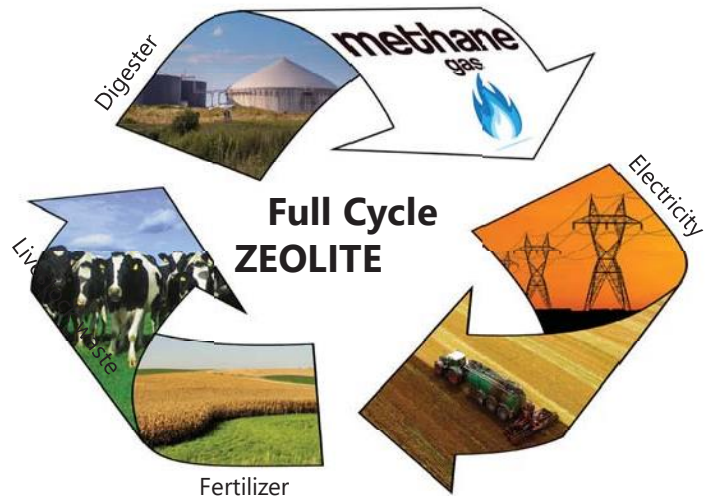


ANAEROBIC DIGESTION RESEARCH REVIEW

The benefits of Zeolite, a volcanic mineral

Recent studies have uncovered benefits that resulted from the addition of Zeolite in the anaerobic digestion process.

This document was prepared to provide a compilation of data from world-wide Zeolite studies to be used as an informational resource.



Zeolite Benefits

METHANE PRODUCTION

(Kougias, P.G., et al., 2013) (Kotsopoulos, T.A., et al., 2008) (Meisinger, J.J., et al., 2001) (Montalvo, S., et al., 201).

- Higher organic matter degradation, resulting in higher methane yield
- 46% increase in methane production (Fig. 1)
- 78% methane content of biogas
- 59% volatile solid (VS) conversion to methane
- Higher methane production when Zeolite is present to hold ammonium nitrogen
- Mitigated ammonium levels to balance the C/N ratio for a higher methane yield

MICROORGANISM DEVELOPMENT

(Montalvo, S., et al., 2012) (Kotsopoulos, T.A., et al., 2008)

- Increases the population of anaerobic digesting microorganisms for higher methane yield
- Immobilizes microorganisms on its large surface area to prevent washout and provide a surface for colonization
- Micronutrients and nitrogen are held in the colonization zone
- Hydrolytic and methanogenic microorganisms increased 100 times and the population of hydrolytic microorganisms was 10 times higher

ODOR AND VOC CONTROL

(Meisinger, J.J., et al., 2001) (Montalvo, S., et al., 2012) (Kotsopoulos, T.A., et al., 2008) (Kougias, P.G., et al., 2013)

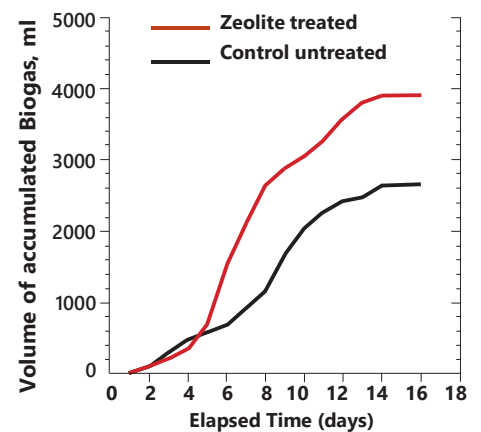
- Odor and VOC (volatile organic compound) reduction
- The high cation exchange capacity (CEC) of Zeolite exchanges the ammonium nitrogen (NH_4^{+1}) into the crystal lattice before it vaporizes to ammonia gas (NH_3), the aerosol of odors

DIGESTATE PRODUCTION*

- Odor reduction during field application
- High fertilizer value from nitrogen (ammonium) and potash (potassium) held in the Zeolite lattice
- Higher methane production reduces the carbon content - digestate is lighter and less costly to handle

GROUNDWATER POLLUTION*

- Ammonium is held in the Zeolite lattice and doesn't oxidize into nitrates and nitrites
- Reduction in ground water contamination



Anaerobic Digestion Stages

1. HYDROLYSIS

Carbohydrates/cellulose, fats and proteins are broken down into monosaccharides, fatty acids and amino acids.

2. ACIDOGENESIS

Monosaccharides, fatty acids and amino acids are converted into volatile fatty acids, alcohols, ketones, hydrogen and carbon dioxide.

3. ACETOGENESIS

Volatile fatty acids, alcohols, ketones, hydrogen and carbon dioxide are converted into hydrogen, CO₂ and acetic acid.

4. METHANOGENESIS

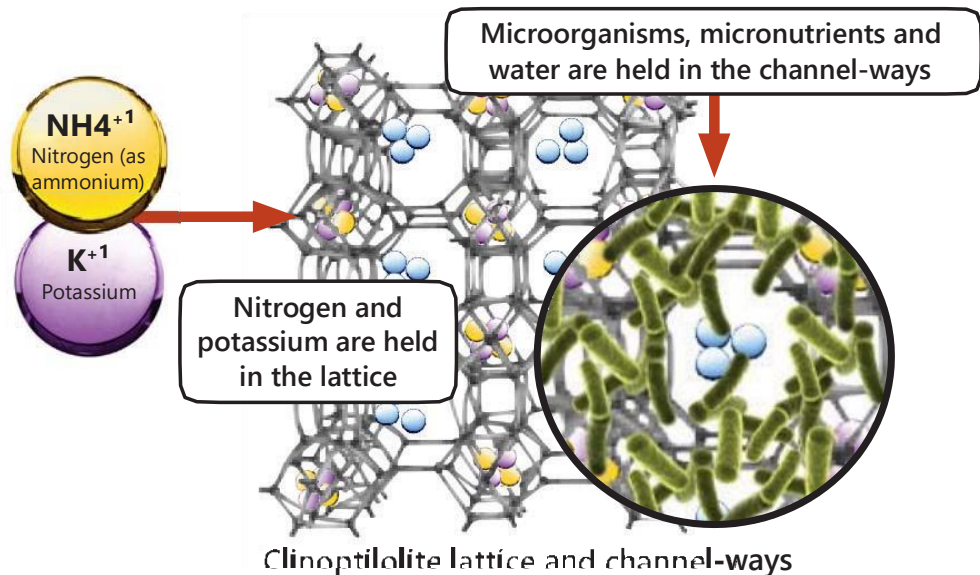
Hydrogen, CO₂ and acetic acid are converted into methane, CO₂ and nutrients (fertilizer, bedding, and waste water).

Specific microorganisms are needed for each stage in the anaerobic digestion process. Zeolite increases the populations required for each stage. (Montalvo, S., et al., 2012) (Kotsopoulos, T.A., et al., 2008)

How Zeolite Works

Zeolite has the ability to capture ammonium (NH₄⁺) through its cation exchange capacity (CEC).*

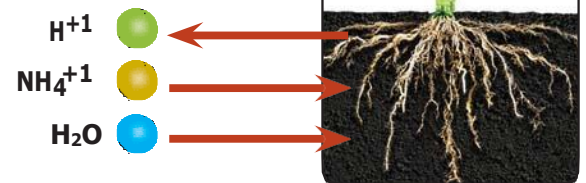
The Zeolite negatively charged and are able to hold positively charged ammonium (NH₄⁺) and potassium (K⁺), which are accessible to microorganisms as needed for growth but not water soluble.



ZEOLITE IN DIGESTATE FERTILIZER

The plant releases hydrogen (H⁺) during growth, which exchanges with nitrogen (NH₄⁺) held in the Zeolite lattice, which is plant accessible but not water soluble.

Available water (H₂O) is held in the open pore spaces of the Zeolite near the root zone.



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