Biosolids Thermal Dryer Safety Fact Sheet

Introduction

This safety fact sheet is directed to persons involved with operating, maintaining, and designing biosolids thermal dryers and reviews the fire and explosion safety hazards associated with thermal drying of biosolids and offers both prevention and mitigation measures to address these hazards at water resource recovery facilities. It also summarizes applicable codes and identifies additional resources that may be consulted for further research, education, and remediation.

Since the 1920s, thermal drying produces easily handled, virtually pathogen-free biosolids that promote the beneficial use of nutrients present in wastewater solids. However, thermal-drying systems can be hazardous to operate. Managing this sometimes friable, combustible, and self-heating product can be a delicate task for operators and components of a dryer system can be at risk of fire or explosion.

Ensuring the safety of thermal drying facilities and their processes is a shared responsibility among three important parties:

1. Code officials who establish regulatory requirements for systems and buildings
2. System designers who use their knowledge of the biosolids-handling process and materials to build protections into equipment
3. Utility operators who use training and operating experiences to identify unsafe conditions, develop mitigating procedures, and recommend system improvements

Explosion and Fire Safety Hazards Related to Drying Biosolids

Why do thermal-dried biosolids pose risks for fires and explosions?

Wastewater solids consist of volatile content that, when stripped of moisture via thermal drying, becomes a combustible material. As with other combustible materials, dried biosolids will burn in the presence of an ignition source and oxygen. Thus, the design and operation of biosolids-drying facilities must incorporate common fire safety measures, such as minimizing ignition sources, monitoring the process for above-normal temperatures and fires, and providing effective and immediate protection systems.

Thermally dried biosolids also pose several unique hazards beyond those presented by typical combustible materials. First, when sufficient moisture remains in the solids after the drying process, they will begin to self-heat from chemical and biological reactions. If the material is undisturbed, has sufficient mass, and remains insulated with limited heat dissipation, smoldering and fires can occur. This is why self-heating is a significant issue in receptacles and spaces where dried biosolids are typically stored, such as silos or bins. In general, thermally dried biosolids should have less than 10% moisture content before being stored.

Too wet or dry dewatered solids fed to a thermal dryer system with recycle equipment can also lead to unstable operating conditions. Instead of forming stable pellets, cake that is too wet generates wet, clumpy materials that not only adhere to infrastructure walls and plug equipment but can also smolder, creating another ignition source in the system. Cake that is too dry will not properly coat recycled material and can also lead to clumping. The optimal moisture content for the feed will vary based on the type of system and the manufacturer and should be evaluated during system design.

Thermally dried biosolids, especially those that have become friable, generate fine, combustible dust. Sufficient concentrations of suspended dust confined inside equipment with enough air and an ignition source can explode. If this equipment has not been adequately isolated, a dust explosion can spread through ductwork and connected chutes to other equipment with dust, triggering numerous other explosions. Hence, equipment that accumulates large quantities of dust, such as bag houses, pose the highest risk for a sizable dust explosion.

Thus, thermally dried biosolids can pose fire and explosion safety hazards in various ways and require close attention to many operational variables, including:

- Proper moisture content in the feed solids to reduce the potential for buildup of wet material in the system that could promote self-heating
- A low enough moisture content in the finished product to prevent self-heating, but enough moisture so that the material is not dusty, thereby reducing the potential for combustible dust.

What other factors increase the risk for a biosolids-related fire or explosion?
Most thermal-drying systems generate heat by combusting fuel, such as natural gas, digester gas (methane), or fuel oil. These systems have associated risks and safety hazards either from (a) improper combustion in the devices themselves or, specifically for direct-fired systems, (b) fuel leaks in furnaces and downstream drying equipment.
Some drying technologies include more hazards than others, such as those with recycle systems that have additional dried material handling stages and those with higher temperatures, such as above the minimum ignition temperature of the material's suspended dust (which can range from 360 ºC to 550 ºC [ECS, 2007]). Hazards are inherent to the drying process, and fires or explosions have been reported from facilities using all types of common dryers, including drum, fluid bed, multitray, indirect chamber, and belt.

Furthermore, the drying components shown in Table 1, common to many drying systems, can pose enhanced risks. Other drying system components may pose risks as well.

Table 1 Dryer System Components—Hazards and Mitigation

Equipment	Hazard	Mitigation
Recycle bins	• Stored material has self-heated, causing smoldering and fires • Accumulated dust ignited by burning material has created explosions	• Maintain optimum moisture for mixing and recycle stages to reduce dust/self-heating • Empty bins ahead of shutdowns • Monitor temperature and carbon monoxide concentration • Inject nitrogen to create inert atmosphere • Use deflagration vents to safely relieve explosions
Product storage silos	• Stored material has self-heated, causing smoldering and fires • Accumulated dust ignited by burning material has created explosions	• Cool material before storage • Minimize moisture in product (<10%) • Monitor temperature and carbon monoxide concentration • Inject nitrogen to create inert atmosphere • Use deflagration vents or break-away roofs to safely relieve explosions • If needed, limit duration of storage period
Bucket elevators	• Accumulated dust in bottom of housings has been suspended by buckets and ignited by smoldering material, causing explosions	• Maintain optimum moisture for mixing and recycle stages to reduce dust/self-heating • Ventilate equipment to reduce dust levels • Use chemical injection systems to suppress explosion • Use deflagration vents to safely relieve explosions

<u>Protection and Mitigation Systems</u>

Thermal drying systems can be protected by both prevention and mitigation systems.
The following prevention strategies help eliminate conditions that may lead to safety hazards related to drying biosolids:

- **Inerting:** Inerting systems prevent flammable materials from combusting by replacing air that has oxygen in processing or storage spaces with a chemically non-reactive or "inert" gas. Dryers, material-handling equipment, and storage areas can all be inerted with nitrogen or steam to ensure that the oxygen levels stay below the lower explosive limit, that is, the level of oxygen concentration that can sustain a dust deflagration. This limit will vary based on material composition but, typically, is in the range of 8% to 10% oxygen.
- **Water suppression for fires**: Water systems can be activated by high temperature or manually to deluge smoldering or burning materials in the drying area.
- **Temperature control and monitoring**: Controlling temperatures in heating and drying spaces helps to maintain safe conditions, whereas monitoring temperatures in storage areas can help reduce the risk of excessive self-heating. Specific temperatures in the operating systems will vary based on the system and manufacturer but, in general, the product should be cooled to 38 ^{o}C (100 ^{o}F) before being stored.

- **Ventilation**: Ventilated equipment that handles dried materials can keep dust concentrations low and remove moisture.
- **Fire detection:** Spark-detection devices can identify burning material at key transition areas and activate water-deluge systems as required.
- **Chemical suppression**: Suppression systems can detect the beginning of an explosion and inject chemicals (e.g., sodium bicarbonate) into equipment to smother the burst and prevent excessive pressure.

The following mitigation strategies remediate or reduce the potential damage caused by fires or explosions at dryer facilities:

- **Explosion venting**: Explosion venting on equipment and storage vessels can relieve excess pressure and prevent them from rupturing. These systems should be sited to relieve the pressure away from areas typically occupied by personnel. When that is not possible, they should be provided with flame-arrestance and particle-retention systems.
- **Isolation**: Isolating drying system components from one another can prevent dust-related deflagration events from propagating to other areas with similar dust hazards. Equipment can be isolated using physical barriers, such as rotary valves or chemical-injection systems.

Industry Standards and Regulations

Many federal, state, and local regulations and codes are in place to guide the safe design and operation of thermal-drying facilities. In particular, the standards and guides described in Table 2 established by the National Fire Protection Association (NFPA) aim to eliminate the risk of fires and explosions associated with these facilities.

Table 2 Summary of National Fire Protection Association Standards

NFPA Standard	Scope	Requirements
NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids (2020)	All phases of processing, manufacturing, and handling of combustible dust and particulate solids that pose fire or explosion hazards	• Protection standards, including dust explosion prevention and mitigation measures for facilities, buildings, process systems, and equipment components, such as dryers, storage bins, and conveyors • Identifies what items require explosion prevention systems (NFPA 69) or deflagration vents (NFPA 68) • Fire protection • Training, inspection, maintenance, and housekeeping
NFPA 652: Standard on the Fundamentals of Combustible Dust (2019)	Basic principles of identifying and managing fire and explosion hazards posed by combustible dust and particulate solids	• Dust hazards analysis , including (1) analysis of dust sample to determine explosion characteristics, (2) evaluation of each process area for fire or explosion hazards, and (3) identification of safe operation, existing safeguards, and additional recommended safeguards for hazardous areas • Similar requirements for training, inspection, maintenance as NFPA 654; both standards are intended to complement each other.

NFPA 69: Standard on Explosion Prevention Systems (2019)	Design and use of systems for the prevention of explosions	• Systems covered include those used for drying systems: (1) oxidant-concentration reduction (i.e., atmosphere inerting); (2) explosion suppression with chemical agent; (3) equipment isolation, including (a) active (chemical barrier and fast acting valves) and (b) passive (rotary valves); and (4) deflagration pressure containment • Inspection and maintenance
NFPA 68: Standard on Explosion Protection by Deflagration Venting (2018)	Design and use of systems that vent gases and pressure caused by an explosion within an enclosure	• Design criteria for sizing, locating, constructing, and using deflagration vents to mitigate combustible dust and gas explosions • Inspection and maintenance
NFPA 86: Standard for Ovens and Furnaces (2019)	Ovens, dryers, and furnaces that are used to process materials	• Safety systems, including burner control, fuel supply, combustion air, flame supervision, and purging • Commissioning, operations, maintenance, inspection and testing • Fire protection
NFPA 820: Fire Protection in Wastewater Treatment and Collection Facilities (2020)	Protection against fires and explosions in WWRFs	• Hazardous classification, materials of construction, ventilation, and fire protection requirements for buildings and areas, including those housing sludge drying processes (Table 6.2.2(b)1) and dried sludge storage (Table 6.2.2(b)2)

Reference

European Committee for Standardization. (2007). *Characterization of Sludges – Good Practice for Sludges Drying*. Technical Report CEN/TR 15473. British Standards Institution.

Suggested Readings

FM Global. (2020). Property Loss Prevention Data Sheets 7-76, Prevention and Mitigation of Combustible Dust Explosion and Fire. https://www.fmglobal.com/research-and-resources/fm-global-data-sheets#search

Information document (ID) on risks from sewage sludge drying plants. United Kingdom Health and Safety Executive. https://www.hse.gov.uk/pubns/risks-from-sewage-sludge-drying-plants.pdf

Occupational Safety and Health Administration (2015). Combustible Dust National Emphasis Program. Directive Number CPL 03-00-008. https://www.osha.gov/sites/default/files/enforcement/directives/CPL_03-00-008.pdf

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