FERTILIZERS, MANURE, OR BIOSOLIDS?

Researchers compare the benefits and risks of fertilizers and soil amendments

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Farmers in the United States have several choices when providing nutrients to their fields. Many use readily available, organically rich manures. Others use commercially purchased mineral fertilizers. A smaller number choose to use biosolids. Each material has its own set of benefits and detriments, and choosing one can be daunting.

In an attempt to help farmers make a more informed decision on which product to use, the Water Environment Research Foundation (WERF; Alexandria, Va.) has complied much of the research that has been done on these materials as part of a new study.

According to Lynn Moss, the study's principal investigator and an engineer at Camp Dresser and McKee Inc. (CDM; Austin, Texas), "We want this document to be useful to operators of biosolids programs who are getting questions on a daily basis regarding biosolids and how they compare to other products they're more familiar with, such as mineral fertilizers. Both manures and biosolids are considered to be byproducts, and their benefits are really not as clearly understood as they could be."

The study, *Comparing the Benefits and Risks of Agricultural Amendments and Fertilizers* (99-PUM-1), focuses mainly on biosolids, manures, and mineral fertilizers. It examines how to reconcile agricultural needs with several controversial biosolids land application issues, such as agricultural properties, metal accumulation in soils, plant uptake of metals, contamination of groundwater by organic compounds, and potential environmental effects from pathogens and viruses.

Nourishing the Earth

Each year, farmers landapply 117 million dry ton (106 dry Mg) more manure than biosolids. Annually, farmers use 120 million dry ton (109 dry Mg) of animal manure, 50 million dry ton (45 Mg) of mineral fertilizers, and 2.8 million dry ton (2.5 Mg) of biosolids on their farmlands, according to the draft study (see Table 1, p.2).

Why use 40 times more animal manure than biosolids? Two reasons present themselves immediately: First, there's simply far more manure generated and land application is the easiest way to use this material; and secondly, it's always been done this way.

"Manures have been used since the beginning of time, and they've been used for so long that people don't think about comparing risks and benefits of their use – manures are simply accepted and they have been for over 2000 years," Moss said.

Yet, **"for biosolids, it appears that the risks associated with their use are no greater than – and, in many cases, may in fact be less than – risks associated with manure use,"** Moss noted.

Generally, manures and biosolids contain similar amounts of macronutrients, such as nitrogen, phosphorus, and potassium. Study data indicate that nitrogen comprises 1% to 10.8% (dry weight) of

Table 1. Relative Use of Biosolids, Manures, and Mineral Fertilizers

	Biosolids	Manures	Mineral fertilizers
Produced (ton)	6.9 million	133 million	50 million
Land applied (ton)	2.8 million	120 million	50 million

amendments and that phosphate makes up another 0.7% to 7.5% of the total. But Moss explained that in amendments, the key nutrient, nitrogen, is organic and is only gradually made available to plants.

In comparison, chemical fertilizers are 15% to 82% nitrogen and 8% to 76% phosphate. Further, all of the nutrients in chemical fertilizers are designed to be available to plants, Moss notes. To maintain the proper agronomic loading rate for nutrients, farmers must apply more amendments than fertilizers. The same amount of nutrients can be delivered with either material, but the amount of work involved can vary greatly, she added.

Extra Helpings

If chemical fertilizers have more available macronutrients, require less material, and eliminate many application hazards, why use manures and biosolids at all? Because amendments do more than provide nutrients for plants to grow, they also improve soil health.

Landapplying amendments literally delivers tons of organic material to the soil, and the study found that those organic materials improve the soil's water retention, water infiltration, bulk density, and porosity. For example, the study of documents a Yuma, Ariz., site where repeated application of biosolids resulted in a 26% reduction in irrigation needs and increased crop (alfalfa and barley) yields.

Further, organic materials, which are negatively charged, also help improve pH and increase the cation exchange capacity, which dictates the soil's ability to retain such positively charged nutrient ions as ammonium and calcium.

In addition to physical changes to the soil, amendments also produce chemical changes that aid in crop production, the study reports. Over time, the organic nitrogen in amendments undergoes mineralization, continuously replenishing plant-available nitrogen in the soil. Further, Moss explained that microbes from the amendments help to increase the soil's biomass and maintain healthy levels of bacteria and fungi.

'Metaling' with Nature

Biosolids and manures also contain micronutrients, trace metals that replenish the soil, Moss said. While both biosolids and manures deliver these needed micronutrients, the study found that, generally, biosolids have higher concentrations of these metals than dairy and beef cattle manures, but that metal concentrations in swine and poultry manures can be comparable to biosolids.

While metal concentrations have been a focal point in biosolids land application, the study found that average metal concentrations fall far below the most stringent U.S. Environmental Protection Agency standards, as outlined in the 40 *CFR* 503 biosolids regulations. Further, the study stated that even though metals content usually is not associated with chemical

Table 2. Metal Content in Biosolids, Manures, Chemical Fertilizer (ppm)

Metal	Biosolids	Poultry Manure	Beef Cattle Manure	Phosphate Fertilizer	40 *CFR* 503 Limits
Arsenic	5.0	13	NA	11.3	75
Cadmium	4.4	2.4	NA	65	85
Copper	425	465	36	56.5	4300
Lead	76	46	NA	12.2	840
Molybdenum	12	19	4.94	NA	75
Nickel	33	16	NA	27.5	420
Zinc	735	602	129	240	7500

fertilizers and manures, few data are available to support that assumption.

In fact, chemical fertilizers contain relatively high concentrations of metals, especially cadmium, which is used in phosphate fertilizer production (see Table 2, above). On the other hand, based on the limited data available on manures, beef or dairy cattle manure contains the smallest amount of metals, she said. However, chemical fertilizers require much less material to be applied, so application rate needs to be considered when calculating the amount of metals introduced with chemical fertilizers.

If total metal concentration is one side of the equation, metal bioavailability and mobility, referred to as leachability, comprise the other side. Inert nonleachable metals pose little to no risk because plants cannot absorb them and they do not run off into nearby waterbodies.

Several factors, such as the metal's form, affect how land-applied metals behave. For example, oxide-bound and organically bound metals largely remain immobile and are not absorbed by plants, while water-soluble species are more susceptible to runoff and plant uptake, the study states. In general, according to the study, these factors indicate the bioavailability of metal, but many sitespecific factors, such as pH and synergistic effects between metals, also play a part.

The study calls for more research on leachability for all three materials, especially manures and chemical fertilizers. Testing performed on biosolids showed that most metals in composted and heat-dried products are organically bound. Metals in alkaline-stabilized biosolids can be more bioavailable than in other biosolids products, but the concentration of metal in alkaline products is generally lower.

Sorting Out the Bugs

The purpose of composting, heat drying and alkaline stabilization is not to reduce metals content, but to reduce pathogen concentration. The Part 503 rule requires that Class B biosolids either contain less than 2 million colony-forming units of fecal coliform per gram of total solids or be treated with a process known to reduce pathogens to accepted levels. To produce Class A biosolids, indicator pathogens for *Salmonella*, enteric viruses, and helminth ova must be undetectable or the materials must have undergone a treatment approved to remove pathogens to that level.

"The level of concern over biosolids pathogens may be disproportionate," Moss said, because manures typically are not treated to reduce pathogens and the volume

Table 3. Indicator Pathogen Content in Biosolids and Manures

	Biosolids				Manures	
	Class A Alkaline Stabilized	**Class A Composted**	**Class B Alkaline Stabilized**	**Class B Digested Liquid**	**Daily Manure (plus bedding)**	**Beef Cattle**
Fecal Coliform	3 MPN / g	76 MPN / g	60 MPN / g	104,600 MPN / g	5 to 30 million colonies/dry g	
Salmonella	2 MPN / g	2 MPN / g	2070 MPN / g	NA	3100 organism / g	NA

of land-applied manures exceeds that of biosolids.

Although information on total pathogen content in manures is limited (as it is in biosolids), levels of indicator pathogens in manures are higher than those in biosolids. For example, fecal coliform colonies in manures range from 5 million to 30 million units per gram (see Table 3, above). The study also indicates that healthy cattle manure might contain up to 10 million *Salmonella* per gram of feces. Yet manures still are more readily accepted than biosolids. This acceptance, Moss said, comes from long-term, relatively problem-free use of manures.

Biosolids, though, are "relatively newer and people are afraid of the whole industrial component," she said. "They're less afraid of what's in a cow or in a pig. Biosolids are relatively new and to a large extent postindustrial, so there's a feeling that they contain unknown – and scarier – compounds."

Ironically, the study found no instances of environmental effects from biosolids, (attributed to reduced pathogen loads and regulated application techniques) but did find cases of groundwater and surface water contamination by manures.

Why are biosolids sometimes shunned on the basis of pathogen content? "There's an assumption based upon our years of successfully using manures – 2000 years or more is a long time – that there isn't an issue," Moss said. "The track record for biosolids is certainly shorter, there's a 'fear factor' associated with 'human waste,' and, certainly, there's been a greater focus (until recently) on pathogens in biosolids. And, unfortunately, I think there's a lack of understanding about the benefits that biosolids have to offer, which can diminish any desire to use these products in the face of concerns regarding pathogens.

Next Steps

One goal of the study was to help alleviate such fears through education, Moss said. While the study collects, compares, and presents much of the data already available on manures, biosolids, and chemicals fertilizers so it is accessible to all interested parties, it also points to the necessity of further research.

The topics identified for more investigation include:

- Manure metal content and nutrient availability;
- Amendment emerging pathogen concentrations and detection techniques;
- Long-term field studies of all materials under proper agronomic management;
- Ecological assessments of soil amendments and chemical fertilizers;

- Health effects of odors; endocrine disrupter and pharmaceutical content in amendments and the relative effects of these compounds on the environment;
- And economic benefits of amendment use.

For example, to date, studies about the economic benefits of amendments have focused only on the savings possible from replacing chemical fertilizers with manures or biosolids, Moss said. But many other positive and negative aspects of amendment use need to be quantified and factored into the decision to use amendments. Manures and biosolids can be more difficult to apply, but they provide organic matter and improve water retention and soil productivity over the long-term, Moss said.

The study seeks to educate biosolids program managers, farmers, and the public about the benefits and risks associated with each choice and provide end users with a tool to assess site-specific conditions and make informed decisions about manures, biosolids, and chemical fertilizers. At press time, the report slated for publication between July and October.

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