NATURAL ZEOLITES – REMEDY FOR CONCENTRATED ANIMAL FEEDING OPERATIONS AND SUSTAINABLE AGRICULTURE

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ABSTRACT

The disposal and use of animal manures are major concerns of Concentrated Animal Feeding Operations (CAFO) worldwide. Concerns are both environmental and economic: environmental because of noxious odors from ammonia volatilization, leaching of nitrates into ground and surface waters, and excessive amount of heavy metals in the manure; economic because of disposal costs, compliance of environmental regulations, and the loss of valuable nutrients from the farming system. A central goal of sustainable farming systems is to convert waste products into a valuable resource. Livestock manure from CAFOs is often spread on cultivated fields, but the loss of manure nitrogen (often over 50%) through ammonia volatilization and nitrate leaching makes the nitrogen:phosphorus (N:P) ratio to low for balanced and appropriate crop applications.

Both empirical evidence and the chemical composition/structure of natural zeolites support their mixture with animal manures as an environmentally friendly approach to solve the above problems. Natural zeolites are hydrated sodium or potassium, calcium aluminosilicate minerals found in many countries. In particular, clinoptilolite, one of 82 natural zeolite minerals, is uniquely characterized by its capabilities of absorption, adsorption, and cation exchange. Clinoptilolite has a framework structure that permits adsorption of ammonia, hydrogen sulphide, and other gases. Because the pore openings within the structure are too small for nitrifying bacteria to enter and oxidize sequestered ammonia, this ammonia is safe from either volatilization or bacterial conversion to nitrate. Using clinoptilolite as deep litter, with manure, eliminates noxious odors and nitrate leaching, and removes some heavy metals from solution.

Once saturated with ammonia-N, clinoptilolite has been shown to be an excellent long-term, slow-release fertilizer when applied to agricultural crops. Because crops can extract and desorb N sequestered in the clinoptilolite, many countries use N-loaded natural zeolites for agriculture soil amendments. Furthermore, zeolites, contrary to bentonite and other clay minerals, absorb and release moisture without expansion of their volume. This additional property makes natural zeolites exceptionally valuable for agricultural soils, particularly in the regions where water conservation and its efficient use are important. Thus, composting animal manures with clinoptilolite-rich zeolites can resolve both the environmental and economic concerns of CAFOs. A major liability of manure disposal converting into a valuable natural fertilizer with a balanced N:P ratio and minimal N losses from the farm to the environment.

INTRODUCTION

The concept of agriculture production efficiency has undergone revolutionary changes in recent years. In the past, agriculture farms were relatively small and defined by their borders. Farm wastes were dumped in streams and landfills, or applied on agricultural fields where most of the ammonia-N either volatilized or leached out as nitrate. However, with increasing human populations, the environment outside the farm cannot longer sustain the high input of plant nutrients and organic waste. The challenge now is to improve economic and production efficiencies for broader community needs including affordable food, clean air, and clean water.

Concentrated Animal Feeding Operations (CAFOs) are particularly notorious for the environmental and economic problems they create due to animal manure disposal issues. Animal

manures: 1) are malodorous and degrade air quality because of ammonia volatilization, 2) cause eutrophication of downstream waters due to nitrate leaching from manure piles, 3) looses N making manures less suitable for crop applications without causing excessive P fertilization, 4) invoke environmental regulations that impose severe fines for non-compliance, and 5) represent a significant farm expense for proper handling and disposal.

Improving CAFOs' production and economic efficiencies means reducing the stream of waste and un-useable by-products. Economic and environmental sustainability can be improved by converting what would otherwise be considered a waste into a valuable marketable resource. This paper discusses how clinoptilolite-rich zeolites used as livestock bedding, composted with manure, can achieve this goal while resolving concerns associated with CAFO waste disposal.

NATURAL ZEOLITES

Natural zeolites are hydrated aluminosilicate minerals found in volcanogenic sedimentary rocks worldwide (Mumpton, 1999). Natural zeolites possess several important properties including adsorption, cation exchange, dehydration-rehydration, and catalysis. Considerable scientific research in the last few decades has identified broad applications for natural zeolites in soil improvements, water and nutrient retention, water and wastewater treatment, including microparticles flocculation, and removal of heavy metals, livestock dietary supplements, health care, construction materials, and other beneficial uses (Ciambelli et al., 1985, Mumpton, 1999).

Clinoptilolite $(Na_3K_3)6(Al_{12}Si_{30}O_{72}).24H_2O$, is one of 82 minerals of naturally formed zeolites group. Clinoptilolite possess a cation-exchange capability of about 2.25 meq/g^{-1}, and is able to exchange ammonium-N with sodium (Na) and potassium (K) ions (Mumpton, 1999). Theoretically, one gram of clinoptilolite can take in about 2.2 mg ammonium-N. This cation exchange capability has been utilized effectively for terrestrial agriculture, where clinoptilolite is first saturated with ammonium-N and then incorporated into crop soils. In this way they act as a slow-release fertilizer, with plants able to extract the sequestered ammonia from the clinoptilolite (Barbarick and Pirela, 1984; Lewis et al., 1984; Dwairi, 1998). This supports research by Lefcourt and Meisinger (2001) who report "zeolite has the potential for reducing ammonia volatilization by sequestering ammonium-N on exchange cites. An addition of 6.25% zeolite resulted in a 50% reduction in ammonia volatilization. An additional potential advantage is that zeolite bound ammonium is a good slow-release N source for plants".

Not only does clinoptilolite improve nitrogen fertilization efficiencies, it also reduces nitrate leaching by inhibiting the nitrification of ammonium to nitrate (Perrin et al., 1998). Most of the manure-ammonia sequestered in the zeolite is unavailable to nitrifying bacteria because of the small (4-5 angstrom) pore size of the crystal lattice structure (Mumpton, 1999). Because agricultural crops can desorb nitrogen sequestered in the clinoptilolite, natural zeolites are being beneficially applied for soil amendments in many countries. And contrary to synthetically made polymers, bentonite and other clay minerals, zeolites adsorb and release moisture without expansion of their volume. This property makes natural zeolites exceptionally valuable for agricultural soils, particularly in the regions where water conservation and its efficient use are important.

LIVESTOCK MANURE MANAGEMENT WITH ZEOLITES

Manure production is an inevitable consequence of livestock production. Nevertheless, there is currently no single "best" manure management strategy used by CAFOs because of the varia-

bility among farms of the types of manure, labor, available time, management skills, soil properties, and weather conditions. Furthermore, regulatory differences between jurisdictions regarding the number and size of animals, dilution requirements and length of time between emptying storage facilities increase potential variability between manure management options (MEQB, 1999). Direct manure management costs are primarily related to storage costs, which are related to storage capacity, which is a function of how storage facilities are designed, constructed, and managed. Current approaches to on-farm manure storage and disposal typically involve either direct application to agricultural fields for crop fertilization, temporary storage in earthen pits, or some form of manure decomposition in water (i.e., lagoons) or on land (i.e., composting) to facilitate ease of handling and long distance shipment (MEQB, 1999).

Table 1. *The relative benefits of livestock manure composted with natural zeolites in comparison to ordinary manure, and synthetic N-P-K fertilizer.*

Attributes	Fresh manure	Composted manure	Manure with zeolites	Synthetic N-P-K fertilizer
Manure Management:				
Reduces nitrate leaching during storage/handling	No	No	Yes	
Reduces ammonia volatilization during storage/handling	No	No	Yes	
Reduces noxious odors	No	No	Yes	
Crop fertilizer and soil amendment:				
Adds N and P in proportion to crop requirements	No	No	Yes	Yes
Consistency relatively uniform	No	Yes	Yes	Yes
Slow release of N	Yes	Yes	Yes	No
Reduces nitrate leaching, and ammonia volatilization in soils	No	No	Yes	No
Reduces noxious odors at fields	No	No	Yes	No
Promotes N retention in soils	No	No	Yes	No
Sequesters trace metals	No	No	Yes	No
Contains pathogens	Yes	No	No	No
Adds organic matter to soils	Yes	Yes	Yes	No
Increases soil permeability	Yes	Yes	Yes	No
Reduces surface erosion	Yes	Yes	Yes	No

Unfortunately, commonly used approaches to livestock manure storage, handling and disposal have not satisfactorily or cost-effectively addressed the associated environmental risks described above. The recent spate of environmental legislation regarding CAFOs at both the state and the U.S. federal levels reflects the seriousness of environmental risks (i.e., surface and groundwater contamination, and the dispersal of airborne odors and pathogens) involved with manure management at CAFOs. The fact that many CAFOs will not be able to survive economically under new regulations demonstrates the lack of sustainability of current manure management practices.

Therefore, to improve the economic and environmental sustainability of animal manure management in CAFOs, we propose two basic applications for natural zeolites. First, based on field trials in Guanajuato State, Mexico (unpublished data), we recommend mixing and composting fresh manure with about 10% (by weight) clinoptilolite-rich zeolite. The resultant compost

has become a highly desirable and marketable natural fertilizer. This approach has shown to control odors, prevent surface and groundwater water contaminations, reduce waste, and increase farm operation economics. Table 1 compares this approach with straight manure application, composting without natural zeolites, and the use of synthetic N-P-K fertilizers.

The second use of natural zeolites addresses the equally urgent need to clean up existing earthen pits and lagoons used for manure storage and decomposition. It is widely recognized that these facilities are main sources of odors and nitrate leaching. The simple addition of natural zeolites can make them clean, odor-free, and traps ammonia-N for potential reuse.

The capability of natural clinoptilolite zeolites for sequestering and releasing ammonia-N is well documented. The authors of paper describe an application for converting animal manure into a value-added marketable organic fertilizer. The potential environmental and economic benefits, for CAFOs, producers, and the users of progressive fertilizer are tremendous.

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