July 23, 2007

<Name>
<Address>
<City, State Zip>

Re: Subsurface Landfill Fires

To Whom It May Concern:

Landfill fires, while not common, have the potential to impact human health and safety and the environment, as well as be costly to landfills that must control and suppress the fire. While fires may occur on the surface of the landfill, it is underground, or subsurface, fires that pose the greatest challenge in terms of detection, investigation, and suppression. The purpose of this advisory is to provide solid waste and construction and demolition debris (C&DD) landfill owners/operators with important information regarding how to detect and investigate subsurface landfill fires, so that they may be addressed as early and effectively as possible. General information regarding suppression methods and challenges is also provided in this document, but it is important to remember that each landfill fire situation is unique, and this advisory is not intended to be a comprehensive approach to fire suppression. Additional references are also provided for further information regarding this topic.

Causes of Subsurface Fires

Subsurface fires have a variety of causes. The acceptance of a hot load or hot waste from a previous surface fire may smolder after additional waste is placed over it, or waste may spontaneously ignite. The introduction of oxygen through inadequate daily cover or through poorly maintained well boots or seals may cause a subsurface fire. Overpulling on an active gas extraction system is a common cause of subsurface fires. This overdrawing increases the oxygen in the landfill and increases the potential for subsurface fires. Exothermic reactions, such as the reaction between aluminum production waste and water, and spontaneous combustion are also causes of subsurface fires (see Ohio EPA's July 23, 2007 Aluminum Production Waste Advisory, Part II, found at:
http://www.epa.state.oh.us/portals/34/document/newsPDFs/aluminumadvisory2.pdf)

Detecting Subsurface Fires

While landfill fires may manifest themselves in different ways, there are several characteristics of landfill fires that are nearly universal. To determine if a subsurface fire exists, one must have visual confirmation or other analytical evidence indicating the existence of a subsurface fire. Generally, subsurface combustion can be identified by any of the following conditions:

- Substantial settlement over a short period of time;
- Smoke or smoldering odor emanating from the gas extraction system or landfill;
- Levels of CO (carbon monoxide) in excess of 1000 parts per million (ppm);
- Combustion residue in gas extraction wells and/or headers;
- Increase in temperature in the gas extraction system (above 140° Fahrenheit); or
- Temperatures in the waste mass in excess of 170° Fahrenheit.

Investigating Subsurface Fires

Smoke/Steam

In the situation of a subsurface landfill fire, the combustion event itself may not generate substantial amounts of smoke. The absence of smoke is not confirmation that subsurface combustion (fire) does not exist, as the waste tends to act as a filter for the visible particulate matter in the smoke. At landfills with thermal heating caused by the rapid oxidation of aluminum production wastes by water, “steam” may be observed at the landfill surface or within the waste mass (e.g., rising from a boring). Steam and smoke are not necessarily distinguishable in the field based solely on visual appearance. What appears to be steam may consist of water vapor from which particulate matter in the smoke has been filtered by the waste, or a combination of water vapor and particulate matter. In any event, if the “steam” contains carbon monoxide in excess of 100 ppm it is likely indicative of combustion within the waste mass.

Flame

Gas-phase combustion, or flaming combustion, constitutes what is most commonly thought of as “fire.” But flaming combustion is not possible in highly confined situations, due to a phenomenon known as “quenching distance.” Thus, in the underground situation, flaming combustion will be expected only if there arise substantial voids or cavities. In the absence of these, however, “glowing” or “smoldering” combustion is possible. With glowing or smoldering combustion, flames are not produced, and chemical reactions occur on the surface of the solid material, rather than in the gas phase. Glowing and smoldering combustion are basically similar phenomena, with the only difference being that, by definition, smoldering combustion means the reaction is self-sustained, while the more general concept of glowing combustion can also involve reactions which take place only due to a presence of an external heat source.

There is another factor which is relevant to subsurface combustion. Under most circumstances, flaming combustion will stop if the oxygen level drops below about 12%. However, smoldering or glowing combustion can take place under oxygen conditions barely above zero.

Gas-phase reactions are readily quenched by heat removal and cannot be sustained at low temperatures. But smoldering reactions can persist down to quite low temperatures, since, unlike gas-phase combustion, a chain-reaction process does not need to be sustained. Thus, smoldering reactions—which are ones that a more likely encountered underground—are harder to extinguish, irrespective of whether this is being accomplished by limiting the oxygen or by the removal of heat.

Carbon Monoxide

Both gas-phase/flaming combustion and smoldering and glowing combustion reactions produce carbon monoxide (CO), although in different amounts. Flaming combustion tends to produce primarily carbon dioxide (CO_2) and CO is generally only a small component. But the reaction when oxidation occurs at a solid surface is one that produces CO as the primary combustion product. This can subsequently be oxidized to CO_2, but the process is highly variable. Consequently, if the CO concentration is high and CO_2 concentration is low, it is most likely that glowing or smoldering combustion is taking place.

To confirm a subsurface fire by using carbon monoxide, the results must be acquired through quantitative laboratory analysis; ASTM Method D 1946 is an Ohio EPA accepted method. Most field portable equipment only have qualitative abilities and are susceptible to cross-sensitivity with high temperatures, humidity, and other constituents of landfill gas (for example, volatile organic compounds, hydrogen sulfide, etc.). As a result, landfill gas containing these conditions and constituents may produce artificially high carbon monoxide readings when using portable monitors.

Ohio EPA considers levels of carbon monoxide in excess of 1,000 ppm to be a positive indication of an active subsurface landfill fire. Levels of carbon monoxide between 100 and 1,000 ppm are viewed as suspicious and require further air and temperature monitoring. Levels between 10 and 100 ppm may be an indication of a fire but active combustion is unlikely to be present.

Temperature Survey

When investigating a potential or confirmed subsurface fire it is important to look at the temperature of gas extraction wells, waste, and leachate. Any time a landfill exceeds the New Source Performance Standards (NSPS) operating temperature of 131° Fahrenheit a subsurface fire investigation should be conducted. As previously stated, temperatures in the landfill above 170° Fahrenheit (the temperature at which methanogenesis ceases), or 140° Fahrenheit in the gas extraction system are outside the normal operating temperatures of a landfill and are cause for concern. However, if a landfill is experiencing temperatures below these trigger points, but has experienced a rapid temperature change, that also may be cause for concern and warrant investigation. For example, if a landfill regularly experiences temperatures of 120° Fahrenheit and over a short period of time the temperature rises to 160° Fahrenheit, that significant change in temperature necessitates an investigation to determine the cause of the temperature increase and in order to rule out a subsurface fire.

Infrared Photography

While infrared photography alone is not conclusive to determine the presence of a subsurface landfill fire, when coupled with other investigative techniques it proves very useful. Infrared photography, with the proper resolution and benchmark surface temperature points, can identify the warmest areas in a landfill. This can help direct a temperature survey, gas analysis, and other investigations to the area most likely experiencing a fire. In many subsurface landfill fires (particularly at C&DD facilities), the fire creates "wormholes," or small passages from the primary fire that form a spider-web appearance in an infrared photo. Often these wormholes lead to secondary fires that, without infrared photos, are difficult to detect.

Landfill Gas Analysis

An evaluation of the constituents in the gas extraction system may assist in determining if a subsurface landfill fire exists at a facility. Certain chemical constituents are indicative of combusting waste, and if a subsurface landfill fire is suspected, analysis of the landfill gas from the gas extraction system or observation ports imbedded in the waste mass is recommended. The gas analysis should look for the presence of specific constituents or a significant change in the amount of constituents such as volatile organic compounds (VOCs) and all other analytes detected by US EPA Method TO-15, semi-volatile organic compounds (SVOCs) and all other analytes detected by US EPA Method TO-13A, polynuclear aromatic hydrocarbons (PAHs), chlorinated dibenxo p-dioxins (PCDDs) and chlorodibenzofurans (PCDFs) using US EPA Method TO-9, methane, oxygen, and carbon monoxide. In the case of methane, production often decreases when a landfill fire is present, as the high temperatures destroy microorganisms and inhibit methanogensis. Higher than usual oxygen levels in an active gas extraction system may indicate overdrawing on the system. Therefore, it is not only important to evaluate landfill gas for the presence of constituents indicative of fire, but also to look for changes in the landfill's normal gas composition.

Leachate Chemical Analysis

As with landfill gas analysis, the presence of certain chemicals in the leachate, or changes from what is typical leachate at the landfill, may indicate a subsurface fire exists. Leachate chemical analysis for chemical oxygen demand, OAC Rule 3745-27-10 Appendix I (VOCs, metals, non-metal inorganics utilizing appropriate SW-846 methods), PAHs, and PCDDs and PCDFs using EPA method 1613 should be conducted to assist in determining if a subsurface landfill fire is present. Of particular interest in landfills with a tire chip drainage layer is leachate chemical analysis indicating the presence of any tire derived constituents, such as certain SVOCs and total petroleum hydrocarbons, which would be indicative of tire pyrolysis.

Visual Inspection

One of the best investigative tools for subsurface landfill fires is visual inspection. Observe the landfill for unusual or rapid settlement, stressed vegetative cover, steam or smoke, or combustion residue in gas extraction wells. The majority of landfill fires will be on a slope or at a grade change. Be cognizant of new odors, particularly odors that smell "hot" or "burning". Every landfill is different and as a result inspections should focus on what is normal for that particular landfill as a baseline, and then look for changes that are unusual or unexpected for that landfill.

Suppression of Subsurface Landfill Fires

Suppression Methods

If a subsurface fire is occurring at a landfill it is important to act quickly to prevent or limit toxic air emissions, smoke, damage to engineered components, etc. A number of methods may be used to put out landfill fires, depending on the specific nature of the fire and the structure of the landfill itself.

Application of soil or a thick clay cap (a minimum of two feet of recompacted soil) may starve the fire of oxygen, thereby extinguishing it, provided oxygen is the oxidizer. The use of waste, which may combust and cause a surface fire, is not recommended. While contingent on site-specific conditions, the use of a flexible membrane liner (FML) is not usually recommended. FML may melt in the presence of high temperatures or tear as the landfill settles, thereby not effectively limiting the influx of oxygen. Also, FML is not as easy to repair as a clay cap, and masks settlement, slope failure indicators, leachate outbreaks, or other conditions of concern under the cover of the plastic.

The use of foam to extinguish the fire is an option, but it is important to make sure the appropriate type of foam is used, one that will suppress—not accelerate—the fire. Extinguishing the fire with water is an option, though it is generally not a desirable suppression method for a landfill fire. An excessive amount of water used on a landfill fire has the potential to overwhelm the leachate collection system, contaminate surface water, lead to slope failure, or cause other negative consequences. Additionally, given that the fire is below the surface of the landfill, reaching the fire with water or foam is often difficult. Excavation of the fire is also a potential suppression method. However, with excavation comes the threat of flare ups from the introduction of oxygen, so foam, water, or other fire suppression methods may need to be used in conjunction with excavation.

Any one or a combination of these techniques should be evaluated on a case-by-case basis given the unique circumstances of each landfill and each landfill fire. Remember, there is no “one size fits all” remedy.

Emergency Response Plan

Ohio EPA recommends that every landfill have an emergency response plan that addresses a subsurface fire scenario. These plans should be developed and shared with the local fire department and other emergency responders. First responders should be familiar with the landfill site and general landfill anatomy. Most firefighters have not received any formal training on addressing landfill fires. Accordingly, it is imperative that landfills work with their local emergency response teams to familiarize them with the unique firefighting challenges that landfills present, such as the presence of flammable gases like methane, slope stability concerns, and hazards of using water in suppression.

Landfill fires present a unique set of safety risks. Subsurface fires create voids in the landfill as the waste burns and are prone to cave-ins and collapses. This puts heavy equipment and personnel in a dangerous situation, and the landfill emergency response plan should include a safety plan for a subsurface fire event. The Occupational Safety and Health Administration (OSHA) may be of assistance in the development and implementation of such a plan.

Prevention

The best way to address the issue of landfill fires is, of course, to not allow a fire to develop in the first place. Prevention of subsurface fires may be achieved by applying good daily cover with a low permeability soil, monitoring for changes in landfill gas, leachate chemistry, temperatures, settlement, and odor changes. Maintain gas extraction well seals and boots, and keep engineered components in a state of good repair to minimize oxygen intrusion. In theory, no oxygen should be detected in a gas extraction well during the methanogenesis stage of landfill decomposition; however, extraction wells at the perimeter will tend to show oxygen due to boundary conditions. Ohio EPA recommends landfills target a 1.5% oxygen level in interior gas extraction wells, which can often be accomplished by routine maintenance. Do not overdraw on an active landfill gas extraction system, as this too will introduce oxygen into the landfill. Finally, operators should look for hot loads and manage them in compliance with applicable operational rules, including OAC 3745-27-19(E)(7)(d) or 3745-400-11(F)(4).

Further Reading

California Integrated Waste Management Board Landfill Fires Guidance Document http://www.ciwmb.ca.gov/LEACentral/Fires/LFFiresGuide/default.htm

FEMA: Landfill Fires, Their Magnitude, Characteristics, and Mitigation http://www.usfa.dhs.gov/downloads/pdf/publications/fa-225.pdf

For further questions, please contact the appropriate Ohio EPA District Office solid waste inspector or Gina Gerbasi at (614) 728-5325.

Sincerely,

Pamela S. Allen, Chief
Division of Solid and Infectious Waste Management