



## Biological Manipulation of Manure: Getting What You Want from Animal Manure

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Manure is a biologically active material, alive with bacteria and other microorganisms that depend on the energy contained in manure. The use of manure energy by microorganisms—microbial activity—is a natural process of decomposition. Except in extreme cases of cold, pH, or lack of water, biological decomposition is inevitable. Microbial activity can create a wide range of byproducts. By storing, handling, or treating manure in various ways, farmers can control the byproducts produced by this biological activity. This is important to a farmer desiring to manage nutrients, control manure odors, increase ease of manure handling, or create a marketable product.

### Manure Contains Energy

In a sense, agriculture is all about managing energy flow (Figure 1). This energy flow begins when solar energy is captured by growing crops. Farm animals, in turn, use the energy contained in crops to build body mass and produce milk or eggs. Some energy is lost through respiration and heat from the animal's body. The remaining energy is excreted in manure. This excreted energy becomes a food source for microorganisms that live in the manure. Once the microorganisms deplete the available energy, the manure can no longer support microbial activity. At this point, the manure will not decompose further, and is considered "biologically stable."

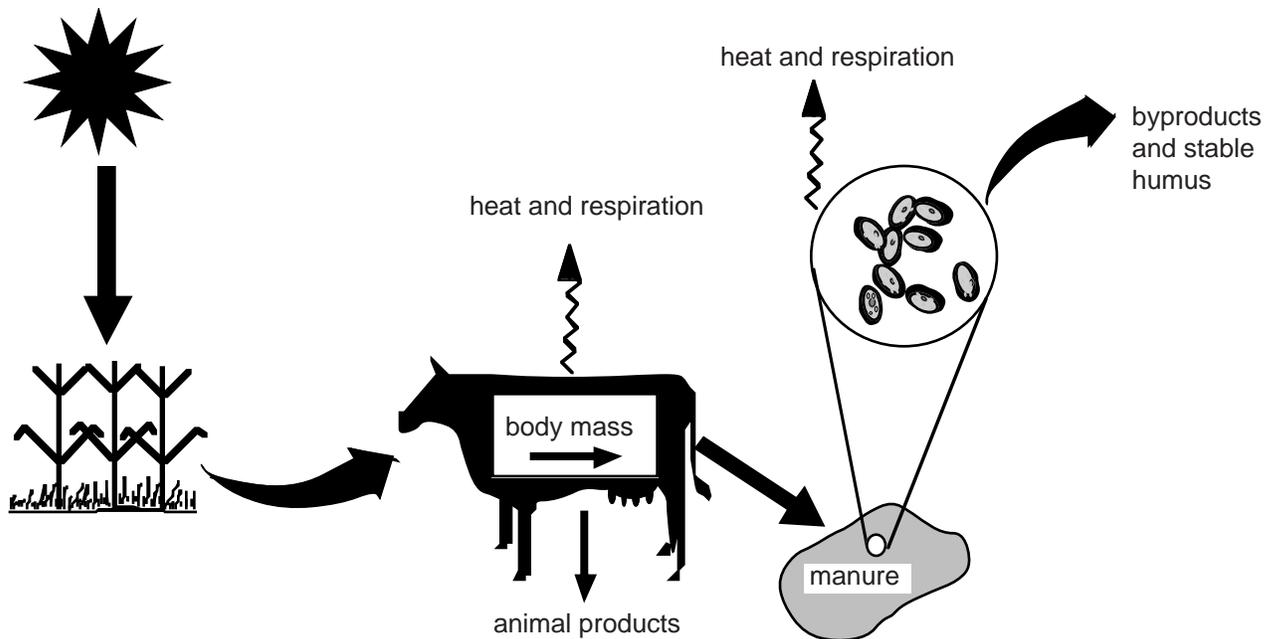


Figure 1. The flow of non-fuel energy in animal production operations. Arrows denote a transfer of energy.

## **Environment Affects Byproducts of Biological Activity**

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Like any other form of life, microorganisms create waste products. Offensive odors, methane gas, and stable humus are all potential byproducts of microbial activity. Different types of microorganisms generate different byproducts. The environment that manure is subjected to will influence the type of microorganisms that use the energy contained in manure. Some type of microorganism will use this energy under almost any conditions. Specific microorganisms, like animals, require particular diets and environmental conditions for optimum growth. Manure can provide the “food” for a wide variety of microorganisms. By carefully selecting the method of manure handling, storage, or treatment, farmers can create the environmental conditions that encourage microorganisms that produce beneficial byproducts and avoid microorganisms that produce undesirable byproducts.

Just as a cornfield hosts different plants, weeds, and insects than an alfalfa field, different manure storage, handling, or treatment practices support very different microorganisms. The type of microorganisms that will use the energy in manure, and the byproducts created as a result, depends on temperature, pH, moisture content, time, and initial manure composition.

## **Biological Manipulation of Manure**

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Biological manipulation can be used to manage odor, nutrients, consistency, and stability of the treated manure product. For example, manure, combined with a carbon-rich material such as sawdust and sufficient air, can be transformed into stable compost. On the other hand, by eliminating all air and adding heat, raw manure that contains little bedding can be transformed into biogas and a low-odor, nutrient-rich, liquefied, stable effluent. Biological manipulation involves providing the proper “diet” and environment for the specific microorganisms that will use the manure energy.

## **Types of Microorganisms Responsible for Biological Manipulation**

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Two main groups of microorganisms are responsible for biological manipulation of manure:

- aerobic, those which need oxygen to survive
- anaerobic, those which thrive without oxygen.

Aerobic microorganisms use the energy in manure to create carbon dioxide, water, heat, and stable humus. They generally do not produce foul odors, but they require an abundant supply of oxygen. In farm

applications, abundant oxygen is usually maintained with the proper mix of manure and a carbon-rich material and effective aeration (such as turning) of the mixture. Aerobic microorganisms can survive in a solid manure system if provisions are made to keep excess water out of the system. However, without purposefully managing for air incorporation, aerobic microorganisms can deplete available oxygen and cause parts of the manure pile or pack to become anaerobic.

Anaerobic bacteria can use the energy in manure to create biogas (methane and carbon dioxide) and a stable, liquefied effluent. If conditions are not suitable for biogas production, they also can create other byproducts that result in objectionable odors. Anaerobic bacteria survive in liquid manure systems where air cannot infiltrate the system and in manure piles that are too wet or compacted to allow air to permeate. Foul odors are the result of incomplete anaerobic decomposition, while biogas and stable effluent are the result of complete anaerobic breakdown of the manure energy. During the creation of odorous compounds, acid-forming bacteria use the energy in manure and create “intermediate” compounds as byproducts. Given enough time, the proper temperature, pH, and amount of “feed,” methane-forming bacteria will break down these intermediate compounds into biogas, resulting in complete microbial decomposition and a stable end product (Figure 2).

## **Managing Manure for a Specific End Product**

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Manure is an energy-rich feedstuff that is filled with potentially active microorganisms. These microorganisms will use the energy in manure, causing the manure to change. The challenge of biological manipulation is to manage the environment in which that change takes place in order to produce (or not to produce) specific byproducts.

## **Animal Species, Feed Composition, and Manure Management Systems—Their Effect on Microbial Activity**

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Microbial activity in manure from different animal species is affected by the solids (Figure 3). High solid content manure, such as poultry manure that contains about 25 percent total solids has a better chance of sustaining aerobic microbial activity than hog manure which is more than 90 percent water. Liquid hog manure provides an ideal environment for anaerobic organisms to grow. Manure handling systems that

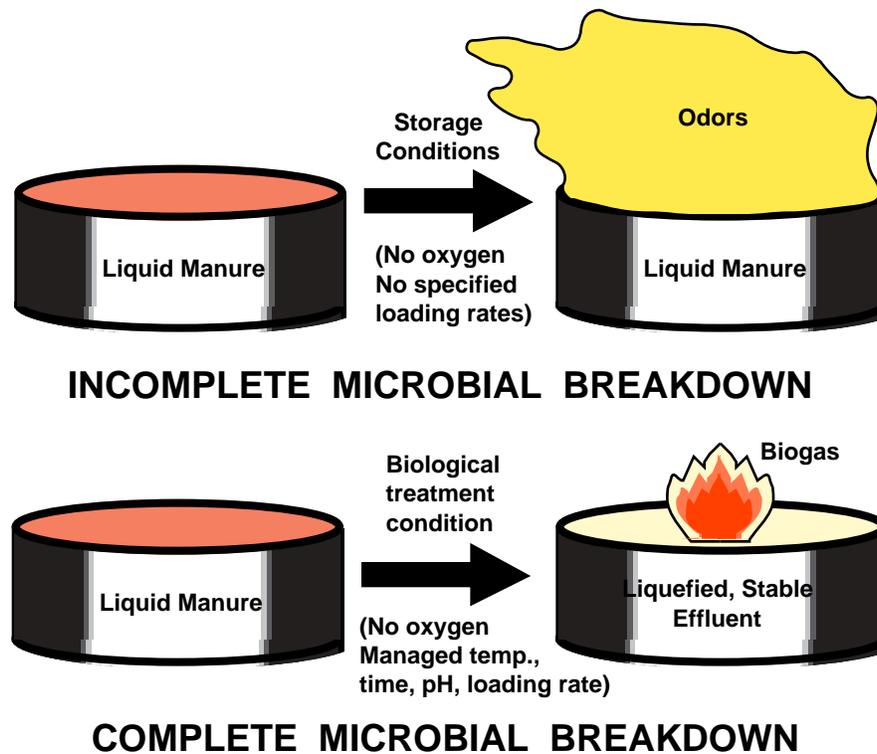


Figure 2. Microbial use of manure energy in anaerobic, liquid manure systems.

alter the solids content by addition of bedding, waste feed or water will also affect microbial activity.

Microbial activity is also affected by pH. Reported values for pH of manures are 6.9 for cage layer manure, 7.0 for dairy cattle manure and 7.5 for swine manure. Addition of waste feed, bedding or other materials to manure can affect these values. Also, because pH is influenced by the balance between volatile acids and ammonia that form during microbial decomposition of manure, the pH can go down or up depending on the conditions created by the management practices. Methane forming bacteria are particularly sensitive to pH.

Feed composition also affects microbial activity. High-protein diets encourage anaerobic conditions and more intense objectionable odors than high-roughage diets. For instance, cow manure is generally considered to be less of a source of offensive odors than nitrogen-rich hog or chicken manure. Nitrogen and oxygen are important “limiting factors” (see sidebar) for aerobic microbial activity. When nitrogen is abundant, the activity of microbes is limited by the supply of oxygen. The microbes in high-nitrogen manures rapidly use the limited supply of oxygen, causing the waste to become anaerobic. In addition, high-nitrogen manures may favor the production of certain offensive-smelling nitrogenous compounds.

## Conclusion

Because manure is energy-rich and alive with microorganisms, planning for microbial change can help farmers get what they want from animal manure. Factors, such as the environment for microbial growth, can be controlled and used as a tool to put the desirable microorganisms to work. Understanding how to “feed and care for” the desirable microorganisms can reduce odor and nuisance problems associated with manure storage and handling systems and also provide a more desirable end product.

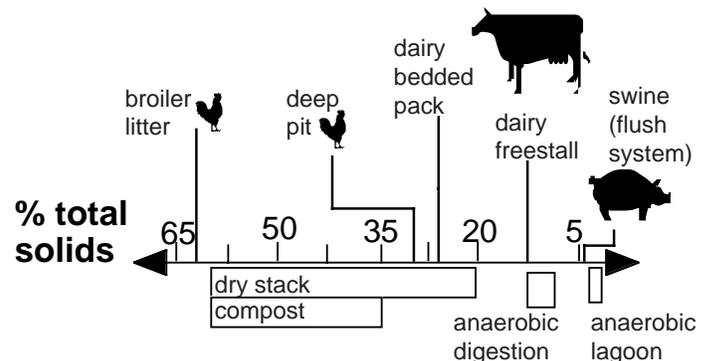


Figure 3. Microbial activity in selected manure management systems is influenced by solids content of manure.

**Environment and food source affect microorganism growth and byproducts of growth.**

**Anaerobic Microorganisms**

Microorganisms	Environment	Food Source	Byproducts of growth
Acid-forming bacteria	<ul style="list-style-type: none"> <li>no available oxygen</li> <li>wide range of temperature and pH</li> </ul>	complex organic compounds	simple organic acids (often odorous), alcohols, CO <sub>2</sub> , H <sub>2</sub> S, stable humus
Methane-forming bacteria	<ul style="list-style-type: none"> <li>no available oxygen</li> <li>constant temperature</li> <li>pH between 6.2 and 7.2</li> </ul>	simple organic acids	biogas (CO <sub>2</sub> , CH <sub>4</sub> , NH <sub>3</sub> , H <sub>2</sub> S), stable humus

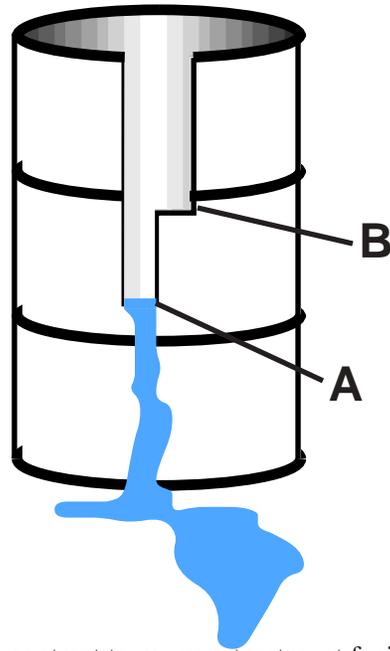
**Aerobic Microorganisms**

Microorganisms	Environment	Food Source	Byproducts of growth
Aerobic bacteria	<ul style="list-style-type: none"> <li>available oxygen</li> <li>adequate but not excessive water</li> <li>narrow range of pH conditions (not acidic)</li> </ul>	readily available organic matter such as organic acids and sugar	CO <sub>2</sub> , H <sub>2</sub> O, NH <sub>3</sub> , stable humus
Actinomycetes	<ul style="list-style-type: none"> <li>dry, warm environment</li> <li>available oxygen</li> <li>pH &gt; 5.0</li> <li>low nitrogen content</li> </ul>	complex organic matter such as fats, proteins, and cellulose such as acids and sugar	CO <sub>2</sub> , H <sub>2</sub> O, NH <sub>3</sub> , stable humus
Fungi	<ul style="list-style-type: none"> <li>available oxygen</li> <li>wide range of pH conditions</li> <li>adequate but not excessive water</li> </ul>	complex organics such as cellulose, hemicellulose, fats, lignin, organic nitrogen	CO <sub>2</sub> , H <sub>2</sub> O, stable humus

## "Limiting Factors"

The barrel on the right illustrates the concept of "limiting factors." The height of opening A limits how much dark fluid the barrel can hold, while the height of opening B has no effect on the amount of fluid. Therefore opening A is the "limiting factor."

Biological treatment systems for liquid manure are usually designed according to the daily biochemical oxygen demand (BOD) or volatile solids (VS) loading per unit volume of the treatment structure. BOD and VS are measures of the amount of energy available in manure for microorganisms. Providing the proper amount of energy is very important for keeping desired microorganisms alive and healthy. This means that microorganisms in manure treatment facilities need to be taken care of like animals—given the proper amount of feed and the right environment in which to live. Other biological manipulation methods such as composting, while not designed specifically according to BOD or VS, depend on the balance between the energy contained in the carbon-rich materials, the energy and nitrogen in the manure, the moisture content of the mixture, and the supply of air to the mixture.



In contrast to manure treatment facilities, manure storage structures are not designed for managed biological activity. Rather, they are designed simply to accommodate a given manure volume for a specified storage time. However, because manure energy is available, some microorganisms live in practically all storage environments. Unfortunately, odor-causing bacteria can survive better in semi-solid and liquid systems than many other microorganisms that create less objectionable byproducts.

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## Definitions

**biochemical oxygen demand (BOD)**—The amount of oxygen needed for aerobic microorganisms to stabilize the organic matter in manure. BOD is an indicator of the energy available for use by anaerobic and aerobic microorganisms in biological treatment systems.

**volatile solids (VS)**—Solids in manure, or other organic material, that are readily converted into a gaseous byproduct. VS is often used as a loading parameter for design of biogas systems.

**microorganisms**—An organism that requires a microscope to be observed. In manure management systems, bacteria, fungi, and actinomycetes are the primary microorganisms found.

**microbial activity**—The use of energy contained in manure or other organic matter by growing microorganisms.

**manure storage system**—A structure or earthen basin and associated loading and unloading equipment designed to accommodate a given volume of manure and other materials such as milking center wastewater, barnyard runoff, and silage leachate for a specified storage time.

**biological treatment system**—A system that utilizes growing microorganisms to reduce the strength, odor, or otherwise alter the properties of manure or other organic materials.

## Additional References

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*Managing Livestock Wastes* by James A. Merkel, AVI Publishing Company, 1981.

Manure Production and Characteristics ASAE Standard D384.1, ASAE Standards, 1995.

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## Related information

*Manure Management for Environmental Protection*, Pennsylvania DEP publication, October 1986. Available from DEP regional and state offices and county conservation district offices.

*Livestock Waste Facilities Handbook*—MWPS-18  
\$8.00

*On Farm Composting*—NRAES- 54 \$15.00

These two publications can be ordered from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802-2602, phone (814) 865-6713.

The following publications are available from the Penn State Agricultural and Biological Engineering Extension, 246 Agricultural Engineering Building, University Park, PA 16802, phone (814) 865-7685 or email mxh16@psu.edu.

*Anaerobic Digestion: Biogas Production and Odor Reduction From Manure* -G77

*Odor Control for Animal Production Operations* - G79

*On-Farm Composting* -C3

*Farm Composting: Plan Ahead to Avoid Problems Later* -C4

*Farm Composting for Profit* -C5

*Farm Odors in the Community: Future Directions* - brochure

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