CHAPTER 1
GENERAL INTRODUCTION

INTRODUCTION

Soil acidity is becoming a grave cause of concern in many parts of South Africa where many soils are very sensitive to acidification and where generally not enough lime is used. Liming materials vary considerably in type and reactivity and this contributes to the "confusion" of which lime and what quantity to use. Slags (metal industry by-products) are regularly used as a liming material on the South African Highveld due to its high acid neutralizing capacity, the proximity of the source and the nature of the soils in the area. Being a waste product, it does not cost the same amount as regular limestones and is therefore an attractive option in an industry where profit margins are low. It is furthermore beneficial to the industry to be able to use the waste product constructively as well as to remove it from the premises.

Agricultural Soil Acidification

Man induced acidification of soils is one of the major concerns in the agricultural and environmental fields today. The soil pH has a major influence on the availability of different nutrient elements (Fölscher, 1975; Sumner, 1975; Sumner, Fey & Noble, 1991) in losses through leaching of the basic cations, P fixation and N uptake by plants. It furthermore influences the pollution hazard of several heavy metals (Løbersli, Gjengedal & Steinnes, 1991). Not only does it impact on crop production on the high potential soils with high rainfall in southern Africa (Manson, 1995), but it also influences environmental aspects such as pollution of rivers and wetlands as well as increased uptake of hazardous elements by plants, animals and ultimately man.

It is estimated that in the summer rainfall area in South Africa west of the Drakensberg, a minimum of 2.7 million ha is acidified to some extent. This figure excludes the extent of acidified soils in areas of Kwa-Zulu Natal. It is furthermore estimated that a total of 2 million ha of land in the summer rainfall area is also affected by subsoil acidity (Beukes, 1995). Soil acidification occurs mainly in areas that are classified as sub-tropical with well drained soils, and in which the nitrification rate of applied N fertiliser is very rapid (Claassens, *et al*., 2000). One such area in the summer rainfall region is the Highveld of the Mpumalanga Province where many soils are very sensitive to acidification (Fey & Dodds, 1998).

Many industrial activities influence the acidifying process through atmospheric pollution (Tyson, Kruger & Louw, 1988; Held, *et al*., 1996), as well as agricultural and forestry activities (Fey & Dodds, 1998). One of the major causes of acid soils in agriculture is the oxidation of applied reduced N-fertilizers, as well as organic material, in the dryland production of crops (Theron & Haylett, 1953; Theron, 1961). This is a global problem, especially in tropical and sub-tropical regions – when reduced N-fertiliser is applied excessively (Wallace, 1994). Without an accompanying liming program, the large-scale application of acidifying fertiliser in summer rainfall production of crops leads to highly acidified soils, especially when well drained and poorly buffered (Adams & Pearson, 1969). Wallace (1994) states that ammonium sources of nitrogen produce the equivalent of 3.5kg sulphuric acid per kilogram nitrogen and that 3.57kg pure $CaCO_3$ per kilogram of applied nitrogen fertiliser is required to neutralise its effect. This translates into the necessity of applying the equivalent of a ton of pure calcite to neutralise the acidity generated by the applied N-fertiliser (Bornman, 1993).

For the effective uptake of nutrients by plants and therefore the effective utilisation of fertilisers, the soil pH must be at an optimum (generally between pH 5.5 and 6.5 in water for most commercial crops). The excessive use of acidifying fertilisers therefore has a negative effect on the uptake and utilisation of other nutrients, thereby increasing the cost of fertilisation. South African figures quoted by Bornman (1985) indicate that the use of N fertilisers increased drastically without an increase in the use of lime – a recipe for the large-scale acidification of soils. As mentioned earlier, this is a global problem, one that has also caused much comment in countries like the USA, Australia, and countries in South America.

Lime Reactivity and Lime Requirement

A factor compounding the problem of inadequate lime use is the fact that in some cases the reactivity of the lime is far from desired levels (Fölscher & Bornman, 1985; Claassens *et al*., 2000). This would not be such a big problem if the users of the lime were correctly informed with respect to the reactivity of the lime they use. Lime from different sources and fineness react differently, therefore creating a further problem for the user. Bornman (1985) developed the Resin Suspension Method (RSM) to predict the reactivity of liming materials. This method, having gained wide acceptance in South Africa, still lacks the international exposure it deserves – an aspect addressed by Claassens *et al*., (2000).

Slags as Liming Materials

Slags are regularly used as liming materials in agriculture due to its high acid neutralising capacity. They originate from a purification step in the manufacturing of steel and different alloys. Lime is added to the molten ore to precipitate different phosphorus and silica compounds that are naturally found in the ore. The precipitate forms foam that is separated from the melt and is discarded in heaps. From here the solidified slag is crushed and then used as and agricultural lime.

Slags contain impurities derived from ore processing, including many heavy metals that hold a potential threat to the environment. The type of impurity depends on the source of the ore and can reach levels of several parts per thousand. Many studies have been done on the effect of heavy metals in the environment and its bioavailability, but most of these have focused on sewage sludges. The "lack of interest" could possibly be ascribed to the fact that the application of slags increases the pH of the acid soils. The solubility or availability of many heavy metals is reduced and therefore poses a very decreased threat compared to metals applied in other materials such as sewage sludges.

In the past slags have also regularly been used as a phosphorus fertiliser mainly due to the high P content. Presently this is not the case due to lower P contents, although there is still the possibility of a beneficial effect on the mobilization of soil P through the application of silica in the slags (Hingston, *et al.*, 1967; Ivanov, 1992)

The guidelines in terms of recommended maximum levels of heavy metal application to soils accepted for South Africa are based on the use of sewage sludge and not slags. Maximum heavy metal concentration guidelines are sometimes difficult to use due to the naturally high concentrations of certain elements in South African soils. The Guidelines need to be refined and updated for the use of slags but this cannot be done without a proper understanding of how slags and the heavy metals therein behave after application. With ever increasing emphasis on and awareness of sound environmental practices, the use of slags has lead to questions with respect to its effect on the environment.

Testing of Slags

When the testing of slags in terms of heavy metal availability is considered there are several possible approaches. The ideal would be to test the identity and quantity of a metal that is released from the slag in the soil through different soil extraction procedures as well as uptake by different crops in the field. The time and cost implications for such tests are immense, especially if a whole range of liming materials have to be tested. A cost-effective alternative usually is the use of pot trials. Pot trials have the restriction that metal uptake by plants is normally exaggerated due to a combination of factors. This in turn leads to the lack of adequate reference materials due to the exaggerated metal levels in the plant. These levels could, if not evaluated in the proper context, lead to the making of erroneous conclusions. This study was therefore planned in the specific way as discussed in the following chapters, keeping in mind the restrictions imposed by the chosen method.

AIM OF THE STUDY

Considering the questions that arise during the use of slags as liming materials, it was decided to set up different trials to determine the plant-availability of heavy metals and phosphorus from these slags. The aim of the study comprises four objectives namely:

- Determine the identity and concentration of heavy metals, added to the soil through the application of slags, and its availability to plants. Furthermore, to determine whether these metals pose a threat to man or the environment and draw a conclusion concerning the desirability of using slags as liming materials.
- Determine the reactivity of the liming materials in the soil and make a deduction as to the desirability of the RH-value as a reactivity index in the determination of lime requirement.
- Compare the two reactivity determination methods used in South Africa today (the Resin Suspension Method and the Calcium Carbonate Equivalent in hydrochloric acid) in terms of accuracy through modelling.
- Determine the amount of P available to the plant from the applied slags and make deductions concerning the influence Si has on soil P and P applied.