4.8 Natural zeolites

Zeolites are a group of naturally occurring framework alumino-silicates with high cation exchange capacities, high adsorption and hydration-dehydration properties. About fifty different species of this mineral group have been identified, but only eight zeolite minerals make up the major part of volcano-sedimentary deposits: analcime, chabazite, clinoptilolite-heulandite, erionite, ferrierite, laumontite, mordenite and phillipsite. The structure of each of these minerals is different but they all have large open 'channels' in the crystal structure that provide a large void space for the adsorption and exchange of cations. The internal surface area of these channels can reach as much as several hundred square meters per gram of zeolite, making zeolites extremely effective ion exchangers (Mumpton 1984). Other useful chemical and physical properties include:

- high void volume (up to 50%),
- low density (2.1-2.2 g cm^{-3}),
- excellent molecular sieve properties,
- high cation exchange capacity (CEC): 150-250 $cmol^{+}$ kg^{-1},
- cation selectivity, specifically for cations like ammonium, potassium, cesium, etc.

Relatively pure zeolite deposits have been discovered in over 50 countries, most of the major deposits being in or close to volcanic areas. Most geologists agree that many deposits have yet to be discovered especially in less investigated volcanic areas of the world. Initial geological investigations in Ethiopia have shown that extensive deposits (several million tonnes) of relatively pure natural zeolites exist in the Rift Valley of East Africa. Other zeolite deposits are known from Kenya and Tanzania.

Zeolites are increasingly being used in aquaculture, agriculture, horticulture, chemical industry, construction, waste management and for domestic uses (Clifton 1987; Mumpton 1984; Parham 1989). In the agricultural/horticultural field zeolites are used as:

- as animal feed additives,
- as soil and compost additives,
- as carriers of pesticides and herbicides,
- as potting media.

Zeolites are useful in agriculture because of their large porosity, their high cation exchange capacity and their selectivity for ammonium and potassium cations. They can be used both as carriers of nutrients and as a medium to free nutrients. The main use of zeolites in agriculture is, however, for nitrogen capture, storage and slow release. It has been shown that zeolites, with their specific selectivity for ammonium (NH_4^+), can take up this specific cation from either farmyard manure, composts or ammonium-bearing fertilizers, thereby reducing losses of nitrogen to the environment. Ammonium-charged zeolites have also been tested successfully for their ability to increase the solubilization of phosphate minerals (Lai and Eberl 1986; Chesworth *et al*. 1987), leading to improved phosphorus uptake and yields for sudangrass (Barbarick *et al*. 1990). Eberl and Lai (1992) developed urea-impregnated zeolite chips, which can be used as slow release nitrogen fertilizers. In Cuba, zeolites have also been successfully used as potting media in horticulture ('zeoponics'), where nutrient-charged zeolites together with other mineral phases provide the plants with substrate and nutrients for growth.

But the performance of natural zeolites must be assessed critically. There are about 50 different species of zeolites, each having a different chemical composition and structure. While most zeolites are beneficial in improving animal and plant growth, there are cases where zeolites do not perform effectively. For example, it has been demonstrated that certain zeolites with sodium as the main exchangeable cation can actually decrease rather than increase plant growth and yield (Barbarick and Pirela 1984). Also, the zeolite erionite can be harmful to health when inhaled by animals and humans (Suzuki and Kohyama 1988). This demonstrates the importance of good mineralogical and chemical characterization of zeolites and an intelligent selection of zeolites to suit their application.