Elevated Temperature Landfill Causation Investigation Report

Chiquita Canyon Landfill
Castaic, California
SCAQMD Facility No. 119219

Waste Connections
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Castaic, CA 91384

Submitted to:

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1 INTRODUCTION

Chiquita Canyon, LLC (Chiquita) operates a municipal solid waste (MSW) landfill/solid waste disposal facility located in Castaic, California under South Coast Air Quality Management District (SCAQMD) Facility No. 119219. SCS Engineers (SCS) prepared this Elevated Temperature Landfill Causation Investigation Report (Report), which is being submitted to SCAQMD on behalf of Chiquita, in accordance with Condition No. 12(b)(ii) of the Stipulated Order of Abatement (SOFA) (Case No. 6177-4) pertaining to the Chiquita Canyon Landfill (CCL, Facility or Landfill), which was approved on September 6, 2023.

SCS' opinion is that a discrete portion of the waste mass at the Landfill is experiencing elevated temperature landfill (ETLF) conditions. This opinion was expressed and expanded upon during testimony by SCS personnel at the SCAQMD Hearing Board for the SOFA hearing conducted on 9/6/23, which was recorded and can be viewed at the following link:

> http://www.aqmd.gov/home/news-events/webcast/live-webcast?ms=MjU87i4XsjM

ETLF conditions can generally be characterized as when the typical waste decomposition processes and corresponding methanogenesis associated with anaerobic digestion of organic solid waste materials disposed in a landfill are impeded because of heat accumulation. As a result, certain abiotic (non-biological) processes and chemical reactions within the buried wastes occur instead. Basically, heat starts to degrade the waste instead of the microbes that normally do.

Condition No. 12 requires Chiquita, through the DMS Committee, to conduct an investigation and study into the cause of the landfill reaction, , which shall include:

> *An investigation and report on 1) the cause of the alleged chemical reaction(s) resulting in the elevated well temperatures, elevated levels of DMS formation in the landfill gas, and elevated levels of NMOC formation in the landfill gas and 2) solutions to slow and stop the reaction(s) in the landfill. Investigation into the cause of the alleged chemical reaction(s) shall include, but not be limited to, waste characterization study of waste disposed within the Reaction Area, to the extent records of such waste are within Respondent's possession, including (but not limited to) analysis of chemical and physical characteristics, BTU, moisture content, biological methane potential. Respondent shall also conduct drill core sampling in the Reaction Area (as defined in Condition 9(a)) to assess waste characterization in areas not affected by elevated temperatures at the time of drilling.*

This Report presents the investigation and study into the potential causes of the ETLF conditions at the Landfill, as well as corrective measures to contain and manage the ETLF conditions, pursuant to SOFA Condition 12(b)(ii). For purposes of this Report, the terms "ETLF conditions", "landfill reaction", and "heating event" are synonymous.

SCS finds that the causes of the ETLF conditions at CCL cannot be definitively identified. It is likely that the heat generated within the waste mass from typical anaerobic digestion processes accumulated to a point, inhibiting the second stage of fermentation, acetogenesis, and methanogenesis processes, and were replaced by abiotic chemical reactions affiliated with ETLFs that became self-sustaining.

2 BACKGROUND – TYPICAL MSW DECOMPOSITION PROCESSES AND ELEVATED TEMPERATURE LANDFILL CHARACTERISTICS

CCL is located at 29201 Henry Mayo Drive, Castaic, California, in northern Los Angeles County. It is a Class III non-hazardous MSW landfill and operates under Solid Waste Facilities Permit (SWFP) No. 19-AA-0052, issued by CalRecycle (formerly the California Integrated Waste Management Board [CIWMB]). CCL accepts nonhazardous solid waste, including MSW from various areas within Los Angeles County in accordance with Title 27 of the California Code of Regulations (27 CCR), Section 20005, et seq.

The site commenced operations in 1972. The permitted landfill disposal footprint totals 639 acres and is comprised of 3 separate areas designated as Primary Canyon, Canyon B, and the Main Canyon (including Canyons A, C, D, subsequent fill modules, and Cells 6, 7, 8, 9, 10, 11, 12, and 13). Cells 6 through 13 remain to be constructed per the expansion plan approved by Los Angeles Department of Regional Planning in July 2017. Cells 6 and 8 are located southwest of Canyon D. Cells 7, 9, 10, 12, and 13 are located northeast of the active area and Cell 11 is located north of the active area. Currently, 253 acres of the footprint have been used for disposal and Cell 6 (16 acres) is currently under construction. All areas except Primary Canyon have landfill liners and leachate collection systems.

Per CalRecycle's solid waste facility listing for CCL, the maximum permitted throughput of any combination of non-hazardous solid waste, beneficial reuse material, and composting green material is 12,000 tons per operating day, the design capacity is 110.366 million cubic yards and the estimated closure date is 2047. The Landfill currently accepts approximately 1.5 million tons per year of MSW.

Leachate is collected and transported off-site for disposal. The landfill gas (LFG) collection and control system was originally installed in Primary Canyon and Canyon B in 1989 and the LFG system was subsequently expanded into the Main Canyon and has been routinely upgraded and expanded over the years.

This Report focuses on the northwestern area of the Landfill, comprised of Cells 1/2A, 2B/3, 4, and Module 2B/3/4 P2 (of the Main Canyon), which are exhibiting ETLF conditions. A drawing depicting the relevant areas of the Facility is included in Appendix A.

TYPICAL MSW DECOMPOSITION PROCESSES

The decomposition of MSW within a landfill typically involves an initial aerobic phase followed by an anaerobic phase. The primary processes that occur within these two phases are hydrolysis, fermentation, acetogenesis, and methanogenesis. Detailed explanations of these processes and the corresponding chemical reactions associated with each are well-documented in existing literature (peer-reviewed published papers, technical journal articles, etc.) relevant to the solid waste industry. Examples of the available literature on waste decomposition processes related to both the typical aerobic and anaerobic phases as well as the atypical ETLF reactions[i,ii,iii] include the papers and articles cited in Appendix B, among many other reference documents. For purposes of this Report, a generalized summary of typical waste decomposition, along with key points related to temperature, are presented below.

Landfill Gas Production

At a typical MSW landfill, microbial colonies decompose or digest the organic waste fraction (e.g., wood, paper, textiles, vegetative matter, food waste) and produce LFG comprised mostly of methane and carbon dioxide, with trace concentrations of volatile organic compounds (VOCs), reduced sulfur compounds (such as hydrogen sulfide), and other chemical constituents. The production of LFG as a byproduct of anaerobic digestion of organic waste materials by microbial colonies in MSW, which is often referred to as methanogenesis due to the generation of methane as the primary component of LFG, is well-understood within the solid waste industry.[iv,v] The metabolic synthesis of organic waste by specific types of microbial communities that constitute the methanogenesis processes are well-documented in the literature addressing anaerobic digestion, and various algorithms and models have been developed as tools to estimate the quantity (both mass-based and volume-based quantities) of LFG that will be generated by the decomposition of wastes with a known composition.

Methanogenic bacteria that synthesize organic wastes to produce methane and other byproducts that comprise LFG (commonly referred to as methanogens) are actually comprised of numerous and diversified microbial organisms. Research suggests that microbes are able to facilitate substantial methane production at low pH, which occurs in the acid-forming phase of ETLF conditions.[iv] The stages of LFG production are well documented throughout the literature.[v,vi]

As stated in various papers,[vii] the stage immediately following consumption of the entrained oxygen yields formation of volatile fatty acids (such as acetic acid) and hydrogen (H_2), which is then used as an energy source and electron donor by methanobacterium. The ASTDR document title "Landfill Gas Primer; An Overview for Environmental Health Professionals," dated November 2001, provides a summary of the four phases of MSW degradation and LFG generation.[vi]

While select organisms classified as methanogens are mesophiles and achieve optimal function in temperatures less than 120°F, certain methanogens function in anaerobic environments with sustained temperatures above 180°F.[viii]

Leachate Production

As noted in the available literature, water produced during the initial aerobic phase of decomposition is subsequently consumed in the anaerobic phase. Accordingly, the sources of leachate generated within a typical MSW landfill are primarily the moisture entrained in the incoming waste materials and precipitation that infiltrates into the waste mass. Water produced by the chemical reactions associated with decomposition processes is relatively insignificant compared to overall leachate generation.

CHARACTERISTICS OF ELEVATED TEMPERATURE LANDFILLS

ETLFs are a relatively recent development in the industry. The first known ETLF event at a landfill in the U.S. occurred around 2008. The landfill industry has documented approximately 10 to 15 landfills that have experienced a heating event in which nearly all of the waste mass (or at least a significant majority) exhibits ETLF conditions. There are also approximately 40 other landfills that have a smaller portion of their waste mass exhibiting ETLF conditions.

At an ETLF, the landfill experiences increased heat accumulation that impacts the microbial colonies' ability to decompose the waste as normal. An ETLF undergoes a different decomposition process that involves abiotic (meaning non-biological) processes. These abiotic processes produce LFG with a different composition than normal (such as increased presence of hydrogen and dimethyl sulfide

(DMS) and other constituents that are not present in large amounts at normal landfills). In addition to elevated temperatures, ETLFs experience high pressures, broad settlement (an indication of significant waste degradation and settlement), an inverted methane to carbon dioxide ratio in the LFG, as well as increased gas generation and increased liquids production.

The MSW landfills that have experienced large-scale heating events share a few common physical properties. In general, they have relatively large waste footprint areas (typically at least 100 acres or more of waste in-place), they have relatively deep waste profiles (typically at least 200 feet of waste depth), and they have excessive free liquids (the moisture content is greater than field capacity).

The most recognizable characteristics (i.e., symptoms) of an ETLF are as follows:

- Increased gas, leachate, and in-situ waste temperatures. The in-situ waste temperatures conform to the "belly-curve" profile in which the maximum temperatures occur at approximately two-thirds of the maximum waste depth.

- Increase in gas production (significantly greater quantities), increase in subsurface gas pressures, and changes in gas composition. The changes in gas composition relative to normal LFG often involve a decrease in methane concentration, an increase in hydrogen concentration, an increase in DMS concentration, and increases in certain trace constituents, such as benzene and acetone.

- A change in the odor characteristics of the gas (often described as a "chemical" odor) compared to typical LFG. Where normal LFG often has a pungent skunk odor, or a rotten egg odor associated with hydrogen sulfide, the gas produced at ETLF sites is somewhat peculiar and noticeably different.

- Increase in leachate quantities, evidence of pressurized liquids, and changes in leachate composition; the changes in leachate composition relative to normal leachate often involve increases in BOD and COD concentrations, increased solids concentrations, increases in certain organic constituents, such as benzene and acetone, and decreased pH.

- Accelerated widespread landfill settlement across the affected area (as opposed to highly localized rapid settlement).

Reaction Gas Production

The production of gas within a landfill in which a discrete portion of the waste mass is exhibiting multiple characteristics that are consistent with ETLF conditions, as generally recognized by professionals in the solid waste industry, is not as well-understood as the typical LFG production processes. ETLF conditions generally occur when the typical waste decomposition processes and corresponding methanogenesis associated with anaerobic digestion of solid waste materials disposed in a landfill are impeded because of heat accumulation. Note that heat accumulation is not synonymous with heat generation, or necessarily a direct consequence of heat generation. As a result, certain abiotic (non-biological) processes and reactions within the buried wastes occur instead. For purposes of this discussion, the gas produced within an ETLF by abiotic processes will be referred to as "Reaction Gas" (RG) to distinguish it from typical LFG produced by traditional methanogenesis.

As noted above, the RG produced at ETLFs often exhibits low oxygen, reduced methane concentrations, elevated carbon dioxide, elevated hydrogen, elevated DMS, and elevated temperatures. ETLFs also experience tendencies to remain in the acid-forming stage of LFG production. However, the presence of some methane indicates that methanogenesis associated with anerobic decomposition is still occurring.

The exact processes and reactions involved in production of RG are not comprehensively well-documented within the literature and corresponding algorithms and models to estimate the quantity of RG are not readily available (specifically no models have been empirically confirmed by field measurements). The use of a first-order decay model similar to LandGEM to estimate projected RG flowrates may not be appropriate because the microbes are not metabolically synthesizing the waste as during traditional methanogenesis.

Accordingly, engineering design exercises for sizing equipment to combust a gas stream that is a composite of LFG and RG typically consider the following:

- ETLF conditions increase composite gas (LFG+RG) quantities (on a volumetric flowrate basis) because the increase in temperature expands gas volume in accordance with the ideal gas law ($pV=nRT$).

- ETLF conditions decrease LFG quantities (on both a mass and volumetric basis) because the increased heat present within the waste matrix distresses certain species of methanogens (those that are characterized as mesophilic) and impedes their metabolic synthesis of the waste materials that produces LFG. However, some practitioners have put forth an opinion that the mass of methane remains consistent but the concentration decreases due to the increased quantity of gas generation.[ix]

- RG, as a byproduct of abiotic processes and reactions, may potentially be produced in greater quantity than LFG produced by anaerobic digestion from the same amount of solid waste. While not a direct comparison, the pyrolytic gas yield of the organic fraction of MSW has been demonstrated to be significantly greater than the pyrolytic gas yield of anaerobic digestion (AD) solid residuals (digestate).[x]

While generation of DMS, along with other reduced sulfur compounds such as hydrogen sulfide, is common at MSW landfills, several ETLF sites have experienced a pronounced increase in DMS generation. The formation of hydrogen sulfide by sulfate reducing bacteria (SRB) within a landfill environment is well-documented within the industry literature references. However, the cause of elevated DMS at ETLF sites is somewhat less certain and research on simulated landfills noted that "DMS generation was active in the acidification and methane fermentation phase of the simulated landfill and was possibly affected by the volatile fatty acid concentration, chemical oxygen demand, total organic carbon concentration and pH of the leachate, as well as total organic carbon in the refuse."[xi]

Reaction Leachate Production

ETLF sites experience a significant increase in leachate production within the Landfill waste mass, which is likely attributed to multiple circumstances, including: 1) a reduction in field capacity of the waste materials (which diminishes the moisture attenuation abilities); 2) when the anerobic phase is inhibited due to heat accumulation, the water produced during the aerobic phase is not consumed at the normal rate; 3) certain other synthesis reactions may be occurring to produce water, especially considering the availability of hydrogen; and, 4) the heat present may facilitate pyrolytic reactions that produce condensable liquids. As noted previously, the strength of the leachate increases significantly at ETLFs. Because the solubility of solids increases with increases in temperature, the heat enables constituents from the buried wastes to solubilize more readily, which results in an increase the concentration of certain constituents in the leachate, such as BOD, COD, and various speciated organic compounds.

3 CAUSES OF ELEVATED TEMPERATURE LANDFILL REACTION

Condition 12(b)(ii) requires investigation on the cause of the alleged chemical reaction(s) resulting in the elevated well temperatures, elevated levels of DMS formation in the landfill gas, and elevated levels of NMOC formation in the landfill gas. A discussion of the chemical reactions that potentially contribute to elevated well temperatures, elevated levels of DMS formation, and elevated NMOC formation in the landfill gas are presented in this section.

The landfill industry has concluded that the exact causes and contributing factors to the heat accumulation and ultimate formation of large-scale heating events and the chemical reactions associated with ETLFs are believed to be different and somewhat unique from landfill to landfill. The "original cause" or "triggering event" at ETLFs is not always obvious because the occurrence is infrequent and there are many MSW landfills that have similar waste streams and are large, deep, and wet, but do not exhibit ETLF conditions.

A potential contributing factor that enables ETLF conditions to develop is where the LFG collection systems and liquids removal systems (leachate collection and/or LFG wellfield dewatering) have experienced some degree of reduced efficiency and performance for an extended period of time.

As noted previously, there are a number of biological and chemical processes that can occur naturally in a landfill environment and can contribute to warm temperature conditions similar to those the Facility is experiencing. The most significant heat-producer in a typical MSW landfill is biological decomposition which creates hydrogen, then methane and carbon dioxide. Heat is removed from the waste mass by gas and liquid extraction and by convection/conduction of heat to the outside environment or the ground underneath the waste. Other sources of heat generation documented in the industry literature references include:[ii]

- Anaerobic, exothermic metal corrosion and oxidation reactions;
- Hydration and carbonation of various oxides/hydroxides;
- Acid-base neutralizations; and,
- Pyrolysis.

Notable documented heating events that have occurred within MSW landfills in the United States can generally be categorized as follows:

- Landfills that have accepted significant quantities of aluminum dross or other types of secondary metals waste. The suspected cause of ETLF conditions at these sites has been attributed primarily to the generation and accumulation of heat from anaerobic, exothermic metals corrosion reactions associated with large deposits of select industrial metals-containing waste materials buried in the landfill in the presence of copious quantities of liquids. The manner in which heat is generated from anaerobic, exothermic metals corrosion is described in the industry literature references.

- Landfills that have accepted significant quantities of waste-to-energy incinerator ash, coal combustion residuals (CCR), and/or other industrial ash waste materials. The suspected cause of ETLF conditions at these sites has been attributed primarily to the generation and accumulation of heat from ash hydration and carbonation reactions associated with large deposits of industrial ash containing various oxides/hydroxides buried in the landfill in the presence of copious quantities of liquids. The manner in which heat is released from ash hydration and carbonation is described in the industry literature references.

- Landfills that have accepted significant quantities of sludge/biosolids. The suspected cause of ETLF conditions at these sites has been attributed primarily to the generation and accumulation of heat due to the higher degradable organic carbon (DOC) content and the increased presence of free liquids under anaerobic conditions. The manner in which heat is released from anaerobic decomposition is described in the industry literature references.

- Landfills that have experienced a slope failure or other large-scale waste relocation in which a substantial portion of the buried wastes are "shocked" by an abrupt reversion from anaerobic conditions to aerobic conditions and, upon replacement of those wastes, back to anaerobic conditions. The suspected cause of ETLF conditions at these sites has been attributed primarily to the generation and accumulation of heat from essentially reverting to composting of the wastes under aerobic conditions. The manner in which heat is released from aerobic decomposition is described in the industry literature references.

- Landfills that have none of the four preceding attributes, and specifically did not accept significant quantities of industrial wastes containing metals or ash, biosolids, or other materials often designated within the landfill industry as "special wastes". The waste streams at these facilities can be described as exclusively (or at least predominantly) MSW containing the typical composition of household, residential, and commercial (business) wastes with perhaps a marginal quantity of construction and demolition debris (CDD) waste materials that are common at nearly all MSW landfills. The suspected cause of ETLF conditions at these sites, and the corresponding generation and accumulation of heat, cannot be readily identified. These landfills do conform to the common characteristics of large, deep, wet landfills, and may have been experiencing a period of less-than-optimal performance in their respective LFG collection systems and/or liquids removal systems. But it is difficult to ascribe the specific cause or trigger of the heating event to be due to these physical characteristics alone, since there exists hundreds of other landfills in the U.S. with similar physical characteristics that have not experienced a large-scale heating event and exhibited ETLF conditions.

CCL has not accepted significant quantities of industrial wastes containing metals or ash, biosolids, or other materials often designated within the landfill industry as "special wastes", which is consistent with SCS' experience that the majority of ETLF landfills fall into the last category listed above in which the suspected cause of ETLF conditions cannot be readily identified. Thus, it is SCS' opinion that CCL falls into the last category of landfills, where a cause cannot be definitively identified.

WASTE CHARACTERIZATION STUDY

Condition No. 12(b)(ii) provides: Investigation into the cause of the alleged chemical reaction(s) shall include, but not be limited to, waste characterization study of waste disposed within the Reaction Area, to the extent records of such waste are within Respondent's possession, including (but not limited to) analysis of chemical and physical characteristics, BTU, moisture content, biological methane potential.

The wastes within the Reaction Area were buried prior to Chiquita's ownership of the Landfill. Chiquita has conducted an internal review of all available records and was unable to locate any records related to the wastes placed within the Reaction Area, including waste manifests, weight tickets, or laboratory analyses reflecting the constituents/nature of the Reaction Area wastes (e.g. - scientific measurements for traits such as BTU value (heat content), biological methane potential (BMP), moisture content (as a percentage), and chemical content (cellulose, lignin, etc.)). As a result, SCS was unable to include a review of those types of records as part of its analysis.

DRILL CORE SAMPLING RESULTS

Condition No. 12(b)(ii) provides: Respondent shall also conduct drill core sampling in the Reaction Area (as defined in Condition 9(a)) to assess waste characterization in areas not affected by elevated temperatures at the time of drilling.

In order to evaluate whether the existing in-place buried waste contains specific waste materials known to contribute to heat generation, CCL provided the boring logs for 49 vertical LFG extraction wells that were installed at the Facility between 7/12/23 and 10/12/23. Confirmation that a subset of these wells are located "in areas not affected by elevated temperatures at the time of drilling", is as follows: 1) the temperatures of the drill cuttings at select boreholes are within the range of typical landfill (non-ETLF) conditions, based on the 40 CFR 63 Subpart AAAA regulatory threshold of 145°F (this is a conservative value); and, 2) the boreholes are positioned within the SOFA-prescribed Reaction Area boundary (depicted on monthly maps using a solid black line), but are outside of the estimated extent of ETLF conditions being experienced at the site based on review of scientific data (depicted as a dashed magenta line).

Of the 49 borings, the drill cuttings from 19 boreholes exhibited temperatures that did not exceed the regulatory threshold of 145°F, thus they do not appear to be affected by elevated temperatures. Also, of these 49 borings, 26 are physically located outside of the estimated extent of ETLF conditions impacting the site based on review of scientific data. A detailed inventory of which of the 49 wells satisfy this requirement based on either of the two criteria (drill cuttings temperatures and well physical positioning), is presented below in the Table 1.

Table 1. Inventory of LFG Well Boring Logs

Temp > 145°F	Well ID		
	Area Within Magenta line	**Area Between Magenta and Black lines**	**Area Outside of Black line**
Yes [30 total]	16 total 1532B, 1534A, 1902A, 2301, 2302, 2304, 2306, 2308, 2310, 2338, 2339, 2340, 2342A, 2343, 2352, 2353	8 total 2305, 2312, 2314, 2322, 2327, 2344, 2345, 2346	6 total 2009A, 2010A, 2208A, 2316, 2319, 2321
No [19 total]	7 total 2303, 2311, 2337, 2341, 2349, 2351, 2354	9 total 2315, 2326, 2328, 2333, 2335, 2336, 2347, 2348, 2350	3 total 2011A, 2324, 2334

These boring logs document observations recorded by SCS' construction quality assurance (CQA) personnel at each borehole for drill cuttings, which is a term used for waste materials removed from the borehole during the drilling process. Visual observations of the drill cuttings were reviewed for this Report. The observations noted by CQA personnel address four parameters: temperature, degree of waste decomposition/
degradation, moisture content of the waste, and waste type/composition.

The waste characterization of the drill core samples refer to the material type: "plastic", "paper", "textiles", "wood", etc., which is common practice in the industry. Since the drill cuttings were not subjected to laboratory analysis, scientific measurements for traits such as BTU value (heat content), biological methane potential (BMP), moisture content (as a percentage), and chemical content (cellulose, lignin, etc.) were not performed.

Ash Hydration: Of the 49 borings, only one (CV-2334) identifies the presence of ash among other waste types, such as plastic, wood, textile, and paper, which suggests that it is present in small quantities that are incidental to the co-mingled nature of typical residential and commercial wastes. Although evidence of the presence of ash can diminish over time because the ash becomes somewhat indiscernible, the fact that large deposits of industrial ash residue were not encountered in any of the borings suggests it is unlikely that ash was a significant portion of the landfilled wastes. Accordingly, it is reasonable to consider ash hydration as an unlikely cause of the ETLF conditions at CCL.

Metals Corrosion: Nineteen (19) of the 49 borings identify the presence of metal among other waste types, such as plastic, wood, textile, and paper. In each case it is listed along with these other waste types, which suggests that it is present in small quantities which are incidental to the co-mingled nature of typical residential and commercial wastes. The fact that large deposits of industrial secondary metals waste (e.g., aluminum dross, casting sands, etc.) were not encountered in any of the borings suggests it is unlikely that reactive metallic waste was a significant portion of the landfilled wastes. Accordingly, it is reasonable to consider metals corrosion as an unlikely cause of the ETLF conditions at CCL.

CONCLUSION ON CAUSATION

Based on SCS' communications with Chiquita, there is no recordkeeping documentation that affirms acceptance of the types of wastes known to have caused other ETLF facilities. Furthermore, based on our visual observation of the drill cuttings at the 49 borings, we see no basis to suspect the cause of the ETLF conditions within the northwestern area at the CCL to be directly attributed to disposal of industrial wastes or special wastes containing dross, other forms of metals, incinerator ash, other types of ash, or sludge/biosolids. Based on SCS' communications with Chiquita, as well as our collective historical knowledge of site operations, we are not aware of slope failures in the northwestern portion of the Facility or substantial waste relocation endeavors that may have contributed to the large-scale heating-event at this Landfill.

SCS finds that the causes of the ETLF conditions at CCL cannot be definitively identified. It is likely that the heat generated within the waste mass from typical anaerobic digestion processes accumulated to a point, inhibiting the second stage of fermentation, acetogenesis, and methanogenesis processes and were replaced by abiotic chemical reactions affiliated with ETLFs that became self-sustaining.

4 SOLUTIONS TO ADDRESS ELEVATION TEMPERATURE LANDFILL REACTION

ETLF CONDITIONS AT CHIQUITA CANYON LANDFILL

To evaluate whether the northwestern area of CCL is exhibiting common symptoms of an ETLF, Chiquita provided the following information for review:

- LFG wellfield monitoring data that includes gas pressure, temperature, and composition (chemical constituents), using both field instrumentation as well as samples submitted for laboratory analysis;
- Landfill liquid (leachate, gas condensate, and LFG wellfield dewatering liquids) quantities, pressure, temperature, and composition data;
- Landfill surface settlement rates based on periodic topographic surveys;
- The frequency and character of on-site odor observations and off-site odor complaints; and,
- First-hand observations of numerous on-site CCL personnel and SCS engineering, construction, and operations and maintenance (O&M) field personnel (on-site daily or with routine periodic frequency), as well as site photographic/video documentation.

Based on interviews of on-site personnel describing their first-hand observations, in conjunction with the information recorded by various parties and reviewed in preparation of this Report, a discrete portion of the waste mass is exhibiting classic symptoms of an ETLF, as opposed to a traditional subsurface oxidation (SSO) or subsurface landfill fire event. The basis for this distinction is as follows:

- Persistent and widespread elevated subsurface and LFG wellhead temperatures in excess of approximately 150°F. While, this condition is present in both ETLF and SSO circumstances, SCS believes the heat observed at this Facility is attributed to ETLF processes and reactions and not attributed to an SSO, because of the absence of charred waste, burning odors, and smoke (differentiated from water vapor).
- Poor gas quality (defined as substantially low methane, e.g., less than 30 percent) in conjunction with methane-to-carbon dioxide (CH_4:CO_2) ratios less than 1.0 and elevated carbon monoxide (CO) concentrations. While this condition is present in both ETLF and SSO circumstances, SCS believes the diminished methane content, inverted ratio, and elevated CO in the LFG at this Facility is attributed to ETLF processes and reactions and not attributed to an SSO. The fact that the LFG has measurable oxygen concentrations, which is unexpected for SSO events because the oxygen is typically fully consumed by the waste combustion, supports this conclusion.
- While there is dramatic and pronounced settlement in the northwest area, SCS does not characterize it as rapid localized subsidence that is typically affiliated with SSO events. SCS believes the overall accelerated settlement of the landfill surface in this area of the Facility indicates ETLF conditions, as opposed to the rapid localized subsidence that typically suggests an SSO event.

- The on-site personnel have noted an unusual increase in leachate quantities as well as numerous instances of pressurized liquids emitting from the landfill surface, from boreholes during drilling, and from LFG wells in the northwest portion of the waste footprint. The production of excess liquid quantities and the presence of pressurized liquids are common for landfills with ETLF conditions, but are atypical of SSO events.

- The concentration of hydrogen (H_2) in the LFG at 25 wells and collectors has been measured in the range of 1 to 20 percent by volume. Hydrogen content in LFG at concentrations generally greater than 5,000 ppm is affiliated with ETLF, not SSO events.

- The presence of DMS in the LFG at concentrations in the range of 100 ppm have been recorded at the Facility. Elevated DMS concentrations, with respect to other reduced sulfur compounds, is typical for sites experiencing ETLF conditions.

- The characteristic of the odors originating from the northwest section of the Facility has been described as "chemical-like" (consistent with correspondence from Los Angeles County, dated 9/1/23) and has been observed by Chiquita and SCS personnel to be notably and distinctly different from typical LFG or landfill working face odors. This is a common observation at ETLF sites.

Based on recent and historical methane concentrations recorded at numerous wellheads within the Reaction Area at CCL that exhibited temperature in excess of 145°F, methanogenic bacteria are continuing to accomplish anaerobic decomposition of organic waste materials in conjunction with a periodic increase of other decomposition byproducts, such as hydrogen.

The conditions at CCL include elevated temperatures measured in the LFG and liquids, high pressures, an inversion of methane to carbon dioxide ratios, an increase in generation of gas and liquids, increased concentrations of hydrogen and DMS, accelerated settlement, and unusual and increased odors. These objective data and conditions occur at ETLFs, and not at landfills undergoing typical decomposition conditions.

The conditions at CCL resemble an ETLF event and do not suggest other types of landfill heating events, such as a subsurface fire. Landfills with subsurface fire events do not produce hydrogen. ETLFs do produce hydrogen. Landfills with subsurface fire events do not produce liquids. ETLFs do produce liquids. The data shows that CCL is producing hydrogen and liquids as well as exhibiting a methane to carbon dioxide ratio indicative of an ETLF. The settlement at the Landfill surface in the Reaction Area is broad and pronounced, rather than in discrete and isolated portions. In addition, personnel involved in daily operation at the Landfill experienced for over multiple months odors of a different character than odors produced from a landfill fire event. In fact, the correspondence from the County cites "chemical-like odors", which characterizes the odors as distinctly different than the odor character usually noted at landfills experiencing subsurface fires.

SOLUTIONS TO SLOW AND STOP REACTION

Previous experience at other ETLF landfills demonstrates that landfill reactions and resulting odors have been mitigated by best management practices, including increased gas extraction and liquid removal (e.g., through expanding systems and providing adequate LFG control capacity and leachate disposal capacity). Another best management practice is to improve cover integrity, which reduces infiltration of precipitation and limits the amount of excess liquids available to sustain various chemical reactions. Implementing these measures will help slow the reaction and mitigate impacts. However, no known method has been identified to quickly stop the reaction leading to elevated temperatures in a landfill. The landfill industry has embraced several approaches to "contain and manage" the reaction area as outlined below:

- Enhanced gas collection and control infrastructure to remove reaction gases, reduce landfill pressures, reduce malodorous emissions, and remove heat.

- Enhanced liquids removal to improve gas collection efficiency and remove heat through the installation of in-well dewatering pumps. Removing landfill liquids removes heat, as well as allows gas to be collected from greater depths in the landfill, the increase in temperature is often a necessary side-effect of pumping operations that remove heat from these portions of the waste mass.

- Enhanced interim or final cover installation to further enhance gas recovery and reduce surface emissions and resulting odors.

As a practical matter, obtaining higher operating values (HOVs) for wells exhibiting elevated temperatures due to abiotic chemical reactions versus subsurface oxidation will assist the Facility in its goal of removing heat via gas and liquid extraction and reduce unnecessary frequent monitoring of carbon dioxide.

As demonstrated at the other landfills that have experienced widespread ETLF heating events during the past approximate 15 years, Chiquita and SCS are confident that implementation of the best management practices developed by the landfill industry to contain and manage the reaction will succeed in slowing the propagation of the reaction area, result in cooling of the buried wastes, enable methanogenesis to ultimately be re-initiated within a large section of the affected waste mass, and mitigate and abate the detrimental impacts, such as odors, being experienced by surrounding off-site communities.

Appendix A

Reaction Area Map

Appendix B

References

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