### 4.10 Wastes from selected mineral-based industries

There are several 'wastes' from mining and mineral-related industries that may be useful for low-input agriculture. They include:

- waste from incomplete calcining in lime operations,
- calcium carbonate wastes from cement and other industries using $CaCO_3$,
- tailings from diamond mining from kimberlites,
- wastes from 'black granite' operations,
- waste from phosphate mining,
- wastes from phosphate processing,
- pyrite wastes,
- wastes from steel production, such as basic slag, and calciumsilicate slag,
- wastes from coal burning operations, for example fly ash, bottom ash, the by-products of fluidized-bed combustion and materials from flue gas desulphurization scrubbers.

Some of the 'wastes' or 'byproducts' disposed of by mineral-based industries should be considered as a potential 'resource' for various crop production systems. Examples of 'waste utilization' for agricultural purposes are the use of incompletely calcined limestones or carbonates, or 'dust' from the cement industry as liming materials. Other already ground up and reprocessed 'dumps' include the tailings fines from kimberlite operations. These resources, characterized by rapidly weathering olivine-rich rocks and other Mg-rich rocks, are potential liming materials and local Mg sources, for example, for pastures.

Also the 'wastes' from phosphate mining operations, for example, phosphate fines, need agronomic testing. The International Fertilizer Development Center (IFDC) tested the phosphate fines of Togo for use as direct application P-fertilizer and the Zimbabwe-Canada agrogeology project currently investigates the use of phosphate fines and vermiculite-rich tailings in agriculture in communal lands in Zimbabwe. Phospho-gypsum should be tested as a soil amendment on sodic soils and for groundnut fertilization.

Mine tailings containing biotite have been tested as slow-release K fertilizers on pasture in Norway (Bakken *et al.* 1997, 2000). Calcium silicate slags, also by-products of the steel industry, have shown considerable yield increases for sugar cane, specifically on low-Si soils (Ayres 1966; Anderson *et al.* 1991). Magnesium-containing fluidized bed combustion byproducts have proved to be effective liming materials with a high effectiveness to ameliorate subsoil Al phytotoxicity (Stehouwer *et al.* 1999). Pyrites and pyritic mill tailings with low heavy metal contents have also been tested as inexpensive Fe-sources for sodic and Fe-deficient soils.

Basic slag is a known P resource that is widely used in European agriculture. Basic slag is a byproduct from the steel industry, either from the basic Bessemer or the basic open-hearth process (Waggaman 1952), has been used in a ground form as a phosphatic fertilizer and liming material since the late 1800s. In recent years, the steel industry in many countries has been using different steel making processes and different ores, thus making P-rich basic slag less available. In the early days of steel making, basic slag was a 'waste' of steel production from highly phosphatic iron ores. A process was developed that completely removed phosphorus from pig iron, resulting in high-grade structurally sound steel, and the byproduct, basic slag (Waggaman 1952). In the late 1800s it was discovered that ground basic slag had considerable fertilizing value. In Europe, basic slag was used extensively as fertilizer and liming material. Before World War II, basic slag supplied about 70% of the phosphate used for fertilizing purposes in Germany, and substantial amounts were used in Belgium, France, and Britain. In 1970/71 about one third of the phosphate used by German farmers was in the form of basic slag (Fleischel 1972). Basic slag was also widely used in Brazil (Sanchez and Uehara 1980).

The composition of basic slag varies from one steel producer to another, depending largely on the iron source material used in the process. In general, basic slags are composed of mainly calcium silico-phosphates and some iron silico-phosphates (Waggaman 1952), and significant amounts of iron, and smaller amounts of Si, Mg, and Mn. Basic slag contains between 11 and 23% $P_2O_5$, 38-59% CaO and 2-8% MgO. It also contains small amounts of Al, V, and S, as well as trace amounts of copper (100-200 mg $kg^{-1}$), molybdenum (5-40 mg $kg^{-1}$), zinc (10-30 mg $kg^{-1}$) and cobalt (2-9 mg $kg^{-1}$).

The fertilizer value of basic slag has been evaluated over the decades under a wide range of climatic and soil conditions, as well as on different crops, grasses and trees. As expected, the agronomic effectiveness of basic slag as a fertilizing and liming material differs from crop to crop and from soil to soil. Successful applications of basic slag are reported from fertilizing potatoes, sugar beet, fodder beet and various cereals (ryegrass, rape, maize) in temperate climates. In comparison to water-soluble phosphate fertilizer, the effectiveness of basic slag was inferior in crops that need readily available P like carrots, lettuce, or broccoli (Mattingley 1968). Basic slag has also been used as P-fertilizer and liming material for grassland on acid soils in many countries, including New Zealand (Lynch and Davies 1964), Germany (Fleischel 1972) and Brazil (Sanchez and Uehara 1980). Basic slag has proved effective in forest soils as a liming material and fertilizer, providing P, Ca and Mg (Mayer-Krapoll 1969; Vandre *et al.* 1991; Belcacem *et al.* 1992). Addition of basic slag improved growth and health of trees, especially on poor sandy soils.

Past 'waste utilization' practices usually centred around application of solitary products. A new concept is that of combining or co-utilizing byproducts. An example is coal fly ash in combination with biosolids, such as sewage sludge and poultry manure (Schumann and Sumner 2000). Large amounts of fly ash and sewage sludges are currently applied for forest fertilization in India and large afforestation projects using fly-ash and biosolids are planned in India and China (Dr. M. Powell, pers. comm. 2002). This concept of blending and co-utilization could easily be expanded into other areas of 'waste' utilization for agriculture and forestry, for example, blending selected mine wastes with sewage sludge.