Evaluation of Remedial Action Approaches for Hot Spot Remediation

Presented to:

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September 9, 2015
File No. 23211003.04

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1.0 INTRODUCTION

In their letter dated August 10, 2015, the Missouri Department of Natural Resources (DNR) requested that Bridgeton Landfill, LLC prepare a Corrective Measures Work Plan that includes:

"...a corrective action measure using inert gas injection as a "hot spot" treatment."

At the Request of Bridgeton Landfill, LLC, SCS was tasked with conducting a review of the site’s current remedial approach to remedy potential hot spots as well as evaluate inert gas injection as an additional measure in addressing potential hot spots in the North Quarry. This report evaluates the following two approaches for remediating a local subsurface oxidation event:

- Oxygen deprivation
- Inert gas injection

Appendix D of the November 2014 Corrective Action Plan describes the identification of and remedial actions for local subsurface oxidation (SSO). As described in Appendix D:

"Subsurface Oxidation Events (SSO) are common events that occur at many landfills that have active gas collection systems. These are local subsurface fires that are caused by a combination of subsurface conditions and well management. Unlike large subsurface reactions (which are extremely rare, do not require oxygen to propagate, and are quite different in nature), SSOs usually only involve a small area and a minimal number of gas wells."

If the actions described in Appendix D of the November 2014 Corrective Action Plan are unsuccessful in controlling the SSO, inert gas injection may be implemented to remediate the SSO event.

2.0 OXYGEN DEPRIVATION

Appendix D of the Corrective Action Plan (attached to this document as Appendix A) describes the current approach for remediating an SSO by depriving it of oxygen. The actions to be taken include:

- Shutdown well(s) that is believed to have been the cause of the SSO.
- Shutdown all wells in surrounding area (within the approximately 300 feet of suspect well(s)).
- Cap or repair any item identified during the physical inspection that may be contributing to oxygen intrusion.
• Carefully add additional cover to areas that show cap integrity issues if necessary. Work slowly and pay special attention to the ground surface as material placement commences.

  o During cover placement activities, there should be a minimum of two people available; the equipment operator, and a line-of-sight person on the ground that is responsible for watching the ground surface as the equipment operator places the soil.

  o Use a low ground pressure (LGP) machine, if available. If LGP machine is not available, use the lightest machine with the widest tracks available. Do not use rubber tired machine to place cover material.

  o Slowly push soil into the area and compact with the bucket or tracks of the equipment.

This approach is essential the industry standard for addressing SSOs. It is typically successful in controlling SSOs. The amount of time needed to achieve sufficient remediation to allow the landfill gas extraction well at and in the immediate vicinity of the SSO can vary.

3.0 INERT GAS INJECTION

Carbon dioxide and nitrogen have been used to combat typical subsurface landfill fires. When the inert gas is introduced into the subsurface under pressure, it cools the fuel and displaces the oxygen that is supporting combustion. Inert gases can be injected in a gaseous or liquid state. Injection of the gas as a liquid allows the material to transform from liquid to gas in the subsurface, providing additional cooling and driving force beyond the injection pressure as the liquid "boils" and the gas expands.

Liquid carbon dioxide (CO₂) is the preferred inert gas for subsurface injection. Liquid CO₂ is easier to work with than liquid nitrogen (N₂) because of the extreme temperatures of liquid nitrogen, which boils at -321 °F. Additionally, nitrogen is a typical parameter monitored to evaluate the presence of potential air intrusion at adjacent monitoring points. A gram-mole of liquid CO₂ at 25 degrees Celsius (°C) and 300 pounds per square inch (psi) will expand to 22.4 liters at standard temperature and pressure (STP) conditions (0 °C and 1 atmosphere). This is equivalent to about 8.2 cubic feet (ft³) per pound or 16,433 ft³ per ton of liquid CO₂.

The injection of inert gas has been successful in extinguishing subsurface oxidation (SSO) events, but it has not been successful in all cases. The challenge for the injection of inert gas is how to ensure that it is introduced into the landfill in such a manner so that it is uniformly distributed throughout the impacted materials. Municipal solid waste in a landfill is a non-heterogeneous material. Depending on the specific items and materials that make up the waste and the variability of the compaction effort, some denser areas may remain isolated from the gas. In these instances, the SSO event may rebound and, in the worst case scenario, continue to expand. In these cases, a repeat of the inert gas injection program or the application of other control measures may be required to remediate the SSO event.
The injection of inert gas may have a negative impact on the gas collection and control system. Typically, the landfill gas (LFG) collection system would be turned off in the immediate vicinity of the injection activity. Alternatively, the landfill gas collection system will be turned off in a wider area extending beyond the impacted area during treatment. If part of the landfill gas collection system remains active, gas extraction wells near the injection area might be able to be used to “steer” the migration of the treatment gas. The downside of leaving the landfill gas collection system active near the treatment area would be the capture of a significant amount of the treatment gas. If the methane (and/or hydrogen and carbon monoxide) content is sufficiently reduced, the flare(s) could require supplemental fuel to burn. Bridgeton Landfill, LLC has a natural gas line connected to the flares that can be used to supplement the landfill gas and keep the flares operating if inert gas is drawn into the collection and control system.

**4.0 SUMMARY**

Based on the review of the site’s current plan to address SSOs and evaluation of the use of inert gas injection, it is SCS’s recommendation that the site continue to use its current plan to address SSOs and to have the inert gas as an a potential secondary option to address shallow SSOs.

**5.0 SCS EXPERIENCE WITH ELEVATED TEMPERATURE LANDFILLS AND LANDFILL H hot spots**

SCS Engineers has significant experience with elevated temperature landfills and landfill hot spots. Landfill fires are often called subsurface oxidation events (or SSOs). These are usually localized and relatively shallow oxidation events that can elevate to the level of active combustion and fire. These are often caused or at least spread by an over-drawing or short circuiting gas collection and control system (GCCS). In this case, the GCCS system may pull atmospheric air and oxygen into the landfill, causing spontaneous combustion and thereafter fueling the SSO with additional quantities of oxygen from the surface above. These are different than working face fires that may develop from "hot loads" freshly deposited at the landfill's working face, where there is no existing cover material in place at all.

SCS has experience in investigating and extinguishing over 170 landfill fires or SSOs since the early 1980s and has published and presented on this topic for decades. The most common and effective approach to extinguishing an SSO or conventional landfill fire, and the one most commonly applied by SCS, is "cover and smother" by covering with fresh or additional soil cover, in an effort to prevent easy entry of the oxygen fueling the SSO. If a GCCS is operating nearby and may even have created the SSO, the GCCS can be throttled down or deactivated in the vicinity of the landfill fire. Other techniques applied often with incomplete success or reduced efficiency include inert gas injection and even excavation and removal of affected waste materials. SCS has applied inert gas injection on at least 6 landfills dating back to 1985.
Appendix A

Corrective Action Plan Appendix D, Local Subsurface Oxidation (SSO – Potential Landfill Fire)
APPENDIX D

LOCAL SUBSURFACE OXIDATION PROCEDURE
Appendix D

Local Subsurface Oxidation (SSO – Potential Landfill Fires)

Subsurface Oxidation Events (SSO) are common events that occur at many landfills that have active gas collection systems. These are local subsurface fires that are caused by a combination of subsurface conditions and well management. Unlike large subsurface reactions (which are extremely rare, do not require oxygen to propagate, and are quite different in nature), SSOs usually only involve a small area and a minimal number of gas wells.

In the North Quarry of the Bridgeton Landfill, it is important to distinguish between an isolated, readily-contained and easily-extinguished SSO from the advancement or initiation of a large subsurface reaction.

Typical Symptoms
- Dramatic localized landfill settlement.
- Charred or cracked surface cover.
- Stressed or dead vegetation in an area that is otherwise properly vegetated.
- Smoke or smoky odor emanating from the landfill surface or wellhead.
- Drastic or unusual increase in flowing gas temperature.
- Abnormal discoloration of wellhead/riser assembly.
- Abnormally high CO concentration in LFG.
- Deformed riser pipes.

Initial Notification and Investigation

Notify Environmental Manager immediately after visually identifying any potential SSO. An initial investigation shall be started within 12 hours after visual identification of a potential SSO.

1) Do not change the condition of the well during the initial investigation.

2) Health and Safety Considerations
- Consult HASP for procedures related to landfill fires.
- Under no circumstances shall an initial investigation be conducted without first consulting the HASP and implementing appropriate controls and procedures.
- Do not breathe landfill gas or smoke. Stand upwind of emissions.
- Wear appropriate PPE. Burns may be caused by hot PVC / HDPE / steel.
- Do not drive heavy equipment / vehicles near well or depression until ground stability has been verified. The burned waste mass may give way and equipment/personnel may fall into sinkhole.

3) Conduct physical inspection
   - a) Inspect the nearest extraction well to the potential SSO location.
   - b) Inspect all wells within 500 feet of nearest extraction well to the potential SSO location.
   - c) Inspect the landfill surface within 500 feet of nearest extraction well to the potential SSO location.
d) Visibly inspect for large localized settlement, cracks, holes, collapse, missing components, and areas that could be sources of air intrusion into the waste mass including:

- Monitoring ports
- Well casing
- Hoses
- Erosion ruts
- Dry soil cracks
- Manways
- Lift stations
- Sumps
- Leachate cleanout risers

4) Measure gas quality, pressure and temperature, at all wells within 500 feet of nearest extraction well to the potential SSO location. *Special precautions may be necessary to address high gas temperatures.*

5) Measure CO concentrations with colorimetric tubes (Draeger tubes) at all wells within 500 feet of nearest extraction well to the potential fire location, and obtain summa canister samples for laboratory CO analyses at all wells that indicate CO detections >500 ppm by colorimetric tube. *Gas temperature and other interference gasses can affect the accuracy of the measurement; therefore, the results of any CO field monitoring should be expressed qualitatively only.*

6) Infrared Thermometer Survey

- Use an IR laser thermometer to measure the temperature of the ground surface in the area of the suspected SSO. *Shallow fires or fires that have consumed large amounts of refuse will produce elevated surface temperatures. Extreme caution must be taken in these areas due to the possibility of the ground giving way.*

SSOs are often caused by “overpulling” a gas well or wells in a certain area. Oxygen is drawn into the waste mass which can generate heat and provide the necessary oxygen for combustion. Since oxygen readings are collected as part of normal Title V, New Source Performance Standards (NSPS) monitoring, a review of the collected historical data from surrounding wells should be made. The data review should trend oxygen readings in from the wells in the general area of the SSO to determine if there was an overpull situation. Temperature should also be historically trended as heat; along with CO data (see below) is a good indicator of an SSO in the area.

Gas quality in wells adjacent to the SSO may be affected. In particular, carbon monoxide levels could elevate based on wellfield operation issues and preferred pathways within the waste mass. It is important to determine if the SSO is constrained to a single gas well and / or a single isolated area. Therefore, laboratory CO analyses will be expedited with results received within seven days of detection by colorimetric tube.
If the above investigation suggests that more than one gas well may be actively involved in an SSO area, then the investigation shall be expanded to include the wells within 500 feet of the SSO area.

**Formal Notifications**

The Environmental Manager shall notify the MDNR (SWMP Engineering Section Chief or Program Director at (573) 751-5401) within one business day of determination. The notification will include the gas well identification, date of initial detection, approximate area of the SSO, and results of initial investigation. The MDNR may observe or conduct confirmatory sampling.

**Data Analysis**

Determine the state of the SSO

- Analyze temperature gradient between monitored wells.
- Analyze oxygen gradient between monitored wells.
- Analyze nitrogen to oxygen ratio gradient between monitored wells. *If nitrogen is not measured directly, assume balance gas of nitrogen.*
- Analyze pressure gradient between monitored wells.
- Analyze methane to CO₂ ratio gradient between monitored wells.

**Removing the Oxygen from the Fire**

The key to stopping a SSO once it has begun is to completely restrict oxygen from entering the smoldering waste mass (snuff out the fire). Once the initial investigation has been performed and a general sense of the extent of the SSO has been determined, safely begin to restrict further oxygen intrusion using the following method:

1) Shutdown well(s) that is believed to have been the cause of the SSO.

2) Shutdown all wells in surrounding area (within the approximately 300 feet of suspect well(s)).

3) Cap or repair any item identified during the physical inspection that may be contributing to oxygen intrusion.

4) Carefully add additional cover to areas that show cap integrity issues if necessary. Work slowly and pay special attention to the ground surface as material placement commences.

- During cover placement activities, there should be a minimum of two people available; the equipment operator, and a line-of-sight person on the ground that is responsible for watching the ground surface as the equipment operator places the soil.
- Use a low ground pressure (LGP) machine, if available. If LGP machine is not available, use the lightest machine with the widest tracks available. Do not use rubber tire machine to place cover material.
- Slowly push soil into the area and compact with the bucket or tracks of the equipment.
Note: Closing wellhead valves to minimize vacuum in the area of concern may cause vacuum levels to increase within the main header. This will redistribute the overall vacuum applied to the wellfield and may cause higher vacuums to other wells in the GCCS. Carefully watch for redistribution of vacuum, and adjust prime mover vacuum set-point accordingly. If greater than 10 percent of the total wells in the wellfield are closed to remediate the SSO, a complete retune of the wellfield may be warranted.

Things to Avoid

- **Flushing the well with water** – Flushing the well with water can potentially clog the well.
- **Excavating soil in the SSO area** – Do not excavate in the SSO area. Excavation will allow additional oxygen to enter the already smoldering waste mass and can potentially auto-ignite.
- **Venting** – Do not remove the wellhead to vent the well. Wellfields are typically under negative pressure. Residual vacuum exists in the waste mass for a period of time when wells are closed. If the wellhead is removed to vent, it is highly possible that the residual vacuum in the area will pull ambient air into the waste mass adding oxygen to the SSO.
- **Introduction of water into open cap fissures** – Applying water to open fissures in the cap where an SSO exists can create a plume of highly odorous stream. It is also dangerous to bring a heavy, rubber tired water truck to the area to apply water. The steam created can be dangerous to workers in the immediate area. If an open cap fissure exists in an SSO area, is shall be safely filled with soil. Removing the pathway for oxygen intrusion is the most effective way to put out the SSO.

Continued Monitoring

Monitor the wells closest to the suspected SSO area and adjacent wells at least once a day for at least two weeks.

- Monitor for gas quality, temperature, and CO. *As the SSO subsides, residual CO will remain in the waste mass for weeks and possibly months. Elevated CO levels are not a reliable indicator that an SSO is still in progress. However, CO levels should generally decline with time if the fire has been extinguished.*
- Once SSO indicators are no longer noted, monitor the well and adjacent wells once a week for at least 4 months before returning to normal monitoring schedule.

It is important that during these monitoring events the valve on the wellhead is opened for a prescribed time at a prescribed vacuum. This must be performed consistently form event to event to pull stagnant LFG form the well and fill the casing with fresh LFG form the Landfill formation. Analysis of this fresh LFG will provide the most realistic picture of the status of the SSO. Once readings are collected, the well must be returned to its closed position.
Repairs

Repairs should be made to the SSO area, as necessary

- Visual Inspection
- O&M Provider shall visually inspect the following:
  - Wellheads and lateral piping,
  - Cover soil and geosynthetics, and
  - Other items within SSO area.
- Provide findings to, and generate repair options for OM&M Manager.
- OM&M Manager shall facilitate repairs, as required.

Timeline for Local SSO Resolution

It is important that a structured SSO monitoring plan and diligent adherence to the plan be carried out to return the wellfield to normal operation as soon as possible. However, it is advisable to take time and slowly ensure the SSO is fully extinguished and that the bacteria population in the area has recovered and is consistently producing gas.

The severity of the SSO, the age of the waste, moisture content, and a number of other variables will all determine how long it takes the wellfield to regain compliance with NSPS. Experience has shown that the timeline from the point when the SSO is identified and extinguished to the point when the wellfield resumes normal operation can vary from 2 to 3 weeks up to (in some serious SSO situations) 1 year or more.

Classification of the Event

The Environmental Manager and the MDNR will actively collaborate to verify and classify the SSO event. Such determination will be made within four weeks of the Initial Notification.

The event will be classified as a local SSO if monitoring indicates that combustion is constrained to one gas well and that there is no evidence that the SSO is enlarging.

If the event is not classified as a local SSO and may, instead, be considered a triggerable action per the North Quarry Contingency Plan, then Bridgeton Landfill and the MDNR will discuss and reach agreement on the appropriate action which may include further monitoring or entering into the path of actions provided in Table 1 of the North Quarry Contingency Plan – Part 1.
Appendix B

Inert Gas Injection Work Plan