Biological Processes

Biological treatment of manure is not a new phenomenon. Manure that is stored in earthen basins, pits, or tanks or is spread on land undergoes biological degradation. In these cases, the processes involved are relatively uncontrolled and may take a long time. Biological treatment systems or technologies can help accelerate the natural process and can be, for most of the cases, well controlled.

The main applications of these systems in the agricultural area are (a) stabilization of manure; (b) removal of odor; (c) removal of organic matter; (d) nitrification; and (e) removal of nutrients.

Aerobic treatment

Complete aerobic treatment eliminates manure odors. Aerobic treatment is usually only suitable for separated slurry or dilute effluents. Solids in manure increase the amount of oxygen needed and also increase the energy needed for mixing. The degree of oxidation depends on the amount of oxygen provided and the reaction time allowed in the treatment process. Slurry aeration allows microorganisms to metabolize dissolved components such as organic acids, phenols, indoles, nitrogen and sulfur compounds, low molecular weight proteins, etc., which are responsible for most offensive odor emissions. Since complete stabilization of livestock manure by aerobic treatment is normally not economically justifiable (Westerman and Zhang 1997b), lower levels of aeration have been recommended for partial odor control. Figure 43-7 shows a diagram of a typical aerobic treatment system.

Complete aerobic treatment eliminates manure odors.

A variety of aerobic reactors can be used for odor control. Many batch aeration treatments carried out in farms can be described as batch fed or semi-continuous, if slurry is either added or removed during the process. This tends to be the result of practical needs rather than process requirements (Burton 1992). Batch treatment may require additional storage facilities other than the tank used for aeration. Without additional storage, the aeration vessel has to be large enough to store slurry longer than the specified treatment time. Aeration can be continuous or intermittent and is carried out during the time the tank is filling (up to 6 months). Continuous aeration offers the option of a controlled steady-state process, and the phenomenon of the initial surge in activity is avoided. On the other hand, energy costs will be higher compared to intermittent aeration.

Lagoons can be aerated to control odor. Aerated lagoons (Figure 43-8) are able to reduce odor significantly by avoiding the anaerobic treatment environment that can produce odorous compounds. The biggest drawbacks to aerated lagoons are (a) the cost of energy to run the aerators; (b) biosolids production, which is higher than in anaerobic systems; and (c) the potential for release of ammonia if the aeration level is not correct.

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If too little oxygen is put into the system, manure will not be stabilized and the anaerobic conditions that result will lead to additional odors. If too much oxygen is put into the system, ammonia and other gases will be released. Research carried out in the United Kingdom and the Netherlands has shown that nitrous oxide is also released to the atmosphere during combined aerobic/anoxic treatment (Pahl et al. 1998, Willers et al. 1996).

Other aerobic treatment systems include aerated filters with fixed media for maintaining a bacteria biofilm. This type of system has been used to some extent for nitrification of municipal and industrial wastewater, but only a few

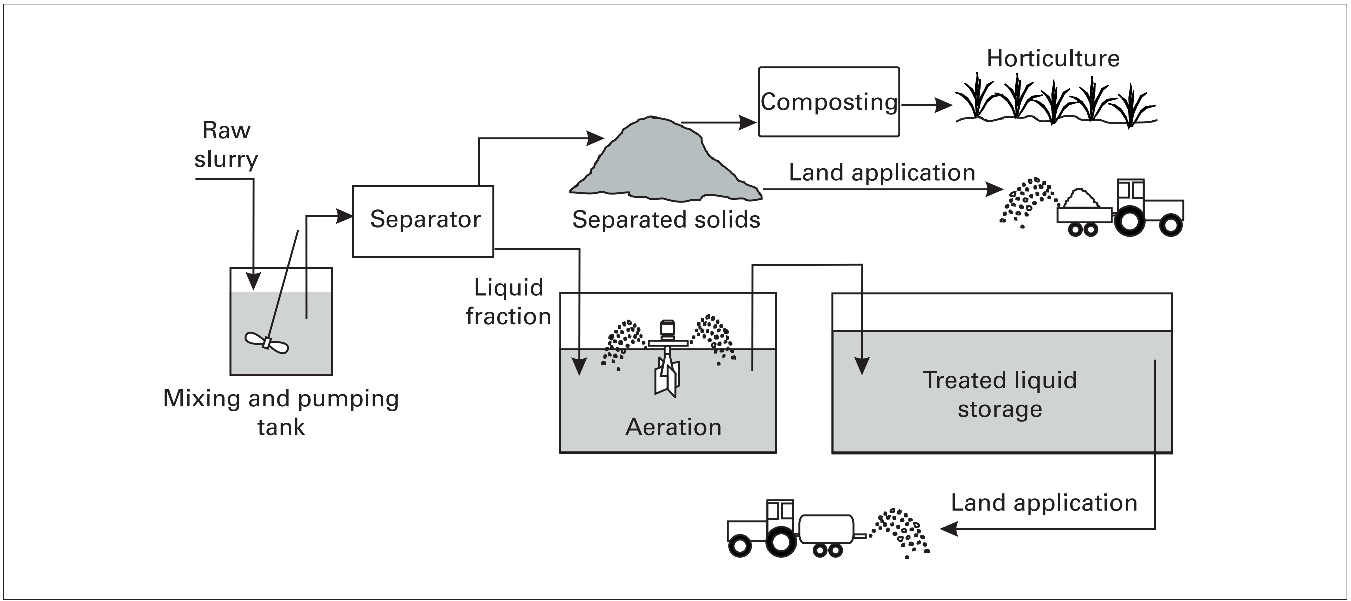

Figure 43-7. Aerobic treatment system.

applications related to livestock manure have been reported to date.

As Table 43-3 shows, several researchers have reported significant odor reduction from manure after aerobic treatment. The costs associated with the operation of such systems are still too high to encourage widespread adoption of the technology by producers.

Burton et al. (1998) have also quantified the effect of treatment duration on odor abatement. No odor regeneration was discerned during the first 28 days after anaerobic storage of pig slurry treated for 2.4 days.

Composting

Composting is another type of aerobic treatment that is applicable to solid or semi-solid manure.

Composting is another type of aerobic treatment that is applicable to solid or semi-solid manure (Figure 43-9). Composting is a biological process in which microorganisms convert organic materials such as manure, sludge, leaves, paper, and food wastes into a soil-like material called compost. It is the same process that decays leaves and other organic debris in nature and offers several potential benefits, including improved manure handling, enhanced soil tilth and fertility, and reduced environmental risk. The composting process produces heat, which drives off moisture and kills pathogens and weed seeds. Composting also reduces the volume of material as much as 50% and produces a very uniform, easy-to-handle material. More details on actual composting methods can be found in NRAES 54, On Farm Composting Handbook (NRAES 1992).

Composting can be used as a treatment system in animal or poultry farms where solid manure and solid material removed from liquid slurries by mechanical separators (with at least 15% dry matter content) are available. It is usually necessary to blend together several materials, in suitable proportions, to achieve a mix with the desired overall characteristics. Efficient composting requires optimum conditions for microbial growth. Composting requires a supply of oxygen, adequate moisture, and a blend of material that meets a specific carbon-to-nitrogen (C:N) ratio. If these parameters are met, carbon dioxide and water will be the primary gas emissions from the process.

Composting can reduce manure volume, stabilize manure nutrients, kill pathogens and weed seeds, and produce a homogeneous non-odorous product.

At many composting sites, odors originate with the incoming ingredients, which may have been stored anaerobically before transport to the site. Once these ingredients are incorporated into the composting system, subsequent odor problems are usually a result of low oxygen or anaerobic conditions. Odors and gaseous emissions from composting operations appear to be most significant in the early stages of the process and during turning. University of Minnesota researchers (Schmidt and Bicudo 2000) have recently reported that odor emissions from a full-scale chicken layer manure composting operation are reduced by 75% after the first two weeks of composting and by 85% after 4 weeks of composting. Hydrogen sulfide emissions were reduced by about 60% after 4 weeks of composting. Management seems to be a key factor in reducing odors and gaseous emissions from composting operations.

Research indicates that the use of sufficiently high initial C:N ratio and drier materials can help minimize odor and gaseous losses from composting operations. Lower ammonia emissions can be achieved by adding a large amount of dry, high-carbon amendment or bulking agent, such as straw. Other products, such as zeolite, have been added to compost mixtures to minimize ammonia volatilization (Burton 1997).

Up to now, composting has not been viewed as a treatment technology intended to reduce odor and gas emission from solid manure systems. Rather, composting has been viewed as a process that produces an odorless, value-

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...sufficiently high initial C:N ratio and drier materials can help minimize odor and gaseous losses from composting operations.

Figure 43-8. Aerated lagoons treating flushed swine manure.

Table 43-3. Odor reduction from manure after aerobic treatment.

Type of Treatment	Duration of Treatment	Target Aeration Level	Reduction in Odor	Estimated Cost	Reference
Fed-batch, continuous aeration	1.7-6.3 days	less than 1 mg O_2/L	50%-75%	$1-$3 per pig	Burton et al. 1998
Sequencing batch reactor, intermittent aeration	HRT[1]: 5 days SRT[2]: 30 days	6 mg O_2/L	88%	N/A	Bicudo et al. 1999
Aerated lagoon, continuous aeration	HRT: 2.1 days	5 mg O_2/L	45%	$6 per pig	Westerman and Bicudo 1999
Aerated filter	HRT: 16 hours	6-8 mg O_2/L	64%	$2 per pig	Westerman et al. 1998

[1]HRT: hydraulic retention time
[2]SRT: solids retention time

Figure 43-9. Windrow composting operation at a dairy farm.

added material. If managed properly, the composting process does not seem to produce significant odor and gas emissions.

Anaerobic treatment

Anaerobic lagoon. Anaerobic treatment of manure takes place in the absence of oxygen. The most common type of anaerobic digestion system used for livestock manure, which also combines storage, is the anaerobic lagoon. Design and management are key factors in maintaining acceptable odor levels from lagoons. Both one- and two-stage lagoon systems are used. When properly sized and managed, an anaerobic lagoon (Figure 43-10) can be operated with a minimum of disagreeable odor.

Volatile nitrogen gases are natural byproducts of anaerobic decomposition and are released from open lagoon surfaces. When released from a lagoon surface, the relative proportions of these compounds and their impact on the environment are not well documented or understood.

Greater potential for odor emission occurs when retention times are too short, or lagoon loading rates increase due to expanding animal numbers, slug loading, concentrated waste streams, and/or inadequate water for dilution. Odor emission from anaerobic lagoons is more likely during system startup, when the lagoon surface is disturbed during windy conditions; during agitation and pumping for land application; and during spring turnover–defined as very vigorous bacterial activity during the spring due to incomplete metabolism of material during winter. When acid-forming and methane-forming anaerobic bacteria are in balance, an anaerobic lagoon produces minimum odors.

When acid-forming and methane-forming anaerobic bacteria are in balance, an aerobic lagoon produces minimum odors.

Distinct purple- or pink-colored anaerobic lagoons have been observed to produce less odor (Chen et al. 1997). The color and odor reduction is caused by naturally occurring purple sulfur bacteria, phototrophic organisms that oxidize sulfide under anaerobic conditions. This type of bacteria metabolizes simple organic compounds, reducing the strength of the lagoon wastewater, removing toxic amine compounds, and producing anti-viral substances. When these organisms are dominant, lagoon odor, chemical oxygen demand, ammonium nitrogen, and soluble phosphorus concentrations are reduced. The purple or pink color is a good indicator of a healthy lagoon.

Anaerobic digesters and filters. Anaerobic digesters are designed and managed to optimize the bacterial decomposition of organic matter under

Figure 43-10. Partial view of an anaerobic lagoon treating swine manure.

more controlled conditions than in a lagoon. A complete anaerobic digestion system is shown in Figure 43-11. One of the most common anaerobic reactors used for the treatment of manure is the plug-flow reactor. In this system, manure is added to one end of a tank, allowing the effluent to overflow and be removed from the other end into a storage facility. Effluent solids may be separated from the liquid and composted if there is an interest in doing so.

Other types of anaerobic digesters include complete-mix, contact, and upflow anaerobic sludge blanket digesters. The anaerobic sequencing batch reactor is another alternative for the treatment of animal manures that is being researched both in Canada and in the United States, mainly at the University of California, Davis, and Iowa State University.

Digesters are more efficient, with better treatment and biogas production, when operated at high temperatures (over 120°F). However, this is not usually cost effective because the energy inputs required to maintain this high temperature are greater than the energy gained in the process.

Usually, anaerobic digesters are operated between 95°F and 100°F. There have also been some successful applications in the 60°F to 75°F operating range, with lower treatment efficiencies offset by higher retention times.

Anaerobic filters have also been used for the treatment of more dilute or pre-screened manure (Sanchez Hernández and Rodriguez 1992). The anaerobic filter is a column filled with various types of solid media (Figure 43-12). The manure flows either up or down through the column, contacting the media, on which anaerobic bacteria grow and are retained. Because the bacteria are retained on the media and not washed off in the effluent, long solids retention time can be achieved with reasonably short hydraulic retention times (HRT). Therefore, the anaerobic filter can be much smaller than other types of digesters with equivalent treatment efficiencies.

According to Lusk (1998), surveyed farmers who have installed and continue to operate digesters are generally satisfied with their investment decisions. Some chose to install digesters for non-economic reasons, primarily to control odor or contain excess nutrient runoff. Although the control of odors by anaerobic digestion has not been the focus of much research, some encouraging results have been published in the last 10 years.

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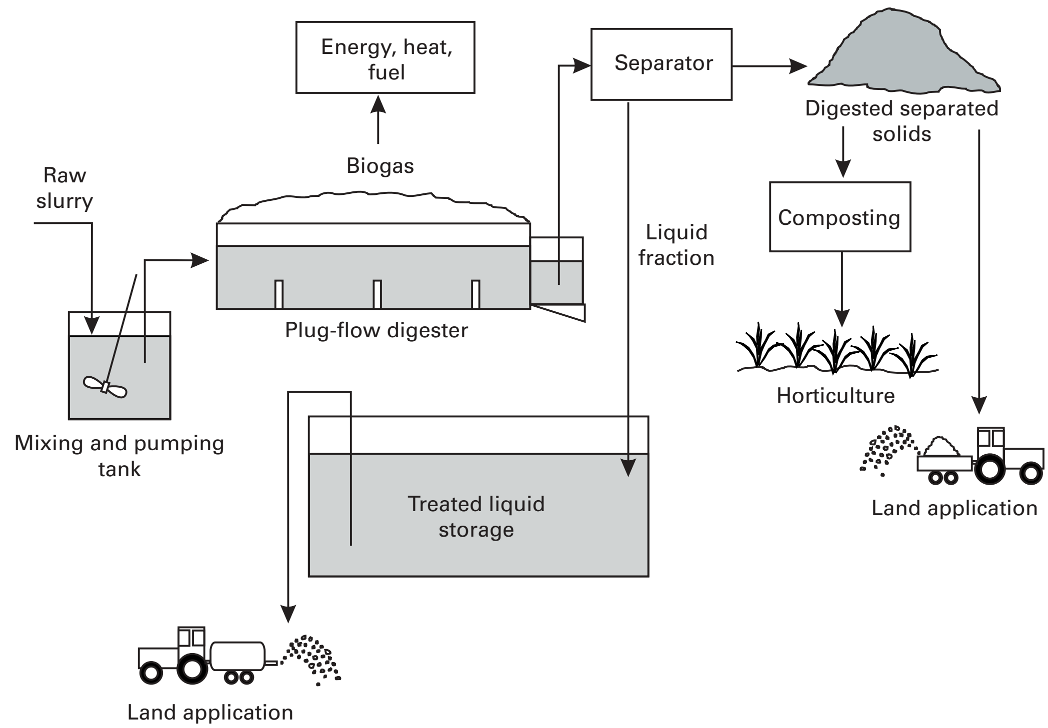

Figure 43-11. A typical anaerobic digestion system showing a plug-flow reactor and optional separation and composting of digested solids.

Very little odor is produced from a properly managed anaerobic digester.

Very little odor is produced from a properly managed anaerobic digester. Provided with adequate retention time and specific temperatures, a well-controlled anaerobic digestion process degrades the vast majority of compounds that contribute to odors. Powers et al. (1997), for example, found that odor intensity from dairy manure decreased linearly with increased HRT in a set of laboratory experiments. The effluent from complete-mix digesters with a 20-day HRT had about 50% less odor than the untreated manure (1.3–2.0% TS). Anaerobic filters with only 2.3-day HRT also reduced odor intensity.

Odor reduction from land-spreading operations achieved with anaerobically digested pig slurry was reported to be between 70% and 80% compared to undigested slurry (Pain et al. 1990). Their results also indicate that digested slurry was relatively stabilized. After 2 weeks of additional storage, odor emission was still 70% less compared to undigested slurry.

Considerable research has been devoted to the recovery and reuse of biogas generated by anaerobic digesters as well as to the odor abatement potential of these systems. Much has been learned about how manure can be used as an energy and nutrient source. Without the environmental benefits provided by anaerobic digestion technology, some farmers might have been forced out of livestock production. Anaerobic digestion is probably one of the few technologies that allow growth in the livestock production business. However, the performance data does not appear to be encouraging to a farmer who is considering whether to install an anaerobic digestion system. Overall, the chance of failure, i.e., the chance of having a non-operating digester, is

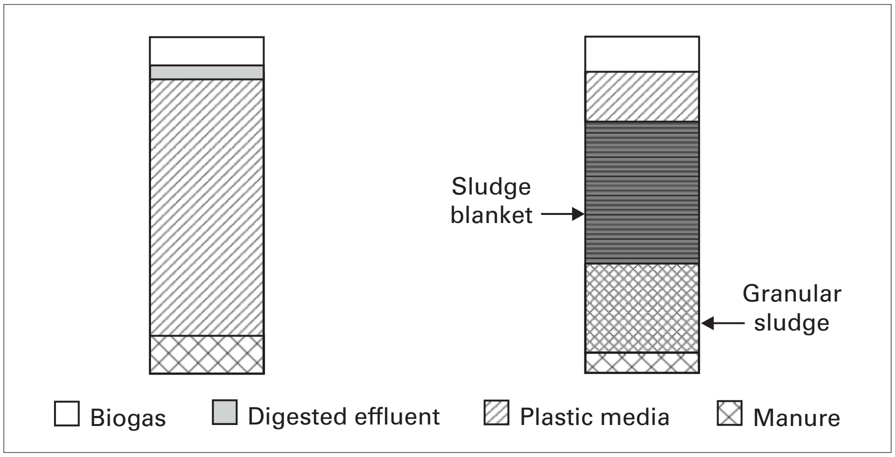

Figure 43-12. Anaerobic filters used for the treatment of livestock manure.

about 50% in the United States (Lusk 1998). The failure rates for complete-mix and plug-flow technologies are 70% and 63%, respectively. The reasons why some anaerobic digesters fail is probably headed by bad design and installation. Poor-quality equipment and materials selection is the second most common reason for failure. Other factors such as economics, erratic biogas production, and increased managerial skill requirements have limited the U.S. adoption of this manure utilization technology. One encouraging note is that the reliability of digesters built since 1984 is far better than for those constructed between 1972 and 1984. This is generally due to a resurgence of interest in farm-based anaerobic technology and the development of more simplified digester design.

...the reliability of digesters built since 1984 is far better than for those constructed between 1972 and 1984.

Biological additives

As a result of the increased public, regulatory, and legal attention directed to the odor issue, many producers are considering the use of commercial manure and/or feed additives to minimize odor and other air emissions from livestock farms. In addition to odor control, many products are marketed as having other beneficial effects such as improved nutrient value of the manure, improved animal performance, fly control, etc. Product additives are generally described as compounds that can be added directly to freshly excreted or stored manure for odor abatement. A recent laboratory study tested 85 different manure pit additives (NPPC 2001) and found that only four product reduced odor by a 75% certainty level. Approximately ten products reduced H_2S by either a 95% or 75% certainty level while 12 products lowered ammonia by the same two percentages.

As a result of the increased public, regulatory, and legal attention directed to the odor issue, many producers are considering the use of commercial manure and/or feed additives to minimize odor and other air emissions from livestock farms.

Microbiological additives, or digestive deodorants, generally contain mixed cultures of enzymes or microorganisms designed to enhance the degradation of solids and reduce the volatilization of ammonia and/or hydrogen sulfide. The microorganisms are meant to metabolize the organic compounds contained in the manure. Digestive deodorants may act to inhibit selected biological or digestive processes by changing the enzyme balance (ASAE 1994). Most digestive deodorants are applied directly into the manure collection area and/or the lagoon and must be added frequently to allow selected bacteria to predominate (Sweeten 1991). Each product has a specific method of application, frequency, quantity, and length of time before the product is considered “most effective.” Some products are pH and temperature dependent

"…supplemental microorganisms, as additives, may not readily adapt to the natural conditions in manure handling systems and are often susceptible to competition from the naturally occurring indigenous microbial populations." [Miner 1995]

There was no significant difference in odor initiation between all [physico-chemical] treatments with flushed wastes.

and only work within narrow ranges of pHs and temperatures.

Although bacterial genera or species exist that can decompose odorous compounds like volatile fatty acids to reduce odor emission, little success has been reported in using these microbes as manure additives to control odor generation in the field.

According to Grubbs (1979), the key in using bacterial cultures for manure deodorization is to have the added bacteria become the predominant bacteria strain in the manure. For the added bacteria to flourish, the real environment should not deviate tremendously from the bacteria's optimum growth range. Past work mainly focused on determining bacterial functions in the digestion of odorous compounds under optimum conditions, which does not guarantee that the bacteria will grow well in the field.

Results from laboratory additive testing are usually subjected to significant variations and do not allow for any definite conclusion. Miner (1995) reviewed several studies of digestive deodorants and concluded that "…the variable success measured for the effectiveness of microbial and digestive agents to control odor may be due to the inability of these products to degrade many of the compounds which collectively make up odor from a swine operation." And "…supplemental microorganisms, as additives, may not readily adapt to the natural conditions in manure handling systems and are often susceptible to competition from the naturally occurring indigenous microbial populations."

Chemical additives

Chemical addition can control sulfides in manure by chemical oxidation, pH control, or precipitation. It involves the addition of chemicals to form new chemical compounds. Table 43-4 gives some of the different chemicals that can be used for odor control and improvement of overall treatment efficiency.

Several researchers have tried adding chemicals (mainly precipitants and polymers or a combination of both) to manure to improve separation efficiency and to concentrate nutrients to a greater extent in the separated material. Volatile solids reductions of over 80% have been reported (Powers et al. 1995, Zhang and Lei 1996). Also high removals of phosphorus from the liquid fraction (over 90%) have been observed (Westerman and Bicudo 1998).

The effect of odors remaining in the effluent after physico-chemical treatment of flushed swine manure and anaerobic lagoon liquid was examined by Westerman and Bicudo (1998). The final effluent was found to have less odor intensity and better odor quality than either flushed wastes or the separated liquid. However, the odor intensity was "strong," and the odor quality was "very unpleasant." There was no significant difference in odor irritation between all treatments with flushed wastes. Treatment of lagoon liquid in the evaluated system resulted in odor increase in all odor parameters (intensity, irritation, and unpleasantness) in both the final effluent and thickened sludge. Odor increase during treatment of lagoon liquid was probably related to the formation of odorous compounds with the addition of chemicals (lime, $FeCl_3$ and polymer). Because physico-chemical treatment is not as effective when more dissolved material is being processed, such as the material contained in lagoon liquid, residual chemicals that did not react with inorganic compounds might have reacted with complex organic materials, originating more odorous-bearing compounds.

Other chemical additives. Masking agents cover one smell with another. They are made from a mixture of compounds that have a strong odor of their own (for example, pine), masking the undesirable odor. They can be effective as an emergency, short-term solution for the symptom, but generally, long-term control of the odor problem is necessary. Masking agents are normally used as vaporized material. They usually consist of organic aromatic compounds such as heliotropin, vanillin, eugenols, benzyl acetate, and phenylethyl alcohol. They are injected into the air right above the liquid surface of the odor source (in this case, stored manure). Nonvaporized agents are applied directly to the manure.

The effectiveness of masking is difficult to predict due to varying odor characteristics and changing weather conditions. Masking agents primarily used where the odor level is relatively low always increase the total odor level. Without any chemical reaction, the individual constituents of the odor remain unchanged. The main advantages of masking agents are their low cost and nonhazardous nature (WEF 1990). The disadvantage is the agent's tendency to separate from the odor downwind. Miner (1995) concluded that "…the organic chemical composition of most masking agents makes them susceptible to degradation by the microorganisms indigenous to manure." And thus, "…the odor control capacity of most masking agents and counteractants may be too short lived for practical use in swine production environments."

Counteractants do not react chemically with the malodor but reduce the perceived odor level by eliminating the malodor's objectionable characteristics. They usually have a neutral pH, are easy and safe to handle, and are moderately more expensive than masking agents (WEF 1990). Counteractant chemicals neutralize the following odor types: phenols, amine, mercaptan, aldehydes, solvent odors, aromatics, and organic fatty acids. They usually lower or maintain the same odor level. Their effectiveness is not always predictable.

Adsorbents and absorbents are chemical or biological materials that can

The effectiveness of masking is difficult to predict due to varying odor characteristics and changing weather conditions.

"…the odor control capacity of most masking agents and counteractants may be too short lived for practical use… ."
[Miner 1995]

Table 43-4. Chemicals used for odor control.

Category	Chemical Compound	Key Reactants	Advantages	Disadvantages
Oxidizers	Ozone	H_2S	Strong oxidizing agent and disinfectant.	Unstable. Onsite generation required. Toxic as low as 1 ppm.
	Hydrogen peroxide	H_2S	Good oxidant. Weak disinfectant. Nontoxic byproducts. Inhibits regeneration of sulfate reducers.	Does not treat ammonia or odorous organics. Long contact time required. Very costly.
	Potassium	H_2S	Strong oxidizing agent. Stable, easily handled. Noncorrosive.	Does not treat NH or disulfides. Costly if large amounts needed. Creates insoluble MnO_2 precipitate.
pH modifiers	Lime, sodium hydroxide	Bicarbonates	Helps reduce BOD, SS, and PO_4 in the liquid stream. Odor-producing microorganisms are destroyed when pH > 12.	High pH induces NH_3 volatilization. Low pH induces H_2S volatilization. Creates insoluble precipitate, usually high in P.
Precipitants	Divalent and trivalent ions such as iron and aluminum (e.g., ferric chloride)	Bicarbonates	Helps reduce BOD, SS, and PO_4 in the liquid stream.	Creates insoluble precipitate, usually high in P. Some products are highly corrosive. Can be expensive.

Adapted from WEF 1990.

It is generally believed that windbreaks reduce odors by dispersing and mixing the odorous air with fresh air, although research has not confirmed these effects.

collect odorous compounds on their surfaces (adsorb) or interiors (absorb). Examples are activated carbon, zeolites, sodium bentonite, sphagnum peat moss, sawdust, rice straw, etc. Zeolites have been used for ammonia emission reduction from composting piles (Burton 1997) and also from swine manure (Cintoli et al. 1995). Absorbents with a large surface area, such as sphagnum peat moss, have been found to reduce odor in some lagoons (Swine Odor Task Force 1995). Floating organic lagoon covers (straw) and soil biofilters are other examples of the use of odor-absorbing materials.

Landscaping

Natural windbreaks. Rows of trees and other vegetation known as shelterbelts, historically used for snow and wind protection in the Midwest, may have value as odor control devices for all species and systems. Similarly, natural forests and vegetation near animal facilities in other sections of the country may serve the same purpose. These shelterbelts also create a visual barrier. A properly designed and placed tree or vegetative shelterbelt could conceivably provide a very large filtration surface (Sweeten 1991) for odorous compounds from manure storages as well as building exhaust air, particularly under stable nighttime conditions (Miner 1995). Currently, a few studies are addressing the total impact of vegetative barriers on odor reduction from animal farms, but many people already attest to their value. Shelterbelts are inexpensive, especially if the cost is figured over the life of the trees and shrubs, but it may take 3 to 10 years to grow an effective vegetative windbreak.

It is generally believed that windbreaks reduce odors by dispersing and mixing the odorous air with fresh air, although research has not confirmed these effects. Windbreaks on the downwind side of manure storages create mixing and dilution. Windbreaks on the upwind side deflect air over the storages so it picks up less odorous air.

Table 43-5. Summary of technologies for odor control.

Process/System		Description	Advantages	Disadvantages	Cost
Covers	Straw (wheat and barley)	Straw is blown over the surface of the stored manure manure (about 100 bales to cover 1 acre of surface area with a layer of 12 inches).	Effectively reduces odors, H_2S and NH_3 emissions	Temporary solution; straw sinks after a certain period	$0.10/ft^2
	Floating clay balls	Floating clay balls (Leca® or Microlite®) are placed over manure.	Effectively reduces odors, H_2S and NH_3 emissions	Care must be taken during agitation and pumping	$2-$5/ft^2
	Geotextile	Geotextile membranes are placed over the surface of the manure; for more effective results, straw may be blown over the geotextile.	Helps reduce odors, H_2S and NH_3 emissions	Difficult to access basin for pumping if storage and not lagoon	$0.20-$0.40/ft^2
	Plastic cover	Several varieties of plastic can be placed over manure storages (floating or rigid structures).	Helps reduce odors, H_2S and NH_3 emissions	Capital cost	$1-$2/ft^2
Manure treatment	Solid separation	Solids are separated from liquid slurry through sedimentation basins or mechanical separators.	May reduce odor and NH_3 emissions; easier agitation and pumping	Capital and operational costs; reliability; adds another "waste" stream for farmer to manage	$1-$3/pig marketed
	Aerobic treatment	Biological process where organic matter is oxidized by aerobic bacteria; mechanical aeration is required to supply oxygen to the bacterial population.	Effectively reduces odor, organic matter, and nutrients (if needed)	Capital and operating costs	$2-$4/pig marketed
	Composting	Biological process in which aerobic bacteria convert organic material into a soil-like material called compost; this same process decays leaves and other organic debris in nature.	Reduces odor and organic matter; produces a saleable product; can include other byproducts	Capital and operational costs; if product is to be sold, marketing skills required	$0.20-$0.40/pig marketed
	Oversized permanent pool for anaerobic lagoon	Lagoon permanent pool designed larger to allow more dilution water	Reduces odor by lowering VS loading rate	Additional cost for more earthwork to build larger structure	$200 or more per 1,000 lbs bodyweight capital cost; if properly operated, energy may provide return
	Anaerobic digestion	Biological process where organic carbon is converted to methane by anaerobic bacteria under controlled conditions of temperature an pH	Reduces odor and organic matter; produces biogas; retains nutrients; easier handling of liquid	Capital cost; may require a reasonably skilled operator; attractive where energy supply is an issue	

Table 43-5. Summary of technologies for odor control (continued).

Process/System		Description	Advantages	Disadvantages	Cost
Biological additives		Chemical or biological products are added to manure.	May reduce odor and NH_3 emissions; easy to use	Usually questionable products; may not achieve desirable results under field conditions	$0.20-$1.00/pig marketed
Land-scaping	Shelterbelts	Rows of trees and other vegetation are planted around a building, creating a barrier for dust and odorous compound removal from building exhaust air. Trees can absorb odorous compounds, and they create turbulence that enhances odor dispersion upward.	May effectively reduce dust and odor emissions	May take several years to grow effective vegetative windbreak	$0.06 and up/ pig bldg capacity