BEAR RIVER ZEOLITE
COMPOSTING RESEARCH REVIEW

This document was prepared to provide a compilation of data from world-wide zeolite (clinoptilolite) studies to be used as an informational resource. Some of the benefits from studies cannot be claimed by Bear River Zeolite, Co. due to U. S. and Canadian government restrictions.

WHAT IS COMPOSTING?

Composting of waste is an aerobic (requires oxygen) natural process of "rotting" or decomposing organic matter by microorganisms under controlled conditions. The composting process involves four main components: organic matter, moisture, oxygen, and bacteria.

WHY COMPOST?

- **To convert organically bound nitrogen into a usable form of nitrogen**
- **Kill pathogens, weeds seeds and larvae**
- **Reduce the volume of material**
- **Provide a soil amendment**
- **Reduce contamination of groundwater**

BENEFITS OF CLINOPTILOLITE IN COMPOST

REDUCES ODOR AND GREENHOUSE GAS EMISSIONS *(Eng, K.S., et al., 2003) (Omar, L., et al. 2015b) (Milovanic, J., et al. 2013)*

- Clinoptilolite captures ammonium that is the source of the ammonia gas that is the aerosol of odors.

INCREASES THE VALUE OF COMPOST *(Venglovsky, J., et al. 2005) (Simic, A.,et al. 2013) (Omar, L., et al. 2015a) (Omar, L., et al. 2015b) **

- Clinoptilolite retains the nitrogen in the form of ammonium and the nitrogen is worth $.50 per pound.
- The clinoptilolite also contains more than 3% potassium which is worth approximately $.18 per pound.

REDUCES VOLUME *(Omar, L., et al. 2015b)*

- Reduces the volume of compost feedstock by up to 50%.

REDUCES FLIES*

- By absorbing ammonia gas.

HOLDS NITROGEN IN GROWTH ZONE *(Simic, A.,et al. 2013) (Omar, L., et al. 2015a)*

- Clinoptilolite holds nitrogen in the growth zone where it is not water soluble, but plant accessible on an as needed basis.

INCREASES CROP YIELD *(Simic, A.,et al. 2013) **

- Increases seed germination and growth.
- 20% higher yield.

IMPROVES SOIL QUALITY *(Venglovsky, J., et al. 2005)*

- Increases nutrients, porosity, oxygen content, and mediates the pH.

HOLDS MOISTURE IN GROWTH ZONE *(Venglovsky, J., et al. 2005) **

- Holds up to 50% of its weight in water and rehydrates at night when it is cooler.

PROTECTS GROUNDWATER FROM CONTAMINATION *(Omar, L., et al. 2015a) (Omar, L., et al. 2015b)*

- Inhibits the oxidation of ammonium to nitrates that are very water soluble and contaminate the groundwater.

COMPOST TURNER

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IMPROVES MICROORGANISM DEVELOPMENT *(Venglovsky, J.,et al. 2005) (Koushafar, M., et al. 2011) (Montalvo, S., et al., 2012) (Kotsopoulos, T.A., et al., 2008)*

- Counteracts the inhibitory effect of ammonia overloads on microorganisms.
- Microorganisms colonize on the surfaces of clinoptilolite where nutrients and water are available.

MANAGES OXYGEN LEVELS *(Venglovsky, J.,et al. 2005) (Omar, L., et al. 2015a) (Omar, L., et al. 2015b)*

- Clinoptilolite's porosity maintains the space needed for oxygen.

MEDIATES pH *(Koushafar, M., et al. 2011) (Omar, L., et al. 2015a)*

- Maintains pH levels for composting and nitrogen utilization in soil.

MAINTAINS TEMPERATURE *(Venglovsky, J.,et al. 2005) (Omar, L., et al. 2015a) (Omar, L., et al. 2015b)*

- Enabled aeration for metabolic heat generation by aerobic microorganisms.
- Helps maintain the heat required to kill weed seeds, pathogens, and fly larvae.

MANAGES WATER *(Omar, L., et al. 2015a)* *

- Clinoptilolite holds more than 50% of its weight in water in open channel-ways. and reduces evaporation from the compost.

REDUCES TIME *(Venglovsky, J.,et al. 2005) (Koushafar, M., et al. 2011)*

- Decreases the developmental lag phase of microorganisms.

Ammonia & Steam

HOW TO APPLY CLINOPTILOLITE

FEED ADDITIVE (Eng, K.S., et al., 2003)

Feeding clinoptilolite is the least expensive and most effective way to reduce nitrogen losses.

- 1.25% clinoptilolite in the feedlot cattle diet reduced NH_3 (ammonia) losses from fresh manure by 2/3.
- Moisture reduction to improve manure handling and transport to compost location.

TOP DRESS FRESH MANURE AND COMPOST *(Omar, L., et al. 2015b) (Milovanic, J., et al. 2013) (Simic, A., et al. 2013)*

- Captures ammonium before it can convert to ammonia gas (NH_3), reducing nitrogen losses by 50%.
- Reduces odor and fly attraction.
- Top Dress Rate: 1 to 2%

NITROGEN FORMS

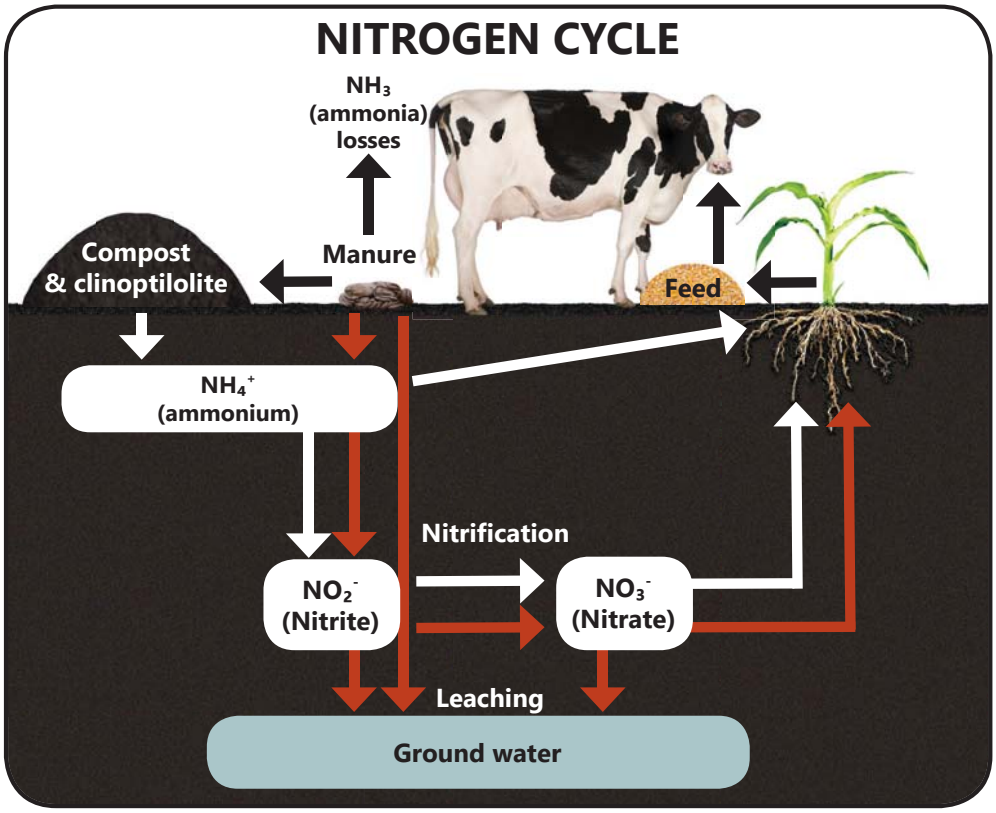
Organically bound nitrogen
Bound in organic matter and unavailable to plants

Ammonia (NH_3)
Gas

Ammonium (NH_4^+)
Plant available

Nitrite (NO_2^-)
Oxidizing bacteria convert ammonia to nitrite, which is toxic to plants

Nitrate (NO_3^-)
Nitrite-oxidizing bacteria convert nitrite to nitrate, a plant available nitrogen, which is very water soluble



COMPOSTING PARAMETERS

COMPOST COMPONENTS: consist of (1) nutrients, (2) carbon and nitrogen

Nutrients: Adequate phosphorous, potassium, calcium, iron, boron, copper, etc. are necessary for microbial metabolism, but they are normally in the compost feedstock.

Carbon and nitrogen: The two basic ingredients in composting are carbon and nitrogen. Ideally the C:N ratio by weight should be 30:1. Too low a carbon ratio will result in excess nitrogen that is lost as ammonia gas that creates odor problems. Too high a carbon ratio inhibits the growth of microorganism populations and the compost will remain cool and the composting degradation will be slowed. When the compost is finished, the C:N ratio will be 10-15:1 because the microorganisms will convert two thirds of the carbon to carbon dioxide. The sources of carbon (generally brown in color) and nitrogen (generally green) are as follows:

Carbon

Carbon (brown)	C:N ratio
Straw	40-100:1
Corn Stalks	60:1
Bark	100-130:1
Paper	150-200:1
Wood chips and sawdust	100-500:1

Nitrogen (green)	C:N ratio
Sewage sludge (digested)	17:1
Cow manure	20:1
Poultry manure (with litter)	13-18:1
Pig manure solids	15-25:1
Horse manure	25:1

Nitrogen

MICROORGANISMS: The main microorganisms in composting are aerobic bacteria and fungi. If not enough oxygen is provided, the compost turns anaerobic (no oxygen), microorganisms die and the compost generates putrid smells, including hydrogen sulfide.

COMPOST CONDITIONS

OXYGEN: Aerobic microorganisms can survive on 5% oxygen, but >10% is considered optimal. Oxygen is most commonly provided by turning the compost or by compressed air.

MOISTURE: Composting materials should contain between 40-60% moisture.

pH: A pH of 5.5-8.5 is ideal for the microorganisms. In early composting acids tend to accumulate and this promotes the fungi and the consequent breakdown of lignin and cellulose.

TEMPERATURE: The temperature in active compost piles range from 135-160° F which destroys pathogens and weed seeds. Temperature is controlled by turning and the addition of water.

COMPOST MANAGEMENT

TURNING: If the temperature falls below 122°F or rises above 150°F, the compost is turned.

WATER: Additional water can be added during turning if the compost is too dry.

TIME: The composting process occurs within 6-9 months. However, some in-vessel operations take only 30 days.

VOLUME: The loss of carbon dioxide and water may reduce the final volume of the compost by 50% or more.

ODOR TROUBLESHOOTING

ODOR	CAUSE	SOLUTION
Ammonia	Ammonia losses are a result of low C:N ratios. NH_3 is at equilibrium with NH_4 at a pH of 9. At a pH of >9, the ammonium gases to ammonia. Little ammonia is generated at acidic pHs.	Add carbon
Hydrogen sulfide	Hydrogen sulfide odors are generated if the compost becomes anaerobic. Hydrogen sulfide is more difficult to disperse because hydrogen sulfide is heavier than air, and they tend to accumulate in the compost area.	Add oxygen Turn compost to aerate

METHODS

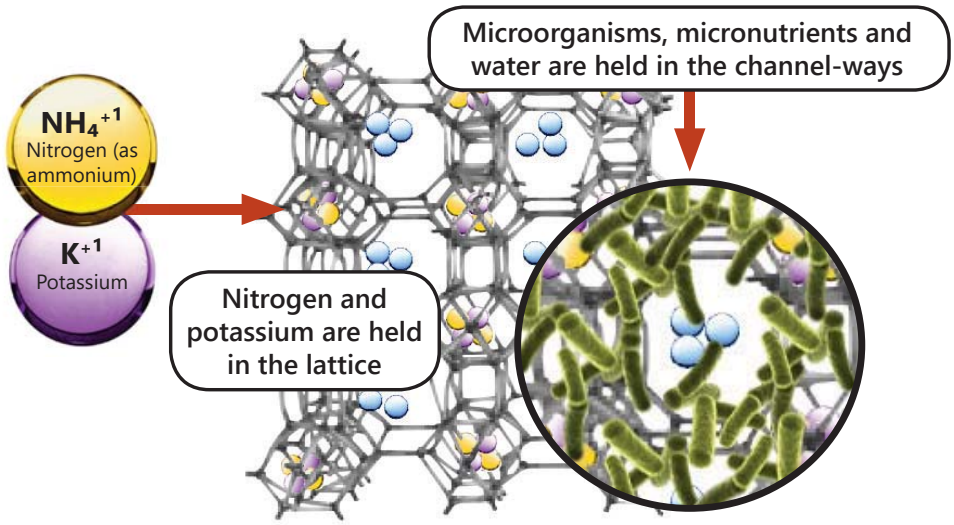
WINDROW COMPOSTING: This is common in fields and is better on a concrete or impermeable surface. The compost can be turned with tractors or compost turners.

IN-VESSEL COMPOSTING: This refers to composting in metal or plastic tanks or concrete bunkers that confine the material in buildings, containers, or vessels which protect groundwater and confine odors. These systems start with anaerobic digestion and finish with aerobic digestion.

How Clinoptilolite Works

Clinoptilolite has the ability to exchange ammonium (NH_4^{+1}) into its lattice through its cation exchange capacity (CEC).*

The clinoptilolite lattices are negatively charged and are able to hold positively charged ammonium (NH_4^{+1}) and potassium (K^{+1}), which are accessible to microorganisms as needed for growth but not water soluble.



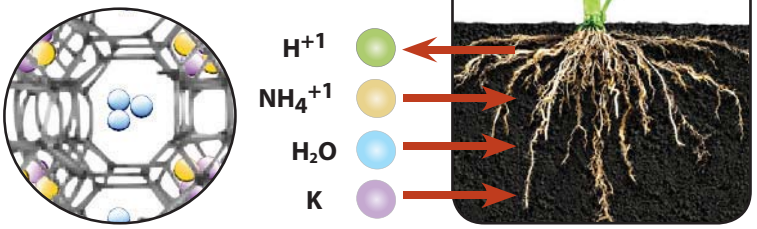
Clinoptilolite lattice and channel-ways

HOW CLINOPTILOLITE COMPOST WORKS IN THE SOIL*

BRZ™ contains approximately 3.47% potassium, which is an important nutrient in fertilizers. BRZ™ holds at least 55% of its weight in water that protects the plant against drought.

The plant releases hydrogen (H^{+1}) during growth, which exchanges with ammonium (NH_4^{+1}) held in the clinoptilolite lattice, which is plant accessible but not water soluble.

Available water (H_2O) is held in the open pore spaces of the clinoptilolite in the growth zone.



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*Additional references for background information on file at Bear River Zeolite Co.

A special thank you to Midwest Biosystems, Tampico, IL for the compost turner image. http://midwestbiosystems.com. Midwest Biosystems is not affiliated with Bear River Zeolite and not liable for the accuracy of the information supplied in this document.