Chapter 2

Odors
Introduction

Malodors are the single most important cause of public dissatisfaction with biosolids or other organics recycling and utilization projects. Thus, odor management is a high priority. Experience and practice have demonstrated that biosolids and other organic by-products, such as animal manure, landscape trimmings, and food processing residuals, can be handled and processed without release of excessive malodorous compounds. However, if any of these materials, including biosolids, are poorly managed, then objectionable odors may develop during storage, and public acceptance of such a project will erode.

This section provides basic information about odor and describes the practices and rationale for various approaches that are used to minimize odor during storage. A variety of options are available, and it will be necessary for the biosolids manager to determine which ones provide the flexibility needed to accommodate the range of situations in their program. There is no “one size fits all” solution. Chapter 5 has details on odor prevention and mitigation practices.

What Is Odor?

The malodorous compounds (odorants) associated with biosolids, manures, and other organic materials are the volatile emissions generated from the chemical and microbial decomposition of organic nutrients. When inhaled, these odorants interact with the odor sensing apparatus (olfactory system) and the person perceives odor.

Individual sensitivity to the quality and intensity of an odorant can vary significantly, and this variability accounts for the difference in sensory and physical responses experienced by individuals who inhale the same amounts and types of compounds. This distinction between “odor”, which is a *sensation*, and “odorant”, which is a volatile chemical compound, is important for everyone

who deals with the odor issue to recognize. When odorants are emitted into the air, individuals may or may not perceive an odor. With biosolids, three conditions are necessary to create malodorous conditions.

BASIC CONDITIONS ASSOCIATED WITH MALODOROUS SITUATIONS

1. **EMISSION:** **Presence of an odorous volatile chemical (odorant)**
2. **TRANSPORT:** **Topographic and atmospheric conditions conducive to transport of the odorant with minimal dilution**
3. **PERCEPTION:** **People are present and they perceive odor**

When people perceive what they regard as unacceptable amounts or types of odor, odorous emissions can become an "odor problem".

Primary Biosolids Odorants

The odorous compounds generated, and most often detectable, at significant levels during biosolids treatment, storage, and use are ammonia, amines and reduced sulfur-containing compounds (for detailed descriptions of these compounds see Appendix B). Amines can be produced in easily detectable quantities during high temperature processes. Amines include: methylamine, ethylamine, trimethylamine, and diethylamine. Amines often accompany ammonia emissions, and if chlorine is used chloramines may be released. The sulfur compounds include compounds such as hydrogen sulfide, dimethyl sulfide, dimethyl disulfide, and methyl mercaptan. The potential for these compounds to be annoying is based in part on their individual and combined quantity, intensity, pervasiveness, and character (see Appendix B for details and definitions).

Amines and reduced-sulfur compounds may be detectable and perceived at greater distances from a storage facility than ammonia because they are more persistent (pervasive), intense, and have very low odor detection thresholds (i.e., people can detect just a few parts per billion in fresh air). Although ammonia is usually the primary odor associated with limed or alkaline stabilized biosolids; it has an intense odor that can often mask other odors, such as reduced-sulfur compounds. However, because the detection threshold for ammonia is much greater than that of many of the reduced sulfur compounds (i.e., it takes more ammonia in air to be detectable than it does sulfur compounds), the odors of reduced-sulfur or amine compounds are more likely than that of ammonia to be detected at distances from the site where ammonia is no longer above its odor threshold concentration.

Odor Management: A Partnership Effort

There is no doubt that untreated wastewater solids have inherently undesirable odor qualities. However, many current treatment processes have the capacity to produce biosolids that are minimally odorous. Despite this, occasional malodorous batches can occur, and thus biosolids generators, storers and land appliers should make provisions to handle these appropriately. These provisions rely on close communication and working linkages among the biosolids management partners (i.e., generator, transporter, storer, and applier). Good management of each process technology and a cooperative effort among the biosolids management partners to ensure proper transportation, handling, and storage of the materials can minimize the potential for unacceptable odor concentrations at storage sites.

Minimizing Odor during Storage

- **Stabilize biosolids at WWTP as much as possible**
- **Avoid use of polymers that lead to malodor**
- **Maintain proper pH during treatment**
- **Meet Part 503 Vector Attraction Reduction**
- **Locate storage at remote sites**
- **Minimize duration of storage**
- **Assess meteorological conditions before loading and unloading**
- **Ensure good housekeeping**

Factors Affecting Ultimate Odor Potential at Critical Control Point 1: The WWTP

The following section addresses *Critical Control Point* 1 issues. Specific situations and conditions associated with biosolids preparation at the WWTP are described along with their relation to storage and especially odors . When an odor situation cannot be averted, management of the emissions and quick response through mitigation practices are required to avoid creating nuisance odor situations. At the WWTP, which is *Critical Control Point 1*, this coordination includes:

- Assessing the stability of the biosolids before they leave the WWTP

- Having contingency plans to provide remedial treatment, or diversion of unacceptably odorous material to suitable land application or disposal sites.

- Notifying the storer and land applier of any changes in mixing (primary or secondary solids), polymer or other additives, pH, moisture content, or stability.

Decisions relative to odor control are a series of trade-offs involving higher degrees of treatment at the WWTP versus the intensity of management at the off-site storage locations. Ensuring that the odor of biosolids leaving the WWTP is minimized is a key consideration, since it is more difficult to treat an odor problem that originated at the WWTP once the biosolids are placed at the storage site. In all cases, the temporary measures invoked to deal with unexpected and unanticipated events that lead to odors must be considered only as such. Persistent problems will require an examination of the treatment and handling processes to develop a better management approach***.

Stability

The success of the various solids treatment technologies with regard to malodor reduction depends largely on the degree of stabilization achieved in the biosolids before it leaves the treatment facility and the preservation of stability until used. Wastewater treatment technologies differ in their capacity to stabilize biosolids.

The potential for odorous emissions depends partly on the extent to which organic matter and nutrients are present in forms that microbes readily use. Stabilization processes may either: 1) decrease the level of volatile organic compounds and the availability of nutrients to reduce the potential for microbial generation of odors; or 2) change the physical or chemical characteristics of the biosolids in a way that inhibits microbial growth. Table 2-1 lists seven commonly used stabilization and/or processing methods. Odor issues associated with each method and/or process are shown along with appropriate corresponding prevention or remediation approaches.

Table 2-1. Prevention and management of odorous emissions associated with biosolids stabilization or processing methods.

Stabilization and Processing Methods	Potential Causes of Odorous Emissions	Long Term Potential Solutions	Short term Temporary Solutions
Anaerobic Digestion	'Sour', overloaded or thermophilic digester; volatilization of fatty acids and sulphur-compounds	Optimize digester; don't overload	Apply topical lime to stored biosolids
Aerobic Digestion	Low solids retention time; High organic loading, Poor aeration	Increase retention time and aeration; Lower organic load	
Drying Beds	Incomplete digestion of biosolids being dried	Optimize digestion	
Compost	Poor mixing of bulking agent; poor aeration; Improperly operating biofilters.	Mix better; adjust mix ratio and aeration rate; improve biofilter function	Aerate more effectively; remix; re-compost.
Alkaline Stabilization	Addition of insufficient alkaline material so pH drops below 9, microbial decomposition may occur with generation of odorous compounds. Check compatibility of polymer with high pH and other additives, e.g. $FeCl_3$.	Increase pH Provide finer mesh grade of alkaline material and mix better to avoid inadequate contact with biosolids	Check pH; apply topical lime
Thermal Conditioning & Drying	High temperature volatilization of fatty acids and sulfur-compounds	Use secondary treatment biosolids; primary solids are less stable and more odorous when heated.	Apply topical lime if biosolids are still liquid

Digested and Composted Biosolids

Properly digested and/or composted biosolids meet stabilization and vector attraction reduction requirements because these extended treatments reduce pathogens and decompose volatile solids (i.e., the organic matter which serves as food for microbes). When such materials are placed in proper storage, they typically do not contain enough readily available nutrients to support a large, rapid growth of microbes that might generate odorous volatiles.

Alkaline and Chlorine Treated Biosolids

Chemical stabilization processes act to inhibit the growth of microorganisms, rather than to decompose the organic matter in the biosolids. Addition of alkaline materials, such as lime, elevates the pH to levels that suppress microbial activity and kill pathogens. As long as the pH remains high in stored materials, no new potential odorants will be produced. Small residual levels of reduced sulfur or amine compounds, which were generated prior to and not released during stabilization, may be present. One of the sulfur products of concern, hydrogen sulfide, is converted into a non-soluble (non-volatile) form at high pH. Raising the pH will liberate ammonia and amines, especially at the time of treatment. For the ammonia, this is unlikely to result in objectionable

off-site impacts because ammonia is not a persistent odorant. However, amines can be persistent and are more likely detected off-site once ammonia has dissipated and thus stopped masking the amines. In addition, when stored, alkaline stabilized biosolids quickly develop a dry crust, which seals the pile and prevents significant volatilization. Disturbing piles during load-out operations exposes fresh surfaces to the atmosphere and increases the potential for volatilization of trapped residual odorous compounds. Hence, avoid load-out during air temperature inversions and periods of low turbulence, since pervasive odorants will more likely be detected under such conditions.

Drying Beds and Thermal Drying etc.
Heat and/or desiccation are the primary means of pathogen reduction in thermal treatment or drying; these methods also halt microbial decomposition of organic materials. They do not appreciably reduce organic matter during the relatively short time periods in which drying is conducted, and thus require appropriate management during storage to prevent significant resumption of microbial decomposition and release of odorants.

Other Odor Prevention Considerations

The type of treatment and stabilization processes used at a WWTP are primary factors influencing the type and level of odors which may be potentially generated by a particular biosolids. Other factors at the wastewater treatment plant that may affect the odor potential of biosolids include:

Other Important Factors at the Wastewater Treatment Plant that Affect the Odor Potential of Biosolids

- Periodic changes in influent characteristics (e.g. fish wastes, textile wastes and other wastewaters with high odor characteristics)
- Type of polymer used and its susceptibility to decomposition and release of intense and pervasive odorants such as amines when biosolids are heated or treated with strong alkaline materials
- Blending of primary and secondary biosolids which may create anaerobic conditions or stimulate a resumption of microbial decomposition
- Completeness of blending and mixing, and quality of products used for stabilization (i.e. type of lime and granule size)
- Effectiveness and consistency of Vector Attraction Reduction Method, use of Part 503 VAR options 1-8 (treatment at WWTP) vs. VAR options 9-10 (at land application site)
- Handling, storage time, and storage method when stabilized biosolids are held at the WWTP prior to transport (e.g. anaerobic conditions developing in enclosed holding tanks when material is held for several days during hot weather).

Vector Attraction Reduction

Stabilization treatment may include processes at the WWTP to reduce the attraction of vectors to biosolids as outlined in the Part 503 rule. The effectiveness and consistency of these treatments may also help to minimize odor potential. Odor is typically less of a problem for biosolids that fully meet one of the first eight Part 503 VAR options (See Appendix C). However, sometimes it is necessary to store materials that will meet VAR by options 9 or 10 (injection or soil incorporation). In such cases, increased management intensity (e.g. storage for short periods of time, storage during cold weather, storage at remote locations, etc.), and self-monitoring for unacceptable odor levels may be needed to prevent nuisance odor conditions.

Factors Affecting Ultimate Odor Potential at Critical Control Point 2: The Transportation Process

The process of transporting biosolids from the generating facility to the field storage site may impede traffic, be unsightly and can potentially emit nuisance odors into the community. The transportation process (referred to as Critical Control Point 2 in this document) must be properly managed as to minimize these problems, including the public's exposure to biosolids odors. One way to reduce public exposure to odors is to choose a hauling route that avoids densely populated residential areas. The fewer residences located along a hauling route, the less likely the general public will be annoyed by the traffic and biosolids odors. Making sure that the trucks used to haul biosolids are clean and well maintained is another effective way to keep road surfaces clean and control odors during biosolids transport. Trucks should be cleaned before leaving the generating facility and after the biosolids have been deposited on the field storage site. These steps are important because odor concerns are exacerbated by increased road congestion, and by biosolids adhering to trucks and roadways.

Factors Affecting Ultimate Odor Potential at Critical Control Point 3: The Field Storage Site

In most cases, biosolids produced at WWTPs with well-operated stabilization processes can be stored off-site without creating odor nuisances. However, if certain conditions occur while material is in storage, the potential for odorous emissions (sulfur- or amine-containing compounds or ammonia) will increase.

Specific Storage Site Conditions that Contribute to Generation of Odorants

- Meteorological conditions
- Distance to sensitive receptors (i.e. housing developments)
- pH drops below 9 in lime stabilized biosolids
- Anaerobic or deficient oxygen conditions within the biosolids
- Storage of primary biosolids with waste activated (digested) biosolids
- Rewetting of dried material
- Ponded water in contact with stored biosolids
- Prolonged storage of inadequately stabilized biosolids
- Inadequate handling methods
- Deficient housekeeping and spill control

Several of the specific site conditions will be discussed later in this chapter or in Chapter 5.

Meteorological Conditions

Meteorological conditions such as wind speed and direction, cloud conditions, relative humidity, and temperature, all of which can change with the season, day to day, and even with the time of day. Warm temperatures and high humidity increase the potential for odor nuisances, while cold, dry conditions reduce the potential for nuisance complaints.

Most odors from a biosolids storage site are area source rather than point source, ground level emissions. Under moderate atmospheric stability (e.g., partly sunny, wind speeds 8-12 mph, moderate turbulence), on flat terrain area source odorants undergo fairly rapid dilution as the distance from the source increases. As such, concentrations of odorants will likely not be objectionable to neighbors, if the biosolids are reasonably well stabilized. Conversely, pervasive odorants from poorly stabilized batches can be detected at considerable distances from the source. Rough terrain, valleys, and other topographical features can increase the complexity of airflow patterns. Odor dispersion analysis can help site managers schedule operations to avoid high odor concentrations from developing at sensitive downwind locations.

Odorants emitted from ground-level sources will remain most concentrated during periods of high atmospheric stability, such as occur with air temperature inversions and low wind speeds at night and very early morning. This means that odor complaints may be higher during non-business hours. Dispersion is enhanced once the sun has warmed the soil surface. For permanent constructed facilities, a basic wind dispersion analysis of the site, including seasonal and annual prevailing wind direction, and typical meteorological conditions for the area will help site operators plan activities so as to minimize odorous emission impacts downwind.

Planning and Monitoring

Whether biosolids are stored in field stockpiles or constructed facilities, odor prevention and mitigation measures need to be part of the operational plans. Also, a complaint response plan to promptly and effectively investigate and respond to local odor concerns or complaints (see Chapter 5 for details on odor prevention and mitigation) also needs to be included. The plan should include provisions for diversion of odorous batches to alternate sites that are remote or other disposal options. In the sections that follow, a notably greater level of effort is required to control odors for constructed facilities than for field stockpiles.

Field Stockpiles

Persons responsible for storage of biosolids should realize that odor is a perceptual, subjective, and frequently emotional issue. In most storage scenarios (particularly small-scale field stockpiles), sophisticated analysis of odorous compounds is not necessary to resolve community odor issues. What is necessary, is a well thought out and implemented odor prevention and mitigation plan designed to be sensitive to local odor concerns. Such a plan should include provisions for prompt response, investigation and follow-up if odor complaints are received (See Chapter 5 for details).

Constructed Facilities

Odor prevention and minimization plans are generally needed for large, longer-term facilities. These plans may need to rely in part on some type of monitoring to determine the extent of odor, and the effectiveness of the procedures used to mitigate odors.

Because sensitivity to the quality and intensity of an odor can vary significantly among individuals, specialized approaches are needed to evaluate the impact of odorous compounds. Odor and Odor Event Characterization Monitoring is a simple, direct approach that relies on odor detection reporting and wind direction recordkeeping. This approach might be considered in place of complex chemical quantification and identification. In this approach, a set of odor characters (descriptors) is identified for use by site operators conducting routine odor inspections and by citizens reporting odor detection events. Examples of odor characters include: sharp pungent (ammonia), unpleasant putrid (amyl mercaptan), pungent suffocating (chlorine), skunk-like (crotyl mercaptan), fishy (trimethylamine), decayed cabbage (dimethyl disulfide), etc. (see Table B-2 for additional descriptors). The odor characters selected should cover the range of odors potentially emitted from a biosolids site, as well as other nearby operations that may also emit distinctive odors.

To the extent possible, descriptors should be identified that can serve as markers for emissions from biosolids. In this way, biosolids managers can focus corrective actions when appropriate. This also will a means to distinguish biosolids odors from those generated by other types of odor emitting facilities in the same area as the storage site, to the extent that they are present.

In order to use the odor descriptors correctly, site managers, personnel, and odor investigators would be trained in the proper use of the odor character descriptors. They would also be trained to recognize field conditions acceptable for selected odor measurements, i.e., intensity and descriptors, and key areas and times for inspection. A simple written report (see Appendix B for example) of odor inspections/investigations can be used to document performance at a site. On-site inspections coupled with use of an immediate odor response plan, can aid in reducing the potential for odor complaints. In some cases, an '*odor hotline*' for citizen complaints can be useful. If complaints are received, the storage facility operator is able to promptly dispatch personnel to follow-up with the caller and initiate an investigation and problem remediation.

Recent advances in odor science, detection/recognition threshold determination, and measurement of odor annoyance have helped to reduce the subjective nature of odor evaluation for biosolids (see Appendix B for details). Measurement, Identification, and Monitoring in response to persistent odor problems that need remediation may involve characterizing the source and type of odorants. This requires sophisticated collection, identification, measurement, and evaluation of gases in air samples. Subsequently, the human sensitivity to these odorants is evaluated in terms of their perceived intensity, pervasiveness, and/or annoyance in the impact zone. This also requires specialized measurement equipment and techniques and may benefit from atmospheric dispersion modeling. Obviously, this relatively complex approach to odor assessment would be used in only those biosolids storage situations in which less intensive approaches had failed to lead to remediation, or if the size, nature and storage capacity of the facility required it.

Length of Storage and Changes in Biosolids Characteristics

Preventing the resumption of microbial activity in biosolids is a primary means of controlling odors at storage sites. Microbial decomposition is likely to occur if the pH of lime stabilized biosolids drops below nine; if anaerobic or deficient oxygen conditions occur within the biosolids (free O_2 concentration less than 15 percent); if primary biosolids are mixed and stored with waste activated (digested) biosolids; or if dried material are rewetted. Ensuring that the materials brought to the facility are thoroughly stabilized and minimizing the length of time materials are kept in storage are two major tools to achieve this goal. In some cases, microbial activity can be halted or controlled by on-site remedial actions such as the addition of lime to lagoons or top-dressing stockpiles with lime slurries, or covering of dried materials.

Accumulated Water and Site Management

Precipitation or runoff that accumulates in contact with biosolids will pick up nutrients and organic matter that promote rapid blooms of microorganisms that rapidly deplete dissolved oxygen levels and lead to anoxic or septic conditions and the generation of significant odors. Proper design and operation of the facility as described in Chapter 5 is key to preventing this problem. Establishing good housekeeping procedures and keeping the storage area,

equipment and trucks clean and free of standing water is another component of avoiding odor generation. Likewise, conducting handling operations in a clean and efficient manner that minimizes the time materials are disturbed will help limit odor.

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