Goals/Objectives of Treatment Systems and Alternative Technologies

Animal manure treatment systems have historically been selected to recover or use valuable fertilizer constituents or feed ingredients and to protect soil, air, and water quality. Over time, however, the protection of soil, air, and water quality has evolved to include such considerations as the management of potentially toxic materials such as copper, zinc, and antibiotics; concerns about proper nutrient management; and increased emphasis on air quality. Odor; ammonia volatilization; the release of hydrogen sulfide, methane, and other gases; and the potential of dust to transport odors and produce biosolids have become major public concerns. There has also been increased emphasis on the utilization of valuable constituents in manure and mortalities through more effective constituent conservation and processing to value-added byproducts.

Manure treatment systems or alternative technologies are evaluated or selected for their capability to provide the required protection of soil, water, and air resources. Some waste treatment systems or alternative technologies can address several of these requirements, while some are so specialized that only individual resources or waste constituents are addressed. A discussion follows of environmental quality concerns and waste treatment systems or alternative technologies required to protect resources or address particular waste constituents or waste management needs or desires.

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Water quality considerations

Animal manure constituents such as organic matter, nutrients, nitrogen (N), phosphorus (P), pathogens, and metals can degrade surface water quality and thus must be removed by waste treatment systems or managed by alternative technologies either in conjunction with existing waste treatment systems or as a new waste management system.

Organic matter. Organic matter supports the metabolism of aerobic or anaerobic microorganisms. When animal manure with high amounts of organics is discharged to receiving waters, rapid microorganism growth occurs that depletes the receiving waters of oxygen, causing either low or zero levels of oxygen to exist and thus either anaerobic or septic conditions to develop.

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) tests are standard wastewater analyses that determine the level of oxygen demand. Strict regulations limit the amount of BOD or COD that can be discharged into receiving streams. Since it is difficult or impractical to obtain these effluent levels with traditional animal waste treatment systems, animal waste is generally not discharged but terminally applied to land as an alternative to commercial fertilizer.

Manure organics and oxygen demand can be reduced by processes that promote the growth of either aerobic or anaerobic bacteria. Under aerobic conditions, 50% of the metabolized carbon (C) goes to biomass, which can be removed by settling. However, this settled biomass or sludge requires further management because of its nutrients and possible harmful constituent contents. Under anaerobic conditions, 90% of the C is released as methane and carbon dioxide. Therefore, with anaerobic treatment, less biomass is generated and methane can be used as an energy source for hot water and electricity.

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Nutrients. The animal waste nutrients of primary concern are N and P. Historically, animal waste has been applied to land, taking advantage of these fertilizer nutrients. However, regulations have been developed or are being developed that require animal waste N and P to be applied at agronomic rates because excess levels are building up in soils and being transferred to surface waters by runoff and to groundwater by infiltration. If sufficient land is not available to apply N and P at agronomic rates, then alternative technologies must be added to the existing waste treatment system or new alternative technologies employed to either use or reduce the amount of N and P. Effluent from conventional biological treatment processes may contain high amounts of phosphate, ammonia, and N because of the limited uptake of these constituents by microorganisms.

Nitrogen (N). Nitrification, the conversion of N to nitrate for conservation as fertilizer N, is becoming an increasingly important component of total farm management systems. High-rate oxidation of manure N to nitrate can also reduce ammonia volatilization.

Nitrogen can be removed by denitrification, which is the conversion of nitrate to N gas under anaerobic conditions when sufficient organics or energy is available. Manure N can be oxidized to nitrates by various aeration techniques, such as lagoon aeration by a surface aerator or compressed air released as small bubbles near the bottom of the lagoon, aerobic bio-filters, sequencing batch reactors (SBRs), and other nitrification treatment systems. Once N is in the nitrate form, transformation into N gas needs two conditions: a source of C and an anaerobic environment.

A lagoon can be partitioned so that the initial part is aerated to convert N to nitrate; then the nitrate can be denitrified to release N gas in the secondary, unaerated portion of the lagoon. Aeration requirements for producing nitrate in an animal waste lagoon vary from satisfying about one to two times the amount of BOD or about one-half of the total COD. Aerated biofilters can be packed with plastic media to provide increased surface area for the microorganisms responsible for treatment to develop at the media surface, forming a biological film. The air bubbles that travel upward through the media provide the oxygen necessary for these microorganisms. With sufficient aeration, the removals obtained can be as high as 90% for BOD and 75% for COD, and ammonia can almost be completely converted to nitrate. The nitrate can then be converted to N gas by denitrification in a following unit that is anaerobic and has sufficient energy. It is possible to remove a large amount of the N as N gas with such a series treatment system.

An SBR is a containment vessel that is operated sequentially as an aerobic and anaerobic unit. It can remove up to 90% of the COD, and ammonia can be almost completely converted to nitrate, which can then be denitrified to N gas under anaerobic conditions. Therefore, the SBR is a single reactor that provides waste stabilization by reducing the COD and also N by sequential nitrification and denitrification.

Phosphorus (P). Phosphorus removal is becoming more important as guidelines and regulations are developed that limit animal manure application to agronomic rates for P. Therefore, processes that provide for biological uptake of P such as an SBR or removal of P by chemical precipitation as in municipal and industrial wastewater treatment are being evaluated for their application to animal wastewater treatment. An SBR is able to remove about 40% to 70% of the total P during short, cyclic aerating/non-aerating periods. Phosphates are biologically removed under cyclic aerobic/anaerobic conditions because the bacteria's overall rate of P absorption is greater than the release rate, resulting in net P removal from the wastewater when the bacteria are settled out as solids or sludge.

Phosphates can be removed from wastewater by chemical precipitation using multivalent metal ions such as iron, aluminum, and calcium. This process results in phosphate precipitates that can be removed by settling; with proper pH adjustment, a high degree of phosphate removal can be achieved. Processes that remove P as calcium phosphate by precipitation provide a product that adds both lime and P when applied to soils, thus serving as a waste utilization technology.

Pathogens. Animal manures are a potential source of human and animal pathogens. Among the pathogens of concern are escherichia coli (*E. coli*), salmonella, giardia, campylobacter, and cyptosporidum parvum (*C. parvum*), which can be transferred from animals to humans. Recently, the presence of the toxic pfiesteria piscicida in East Coast rivers and estuaries was attributed to the presence of excess nutrient sources, some of which may be from animal production areas or from runoff in areas where animal manure is land applied. Documentation of the fate and transport of human pathogens from animal production/manure management systems requires extensive research.

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The level of pathogens remaining after treatment or land application has received additional attention as increased emphasis is placed upon food safety and public health. Generally, pathogen destruction increases with increased exposure to air or sunlight or adequate retention time in manure treatment processes. Thus, manure treatment processes that provide these features result in increased pathogen removal. However, the relationships between exposure to any resulting disease and actual public health impacts remain difficult to define.

Heavy metals. Heavy metals and other nonbiodegradable feed ingredients may be present in either the liquid or solid stream of livestock and poultry manure. Alternative technologies can be used to selectively remove these metals from either stream if their level causes problems or increased costs for utilization strategies and terminal management by land application at agronomic rates for N and P.

Air quality considerations

Odors and gases of environmental concern such as methane, hydrogen sulfide, and ammonia are formed under anaerobic conditions during manure storage or treatment. The release of these gases can be reduced or eliminated by reducing or eliminating atmospheric exposure with covered lagoons or enclosed vessels. The reduced gases resulting from anaerobic conditions can be oxidized by aerobic treatment processes to stable end products such as nitrate, sulfate, and carbon dioxide.

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Research and field experiences have shown that odor intensifies as lagoon loading increases. Therefore, the lagoon loading rate can be reduced by adding less waste or increasing lagoon size. Anaerobic lagoons can also be aerated by floating surface aerators or by compressed air discharged through defusers located near the bottom of the lagoon, which provide small bubbles for maximum oxygen transfer. The recommendations for odor control using surface aerators are to provide sufficient oxygen transfer to satisfy from half to the full input COD. However, aeration may also increase ammonia volatilization. Therefore, recommendations that provide partial aeration to satisfy odor are being reexamined. More intense aeration to provide one, one and a half, or two times the COD may be recommended to convert ammonia to nitrate, which also controls the release of reduced gases such as methane, ammonia, and hydrogen sulfide. The oxidized nitrate can be denitrified or converted to N gas under anaerobic conditions if sufficient energy is available for this biological process. Therefore, ammonia volatilization can be reduced by providing aerobic conditions that enhance the oxidization of ammonia to nitrate and then N can be removed by providing an anaerobic process that converts nitrate to N gas.

Many other treatment processes can reduce loading to an anaerobic lagoon. The municipal and industrial waste treatment processes commonly used for the biological oxidation of reduced products to stable end products can also be used to reduce the air quality impacts from livestock and poultry waste treatment systems. Many of these unit processes are discussed in the section titled "Alternative Treatment Technologies Case Studies." The performance, cost, and ability of these treatment processes to reduce odor are compared in Appendix B, Tables Comparing Alternative Manure Treatment Technologies.

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