EFFECTS OF MANURE AMENDMENTS ON ENVIRONMENTAL AND PRODUCTION PROBLEMS

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The purpose of this paper is to review the state of knowledge regarding the effects of manure amendments on environmental and production problems associated with manure from confined animal feeding operations (CAFOs). The main problems focused on in this paper are the ones that can be remedied, at least partially, by manure amendments. These include ammonia emissions, nitrate leaching, phosphorus runoff, pathogen contamination of food and water resources, and heavy metal runoff.

Problems Associated with Animal Manures

A large proportion of the nitrogen in animal manure is present as uric acid and urea. Shortly after excretion, uric acid and urea are hydrolyzed to ammonia, which can be lost via volatilization. While ammonia emissions from animal manure are dependent on several factors, manure pH has the largest effect. Ammonia emissions from animal manures to the atmosphere can cause several different problems, ranging from human health to production problems to environmental problems. Ammonia levels can reach high concentrations inside animal rearing facilities during the cooler months of the year, since ventilation of these facilities is minimized to avoid high heating costs. Both humans and livestock are sensitive to high levels of ammonia; exposure can result in poor animal performance and negative impacts on health.

The biggest environmental concern with respect to animal manures is currently phosphorus runoff, since is it normally the limiting nutrient for eutrophication. Eutrophication has been identified as the biggest water quality problem in United States surface waters. Since manure typically has a low nitrogen-to-phosphorus ratio, it causes a buildup in soil phosphorus, which may lead to high phosphorus runoff. However, even when soil test P levels are not high, phosphorus concentrations in runoff water can be high. The majority (80-90%) of phosphorus in runoff from pastures fertilized with manure is in the soluble form, which is the form most readily available for algal uptake. In fact, research has shown that the dominant variable affecting P runoff is the soluble phosphorus concentration in the manure.

Tens of millions of people are reported to have cases of microbial food-borne illness each year. One source of food-borne illness is meat contaminated with pathogens, such as *Salmonella*, *Campylobacter* and *Listeria*. These organisms are often present in manure of poultry and livestock. Although food-borne illnesses pose the greatest risks to humans from pathogens derived from animal manures, water quality can also be affected.

Animal manures, particularly poultry and swine manure, contain relatively high concentrations of heavy metals, such as arsenic, copper and zinc. These metals are normally high in manure because concentrations in the diets are high. High concentrations of heavy metals have been documented in runoff water from soils fertilized with animal manure.

Effects of Manure Amendments

Several different types of manure amendments have been used to control ammonia emissions, including clays, organic carbon amendments, microbial inhibitors, enzyme inhibitors, acids and acid salts. Since manure pH is the variable that has the largest effect on volatilization, the most common amendments used for ammonia control

are acids. Weak acids, such as propionic and lactic acid, have been shown to reduce pH and lower ammonia emissions. Likewise, strong acids, such as sulfuric, nitric and phosphoric acid, have been shown to be very effective in controlling ammonia loss from manure. The problems with these acids are difficulty in handling (particulary strong acids) and increased phosphorus runoff for phosphoric acid. The most common manure amendments in the poultry industry are dry acids, such as aluminum sulfate, ferrous sulfate and sodium bisulfate. However, ferrous sulfate is no longer used, since it has caused toxicity catastrophic mortality in commercial broiler houses. One of the most effective (and cost effective) manure amendments for ammonia control is aluminum sulfate ($Al_2(SO_4)_3 \cdot 14H_2O$), commonly referred to as alum. Alum additions to poultry litter have been shown to reduce ammonia emissions by 99% in lab studies, resulting in much higher total nitrogen in alum-treated litter than normal litter. This increased nitrogen content in litter has been shown to result in significantly higher yields by crops. Studies conducted in commercial broiler houses with alum show that the addition of this compound to manure reduces the pH significantly for the first four weeks, resulting in a reduction in ammonia emissions by 75%. This reduction in atmospheric ammonia has been shown to result in improved weight gains, better feed conversion and lower propane use (due to decreased ventilation). Due to these production benefits, this BMP is cost effective, with a benefit/cost ratio of near two. Due to the positive environmental effects of alum, the USDA/NRCS is developing a conservation standard for the use of alum in poultry litter.

Little research has been conducted with manure amendments with the purpose of reducing nitrate leaching. The only method reported in the literature was to slow the conversion of ammonia to nitrate through the addition of nitrification inhibitors, such as nitrapyrin [2-chloro-6(trichlormethyl)-pyridine], to manure to slow the nitrification process.

Manure amendments have also been used to reduce phosphorus runoff. Most of these amendments are aluminum, calcium and iron compounds that form insoluble phosphate minerals when added to manure. Since most of the phosphorus in runoff water from pastures is in the soluble form, the addition of these compounds reduces phosphorus runoff. Additions of alum and ferrous sulfate were found to reduce P runoff from tall fescue plots fertilized with poultry litter by 87 and 77%, respectively. Field-scale studies conducted on small watersheds have shown that phosphorus runoff is 75% lower from pastures fertilized with alum-treated poultry litter, compared to normal litter. Another aluminum compound that has shown promise for reducing phosphorus runoff is aluminum chloride, which may be more suitable for liquid manures, like swine manure, since it does not contain sulfate (which may result in hydrogen sulfide gas formation when added to liquid manures). The effects of waste products, such as fly ash and fluidized bed combustion (FBC) on soluble phosphorus in manures have also been evaluated. Although these results were promising, boron was released from these compounds at levels that would cause crop toxicities. It was also noted that calcium compounds have been used to precipitate P in manure; however, the resulting calcium phosphate mineral would not be stable in acidic environments. Another problem with adding basic compounds to manure would be the increase in ammonia emissions that would be caused by increasing pH.

Many manure amendments, such as acids, affect survival and reproduction of many different types of microorganisms, including pathogens. The effects of alum and sodium bisulfate amendments to broiler litter on *Campylobacter* and *Salmonella* colonization frequencies and populations have indicated that high rates of alum were 100% effective in controlling *Campylobacter* colonization on chickens. Although alum was not as effective at controlling *Salmonella;* alum treatments were significantly better than sodium bisulfate for *Salmonella* control at all times.

Sparse information is available on the effect of manure amendments on metal runoff. Two different studies have shown that alum applications to manure reduce arsenic, copper and zinc concentrations and loads in runoff water. This is believed to be due to the flocculating effect of this com-

pound and subsequent reduction in soluble organic carbon compounds.

Research Needs on Manure Amendments

A systems approach is needed when studying the effects of manure amendments. Researchers need to evaluate how each amendment affects all of the problems, including ammonia emissions, phosphorus runoff, metal runoff, pathogens and crop yields. An economic evaluation should also be made on each amendment to determine cost effectiveness. Specific research needs are:

1. Determination of the effects of amendments on ammonia loss in various animal rearing facilities, including swine facilities, high-rise laying hen houses and milking parlours;
2. Documentation of the effects of manure amendments on ammonia losses throughout the production cycle, including once the manure has been land applied;
3. Evaluation of the effect of manure amendments on soluble phosphorus and phosphorus runoff (including long-term studies to make sure that the minerals formed are stable);
4. Evaluation of the effects of rates and timing of applications of manure amendments needed to reduce or eliminate pathogens at the farm level. Also the mechanisms of action of pathogen reduction need to be determined.

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