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ETLF and Landfill Fires: What's the Difference Science Session

QUESTIONS AND RESPONSES NOT ADDRESSED DURING WEBINAR

1. **Is there any data on the trend of frequency of both ETLF and landfill fires over the past few years? Do data indicate any variation among landfills in different regions of the country? Alternatively, how broad is the sample?**

   The frequency of ETLFs is low. They occur episodically, and we are not aware of increasing or decreasing frequency. We are aware of ETLFs in California, Illinois, Tennessee, Virginia, Ohio, Wisconsin, and Missouri but do not know if this is a comprehensive list. We are not aware of a database or compilation of the number or location of subsurface landfill fires.

2. **Could you explain a little more about CO. It seems like it is observed in both landfills with a fire and in ETLFs. How do we tell the difference?**

   CO is often detected in the landfill gas from both fires and ETLFs. The presence of CO does not automatically mean a fire. In an ETLF, CO may be an intermediate of a biological process that has been interrupted or the result of a chemical reaction. This is why it is important to look at several monitoring parameters concurrently to diagnose a landfill. For example, the slides show that at ETLFs, CO often is correlated with hydrogen which is not the case for a landfill fire.

3. **Has oxygen been detected at the depths where ETLF conditions have been noted and, if so, how would one know that it is an ELTF rather than a fire?**

To our knowledge, oxygen has not been detected at depth in an ETLF. Landfill gas is normally evaluated at the wellhead, rather than deep within the landfill, and reflects a mixture of gas collected from all depths in the well string, along with any leaks that may occur at the surface or in the wellhead. Thus, while we may see oxygen in a landfill gas analysis, we cannot draw an inference regarding where the oxygen was sourced.
As with other parameters, the presence of oxygen in landfill gas should be evaluated along with other data to draw inferences. For example, what other constituents are in the landfill gas? What was the gas flow rate and vacuum at the well head?

4. **What percentage or proportion of landfill fires that occur are on the surface/working face versus subsurface (below multiple layers of daily cover)?**

We are not aware of a database or compilation of the number or location of subsurface landfill fires.

5. **Is there technology available to detect a subsurface fire?**

Drone technology has been used to assist in the location of subsurface landfill fires. However, the results are very dependent on ambient temperatures, site specific conditions, depth of possible fire event, etc. The best method to avoid subsurface fires is the continual review of wellfield data, visible observations of the facility, and a well-trained workforce.

6. **Do you have any insight on fires/heating events at Tire Monofill Landfills?**

We do not have any information on fires or elevated temperatures at tire mono-fills.

7. **How to model leachate production rates during event?**

As discussed during the presentation, the reason that more leachate is collected at ETLFs may be due to changes in the physical characteristics of the waste. We do not think that more leachate is produced but rather that more liquid is released due to changes in the pore structure of the solids and the decrease in surface tension as temperature increases.

In addition, water has accumulated in some ETLFs and aggressive efforts to remove this leachate result in more leachate to manage. While a model could be formulated to predict leachate release, there have not been efforts on this to date. Any such model would likely have considerable uncertainty as the mechanisms causing heat accumulation and their influence on the physical characteristics of the waste are not sufficiently understood to predict water release.

8. Does mere high moisture in the landfill structure cause elevated temperatures?

No. High moisture alone does not cause ETLFs. High moisture can reduce heat release and often interferes with gas collection. High moisture is not desirable due to reduced efficiency of gas collection, the potential for pore pressure development and instability, and the potential for excess head on the liner.

9. Why do some ETLFs experience huge mass loss whereas others do not?

Each ETLF is unique, so a general answer is not possible. Pyrolytic reactions (i.e., thermal decomposition of organic matter in the absence of oxygen) will lead to mass loss, and greater mass loss should be expected at higher temperatures (more pyrolysis). Compression and settlement of the waste also appear as mass loss, and waste compression is larger at higher temperatures. An ETLF with higher temperatures will *experience greater pyrolytic degradation and greater settlement, resulting in greater apparent mass loss. The depth of the waste lens in which elevated temperatures occurs will also influence overburden pressure and settlement, affecting perceived mass loss.*

10. It was mentioned that ETLFs seem to have high levels of accumulated water - why is this?

Every landfill is unique, so a general inference is not possible. However, we are aware that many ETLFs have a greater amount of water in the waste relative to other landfills, and this contributes to heat accumulation.

11. What is the difference between leachate and gas well liquids? Should I sample gas well liquids and if yes, what should I analyze for?

Leachate collected from the collection system in the bottom of the landfill represents a liquid that has flowed through many areas of the waste that may be in different states of decomposition. Thus, leachate from the collection system may not represent conditions in the region with elevated temperatures. Gas well liquids (GWLs) are pumped from an individual well and represent leachate in the pores adjacent to the well string. They will have unique chemical characteristics and temperature as they represent different conditions within the waste mass. Here too, gas well liquids represent liquids that may accumulate over the entire waste column.

If data point towards an ETLF or fire, then testing gas well liquids can be useful. Comparison of the pH of gas well liquids in areas that are and are not suspected of elevated temperatures is a good first step. After pH, the following chemicals have been reported to be elevated at ETLFs: acetone, benzene, methyl ethyl ketone (MEK), phenol, *and tetrahydrofuran. In addition, BOD and COD are often elevated in gas well liquids at ETLFs.*

12. What effective design elements and mitigation strategies have been successfully implemented for elevated temperature landfills? Any case studies/examples?

With respect to design elements, keeping the landfill well drained is important to reduce heat accumulation and facilitate gas collection. Strategies to "stop" or "block" a reaction typically are not effective. Rather, as discussed during the presentation, the focus should be on management. Every site is unique but there are some actions that are typical:

- *remove as much gas and leachate as practical, assuming that there is an accumulation of leachate. If the site is well drained, additional leachate removal may not be necessary.*
- *evaluate the landfill cover and make improvements if needed to facilitate gas collection and manage odors*
- *Prepare for accelerated settlements in the elevated temperature area*
- *On a site-specific basis, evaluate whether an air break is possible between the elevated temperature area and areas that remain at typical temperatures*
- *Prepare for the possibility that gas recovered in regions with elevated temperatures may have low methane content and may not support gas combustion in the gas treatment system. Review contracts with gas developers and determine potential impacts to alternative energy projects.*
- *Prepare for elevated hydrogen in the gas treatment system*
- *Be proactive, and reach out and work with regulators and the community on a collaborative and non-adversarial manner wherever possible.*

- *Liquid disposal options are critical to an effective strategy, as ETLF leachates can be considerably stronger than typical leachates. There is a need to address both the potential volume of liquid along with the concentration thresholds of various analytes.*
- *Wellfield operating staff should be prepared and trained to tune/manage the wellfield as an ETLF rather than tuning and managing under conventional conditions.*
- *Review-site specific health and safety protocols. Ensure site staff are properly trained and have appropriate personal protective equipment (PPE).*

13. What immediate, interim, and long-term actions can be taken to prevent/control mitigate the effects of elevated temperatures within the waste? Which have been most effective?

See response to Question 12.

14. Is there an industry standard way to approach elevated temperature events?

There is no standard protocol, but the methods described in the response to Question 12 have been broadly adopted, found to be effective, and can be considered best response practices.

15. How can environmental regulations be updated (or a change in interpretation of existing regulations) to enable the landfill operator more flexibility in addressing an Elevated Temperature event?

Major changes to regulations, or new regulations, are not needed. A landfill owner has a huge financial incentive to ensure ETLF conditions do not develop or expand, even in the absence of regulations. ETLFs cost in the tens to hundreds of millions of dollars to manage, *and proactive management is a significant incentive. If an ETLF does develop, however, regulators should expect the owner to do everything possible to collect gas, minimize fugitive emissions, and implement strategies to manage the accumulated heat.*

There are several areas, however, where regulatory oversight could be fine-tuned and more flexibility allowed:

- *financial assurance – the owner must have sufficient funds to manage an ETLF, as walking away in bankruptcy can put a huge financial burden on society*
- *regulators could request that each owner have waste acceptance criteria in place that address how to evaluate wastes that may release heat*
- *NSPS criteria must be either updated or paused to ensure that the wellfield is operated efficiently to manage the ETLF. Regulator responses to higher operating value requests need to be timely so the ETLF can be managed effectively (heat removal and odor control).*
- *Liquid management can also be constrained by environmental regulations or treatment plant operators. This can lead to delays and limitations in managing liquids and inhibit expansion of pumping operations that remove heat.*

16. Does drywall waste contribute to elevated temperatures that lead to the emission of sulfur gas?

There is no evidence that drywall waste contributes to ETLFs. Drywall is converted to H_2S in landfills as part of the typical anaerobic decomposition process. Elevated temperatures would interrupt the biological process by which the sulfate in drywall is converted to H_2S.

17. In sites with leachate injection or recirculation, could removing carbonates from leachate through lime softening potentially protect against ETLFs?

There is no evidence that leachate hardness affects heat accumulation at ETLFs. Removal of carbonates would reduce ash carbonation. However, removal of carbonates (dissolved CO_2*) would be trivial compared to the gaseous* CO_2 *in the waste. Thus, the reduction in carbonation reactions would likely be negligible.*

18. What provisions do you recommend for new regulations? Controlling wet waste, pumping liquid from gas wells? limiting total waste depth...?

See response to Question 15 above.

19. Why do some landfills manifest as ETLFs and many are not?

Causation is not understood at every ETLF, and it is often a combination of factors (e.g., reactive waste and poor heat release). Ultimately the key issue is an imbalance between heat generation and heat release that results in excessive heat accumulation.

20. Can additional design elements be used / implemented as waste is being placed to manage the future heat transfer mechanism better? For instance, HAPP by WM? Have these design elements been beneficial in not developing ETLF conditions?

The WM HAP (Heat Accumulation Prevention) Program focuses on the implementation of methods to reduce the potential of excessive internal waste temperatures caused by entrained liquids and gas. Mechanisms to optimize the extraction of both liquids and gas are generally considered best management practices today. We do not know yet *whether these mechanisms will prevent ETLFs, as they are relatively new and only time will tell.*

21. **Have features such as pipe networks across the waste mass in which cold water could be introduced been considered? Basically, similar to radiators but for heat absorb absorption?**

    Heat extraction and cooling strategies have been investigated. However, there are numerous challenges from both the perspective of capital and operational costs and logistics. Design challenges would include coverage area of the cooling wall, depth and distribution methods, design to accommodate landfill height / dimensions, etc. Operational costs would include utilities, infrastructure maintenance, duration of cooling wall operations, etc.

22. **Can you have a landfill fire without seeing smoke? Or does there have to be smoke to be a fire and not an ETLF?**

    Since a subsurface landfill fire is a combustion event, there will always be smoke associated with a subsurface fire. Some have suggested that the smoke can be captured by the gas collection and control system, but smoke collected in a GCCS likely would be detected at the point of treatment (e.g., flare) either visually or though gas composition that is radically different.

23. **On slide 28, you're showing that wellhead temperatures are low when O2 is 5 to 21%. But at 21% O2, you are measuring ambient air, not LFG. At 10%, half of your "gas" flow is ambient air. Couldn't that be the reason for the low temperatures?**

These measurements were from across the country and in Canada. In some situations, there was the indication that air was brought into the gas collector and gas temperature would be influenced by ambient temperatures. In other cases, the data illustrated an over pull situation which inhibited the generation of methane. In these situations, the resultant wellhead gas temperature would be influenced by the in situ waste temperatures. The primary purpose of this slide was to illustrate that atypical concentrations of oxygen do not automatically cause subsurface landfill fires.

24. **Can an ETLF be beneficial to water quality by creating a barrier layer with low permeability? Can this also occur under saturated conditions?**

    Mechanisms by which an ETLF would benefit water quality are highly unlikely. ETLF conditions can create waste mass with very low hydraulic conductivity. However, the leachate in ETLFs tends to be much stronger than in landfills operating at temperatures supportive of biological anaerobic decomposition.

25. **Curious if the panelists have seen any effective treatment technologies for DMS removal in landfill gas in ETLF situations?**

    LFG with DMS has been treated using thermal oxidizers (TOX). The TOX will burn and convert the DMS and all other sulfurs to SO_X. From the TOX, the exhaust will get diverted into a quench using a water spray. This will cool the exhaust down and it will then go through a sulfur scrubber using a diluted hydrogen peroxide solution. The exhaust stream then emits through the scrubber stack 95% sulfur free.

26. **The landfill temperature is a function of the vacuum applied. The higher the vacuum, the higher the gas flow rate and higher degree of gas expansion, which all affect the**

gas temperature. Do you think that vacuum applied during temperature measurement be standardized?

There is no general correspondence between vacuum applied and landfill temperature. One has to be careful in applying the ideal gas law to a landfill as the volume is not constant given that the system is not perfectly sealed. Moreover, in an actual landfill, the vacuum applied differs between wells and is adjusted periodically depending on the gas composition. Thus, a general rule is not appropriate. In addition, the gas temperature is lower than the solids temperature, so equating gas temperature and landfill temperature is not accurate.

27. **On Characteristics and Indicators slide: Leachate composition ---- The phenol, Acetone, MEK, Benzene.... Are these chemicals produced only by reaction for ET event? Also, it was said that the water volume produced may not be from reaction water, but it is just from water coming into solution with the temperature. Are we sure the ET reaction that produces the benzene is not condensation reaction (One that produces water as a product)?**

The specific reactions that occur in ETLFS are not well understood. Thus, we cannot opine on a specific reaction mechanism. Organic compounds are commonly found at elevated concentrations in leachate from ETLFs. These compounds are thought to be byproducts of thermal decomposition of organic matter in the waste under anerobic (i.e., oxygen absent) conditions, aka pyrolysis. They can also be derived from enhanced solubility and thermal desorption due to elevated temperatures. Many organic compounds are common in MSW, as they are present in the waste stream through domestic and commercial/industrial activities.

28. I've been looking at O2:N2 ratio. When out of balance (missing O2) it could be due to composting or fire, but I see no increase of temperature or CO2. Could it be that N2 is being generated by the LF? For example, by annamox bacteria?

We are skeptical of the potential for N_2 generation in a landfill. While nitrate reduction to nitrogen will occur, the mass of nitrate required to generate hundreds of cubic feet per minute is high. Theoretically, 1 lb of NO_3-N would result in 12.8 ft^3 of N_2. While estimates of NO_3-N in landfills are not available, it is hard to imagine that the NO_3-N input is sufficient. It would be interesting to conduct stable isotope studies to put to rest the idea that N_2 is produced. The more likely source of N_2 is air intrusion.

29. One primary leading indicator is if the compressor supplying the air is running a higher duty cycle or running continuously, even better if you are collecting continuous data on compressor flow, pressure and run times

Yes, the tracking of air compressor operations will give an indication if the compressed air conveyance system has been damaged. Equally important, abandoned gas, liquid, or air conveyance lines must be properly abandoned (butt fused HDPE caps). Abandoned pipe sections must also be properly identified on the Site's GCCS as built.