Evaluating Impacts from Landfill Gas in a Litigation Setting

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Introduction

Landfill gas (LFG) emissions or subsurface migration impacting nearby properties is not a new concept. However, increasingly, landfill owners and operators are seeing lawsuits filed by nearby land owners claiming a variety of health, nuisance, odor, and/or other environmental impacts resulting from their alleged exposure to LFG and its constituents. These lawsuits can create significant liability for the landfill owners due to potential litigation awards and settlements, regulatory action, and negative public opinion, which can damage efforts for future landfill projects like expansions or new operations. Even when cases are won, significant monies can be spent in defense against the lawsuit.

Background

It is well known that LFG migration/emissions and their impacts on the environment are difficult to quantify. However, through several legal cases and projects, specific quantitative and semi-quantitative tools for evaluating LFG emissions, migration, and dispersion and their related impacts have been deployed.

One of these tools includes "fingerprinting" LFG for the purposes of comparing it to detected gaseous impacts in the subsurface (or ambient air) and comparing that fingerprint back to the landfill. This fingerprinting technique can also be used to trace the source of methane (i.e., the primary component of LFG) to its source, which can include LFG, but also natural (i.e., thermogenic) gas, petrogenic (i.e., petroleum-derived) gas, or other sources of biogas (e.g., swamp gas). Another technique includes “tracer” studies, which are used to confirm the existence of releases of LFG, as well as to quantify the resulting off-site impacts. Traditional chemical release, air dispersion modeling, and risk assessment techniques have also been used.

In some cases, it has been shown that the off-site detections of methane and other “typical” constituents in LFG are not from LFG but from other industrial, commercial, residential, or institutional sources, which can cause similar contamination containing one or more of the constituents in LFG.

This paper provides details regarding the use of the noted methodologies for assessing off-site LFG migration and/or emissions, as well as summaries of case studies where these tools were used. Each is a landfill in California that was faced with litigation due to suspected off-site impacts of LFG. In each case, the landfill was able to defend itself using the noted tools to show that the impacts were not from LFG and/or that the impacts were not as significant as the plaintiffs had alleged.

Regulatory Requirements

There are very limited regulatory requirements that apply to subsurface migration of LFG, and these requirements are focused on the potential fire or explosion hazard resulting from the methane in LFG. Under federal landfill regulations contained within the Resource Conservation and Recovery Act (RCRA) Subtitle D, or state equivalents, LFG migration is limited to less than five percent methane at the landfill's permitted facility boundary. Monitoring is required to assess compliance using subsurface gas monitoring probes installed at the point of compliance around the landfill.

The compounds that make up LFG, including various toxic organic and odor-causing chemicals, are not specifically regulated in terms of subsurface LFG migration. In contrast, airborne releases of LFG can be regulated by federal, state or local air agencies. Some of these air agencies have the ability to limit health risk impacts caused by these toxins. Odor or nuisance caused by airborne releases of LFG can also be regulated by air agencies, solid waste agencies or by other local ordinances. However, in most cases, odor or nuisance are regulated through qualitative requirements, from which it is difficult to assess the real-world impacts on receptors. Due to this lack of specific regulation, suspected LFG impacts on nearby properties have sometimes been handled through legal action, which can be a very cumbersome and expensive way to address the issue.

Case Studies

Provided below are summaries of four projects where the alleged migration/emission of LFG resulted in litigation from a plaintiff living in the vicinity of the landfill. As part of each case study, the techniques used to assess and quantify the LFG migration/emissions, determine the source of the impacts, and assess the magnitude of impacts are also explained.

Landfill #1

The case study for Landfill #1 is an example of how publicly-available monitoring data from a landfill can be used by a plaintiff to claim environmental impairment, and how the validity of environmental data can be questioned by the defendant in court, and have a significant influence on the court's decision.

Landfill #1 has been in operation since 1973 and is encompasses approximately 609 acres. In June 2008, a local family filed a lawsuit against the landfill owner claiming (among other things) diminution of property values and health impacts due to contamination beneath their adjacent property, caused by the landfill. The site includes four unlined units (89 acres); one composite-lined unit (23 acres); a 200-acre expansion area; a lined leachate management pond; several unlined storm water management ponds; and a wetland preserve (168 acres). The landfill accepts an average waste stream of about 450 tons per day. Groundwater monitoring began at the site in 1988 with 31 wells in the system (some are no longer in service), and LFG monitoring began in 1998 with 24 multi-zone gas probes.

At the time the initial complaint was filed, the plaintiffs had collected no data on their property to support their position, but based the claim on documents available through the public record, including the historic monitoring data for the landfill. Between August 2008 and August 2010, the plaintiffs' environmental consultant collected a few samples of soil gas and groundwater from underneath the plaintiffs' property, which is located across a road from the landfill, using various methods.

Using the few sample results obtained from their property, and the large historic set of monitoring data from the landfill itself, the plaintiffs argued that their data showed environmental impairment caused by the landfill. The case was tried in United States District Court, Eastern District of California, in January 2011. A decision was rendered by the Court in February 2011.

The plaintiffs argued that sampling conducted on their property showed environmental impacts to groundwater and soil gas under their property, resulting in diminution of property value. However, they collected only a few samples; their sample collection methods were questionable; sample collection was not done in compliance with their documented standard operating procedures; and their quality assurance/quality control (QA/QC) samples were not appropriate and/or failed QA/QC tests. The plaintiffs dropped the claim of groundwater impact after their own data were unsupportive of that claim.

The plaintiffs continued to press their case based primarily on soil gas data from four soil gas samples, collected on two occasions, separated by almost two years, and collected using different methods. Much of the data they collected did not correlate between sampling events, but the plaintiffs claimed they detected low concentrations of some volatile organic compounds (VOCs) in soil gas, mostly compounds that are commonly petroleum-related (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]) compounds. The plaintiffs argued that since these were detected on their property, and that some of these VOCs had also been detected in LFG at some time, the impacts must be caused by the landfill.

This argument ultimately failed for several reasons including: (1) the plaintiffs' data collection methods for soil gas were inappropriate, including high volume sampling of a soil gas probe through a cemented polyvinyl chloride (PVC) sampling train (i.e., PVC cement contains certain VOCs); (2) their QA/QC data were incomplete and the duplicate sample data did not provide reproducible, and thus defensible, data; (3) they failed to test soil gas for the most important and predominant components of LFG – methane and carbon dioxide; and (4) the VOCs they claimed to have been detected did not match the predominant species of VOCs known to be present in LFG from probes at the outside perimeter of the landfill, such as the chlorofluorocarbons (CFCs or freons), and other chlorinated hydrocarbons.

The defendant's expert witness was able to show that a "fingerprint" of VOCs that the plaintiffs claimed to have detected on their property did not match any LFG fingerprints obtained from the large set of historic LFG data. This fingerprinting showed that the mix and concentration of VOC compounds found in LFG at the landfill did not match the fingerprint of VOCs the plaintiffs alleged were under their property, especially given that none of the primary components known to be in LFG were detected on their property. In addition, the VOCs alleged to be detected on the plaintiffs' property were primarily BTEX compounds. BTEX compounds, which are not the only or most common components in LFG, are found in gasoline and diesel fuels at significant concentrations. In some cases, the BTEX compounds were detected at higher concentrations offsite than detected in the on-site LFG. These factors suggested that the VOCs were from another source, either a fuel release or sampling cross-contamination. Table 1 summarizes this fingerprinting analysis. Note that the "GW" samples are from the landfill and the "AMEC" samples are from the plaintiff's property.

Table 1. VOC "Fingerprint" Comparison of Closest LFG Probe (GW-9) to Soil Gas Samples from Plaintiff Property

VOC DETECTED IN GW-9[1]	GW-9 AVERAGE CONCENTRATION[2] 1998 – 2009 (ppbv)	GW-9 AVERAGE CONCENTRATION[2] 2008 – 2009 (ppbv)	AMEC SV-2 8/27/2008 (ppbv)	AMEC MW-1V 5/11/2010 (ppbv)	AMEC MW-2V 5/11/2010 (ppbv)	AMEC MW-1V 6/11/2010 (ppbv)	AMEC MW-2V 6/11/2010 (ppbv)
Freon 12	84.05	176.23	ND	ND	ND	ND	ND
Toluene	42.56	13.00	55	ND	ND	1.2 (B)	ND
Freon 11	29.00	49.75	ND	ND	ND	ND	ND
Chloromethane	25.48	4.70	ND	ND	ND	ND	ND
Freon 114	17.44	27.50	ND	ND	ND	ND	ND
Methylene Chloride	16.00	16.00	ND	ND	ND	ND	ND
Xylenes	11.99	2.75	30.5	ND	ND	5.3 (B)	ND
Acetone	11.00	NA	270	11	3.6	16.4	5.9
1,2,4-TMB	9.52	ND	6.7	ND	ND	5.1	ND
Freon 113	9.04	14.00	ND	ND	ND	ND	ND
PCE	7.60	2.50	ND	ND	ND	ND	ND
Ethylbenzene	6.45	ND	6.3	ND	ND	ND	ND
Ethanol	5.30	NA	39	ND	5.5	4.8 (B)	5.1 (B)
1,3,5-TMB	4.93	ND	1.7	ND	ND	1.6	ND
cis-1,2-DCE	4.70	ND	ND	ND	ND	ND	ND
TCE	4.55	ND	ND	ND	ND	ND	ND
1,4-DCB	3.90	ND	ND	ND	ND	ND	ND
Benzene	3.53	ND	6.6	ND	ND	ND	ND
Heptane	3.10	NA	9.5	2.9	ND	ND	ND
Vinyl Chloride	2.30	ND	ND	ND	ND	ND	ND
Tetrahydrofuran	1.90	NA	1.4	0.82	2.2	3.6 (B)	ND
Hexane	1.20	NA	8.2	0.75	ND	ND	ND

CFCs
Chlorinated Solvents
Fuel Components

[1] VOCs detected in LFG Probe GW-9 from September 1998 through December 2009
[2] Average concentration for all detections during period - does not include non-detects
ND = Not Detected
NA = Not analyzed during this period
(B) = Analyte also detected in QA/QC blank sample

In the Memorandum of Decision rendered by the court in February 2011, the judge stated, "Defense expert [name], a geologist for SCS Engineers, testified at length regarding problems with the testing performed in Lot 1 [Plaintiffs' property]. He concluded that the tests performed by the plaintiffs were "indefensible" and could not be relied upon. His testimony on the subject was unimpeached." The court also found, "According to [defense witness name], there was no "fingerprint match" between the chemicals found in the landfill and those found in Lot 1. This makes it much less likely that the chemicals in Lot 1 came from the landfill. Migration from a landfill would almost certainly contain methane, carbon dioxide, and freons. Freons were found in the landfill but not in Lot 1, and the plaintiffs failed to test for methane and carbon dioxide." (U.S. District Court, 2011).

The plaintiffs' inability to show a match to the known LFG fingerprint, as well as the indefensibility of the plaintiffs' data, played a significant part in the court's decision. Without applicable and defensible environmental data to support their case, the plaintiffs were unable to prove their case based on a preponderance of the evidence. The court found in favor of the defendant and further found the case to be frivolous regarding damages.

Even though the landfill operator was successful in its defense, the cost of the defense was approximately $500,000, including in-house counsel and retained expert witnesses. The court has since awarded recovery of attorney fees to the defendant, and a motion has been made to recover other associated costs of defense. However, recovery of legal and expert fees is uncommon, and in most cases, a prevailing defendant still bears the brunt of its own cost of defense.

Landfill #2

Landfill #2 is an active refuse disposal site, where litigation was brought against the landfill owner in 2013 for odor and nuisance impacts on nearby properties. The plaintiff relied on LFG models and other estimation methods to assess LFG emissions and subsequent offsite impacts, but ignored other sources in the area, which could cause the same impacts.

The defendant was able to demonstrate that the methodology used by the plaintiff had serious flaws due to the use of theoretical models, lack of site-specific data, and the large range of uncertainty of the plaintiff's calculations. Through on-site flux testing, the defendant was able to refute the findings of the plaintiff and demonstrate much lower emissions and impacts. The defendant's analyses also identified other potential sources of odor and nuisance, which may be more significant than the landfill.

The plaintiff's experts made several fundamental errors in their analysis of odor emissions from the landfill, including the inaccurate use of a default value for LFG collection and control system (GCCS) collection efficiency, an LFG generation model instead of on-site flux rate sampling, an odor concentration from landfills in another country instead of on-site testing data, and other unreliable data. The overall uncertainty of the values presented in the plaintiff's expert's report made the conclusions of that report wholly unreliable. The plaintiff also tried to use potential to emit (PTE) emissions published by the landfill as part of various permitting efforts as actual values, without understanding that the PTE values were worst-case numbers that are much higher than actual emissions. Finally, other potential sources of odor were ignored, discounted, or not subjected to the same level of analysis as the landfill.

The collection efficiency of the GCCS used by the plaintiff was a critical parameter for determining the odor emission rate, but the plaintiff did nothing to substantiate that the value is representative of the actual collection efficiency over the period analyzed. In fact, the collection efficiency used by the plaintiff was inconsistent with their own analysis, which demonstrated an obvious lack of understanding of landfill emissions by the plaintiff. This lack of understanding was most apparent in the plaintiff's analysis of the GCCS coverage based on aerial photos, suggesting that if an area did not have vegetation then it was active, and an all active areas did not have GCCS coverage (0% collection efficiency). The defendant was able to show that the landfill currently occupies most of its maximum lateral footprint with a GCCS present across the entire site. As such, new waste is being placed on and adjacent to areas already under the influence of the GCCS and an analysis of the area with lack of vegetation is, therefore, an unreliable method for determining the GCCS coverage and collection efficiency.

The plaintiff used modeled LFG generation (with the range of error introduced with the use of the model) combined with a default LFG collection efficiency to determine LFG emissions, which resulted in additional inaccuracy beyond the use of the model itself. This is due to the fact that not all uncollected gas is emitted through the surface of the landfill. Uncollected LFG, and specific LFG constituents, can remain within the waste (which has a certain holding capacity), migrate laterally within the subsurface vadose (soil) zone, and/or be attenuated as the LFG moves through the landfill and cover soil. Attenuation---a significant factor in any discussion of LFG emissions---includes oxidation, adsorption to soil particles, solubility in soil moisture, and/or other chemical and biological processes, which reduce the concentration and resulting flux of LFG constituents. The net result of these phenomena is that the amount of LFG emissions cannot be predicted to within a degree of reasonable scientific certainty by simply using the combination of modeled LFG generation and a default, non-site-specific collection efficiency and assuming the result is equal to emissions.

The plaintiff calculated odor emissions flux using an estimated LFG generation rate from a model, applying a default collection efficiency, to estimate fugitive emissions of LFG, and then assuming the emitted LFG had an odor concentration equal to landfills studied in another country The plaintiff made no effort to determine whether landfill management practices, climate conditions, waste stream composition, and/or concentrations of odorous chemicals in the LFG from the out-of-country landfills were comparable to conditions at the landfill under scrutiny. In reality, odor concentrations in LFG, particularly odorous compounds such as hydrogen sulfide, can vary significantly from site to site or even season to season at a single site. Every landfill operation is different in terms of the odors they produce, which is a result of many site-specific factors including waste streams accepted, composition of the LFG, management practices, control technologies used, age, climate, cover type, etc. Therefore, it is almost impossible to accurately use odor data from one landfill and extrapolate it to another, and it is critical to utilize site-specific data for this purpose. The only accurate way to estimate LFG odor emissions is to conduct direct flux measurements from the specific landfill, including testing for site-specific odor concentrations. This is absolutely essential if the odor flux is to be used to determine real-world odor impacts at specific receptor locations in the surrounding neighborhood.

The defendant collected site-specific flux measurements from the landfill to determine the overall LFG flux and odor emission rate from the site. During the flux testing, areas of the landfill, which exhibited high surface emissions monitoring (SEM) results based on pre-screening, were specifically targeted for flux testing. This targeting ensures that the flux calculated by the defendant's experts was biased high and did not miss any areas of surface leaks; this is also standard practice when doing flux chamber measurements at landfills. The flux sampling approach is the most direct way of determining flux from a landfill and bypasses the uncertainty with estimating LFG collection efficiency or modeling LFG generation. It is also based on actual odor concentrations in the LFG at the specific landfill determined by an odor panel convened for the purpose.

The flux chamber study completed by the defendant measured an odor flux from LFG, which was approximately six times lower than what was estimated by the plaintiff's experts. Since the flux rate is directly proportionate to the modeled odor impacts (i.e., dilution to threshold, D/T) at the receptor locations, the D/T values used by the plaintiff as the basis for the lawsuit would be reduced by a proportionate amount, resulting in impacts well below any relevant odor thresholds. Through this litigation, a ruling was made in favor of the defendant whereby the proposed class was not certified for a class action lawsuit, which should reduce or eliminate the potential for the plaintiff to bring continued litigation. Despite this success, the landfill owner has borne significant costs for the litigation defense, and the litigation has had a detrimental effect on a proposed expansion of the landfill.

Landfill #3

Landfill #3 is a closed landfill in Central California. The site is a Class III landfill, and it accepted municipal and non-hazardous industrial solid waste, mostly originating from fruit, vegetable, and nut canneries in the area. The landfill was operated, and is currently maintained, by a municipality, and accepted waste from November 1970 until July 1990. The site occupies approximately 168 acres adjacent to a river. The land use surrounding the landfill site is predominately agricultural. Orchards exist adjacent to the landfill on three sides, and a vineyard is present on another side, across a road.

There are three residences adjacent to the landfill. One is a single family home near the landfill's northwest corner (Family No. 1). A second single family home is to the south, and a mobile home park is to the east of the landfill.

A groundwater extraction and treatment system was installed in 1991 and upgraded several times since the original installation. This system filters the water to remove sediment and VOCs and then returns it to the groundwater aquifer. A GCCS was installed in two phases beginning in 1992 and concluding in 1995 and continually upgraded since then. The Landfill was capped in 1995 with a geomembrane top deck and clay on the side slopes. Operation and maintenance of the GCCS has been conducted by the municipality, with consultation from several privately contracted firms. The landfill is currently in a corrective action phase due to non-compliance with the site's Waste Discharge Requirements (WDRs), resulting from groundwater impacts from LFG and leachate.

Family No. 1 first took residence on the property adjacent to the northwest corner of the landfill in 1989. Various members of Family No. 1 had resided on the property for different durations. Family No. 1 had been in contact with the municipality regarding concerns about landfill contamination since April 2000. The family operates one domestic well on its property. This well has supplied domestic and drinking water to the residence on the property except at times when bottled drinking water was supplied by the municipality.

In this case, there was no doubt that the impacts on the neighboring property were from LFG, and the municipality had acknowledged this. However, a lawsuit was filed seeking damages for various health impacts caused by this contamination. Therefore, the issue at hand related to what level of health risk the LFG contamination represented.

To assess this risk and the likelihood of family members having health impacts related to the LFG contamination, a human health risk assessment (HRA) was conducted. The HRA was used in defense of the municipality as part of a litigation filed by the family. The objective of the HRA was to provide upper-bound health conservative estimates of the potential human health impacts that may have been attributable to chemicals originating from the landfill. Specifically, this assessment evaluated risks as they applied to members of Family No. 1, who resided on the property adjacent to the landfill from the time of their initial occupation in 1989 to the time of the lawsuit.

The HRA evaluated all possible exposure pathways for completeness based on the chemicals of concern identified through a review and evaluation of site-specific and industry default contamination data. Non-carcinogenic and carcinogenic risk levels for chemicals with complete exposure pathways were calculated for each receptor (i.e., member of Family No. 1).

A variety of techniques were used in the HRA. These included: (1) vapor intrusion modeling using the Johnson and Ettinger model to assess the migration of VOCs from the subsurface into indoor living spaces; (2) chemical release models to assess the impacts in outdoor air resulting from subsurface contamination, as well as landfill surface emissions; and (3) air dispersion modeling. The results of the modeling techniques were used within the construct of a formal HRA conducted in accordance with federal and state risk assessment guidance.

Based on the results of the HRA, the following conclusions were made. The hazard indices for all known contaminants in groundwater and all known and suspected contaminants in LFG that potentially originated from the landfill were calculated on a per annum basis and as an average over the 14 years of potential exposure for an adult and child resident of Family No. 1. The risk results are shown in Table 2 below.

Table 2. Summary of Risk Assessment Results

Receptor	**Hazard Index (HI)**	**HI Threshold**	**Cancer Risk (CR)**	**CR Threshold**
Child Resident (highest year)	0.28	1.0	2.1E-07	1.0E-06
Adult Resident (highest year)	0.11	1.0	2.1E-07	1.0E-06
Child Resident (14 years)	0.12	1.0	8.4E-08	1.0E-06
Adult Resident (14 years)	0.04	1.0	8.4E-08	1.0E-06

The results of the HRA were used during expert testimony to assist in the defense of the landfill owner. Although the defendant felt its case was strong, they chose instead to purchase Family No. 1's property at its appraised value, as part of a settlement. This settlement decision was made both to eliminate the monetary risk of a large jury award, and to avoid future conflict with Family No. 1. Despite the settlement, the jury was polled to see what their award would have been had the case continued. The jury was planning to rule in the favor of the defendant and award Family No. 1 no monetary damages except a requirement for the defendant to continue to provide potable water to the family at no cost to them. All told, the defendant paid over $750,000 in legal costs and costs for purchase of the plaintiff's property.

Landfill #4

Landfill #4 is a small, closed landfill in Southern California. Since closure it had been used for many years as a trailer park for both mobile homes and storage of vehicle and equipment. A former mobile home park resident sued the current property owners, who were not the original landfill owners, for various health effects due to exposure from LFG. Health effects included both physical and mental effects.

Since this was a jury trial, it was necessary to cover the basics of LFG, so testimony included the following points:

- LFG is created from microbial breakdown of organic waste.
- LFG contains approximately 50% (500,000 parts per million by volume [ppmv]) methane, 45% carbon dioxide, and other VOCs and sulfur compounds in the ppmv or even parts per billion by volume (ppbv) range.
- As LFG builds up in the landfill, the gas can move outside of the refuse mass including toward the surface; this is expected and common.
- As it moves into the soil zone (soil vapor), attenuation occurs, which is combination of mixing with air in soil pores, dissolving into soil moisture, oxidizing in soil cover, and other chemical degradation processes.
- Thus, the concentrations of methane and other constituents will continue to decrease as gas moves away from the refuse mass through the soil and toward the surface.
- Emissions occur as LFG comes through the cover and is released into ambient air (or into a building through slab on grade or basement structure).
- Additional reduction in concentrations occurs in ambient air due to mixing and dispersion.
- For structures, ventilated sub-floors can be used to enhance this mixing and reduce concentrations further.
- This occurs naturally with mobile homes with space under trailers used for this ventilation and mixing; more so if apron not enclosed.
- Not all generated LFG is emitted; some is held in storage within the refuse, some moves laterally or downward toward groundwater, and some is attenuated or oxidized.
- The final exposure concentration in the breathing zone is a combination of all of the attenuation processes described above and can be predicted by emission estimates, air models, and/or vapor intrusion models, etc. or measured.

- Concentrations in soil, air, and/or inside a structure can be determined by modeling or testing. Each method has its pros and cons. Testing data is one time snap-shot and may not be representative of long-term, average conditions.

The defendant was able to show that this landfill did not generate or emit significant quantities of LFG during the time the plaintiff was a resident. This opinion was based on the following:

- The landfill is very small by the standards of landfills in California, and less trash means less potential for LFG generation.

  - The CalRecycle (the state solid waste agency) database for the Assembly Bill 32 Landfill Methane Rule (LMR) says that it contains only 250,000 tons trash; this is extremely small by landfill standards.
  - By comparison, the largest landfill in California took this amount of waste in one month.
  - A large landfill down the road from the landfill in question has 19 million tons in place (76 times larger).

- The landfill is very old and operated approximately from 1956 to 1964; it was already closed for 30 years before the plaintiff took up residence and 40 years before the defendant became the site owner.

  - Landfills generate (and emit) less gas each year after closure per the first-order decay model prescribed by USEPA and the California Air Resources Board (CARB).

- The Los Angeles area is a dry climate with rainfall less than 15 inches per year.

  - Moisture is required to increase the rate at which waste degrades and the effective methane generation potential of the waste.
  - Dry climate landfills generate less gas than similarly-sized moderately wet or wet sites, and the models used tend to overestimate LFG generation for dry climates.

- The estimated LFG generation for the site was minimal per the USEPA LFG emissions model (LandGEM) for the years in question.

  - 56 cubic feet per minute (cfm) in peak year of 1965.
  - 30 cfm in 1996.
  - 28 cfm in 2008.
  - 23 cfm in 2010.
  - In the LMR rulemaking, CARB indicated that 100 cfm of gas generation is the level required to warrant gas collection and control; this landfill never generated this amount even at its peak.

- Concentrations of toxic VOCs in LFG are very low at this site as compared to other landfills. This is the second component of estimating potential emissions. Thus, low gas generation times low concentration equals low emission rate.
    - Maximum detected levels on-site are lower than regulatory defaults or data for similar landfills; several examples of common LFG VOCs are noted below in Table 3 (all in ppbv).

Table 3. Comparison of VOCs in LFG (ppbv)

Chemical	**Maximum On-Site**	**USEPA AP-42**	**Waste Industry Air Coalition (WIAC)**
Benzene	109	1,910	972
Tetrachloroethylene	43	3,730	1,193
Vinyl chloride	11	7,340	1,077
Toluene	424	39,300	25,405

- LFG emissions estimated by the defendant were very low.
    - Using maximum on-site VOC detections in LFG and assuming all generated gas was emitted, the USEPA LandGEM analysis showed maximum benzene and toluene emission rates as follows as listed in Table 4. Benzene and toluene were cited as the primary chemicals of exposure and related health effects by the plaintiff and the plaintiff's experts.

Table 4. Benzene and Toluene Emission Rates over Time

Year	**Benzene (lb./year)**	**Toluene (lb./year)**
1965	0.65	2.98
1996	0.35	1.60
2008	0.28	1.26
2010	0.27	1.21

- Toxic VOC concentrations decrease over time after a landfill closes. This has been documented in several studies by the Los Angeles County Sanitation Districts (1999) and by SCS Engineers for Waste Management (as published in the Proceedings of the Solid Waste Association of North America [SWANA] LFG Symposium from 2004). Therefore, emissions in later years of the plaintiff's occupancy were likely less than those shown in Table 4 above.

- The concentrations of VOCs emitted through surface of the landfill are much less than deep soil-vapor concentrations due to attenuation effects.

  - Comparison of shallow soil-vapor levels to deeper soil-vapor levels throughout the site document this trend; the highest readings on-site are in the deepest sample locations.
  - Air district LFG and ambient air sampling from 1994 showed the following detections of toluene as listed in Table 5.

Table 5. Toluene Concentrations On-site from 1994

Site Location	Concentration (ppbv)
Highest Detected in Raw LFG	424
Under One of the Mobile Homes	18.9
In Ambient Air	<10 (non-detect)

  - Studies have shown the soil cover can oxidize VOCs, and the thicker the soil cover (over 20 feet under the plaintiff's trailer in this instance), the more oxidation that is expected.

- Methane data collected from site also helps to support the opinion that LFG chemicals attenuate by a significant degree prior to emissions through the landfill surface.

  - Methane is generated at 50% (500,000 ppmv), so the very limited number of 500 ppmv exceedances at the site represented dilution by a factor of 1000 from deep soil vapor to surface emission levels.
  - Most surface methane levels recorded are below 10 ppmv, which is a dilution factor of 50,000 from the deep soil vapor.
  - Further reduction occurs from the immediate landfill surface into the breathing zone based on air dispersion.
  - In January 2010, greater than 500 ppmv of methane was detected under the plaintiff's trailer. During this same sampling event, less than 10 ppmv (non-detect) was found inside his trailer (i.e., a minimum dilution factor of 50 from under the trailer to inside the trailer).

- Once emitted into air, mixing and dispersion occurs, reducing concentrations further prior to actual inhalation.

  - Additional mixing – dispersion – will occur even from the near surface levels to the breathing zone. We have seen multiple orders of magnitude reductions depending on meteorological conditions, ventilation, and other criteria.
  - Mobile homes are more effective at reducing VOCs in the living area than slab on grade or basement structures as the floor is off the ground and the soil containing

VOCs does not come in direct contact with the foundation or floor, allowing more ventilation.

Based on the above analysis, an HRA was completed by the defendant's expert using a very conservative methodology as detailed below.

- LandGEM was used for LFG generation, assuming maximum year emissions in 1965 existed for entire exposure duration period.
- WIAC concentrations for toxic concentrations in LFG were used even though higher than any concentrations detected on-site.
- All LFG generated was assumed to be emitted; no attenuation or containment was considered.
- An area source was assumed to be the size the landfill surface.
- The HRA used a conservative "Box" model over entire landfill to estimate exposure concentration, which allowed for minimal dispersion inside the box.
- The maximum concentration was assumed to be present on plaintiff's location, even though his trailer was near edge of landfill.
- The HRA assumed default 30-year exposure duration even though plaintiff only lived on property from 1996 through 2010.
- All other exposure factors were regulatory default factors for residential exposure.

The conclusions from the risk assessment were the following:

- Risks were multiple orders of magnitude below carcinogenic (one in a million) and non-carcinogenic risk thresholds (hazard index of 1.0) used in California.
- At these levels, no mitigation would be required by any environmental agency or regulations to reduce toxic levels or risk.
- Residential development is allowed under these conditions.
- No adverse health effects were expected from the plaintiff's exposure.

The defendant's experts were able to show that the plaintiff was not exposed to chemicals derived from LFG at levels that would cause health risks above regulatory allowable levels. Adverse health impacts were not expected from this level of exposure, and the plaintiff's health issues could not be attributed to the exposure that likely occurred. The plaintiff's case focused simply on the presence of LFG and presumed exposure that the plaintiff had.

The case went to the jury resulting in a mistrial because the required three-fourths decision could not be reached in the civil case. The jury was polled and had voted eight to four in favor of the defendant. Although the plaintiff received no monetary award, the defendant paid over $800,000 in legal costs, and the plaintiff could decide to refile the case. Also, four jury members wanted to award the plaintiff damages despite a very weak case, which illustrates the uncertainty of a jury trial. Legal costs were covered in part by insurance coverage, illustrating the importance of environmental liability coverage.