed as percent calcium oxide (% CaO) and is known as the neutralisation value (NV). The overall effectiveness of aglime can be determined by relating the degree of fineness to the CCE.

Reactivity is defined as the rate at which aglime will neutralise a soil. The relative proportions of dolomite and calcite, the degree of fineness and the physical properties such as porosity and hardness influence reactivity. The most appropriate method for this work involved determination of reactivity using a “resin suspension” which simulates in the laboratory the interaction between an aglime and soil.

Grindability is an indication of the ease of pulverisation of limestone and dolomite. This is useful as the production of aglime involves grinding. The ASTM method involves the determination of the proportion of <0.075 mm material produced from samples of limestone and dolomite by standard milling conditions. The higher the proportion of <0.075 mm material the easier the limestone or dolomite was to grind.

In the UK, aglime products conform to strictly defined parameters, typically the neutralising value and the proportion of material finer than 0.15 mm.

An objective of the project was to establish a laboratory at the Zambian Geological Survey Department for testing limestone and dolomite for use as aglime. Five properties were identified as being particularly useful for such a laboratory evaluation including: neutralisation value (CCE), plant nutrient content (CaO / MgO content), ease of pulverisation (grindability), fineness (dry sieve analysis) and agronomic effectiveness (reactivity). Laboratory trials were carried out at the BGS, using samples of limestone and dolomite collected from Zambia, to validate the test methods chosen to determine these key properties. A summary of the results is given in Table 3.

Table 3. Results of the laboratory trials carried out at the BGS

Sample	CCE ¹ (%)	CaO ² (wt %)	MgO ³ (wt %)	Grindability ⁴ (wt %)	Reactivity ⁵ (%)
1. Dolomite (Chivuna, Southern Province)	106	31.3	25.39	64.0	65.9
2. Limestone (Masangu Farm, Mazabuka, Southern Province)	97	53.88	0.68	67.2	86.8
3. Dolomitic limestone (Ndola Lime Ltd, Copperbelt Province)	99	51.57	3.20	84.2	89.3
4. Dolomitic limestone (Ndola Lime Ltd, Copperbelt Province)	99	53.32	1.48	78.6	91.58
5. Dolomite (Solwezi, NW Province)	107	30.47	23.64	41.1	70.4
6. Dolomite (Chombela, NW Province)	107	32.28	23.67	51.3	71.7

NB 1 = Neutralisation values is expressed as percentage Calcium Carbonate Equivalent (CCE), 2 & 3 = Plant nutrient content is expressed as weight percentage Calcium Oxide and Magnesium Oxide respectively, 4 = Ease of pulverisation (grindability) is expressed as the weight percentage of material finer than 75 microns after standard milling conditions, 5 = Agronomic effectiveness is expressed as percentage reactivity.

The dolomites (1, 5 & 6) have the highest neutralising ability. There is a good correspondence between the CaO & MgO results obtained by wet chemical analysis and XRF, although the former tended to underestimate MgO and overestimate CaO. Generally, the limestones (2, 3 & 4) were easier to grind than the dolomites. Reactivity tests were carried out upon the ground products from the grindability test. Generally, the softer limestone samples are more reactive than the harder dolomite samples.

3.4. Lime evaluation programme: results & findings

As part of the lime evaluation programme a suite of limestone and dolomite samples was collected from across Zambia and evaluated to determine their suitability for use as aglime (Plate 6). A complete listing of all the samples collected (including locality grid reference, brief lithological description and lithostratigraphy) is given in Section D of the project technical report.

The mineralogy and chemistry of the samples was determined by petrographic analysis and X-ray fluorescence analysis carried out at the BGS. Also, the samples were evaluated using the test methods, identified in 3.3, in a laboratory established at the Zambian GSD (Appendices D1 – D3 in Section D of the project technical report).



Plate 5. Outcrop of dolomitic marble on the banks of the Luapula River, Matanda, Zambia

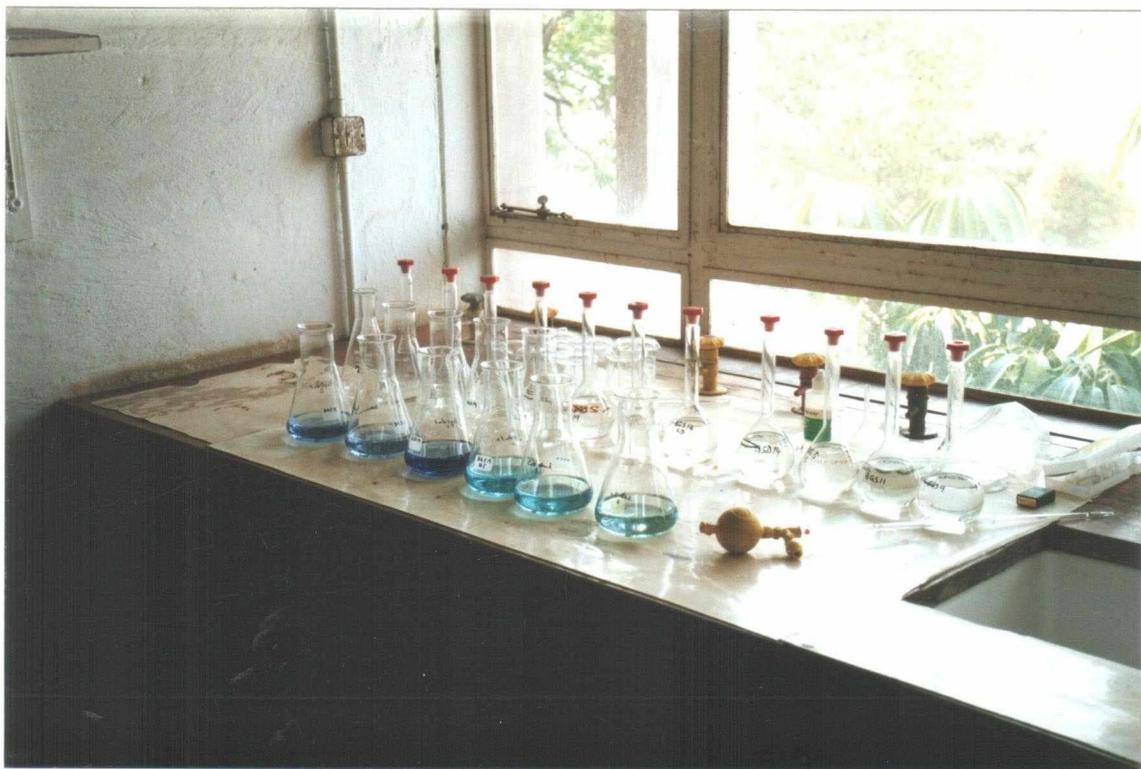


Plate 6. Lime evaluation laboratory, Geological Survey Department, Lusaka, Zambia

The test work revealed that the dominant rock types sampled were dolomitic marbles, marbles and dolomites. Using the results of the test work the samples were “screened” to identify those suitable for use as aglime. The most important criteria for aglime are its neutralising ability, as well as its plant nutrient content (especially magnesium). Those samples with a Neutralising Value higher than 80% CCE and a magnesium oxide content higher than 6% were considered to have potential for use as aglime (as listed in Table 4).

Table 4. Samples with potential for use as agricultural lime

Sample	Neutralisation Value % CCE	MgO Wt %	CaO Wt %	Reactivity %	Grindability % < 75 µm
1 Dolomitic marble Chivuna Limestone, Chivuna	106	21.83	30.24	65.9	64.0
5. Dolomitic marble Mujimbeji Marble, Solwezi	107	21.86	30.96	70.4	41.1
6. Dolomitic marble Mujimbeji Marble, Chombela	107	20.08	33.06	71.7	51.3
10. Dolomite Upper Roan Fm, Mpongwe	105	18.59	43.4	89.3	97.1
11. Dolomite Muchinda Limestone, Lilyvale Farm, Kabwe	106	21.55	31.22	84.2	97.2
18. Dolomite Mujimbeji Marble, Lukunyi	106	21.31	30.93	73.7	98.0
29. Dolomitic marble Lower Roan Fm, Mkushi	103	20.94	29.6	63.2	98.4
30. Dolomitic marble Lower Roan Fm, Mkushi	104	21.25	30.04	68.4	98.6

4. SMALL-SCALE LIME PRODUCTION RESEARCH

4.1. Review of lime production

A review of the methods used by small-scale lime producers was carried out as part of the research aimed toward identifying a low cost method of producing lime (Section E of the project technical report). Intermediate Technology Zimbabwe (ITZ) based in Harare carried out the review by visiting lime producers, equipment manufacturers and suppliers throughout Zimbabwe. The review encompassed the different approaches taken to extract and process carbonates during the production of ground and burnt lime (including those methods undertaken manually and/or employing appropriate technology). Production of lime involves the following processes:

- i) Removal of overburden (“stripping”). Soft or unconsolidated material can be removed manually using hammers, picks, shovels and wheels barrows. Harder material may require the use of graders, bulldozers or rippers.
- ii) Extraction / quarrying. Opencast quarrying is preferred. Soft forms of carbonate (such as calc-tufa) can be removed manually using picks, hammers and crowbars. Harder carbonates may require drilling and blasting.
- iii) Dressing, to reduce the quarried rock to a manageable size for the crushing stage. Manual dressing involves the use of sledge hammers to reduce the quarried rock from >500 mm to <200 – 300 mm. NB Soft carbonates do not require dressing.
- iv) Crushing, to reduce the dressed rock from <200 – 300 mm to <20 mm. Manual crushing is possible using hammers, but is labour intensive. Jaw crushers are a commonly used means of mechanical crushing.
- v) Grinding / milling, to reduce the crushed rock from <20 mm to <2 mm. Manual milling is possible but is even more labour intensive than crushing. Ball mills and hammer mills are commonly used means of mechanical milling.
- vi) Screening. This is carried out to return unmilled rock for further milling. Manual screening is possible. Standing screens, rotating barrel (“trommel”) screens and vibrating screens are commonly used means of mechanical screening.
- vii) Bagging / packaging. Milled carbonate can be manually bagged, with the use of platform scales. Mechanical bagging is rarely used in small-scale lime production.
- viii) Calcination / lime burning. Crushed carbonate rock is fired using a kiln to produce burnt lime. The firing process can be carried out using one of the following means: heap burning, box or pit kilns, or vertical shaft kilns. Water is added to burnt lime to produce hydrated lime.

Production costs depend upon the nature of the material and the processes used to produce lime. Table 6 gives a summary of the production costs, considering both manual and mechanical processes.

Table 6. Costs of small-scale lime production

Production stage	Manual production (US\$)	Mechanical production (US\$)
Ground lime production		
Overburden stripping	0.13	0.85
Extraction	5.22	4.36
Dressing	4.11	As manual
Crushing	10.24	0.94
Milling	As mechanical	3.32
Bagging	3.34	As manual
Total (inc. 10 % overheads)	28.99	18.61
Burnt lime production		
Stripping, extraction & dressing	16.17	15.9
Firing & hydrating	32.93	32.93
Screening & bagging	7.34	7.34
Total (inc. 10 % overheads)	62.08	61.79

NB Assuming unconsolidated overburden (1 metre thick), 10 metre thickness of workable carbonate, 200 working days per year, built-in equipment purchase / hire / depreciation costs, and a labour cost of US\$2.50 per day.

4.2. Lime production trials

A small-scale lime production trial was carried out as part of the research aimed toward identifying a low cost method of producing lime (Section F of the project technical report). The trial was carried out by the TDAU, UNZA, using a locally manufactured mill (TD Hammer mill, as shown in Plate 7).

The TD Hammer mill is of a relatively lightweight construction, making it portable and flexible in operation. It has a milling compartment containing 12 hardened steel hammers directly driven by a small petrol engine. Mill feed is introduced to the milling compartment, by gravity, and is broken down by the flailing action of the hammers. Fine milled material drops through the screen at the base. Oversize material is retained in the milling compartment until it is reduced to a size whereby it can pass through the screen.

The aim of the milling trial was to produce ground carbonate suitable for use as aglime. An 80kg sample of dolomitic marble from Mkushi was collected and jaw crushed to pass 20 mm. This initial preparation stage represented the initial extraction, dressing and crushing stages of a small-scale production operation. The jaw-crushed carbonate was



Plate 7. TD hammer mill, as used in lime production trials by the Technology Development & Advisory Unit (TDAU), Lusaka, Zambia



Plate 8. Local development of affordable lime in Southern Africa Workshop, Pamodzi Hotel, Lusaka, Zambia

split into two equal sub-samples (each approximately 40 kg). These were used as the feed material for two separate milling trials; one using the TD Hammer mill fitted with a 1.5 mm aperture screen and the second with a 1 mm aperture screen. During the milling trials the production capacities and costs were determined. The milled products were screened to determine their particle-size distributions.

The results of the milling trials are summarised in Table 6. Both of the trials exceed the “target” particle-size distribution requirements. The material milled through 1.5 mm contains approximately 75% finer than 0.4 mm and the material milled through 1 mm contains approximately 80% finer than 0.4 mm. The 1.5 mm trial has a higher throughput capacity, as less “work” was required to mill the material to the screen size, than the 1 mm trial. This also meant that the production cost per tonne for the 1.5 mm trial was lower than for the 1 mm trial.

If anything, the carbonate has been overground, i.e. there is an excessive amount of fine-grained material. In order to avoid overgrinding the mill screen size could be increased (e.g. to 2 mm). This should have the effect of increasing the particle-size of the product, as well as increasing the throughput capacity and also reducing the production costs.

Table 6. Results of the milling trials using the TD Hammer mill

Property	Feed	1.5 mm trial	1.0 mm trial	Target
Particle-size (wt %)				
<10 mm	82.2	nd	nd	na
<5 mm	55.8	nd	nd	na
<2 mm	29.5	96.1	97.5	100
<1.5 mm	nd	94	95.7	na
<1 mm	20.6	90.8	92.8	na
<0.4 mm	nd	74.4	79.5	40
<0.1 mm	nd	63.9	79.3	na
Capacity (kg / hour)	na	174	142	na
Cost (US\$ / tonne)	na	4.76	5.66	na

NB Production cost assuming a labour cost of US\$0.12 / hour and a fuel cost of US\$0.63 / litre of petrol.

5. DISSEMINATION

As part of the dissemination of the project findings and results a one-day workshop entitled “Local development of affordable lime in Southern Africa”, was held on the 27th February 1998 in the Pamodzi Hotel, Lusaka (Section G of the project technical report). Fifty delegates attended the workshop (Plate 8) from a wide range of backgrounds including the Ministry of Mines and Minerals Development (MMMD), the Ministry of Agriculture, Food & Fisheries (MAFF), UNZA, Zambian National Farmers Union

(ZNFU), the farming community, the mineral industry and Intermediate Technology Zimbabwe (ITZ). Section G of the project technical report includes the presentation abstracts and delegate listing.

The Director of the Geological Survey Department officially opened the proceedings on behalf of the MMMD. The workshop opened with an overview on lime that related the activities of the project to the need for small-scale lime production in the SADC region. This was followed by a review of the agricultural lime potential of Zambia and testing of limestone & dolomite for use as agricultural lime: The following presentations reviewed the current research into the use of aglime, focusing on liming trials and their effect on soil chemistry and crop yields. This included work carried out for ZCCM on the evaluation of Nampundwe mine tailings as a source of aglime.

These were followed by a review of the carbonate resources of Zambia. ITZ reviewed the methods used for the small-scale production of aglime in Zimbabwe and the relative costs of production. The School of Mines, UNZA reviewed agricultural lime production in Zambia and identified the need for co-ordinated research, technical information, and the simple production methods and incentives to encourage small-scale lime production. The MMMD gave a presentation on Government policy on mining, especially in relation to the small-scale mining of limestone. This was followed by a presentation from TDAU, UNZA on the results of the milling trials carried out with the TD hammer mill.

A brainstorming session was used to ascertain the views of the workshop delegates as to the best means of encouraging the use and production of aglime in Zambia. A summary of these views, or the “way forward”, is given below (not in any order of priority):

- Economic benefit Research must demonstrate the economic benefits of liming.
- “Tolerant crops” Low crop yields could be solved by using acid-resistant crops.
- Education The benefits of using aglime needs to be demonstrated to farmers.
- Transport The cost of transporting aglime could be offset by the use of rail.
- Effective lime use Relating aglime to soil type, plus more information on aglime quality, may allow more efficient use
- Government involvement Targeted subsidies to encourage the use of aglime.
 Tax-breaks to encourage investment in the mining-sector.
- Appropriate Technology Development of the small-scale production of aglime using appropriate technology.
- Lime spreaders The absence of lime spreaders discourages its use.

The Director of the Geological Survey Department officially closed the workshop on behalf of the MMMD.

6. RECOMMENDATIONS

The recommended procedures for the evaluation and small-scale production of lime are summarised below. Figure 1 gives a flowchart for the suggested small-scale production of lime.

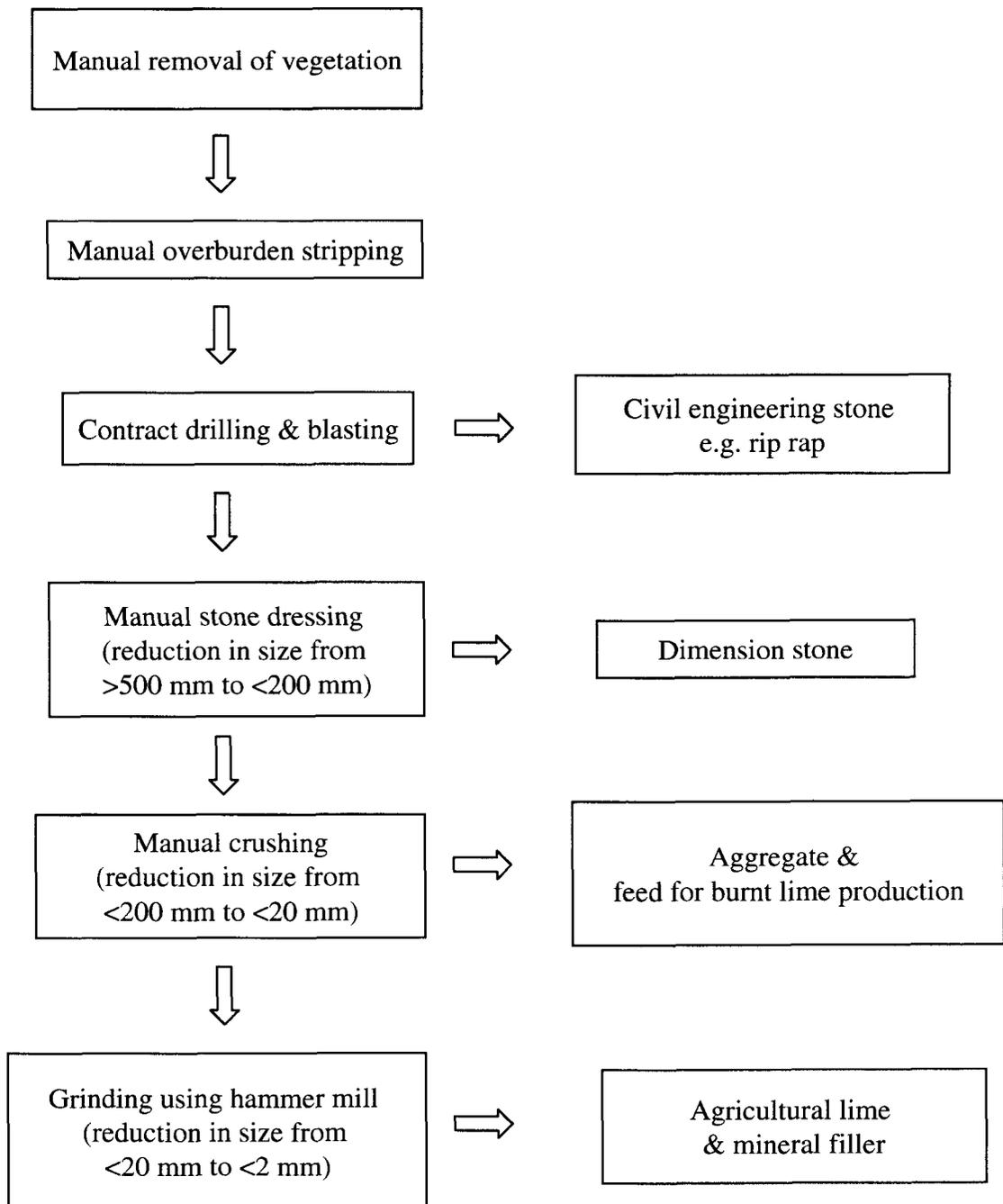


Figure 1. Recommended process route for small-scale production of lime (and other products)

Recommended survey of lime market & carbonate resources

- 1. Market survey** to determine the nature of the lime market, the quantities & qualities required, plus the constraints on production and consumption (as carried out for aglime in Zambia and detailed in Section A of the project technical report).
- 2. Review of carbonate resources** to identify the locality and nature of the limestone and dolomite resources (as carried out for Zambia and detailed in Section B of the project technical report).

Recommended laboratory evaluation procedures

- 1. Identification of laboratory procedures** for the evaluation of limestone and dolomite for use as lime (as carried out for aglime in Zambia and detailed in Section C of the project technical report).
- 2. Lime evaluation programme**, involving sampling of limestone & dolomite, evaluation in a dedicated testing laboratory and identification of those suitable for use as lime (as carried out for aglime in Zambia and detailed in Section D of the project technical report).

Recommended small-scale lime production procedures

- 1. Review of small-scale production methods and practices** to identify the most appropriate procedures for the setting and nature of the limestone & dolomite resources available (as carried out, for lime production in Zambia, by reviewing the small-scale production of lime in Zimbabwe and detailed in Section E of the project technical report).
- 2. Small-scale production trials** to determine the suitability of production methods identified in the review (as carried out for aglime in Zambia using a Zambian-built hammer mill and detailed in Section H of the project technical report).

Recommended procedure for the small-scale production of lime

Small-scale production of lime should involve, where possible, manual procedures. Avoiding mechanical production methods reduces the initial capital costs, simplifies the production process and maximises the employment potential. The recommended procedure for the production of lime is summarised as a flowchart in Figure 1. The production process should involve the manual removal of vegetation and overburden, contractors to carry out the necessary drilling and blasting (once or twice a year), manual stone dressing & crushing, mechanical grinding using a hammer mill and bagging. As well as producing ground limestone & dolomite for use as aglime, this production procedure could also satisfy the demand for aggregate, feed material for the production of burnt lime and, potentially, mineral filler for various applications (e.g. paint).

7. CONCLUSIONS

- i) A lime market survey confirmed that aglime is under-utilised in Zambia, mainly due to poor availability and cost of transportation.
- ii) A review of the carbonate resources of Zambia revealed that there is ample material for use as aglime. This was confirmed by evaluation of a suite of carbonate samples, taken from across the country and analysed at the Zambian Geological Survey Department.
- iii) A review of small-scale lime production indicated that aglime could be produced using appropriate technology. Lime production could involve contract extraction, manual crushing and mechanical milling. Successful trials using dolomitic carbonate from Mkushi indicated that milling could be accomplished using a Zambian built TD Hammer mill.
- iv) The findings of the project were disseminated at a workshop held in Lusaka. The delegates expressed their views on the future development of small-scale lime production. These touched on educating people as to the economic benefits of liming, the use of tolerant crops, effective lime use, government intervention and the use of appropriate technology.
- v) Recommendations for the evaluation and small-scale production of lime include:
 - i) Market survey of lime and a review of carbonate resources
 - ii) Identification of test methods and a lime evaluation programme
 - iii) Review of small-scale lime production and lime production trials
- vi) It is considered that the approach adopted and the methodologies developed and applied by the project are replicable elsewhere within the region, and that this could be facilitated by the SADC Mining Co-ordination Unit.

8. REFERENCES

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