THE SUBJECT of fires at composting facilities is a bad news/good news situation. The bad news is that fires are more common than we realize. Ask a group of facility operators if they have had to deal with a fire, and the majority will quietly admit they have. The good news is that we don’t realize that fires are fairly common at composting facilities. Most are neither frequent nor destructive enough to attract attention beyond the facility gates, with notable exceptions. Generally, operators are recognizing and containing fires without a great deal of damage or publicity. A devastating fire, such as the one that occurred at the Hartford, Connecticut biosolids composting facility (see accompanying article), is rare.

Nevertheless, a fire is a serious matter. A minor one threatens to attract public inquiry about the risks and nuisances of composting activities at a particular site and within the compost industry generally. A major fire threatens a multimillion dollar investment and presents a potential danger to workers and firefighters. Therefore, it is extremely important to understand how fires start and how they should be managed in the presence of large volumes of organic materials. This is not an issue to hide under the curing pile. BioCycle has covered fires in previous Compost Operators Forums (see “Controlling And Preventing Fires At Composting Facilities,” May, 1999 and “Feedstocks, Conditioning and Fire Prevention,” April, 1997), but in light of the fire in Hartford, it deserves another visit.

Part I of this article covers the causes of fires at composting facilities and how conditions should be managed to prevent them. Part II, which will appear in next month’s issue, will cover procedures for controlling and extinguishing a fire once it begins. While this article speaks of fires at “composting facilities,” the same conditions, risks and recommendations apply to nearly any facility that handles large volumes of bulk organic materials, including wood and bark grinding sites, paper mills that store wood chips, hay barns, transfer stations and landfills.

A Few Of The Basics

Fire is a rapid oxidation of chemicals that releases energy as heat and light. A fire requires fuel and oxygen. In this way, it is not unlike aerobic composting, except that fire is a chemical oxidation while composting is a biological oxidation. In fact, a simplified chemical equation for combustion by fire shows the same inputs and outputs as a simplified equation for composting:

\[ \text{Organic hydrocarbon (fuel) + oxygen} \rightarrow \text{carbon dioxide + water + heat + residue} \]

(e.g. compost, ash)

Organic materials that typically are composted or recycled contain chemical energy (derived originally from photosynthesis). Therefore they can provide fuel for a fire. Although the composting process has diminished its energy content, even finished compost retains plenty of energy to support a fire. However, organic materials do not release their energy just because oxygen is present. First, they must heat to their ignition temperature via a spark, pilot flame, or other heating mechanism. The amount of energy needed to reach this point is called activation energy. Typical composting materials ignite at temperatures roughly in the 150°C to 200°C (300°F to 400°F) range.

If materials reach their ignition temperature but oxygen is limited, they burn by a smoldering fire. This is an inefficient fire, producing various partially combusted gases, smoke and heat but no light. With more oxygen, a glowing fire can occur which is still inefficient, yielding smoke, more heat and
higher temperatures. Abundant oxygen creates a flaming fire with very high temperatures, heat and light. Combustion is generally considered to occur when flames appear, but a smoldering fire may have persisted for a long time prior to that point.

**Causes Of Fires**

Spontaneous combustion is among the most common — yet also one of the more mysterious — causes of fires. Because it is more difficult to recognize and control, spontaneous combustion is the main focus of this article. However, fires at composting facilities also have developed from other causes, including lightning strikes, heat from equipment, sparks from welding activities, wildfires and arson.

Lightning was suspected of starting a fire at the Silver Creek composting site in Texas, an outdoor window composting facility. Lightning apparently struck a large pile of unprocessed wood waiting to be ground. The fire was contained to the wood pile but, because the pile was so large, it was difficult to extinguish. The pile eventually was covered with sand from the facility’s mining operation and allowed to burn itself out.

With dry organic materials, hot surfaces or a spark from any source presents a fire threat. Vehicles, welders and the carelessly tossed cigarette have the potential to ignite a fire, particularly where dust is abundant. Tub grinders have caught fire from build up of small particles near engine manifolds and exhaust pipes (see “Keys to Safe Grinder Operation,” April, 1999). Because composting usually involves mechanical equipment, welding is a common activity. Sparks from welding appear to be one of the more common fire-starters. At a Philadelphia composting facility, a fire occurred when sparks from a welder ignited wood chips and some stored oil. The fire suppression sprinklers had been out of service due to flooding damage to the pumps.

**Prevention Of Surface Fires**

Fires due to lightning, sparks, wildfires and arson can be thought of as surface fires because the fire usually starts and spreads along the exterior. Surface fires are more easily detected and controlled than internal fires, as occurs with spontaneous combustion. Prevention of surface fires involves preparation, safety procedures, maintenance and fire protection equipment. For example, following OSHA hot works permit procedures greatly reduces the risk from welding conducted on site.

Good housekeeping practices minimize dust and keep combustible materials away from areas and equipment that might produce sparks. If necessary, combustible equipment components, such as rubber conveyor belts, can be replaced with noncombustible materials. Although building sprinkler systems are not effective against fires deep in large piles of organic materials, sprinklers can suppress surface fires in enclosed areas. Other protection measures against surface fires include an adequate supply of water, easy access for fire department vehicles, lighting protection devices, fire extinguishers on vehicles, and fire breaks between the facility and adjacent lands that are susceptible to wildfires.

**The Case Of Spontaneous Combustion**

Spontaneous combustion may be the most frequent cause of fires at compost facilities. It happens when materials self-heat to a temperature high enough to cause them to ignite. No external energy source is needed. The temperature increases because more heat is generated internally than lost to the surrounding environment. Although it is often thought of as a single process, spontaneous combustion is actually a chain reaction of several different heat-generating processes that vary with different materials and conditions (although the patterns are typically the same). Each process in the chain raises the temperature to a point where the next one takes over and raises temperatures still higher until eventually, the material ignites.

Each succeeding process advances faster than the previous one and each process speeds up as temperatures rise. The rule of thumb states that the reaction rate roughly doubles with each 10°C (18°F) rise in temperature. So heat is released about 16 times faster at 100°C (212°F) than at 60°C (140°F). As spontaneous combustion progresses through the steps in the chain, there is less and less time to react and halt it.

The processes that initiate spontaneous combustion raise the material’s temperature to a point where self-heating reactions sustain themselves. For example, the initial temperature rise can be from external sources. However, for fires that occur in bulk organic materials, the first steps are usually due to biological self-heating. Respiration of living plant cells and microbial activity generate heat and start the temperature rise. Through biological activity, temperatures can reach 70°C (160°F) to 80°C (175°F). At this point, the microorganisms die or become dormant and the biological heating stops. As Tim Haug, author of The Practical Handbook of Compost Engineering, points out, there is a gap between the temperature limits of biological activity (80°C or 175°F) and temperatures at which
organic materials ignite (+150°C or +300°F). This gap is bridged by chemical processes (see Haug’s April, 1997 article, referenced earlier).

In the chain of reactions that leads to spontaneous combustion, the biological processes create temperatures high enough to sustain heat-releasing chemical reactions. The chemical processes include chemical oxidation, slow pyrolysis, and adsorption or condensation of gases within dry charred particles. In particular, chemical oxidation of dry materials noticeably increases at around 80°C (175°F). For moist materials — when there is enough moisture to feed the process, but not enough to cool the pile — the threshold temperature is slightly lower because water facilitates or catalyzes chemical oxidation (as it does when wet iron oxidizes to rust). It has been suggested that the presence of oils, certain salts, and some forms of metals also speed chemical oxidation but, except for oils, this isn’t well documented.

As the temperature increases, chemical oxidation happens even faster and the material accelerates toward ignition temperatures. In large piles of organic materials, with limited available oxygen, spontaneous combustion usually leads to a smoldering fire, generally at temperatures between 150°F to 200°C (300°F to 400°F). If enough oxygen is suddenly supplied by the aeration system or by opening up the pile, temperatures will increase immediately and dramatically to create a flaming fire. Chemical oxidation requires a continued supply of oxygen to proliferate, but it advances slowly even under low oxygen conditions. With no oxygen, oxidation stops. However, at high enough temperatures, other reactions that do not involve oxygen can continue to release heat (e.g., gas adsorption). A review article in Forest Products Abstracts by Hans Kubler gives a comprehensive review about the processes involved in spontaneous combustion (“Heat Generating Processes As Cause of Spontaneous Ignition In Forest Products,” Hans Kubler, Forest Product Abstracts, 1987, Vol. 10 No.11, C.A.B. International).

**Conditions Contributing To Spontaneous Combustion**

Key conditions that lead to spontaneous combustion are biological activity, relatively dry materials or dry pockets, large well insulated piles or vessels, limited air flow, and time for temperature to build up. In addition, there may be other contributing factors such as short circuiting of air flow, a nonuniform mix of materials, poor moisture distribution, difficulty in knowing temperatures throughout a pile, and sometimes a lapse or oversight in monitoring.

These key conditions are usually more prevalent within large undisturbed piles containing raw feedstocks, curing compost and finished compost than in the active composting system. Actively composting piles and vessels tend to be monitored and controlled for temperature, moisture, and aeration while storage and curing piles are often neglected. Furthermore, the relative low moisture content of compost and many raw feedstocks are well suited to the onset of spontaneous combustion. Therefore, fires are more common in storage areas than in the composting system.

The path to spontaneous combustion at composting facilities begins with the heat release and temperature rise of biological activity. This is an inherent consequence of composting, and normally a goal. Usually, the temperature is moderated by heat loss from the evaporation of moisture, air movement and exposure to the cooler ambient environment. Piles are deliberately cooled by aeration and turning. However, in large, well insulated, stationary piles with limited air movement, the temperature can build to higher than desired levels (over 60°C). Compost and composting feedstocks are good insulators and they become even better insulators as they dry. Temperature also rises to high levels when the moisture content is low because evaporation, the primary means of heat loss, is reduced. In a small or well ventilated pile, cooling takes place even at low moisture levels. In a large pile with moist materials, evaporation keeps the temperature at reasonable levels, at least as long as moisture continues to evaporate. However, the combination of low moisture, large piles (or containers), and little air exchange is a prescription for spontaneous combustion.

Moisture is a crucial requirement for composting and spontaneous combustion. In both cases, proper moisture is a matter of balance. The critical moisture range that supports spontaneous combustion is roughly 20 to 45 percent. Above 45 percent, there is enough moisture available for evaporation to hold down temperatures. Below 20 percent, there isn’t enough moisture to sustain the biological activity that initiates the temperature rise. This is one reason why hay is put in the barn dry and corn is put in the silo wet. For composting, operating moisture contents range from 40 to 70 percent, although the optimal range is typically 50 to 60 percent. However, materials being composted often drop below 40 percent moisture as process heat drives off water.

In an active composting system, the possibility of spontaneous combustion grows as time increases because the compost dries. Periodically replacing
the lost water reduces this possibility. Pockets of dry material can exist even when the pile looks wet because of localized drying and because it is difficult to evenly distribute added water. It is particularly difficult to achieve uniform moisture in large piles and vessels without agitation or turning.

In the later stages of composting, low moisture may be deliberately maintained to improve the handling and appearance of the product. Therefore, compost in curing and storage piles is especially vulnerable to spontaneous combustion. Extremely dry piles of compost or raw feedstocks do not heat because biological activity is greatly reduced. However, if a section of these materials is moistened by rain, heating resumes and fire becomes a possibility.

Pile size is a factor because large piles slow both heat loss and air movement. Heat generation is determined by volume while heat loss is mostly determined by surface area. As a pile grows in size, there is less surface area per unit volume so more of the generated heat is retained and temperatures increase. The consequences of reduced air flow are complicated and depend on the materials in the pile or vessel, their porosity, uniformity and stage of composting. One possible scenario is that air flow is restricted enough to supply oxygen for microbial activity and chemical oxidation, yet not enough to remove the heat generated. In this scenario, the resulting rise in temperature can lead to spontaneous combustion. Another possible scenario is that reduced air flow leads to anaerobic piles and less heat is generated. In either case, the consequences are undesirable and argue against very large piles.

What is a reasonable pile size? Of course, it depends on the material, the porosity, moisture, stage of composting, temperature monitoring and controls, frequency of movement, length of storage, etc. For static composting piles, recommendations for maximum heights range from eight to 12 feet. Higher piles are acceptable with materials that are coarse and allow more air flow, as well as with ones that degrade slowly and therefore generate less heat. Thus dry wood chips can be piled higher than wet chips. Wet wood chips can be piled higher than wet sawdust. And mature compost can be stored in larger piles than immature compost.

The Ontario Office of the Fire Marshal has a technical guideline that recommends maximum sizes for outdoor piles of wet wood chips from storm debris. For wood chips to be stored for more than three months, the recommended maximum height is 25 feet (7.5 m).

In general, pile size is less of a factor in systems that employ forced aeration. Still, forced aeration systems can be plagued by air channels and short-circuiting, made worse by poorly mixed composting materials. Short-circuiting can reduce the air flow to sections of the pile, possibly resulting in overheating in those sections. If hot sections remain undetected and reach 80°C (175°F), continued aeration can accelerate chemical oxidation and start a fire. It is therefore important to know the maximum temperature in the system.

Another problem with large piles is that they are difficult to monitor. Most thermometers and temperature sensors cannot penetrate deep enough or cover enough locations to detect all potential hot spots in a large pile. For this reason, Lew Naylor, composting specialist with Black & Veatch, recommends that operators find the hot spots by looking for evidence of aeration vents in large piles and then regularly measure the temperature near those vents. Fissures of steam and wet spots on the pile surface indicate vent locations.

Parting Comments For Part I

The nature of composting and organics recycling activities presents ample opportunities for a fire to develop. Large, undisturbed piles of partially dry decomposing materials pose the greatest risks. However, the fact that serious uncontrolled fires do not often develop suggests that composting operators are keeping potential fires in check. With diligent monitoring, the beginnings of a fire can be detected and reversed. Problems occur when regular monitoring is reduced or interrupted.

At a compost facility in Georgia, a surface fire probably spread because it occurred on Christmas Eve during a period when the facility was shut down for construction. This fire apparently started from embers left by welding work done earlier in the day. Fires sometimes occur during periods of construction and shut down because the facility has suspended normal operations — ordinary precautions are relaxed, process monitoring stops, fire suppression systems are being serviced, or welding is performed in unusual areas or by outside crews that are not accustomed to the conditions. Similarly, storage and curing piles and vessels are prime candidates for fires because they receive less manipulation and attention. Awareness of what causes fires and constant attention to the relevant conditions at the facility are perhaps the keys to preventing fires. Part II of this article will review how to control and extinguish a fire after it begins.