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ZEOLITE - A Technical Summary

Introduction:

This paper was produced for Zeolite WA to give a reader-friendly technical overview of zeolites and their uses. The author viewed nearly 300 scientific abstracts, research papers, web-based information pages and information supplied by producers of zeolite in Australia. A full list of references, abstracts and citations can also be found on my website. If you want to read further, here is a list of basic information sources you may find useful:

1. Aussie Zeolite, Albany, WA – http://aussiezeolite.com.au/home
2. Castle Mountain Zeolite, Quirindi, NSW - http://www.cmzeolites.com.au
3. Zeolite Australia Pty Ltd, Werris Creek, NSW - http://www.zeolite.com.au
4. Reid, Aileen, **Cation exchange capacity – how soils and potting mixes hold onto nutrients**. Gardening WA Style Wordpress blog (link)
5. Chemistry Explained – **Zeolites** (link)
6. Wikipedia – Zeolite summary (link)
7. Two pages from the Sydney Environmental & Soil Laboratory: **What is cation exchange capacity?** (link), and **Cation exchange versus ammonium sorption in zeolites.** (link)
8. Literature Review: **Zeolite (Clinoptilolite tuff) and its Beneficial Effects in Horticulture to Increase Plant Growth.** Compiled by Michael Leu & Daniel FitzHenry (link)

History:

Zeolites first came under real notice in the 1750's, when Alex Cronstedt (a Swedish mineralogist) collected stilbite crystals and found that if they were rapidly heated would release steam from the water held within. Thus the name 'zeolite', from Greek words meaning "boiling stones".

Since then, research and uses have increased at a steady rate, with different forms of zeolite finding all sorts of uses. But it wasn't until the 1960's in Japan that research into agricultural uses of zeolite made their mark, with farmers there using it to control moisture content and to buffer the pH of acid volcanic soils.

In recent decades, research and usage of zeolite has increased significantly. However, there is room for much more in both agriculture and horticulture (particularly here in Western Australia), as our arable soils continue to degrade or are lost forever and water supplies become more and more precious.

1. Zeolite properties:

Zeolites are hydrated crystalline aluminosilicates, a naturally occurring mineral rock formed after volcanic ash fell into brackish water basins. Over millions of years it became compressed into hard rock made up of tiny molecular sieves, forming a very porous honeycomb-type structure with a huge surface area to volume ratio. Depending on the source, the geometrical specific surface area (GSSA) ranges from 0.921 m^2/gm to a staggering 1.630 m^2/gm, the largest of any ion.

They are similar in composition to many clay minerals, and are the most common minerals present in sedimentary rocks. There are 48 known natural types, and nearly 200 different synthesised products (often heated montmorrillonite clays). Of the natural types, clinoptilolite, erionite, chabazite, heulandite, mordenite, stilbite and phillipsite are the most commonly known.

However, zeolites have a much different structure than clay minerals. Aluminium, silicon and oxygen are arranged in a regular, well-defined three-dimensional nano- and micro-porous framework of tetrahedral units. The small pores in these frameworks are tiny: 0.1-2 nm (1.0 nm is 10^{-9}m!).

These pores and interconnected voids contain cations and water molecules, and together with the huge surface area make zeolites extremely effective ion and cation exchangers. Cations can be exchanged by ion exchange and water can be removed reversibly by application of heat.

Many overseas zeolite sources contain dissolved salts, and sometimes the zeolite is in a sodium form. The positively charged sodium ions may balance the negative charge in the framework, and because of their size these ions may reduce the diameter of pore openings. Our Australian sources of zeolite do not have this problem.

2. Mineral element (cation) adsorption.

Zeolite is able to bind damaging or dangerous heavy metals such as Cadmium, Cesium, Chromium, Copper, Lead, Lithium, Mercury and Zinc, some permanently. It also greatly reduces Ammonium leaching from wastewater, animal manures and excessive water-soluble fertilisers. A number of overseas studies have shown that zeolite can help to revert contaminated soils and make them suitable for agricultural use.

Zeolite adsorbs positively charged cations, including many essential for plant growth, especially ammonium, potassium, calcium, magnesium and trace elements. Thus it can play an important role in agriculture and horticulture to hold these elements in the topsoil, keeping them in an available form within the feeder-root system while at the same time reducing nutrient loss through leaching.

3. CEC, soils and zeolite.

CEC (cation exchange capacity) is the measurement of how many cations a soil or growing medium is able to hold, and is measured as the number of cations per dry weight and expressed as milliequivalent of hydrogen per 100g of dry soil (meq/100g). Therefore, it can be used as a measure of both soil fertility and nutrient retention capacity.

The 'exchange' in CEC is the important component because cations can be removed from soil particles and replaced with others. So a soil or growing medium with a high CEC has the ability to store more cations and replace them when they are used by plant roots or soil organisms.

It is commonly accepted that soils should have a minimum CEC of 5-10 meq/100g, and ideally over 30 meq/100g. Sands range from 1-5, loams and silt loams 5-15, clay loams 15-30 and clays are 30 or more. Our zeolites have a CEC of 147, so its addition to soil (especially sand) has the ability to drastically improve that soil's CEC.

Organic matter (OM) has a very high CEC, with humus coming out on top at 100-300 meq/100g. OM also has very good water holding capacity (WHC), so the addition of both zeolite and OM can vastly improve plant performance in sands through to loamy sands, and various investigations both here and overseas have shown this addition can improve WHC by up to 35%.

pH is the measurement of hydrogen ion activity in a solution on a logarithmic scale of 0 to 14, with 7.0 being neutral and below this termed acidic and above this termed alkaline. Soil pH affects the availability of mineral nutrients.

Australian zeolites in general have a pH of 7.5 to 8.0 (up to 9.5 with overseas products), so that only very heavy applications will have a noticeable impact on the pH of soils or growing mediums with a pH >7.0, so it is still valuable to add to our alkaline sands at recommended rates without negative impact.

However, zeolite has a positive impact on neutralising acidic soils due to its ability to adsorb positively charged ions. Overseas research has shown that zeolite can increase the pH of acid soils by 0.4-0.6, thus reducing the need for applications of lime. This makes it a very valuable addition to composts, potting mixes and acidic soils (especially waterlogged soils with high OM content).

Salinity (EC): Our Australian source of zeolite does not contain dissolved salts and therefore will not increase salinity. In fact, zeolite has been documented to significantly reduce the EC of salt-affected soils.

4. Specific uses and rates of zeolite.

(a) Soils and crops: The benefits of applying zeolite to most soils, especially sands, are well documented. Experiments conducted around the world have shown yield increases of 5-15% in crops such as field legumes, vegetables etc.

The following rates have been suggested for incorporation into the top 100-150mm of soil. Heavier rates can always be used, especially if incorporated more deeply.

Sands	200-500g/m^2
Loamy sands	150-300g/m^2
Sandy loam	100-200g/m^2
Poor clays	50-100g/m^2
Lawns	25-100g/m^2 (depending on depth)

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(b) Compost (and Silage): Adding zeolite to the composting process is valuable in odour removal, buffering pH and helping to maintain moisture and aeration levels, as well as retaining valuable nutrients.

Rates: 5-50kg/m^3, depending on product requirements.

(c) Potting mixes: Percentage porosity is very important in potting mixes, and as with composts, zeolite buffers pH and helps to maintain moisture and aeration levels. Zeolite at 1.4-1.5kg/L is also lighter than sand, so heavier rates can be used without adversely affecting pot weights.

Rates: 8% by volume (80kg/m^3), though a range of 2-10% is acceptable.

(d) Other uses:

- Aquaculture, fishponds and aquaponics. Zeolite has excellent ammonium adsorption properties, thus is the preferred filtration medium to clean fishponds and pools. It also removes many other impurities from this water. With aquaponics (growing plants using fish water), zeolite can be used in conjunction with expanded clay as a growing medium for veggies and other plants.
- Animal bedding. Zeolite is very effective in trapping malodorous volatile gases, so it is useful in both animal bedding but also for treating manures.
- Stock feed additives. Zeolite can be added to stock foods and animal licks as a binder but also to carry mineral nutritional supplements.
- Soil wetting agents. Both zeolite and spongolite are used as carriers for liquid soil wetting concentrates, which have been released into the soil given sufficient levels of moisture. The used zeolite and spongolite granules remained to be a useful soil additive as previously mentioned.
- Swimming pool and spar filters. Zeolite is a far superior filtration medium than sand in removing both chemical and physical impurities.
- Soil activator products. Zeolite is increasingly being found to be an effective carrier for biological soil improvement products, such as liquid humates, fulvic acid, mycorrhizal spores, various soil and seed inoculants, etc.

5. Health issues:

There are two fibrous zeolite mineral, mordenite and erionite. However, only the latter is classified as a carcinogen by the International Agency for Research on Cancer. Our Australian source of zeolite is predominantly clinoptilolite, with some mordenite (<15%).

Zeolite is available in different size grades, from small granules down to fine powders. Obviously, when handling or working with any very fine or powdery substance, some personal dust protection would be advised, especially in confined spaces.

Animal and human ingestion. There is a plethora of claims and apparently scientifically backed information about the use of zeolite in both food and medicinal supplements. This includes claims of helping to detoxify digestive systems in both animals and humans. However, we have no specific training or knowledge in this area, and any information on this should be gleaned elsewhere.

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