Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

Third Annual Report of Ambient Air Quality Monitoring at Sunshine Canyon Landfill and Van Gogh Elementary School: A Three-Year Summary

(November 22, 2007–November 21, 2010)

Annual Report
Prepared for

Planning Department, City of Los Angeles
Los Angeles, California

March 2011

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STI-910035.06-4101-AR

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March 10, 2011

Acknowledgments

We would like to acknowledge Charles M. McGinley, P.E., and Michael A. McGinley, P.E., for granting permission to reprint their paper in Appendix A of this report.

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Executive Summary

Continuous monitoring of meteorological and air quality parameters began at the Sunshine Canyon Landfill (Landfill) and at Van Gogh Elementary School (Community) in the nearby community of Granada Hills in fall 2007. Ambient concentrations of particulate matter less than 10 microns in aerodynamic diameter (PM_{10}) are determined by integrated hourly measurements employing a beta attenuation monitor (BAM). Wind speed and wind direction are measured as 1-minute averages, and black carbon (BC)—a surrogate for diesel particulate matter (DPM)—is measured as 5-minute averages. All data are reported as hourly averages. The collected data undergo quarterly validation and are evaluated for completeness. PM_{10} concentrations are compared with federal and state PM_{10} standards and with the historical, regional, and annual ambient PM_{10} concentrations. The PM_{10} and BC data undergo further analysis to characterize the impact of landfill operations on ambient air quality on a neighborhood scale. The validated hourly data and a summary of the analytical results and field operations are reported to the Planning Department of the City of Los Angeles quarterly and annually.

This Third Annual Report includes data summaries, accompanied by analysis and interpretation, drawn from three complete years of continuous monitoring of PM_{10}, BC, and meteorological data at the Landfill and Community monitoring sites. This represents an extensive repository of highly temporally resolved data. These annual data sets, characterized by high data quality, increase the level of confidence for inferences made from comparisons with standards, from comparisons between the two sites, from observed seasonal or annual trends, and from comparisons with regional observations reported by South Coast Air Quality Management District (SCAQMD) monitoring sites in the South Coast Air Basin (SoCAB). Baseline-year data, collected between November 22, 2001, and November 21, 2002, at the Landfill and Community monitoring sites, provide additional historical perspective. This annual report uses the available data to characterize ambient PM_{10} and BC concentrations on a neighborhood scale and in the context of the SoCAB, and to continue to evaluate the impact of landfill operations on air quality in the community.

The specific analytical approaches include evaluation of PM_{10} exceedances, regional comparisons of PM_{10}, effects of meteorology and work activity level on ambient concentrations of PM_{10} and BC, quantitative estimates of landfill operations on ambient concentrations of PM_{10} and BC, landfill gas (LFG) sampling, and odors.

Results from the three years of continuous monitoring, regional data, and the baseline year suggest the following general conclusions, by category:

- PM_{10} exceedances
  - The Landfill site is more prone to exceeding the Federal 24-hr PM_{10} standard than is the Community site (seven exceedances versus two exceedances, respectively, over three years).
  - PM_{10} exceedances at the Landfill site are accompanied by high average wind speeds within a narrow wind direction sector over the landfill from the northwest.

  - PM_{10} exceedances at the Community site are accompanied by exceedances at the Landfill site and by elevated regional PM_{10} concentrations, suggesting a synergy between regional concentrations and landfill impacts.
  - PM_{10} exceedances at the Landfill site and Community site cannot be attributed to regional PM_{10} concentrations alone, since there were no exceedances recorded at the nearby regional sites during the three-year period.
  - There were no exceedances of the Federal 24-hr PM_{10} standard in 2010, as opposed to four exceedances in 2008 and three in 2009.
- Regional comparisons of PM_{10}
  - Annual average PM_{10} concentrations at the Landfill site and at the Community site are lower than those measured in downtown Los Angeles (N Main St., continuous monitor).
  - Annual average PM_{10} concentrations at the Landfill site and the Community site are higher than those measured in Santa Clarita (1-in-6 day Federal Reference Method [FRM]).
  - Annual average PM_{10} concentrations were lower in 2010 compared to 2009 at all proximal monitoring sites (the Landfill Site, the Community site, downtown Los Angeles (N Main), Burbank (W Palm), and Santa Clarita).
  - On average, regional influences are large compared to landfill impacts. The observed patterns in seasonal or monthly average PM_{10} concentrations, within years, are similar among the Landfill site, the Community site, downtown Los Angeles (N Main), Burbank (W Palm), and Santa Clarita. However, the neighborhood-scale impacts of the landfill are apparent during discrete time periods at the Landfill and Community monitoring locations.
- Wind direction and work activity level can impact the ambient concentrations of PM_{10} and BC, according to the three-year averages
  - During the highest activity levels (working hours on working days):
    - When the wind is from the SoCAB, the Landfill and Community monitors measure about the same average PM_{10} concentration.
    - When the wind is from the SoCAB, the Landfill and Community monitors measure about the same average BC concentration.
    - When the wind is from the SoCAB, the Community monitor measures almost twice the average concentration of PM_{10} and about three times the average concentration of BC as when the wind is from the landfill.
    - When wind is from the landfill, the Community PM_{10} and BC concentrations are about one-half of those measured at the landfill.
  - During the lowest activity levels (non-working days):
    - Ambient concentrations of PM_{10} and BC are lower on non-working days, but the extent of the decrease is influenced by wind direction:

    - For PM_{10}, the proportional decrease in daytime (working hours) ambient concentrations between working and non-working days was larger when wind direction was from the landfill (about 70% lower) than when it was from the SoCAB (about 20% lower), reflecting the larger regional PM_{10} influence of the SoCAB under these wind conditions.
    - For BC, the proportional decrease in daytime (working hours) concentrations between working and non-working days was larger than that observed for PM_{10}. Compared to working hours, BC concentrations during non-working hours decreased by a factor of 3 when winds were from the landfill, and by a factor of 2 when winds were from the SoCAB.

- Quantitative estimates of landfill impacts on ambient concentrations of PM_{10} and BC during working days when wind direction is from the landfill
    - PM_{10}
        - The landfill may be contributing small additional amounts of PM_{10} to concentrations monitored at the Community site. This additional contribution is estimated as 4, 6, and 9 $\mu g/m^3$, respectively, for the last three consecutive years.
        - The estimated contribution as measured at the Landfill site is, depending on year, a factor of 2 to 3 times greater than that estimated for the Community site.
        - The contributions of PM_{10} at the Landfill site that are attributed to landfill activities are increasing, roughly doubling, on average, from 2009 to 2010. This increase remains largely localized to the immediate area of the Landfill.
    - BC
        - On average, landfill operations are estimated to have a very small additional impact on ambient community BC concentration beyond regional levels. This additional contribution is estimated to be 0.06, 0.08, and 0.09 $\mu g/m^3$, respectively, for the three consecutive years.
        - The estimated BC contribution as measured at the Landfill site is, depending on year, a factor of 3 to 10 times greater than that estimated for the Community site.
    - As a general conclusion, the landfill contributes additional PM_{10} and BC to ambient concentrations at both the Landfill site and the Community site.
- LFG sampling and odors
    - Ambient concentrations of LFG in samples collected over the last three years have generally been either within range of Los Angeles regional levels or below the method detection limits (MDLs). Methane levels have been near the global average ambient concentrations of ~1.8 ppmV. A few isolated short-term spikes in volatile organic compounds (VOCs) have been detected, but to date no strong correlation is evident between spikes in concentrations measured at the Landfill site and those measured at the Community site.
    - Because of the dominating presence of odor issues in the Community in recent years, a brief background discussion of odors is provided in this report.

1. Introduction

Two air quality monitoring sites were initially established by operators of the Sunshine Canyon Landfill in 2001 to monitor particulate matter less than 10 microns in aerodynamic diameter (PM_{10}), black carbon (BC), wind direction, and wind speed, in fulfillment of the stipulations set forth in the City of Los Angeles' Conditions of Approval for the expansion of the Sunshine Canyon Landfill in the City of Los Angeles (Section C.10.a of Ordinance No. 172,933). The Conditions of Approval also required sampling of landfill gas (LFG) on four occasions throughout each year at each of the locations. In 2009, The County of Los Angeles adopted conditions (County Condition 81) very similar to the City's conditions, governing ambient air quality monitoring for the County portion of the landfill.

One monitoring site is located on a high-elevation ridge on the southern edge of the Sunshine Canyon Landfill (Landfill site). The second site is located at Van Gogh Elementary School in the nearby community of Granada Hills (Community site).

A baseline year of continuous monitoring of PM_{10} and BC occurred between November 22, 2001, and November 21, 2002, and a report of the baseline year results was produced by ENVIRON International Corporation[1]. A baseline study of LFG was conducted in 2003 and served as the basis for the establishment of a LFG monitoring protocol.[2] Between the time that the baseline studies were completed and November 2007, when continuous monitoring began, ambient sampling for PM_{10}, BC, and LFG was presumably done at a nominal frequency of four times each year by ENVIRON International Corporation. Data from those years are not included in this report.

Beginning in 2007, ambient monitoring of particulate matter and LFGs at the Landfill and Community sites became the responsibility of Sonoma Technology, Inc. (STI). STI's technical approach for PM_{10} and BC was based on continuous monitoring (hourly, year-round), whereas previous monitoring was limited to four events per year. Continuous all-year monitoring of PM_{10} and BC allows greater potential for evaluation of times when air flows from the landfill to the Community receptor site at Van Gogh Elementary School, as well as for evaluation of diurnal trends, day-of-week differences, seasonal differences, and annual trends. LFG sampling, however, remained limited to four sampling events each year.

November 22, 2010, marked the completion of three full years of continuous monitoring of PM_{10}, BC, and meteorology at the two monitoring locations. Data capture rates and the quality of the captured data have generally been very high. A few discrete events have interrupted data capture at one or both sites; for example, the Sayre Fire in late 2008 took out power at the Landfill monitoring site for several weeks. In addition, equipment upgrades in 2010 caused some loss of data as instruments were temporarily removed. Even with these interruptions, however, annual completeness statistics for the three years indicate greater than

[1] ENVIRON International Corporation (2003) Results of the baseline ambient air monitoring program for the Sunshine Canyon Landfill. Final report prepared for Browning-Ferris Industries of California, Inc., by ENVIRON International Corporation, Contract No. 03-9660A, June 6.
[2] ENVIRON International Corporation (2003) Proposed landfill gas baseline ambient air monitoring protocol for the Sunshine Canyon Landfill. Report prepared for Browning-Ferris Industries of California, Inc., by ENVIRON International Corporation, Contract No. 03-9660A, March 27.

85% data capture for all measured variables (see Section 2). Less than 4% of all captured data were judged as invalid.

The high-quality, high-time-resolution data captured over the three years between November 2007 and November 2010 are analyzed and summarized using a number of different approaches in an attempt to offer a realistic characterization of ambient air quality concentrations at the two monitoring locations, and to provide perspective on air quality at the landfill and the local community in the context of the greater South Coast Air Basin (SoCAB).

Regulatory standards for pollutants are commonly used to judge the compliance status of air districts and air basins. Currently, the only federal health-based standard for PM_{10} is the daily (24-hr) average concentration of 150 $\mu g/m^3$. The State of California's PM_{10} standard (50 $\mu g/m^3$) is more stringent than the federal standard. (The previously existing federal annual standard of 50 $\mu g/m^3$ was revoked because of the lack of substantial evidence of health effects attributable to long-term exposures.) In this report, the 24-hr federal standard of 150 $\mu g/m^3$ is used as a benchmark metric for evaluating the specific monitoring locations in relation to each other and to the federal standard.

Regional comparisons of ambient PM_{10} concentrations are used to place the Landfill and Community monitors within the larger context of regional concentrations. For these comparisons, three of the closest regional monitoring sites, operated by the South Coast Air Quality Management District (SCAQMD), were chosen: downtown Los Angeles (N Main St.); Burbank (W Palm), and Santa Clarita**.** **Figure 1-1** shows the relative locations of the sites.

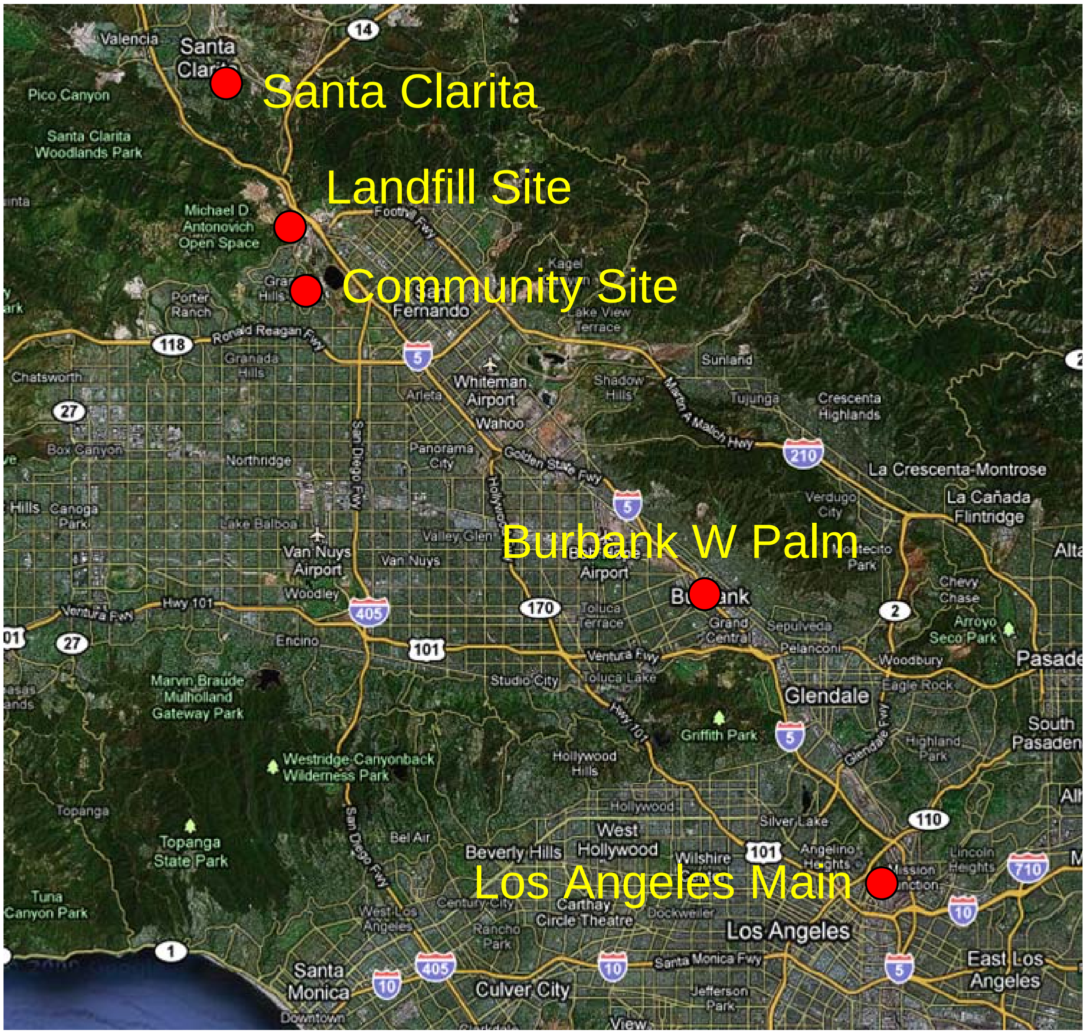


Figure 1-1. Locations of the Landfill monitor and Community monitor in relation to the three SCAQMD sites that are used for regional comparisons.

Meteorological factors and work activity levels are known to have an impact on local and regional pollutant concentrations. An analysis based on wind direction and landfill working versus non-working days and hours is used to quantify the relationship of these factors to PM_{10} and BC concentrations. This analysis also provides quantitative estimates of landfill contributions to ambient concentrations of PM_{10} and BC. A summary description of the analytical method is presented in Section 6.

One area of utmost concern to the residents of nearby communities is the occurrence of offensive odors. This has received considerable attention over the last two years, leading eventually to an abatement hearing, the outcome of which was to place several additional requirements on landfill operations. In the interest of fostering a better scientific understanding of odors, a brief discussion of some basic concepts regarding monitoring for odors and the chemical compounds with which they are associated is included in Section 7.

2. Data Completeness

Table 2-1 gives completeness statistics for all measured variables for the three years considered in this analysis. Because the Sayre fire shut down the Landfill monitoring site data collection effort from November 15, 2008, through January 8, 2009, data capture rates were lower for Year 2 at the Landfill site. Note that the values in this table are based on valid hourly averages and may differ slightly from percentages based on 1-minute or 5-minute data.

Table 2-1. Data completeness statistics for hourly data during Years 1, 2, and 3 of continuous monitoring. The begin and end dates for each year are chosen to allow comparison with the baseline year data collected from November 22, 2001, through November 21, 2002.

Years	Monitoring Location	Percent Data Capture[a] (%)			Percent Data Valid or Suspect (%)[b]			Percent Data Suspect (%)[c]		
		PM_{10}	BC	WS/WD[d]	PM_{10}	BC	WS/WD	PM_{10}	BC	WS/WD
Year 1[e] November 22, 2007–November 21, 2008	Sunshine Canyon Landfill Site	94%	89%	88%	99%	100%	100%	0%	0%	0%
	Van Gogh Elementary School Site	96%	91%	94%	96%	100%	100%	0%	0%	0%
Year 2 November 22, 2008–November 21, 2009	Sunshine Canyon Landfill Site	87%	86%	87%	98%	100%	100%	0%	0%	0%
	Van Gogh Elementary School Site	99%	99%	100%	97%	100%	100%	0%	0%	0%
Year 3 November 22, 2009–November 21, 2010	Sunshine Canyon Landfill Site	100%	88%	98%	98%	100%	100%	0%	0%	4%
	Van Gogh Elementary School Site	98%	88%	98%	97%	100%	100%	0%	0%	0%

[a] Percent Data Capture is the percent of hourly data values that were collected divided by the total number of expected data intervals in the date range (e.g., 24 hourly data values are expected per day, and 8760 hourly data values are expected per year, 8784 during the 2008 leap year).
[b] Percent Data Valid or Suspect is the percent of data values that are either valid or suspect divided by the number of **captured** data values.
[c] Percent Data Suspect is the percent of data values that are labeled as suspect divided by the number of captured data values.
[d] Wind speed/wind direction.
[e] The percentages given here for Year 1 are corrected values, and are different from Year 1 values as cited in the Second Annual Report (STI Annual Report 907032.19-3671-AR). The Second Annual Report incorrectly placed statistics from rolling average Year 3 into Year 1 in its Data Completeness table.

3. PM_{10} Exceedances

Table 3-1 lists all the days during the past three years of continuous monitoring on which there were exceedances of the Federal 24-hr PM_{10} standard at one or both monitoring sites, along with 24-hr average concentrations from those days at the three comparative SCAQMD sites. The Burbank and Los Angeles sites have continuous PM_{10} monitors, but the Santa Clarita site employs Federal Reference Method (FRM) sampling (integrated 24-hr samples on filters) on a 1-in-6 day schedule. Only one of the days listed in Table 3-1 happened to fall on the 1-in-6 day Santa Clarita sample schedule.

Table 3-1. Summary of Federal PM_{10} exceedances (more than 150 $\mu g/m^3$) at the two monitoring sites and at three nearby regional sites operated by SCAQMD.

Date	Landfill Site PM_{10} ($\mu g/m^3$)	Community Site PM_{10} ($\mu g/m^3$)	Burbank West Palm PM_{10} ($\mu g/m^3$)	Los Angeles Main Street PM_{10} ($\mu g/m^3$)	Santa Clarita PM_{10} ($\mu g/m^3$)
2/14/2008	167	48	19	30	-- [b]
5/21/2008	290	152	119	140	-- [b]
10/9/2008	158	104	-- [b]	59	91
11/15/2008	269 [a]	136	-- [b]	85	-- [b]
1/9/2009	185	71	-- [b]	68	-- [b]
5/6/2009	257	91	-- [b]	49	-- [b]
10/27/2009	239	165	130	147	-- [b]

[a] Only 6 hours of data available
[b] No data available

The Federal standard was exceeded on seven occasions at the Landfill site, and on two of those seven days the Community monitor also registered an exceedance. The SCAQMD sites did not report any exceedances on those days (nor on any day during 2008-2010). However, the SCAQMD sites did report high 24-hr PM_{10} concentrations on the two days during which the Community monitor recorded PM_{10} exceedances. The downtown Los Angeles monitor was only 3 $\mu g/m^3$ below the PM_{10} threshold on one of these days, suggesting a synergistic effect between landfill contributions and regional concentrations that helped push the Community site's PM_{10} concentrations over the federal standard.

The PM_{10} exceedances listed in Table 3-1 were generally accompanied by high wind speeds, with wind direction falling within a narrow sector that encompasses the landfill. **Table 3-2** shows the daily average wind speed and wind direction, measured at the Landfill site, for the seven days on which exceedances occurred at the Landfill site. Except for the exceedance occurring on February 14, 2008, the average wind direction fell within a narrow sector spanning only six degrees in the northwest direction. (Wind data from two days did not meet the 75% data completeness criteria and are not shown.) Wind data and PM_{10} data from the Landfill site on those days when wind data met the completeness criteria are plotted in

Figure 3-1. Wind speeds were highest when the wind direction was from the northwest, and this corresponds to the highest PM$_{10}$ concentrations.

Table 3-2. Daily average wind speed and wind direction for the days exceeding the federal 24-hr PM$_{10}$ standard at the Landfill site.

Date	Landfill Site PM$_{10}$ (µg/m^3)	Wind Speed (mph)	Wind Direction (°)	Community Site PM$_{10}$ (µg/m^3)	Wind Speed (mph)	Wind Direction (°)
2/14/2008	167	8.3	22	48	6.9	39
5/21/2008	290	18.4	342	152	6.3	331
10/9/2008	158	--	--	104	1.5	310
11/15/2008	269*	18.7	344	136	8.0	27
1/9/2009	185	--	--	71	7.3	9
5/6/2009	257	30.1	348	91	10.3	342
10/27/2009	239	19.9	345	165	5.5	350

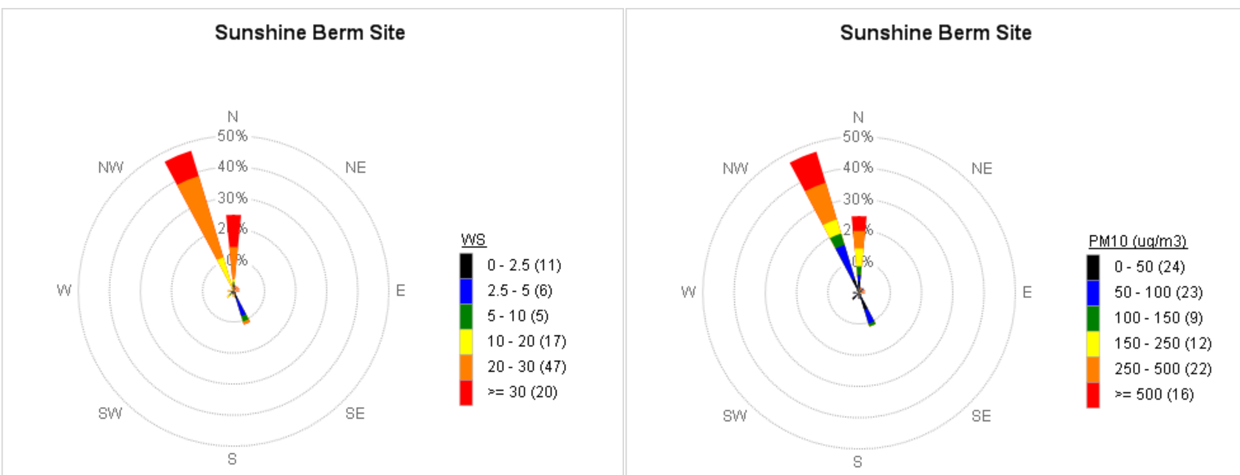


Figure 3-1. Wind rose (left panel) and PM$_{10}$ pollution rose (right panel) from exceedance days at the Landfill monitoring site when there was adequate data completeness for wind data. Wind speed units are mph.

Figure 3-2 shows PM$_{10}$ pollution roses for the Community site on the exceedance days. On the two days for which the Community monitor measured exceedances, the wind direction was more northerly, while the other five days (when the Landfill site exceeded but the Community site did not) had an easterly component.

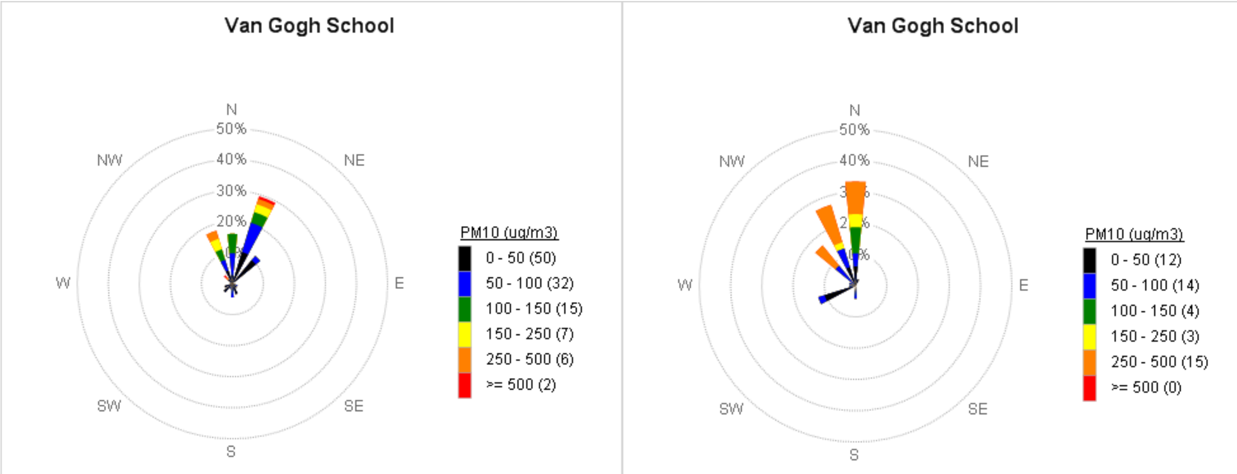


Figure 3-2. PM$_{10}$ pollution roses for exceedance days at the Community site (Van Gogh School) The left panel depicts PM$_{10}$ concentration and wind direction for the five days when the Landfill site exceeded the standard but the Community site did not (note easterly component). The right panel depicts the two days when the Community site exceeded the standard (winds more northerly).

4. Regional Comparisons of PM_{10}

Comparing the PM_{10} concentrations measured at the Landfill and Community monitoring sites with those measured at nearby regional monitoring sites places the locally collected data in a larger, more regional, context. The Landfill and Community sites are not isolated. These sites are directly affected by the large South Coast Air Basin, and by the nearby highly trafficked freeway system. The sites chosen for comparison, depicted earlier in Figure 1-1, are the closest regulatory sites that conduct routine PM_{10} monitoring. (Note: BC is not monitored at the regional locations.)

Figure 4-1 shows the monthly average PM_{10} concentrations for the Landfill and Community monitoring sites, and the three regional locations, for 2008, 2009, and 2010. The SCAQMD monitor at the downtown Los Angeles location has, on average, the highest PM_{10} concentrations. The regional monitor in Burbank follows a month-to-month pattern that is similar to the Los Angeles pattern, but at a lower average PM_{10} concentration. The FRM monitor at Santa Clarita, on the very northern edge of the air basin, has the lowest PM_{10} concentrations of the regional sites. The Landfill and Community measurements tend to track between the Los Angeles and Santa Clarita data.

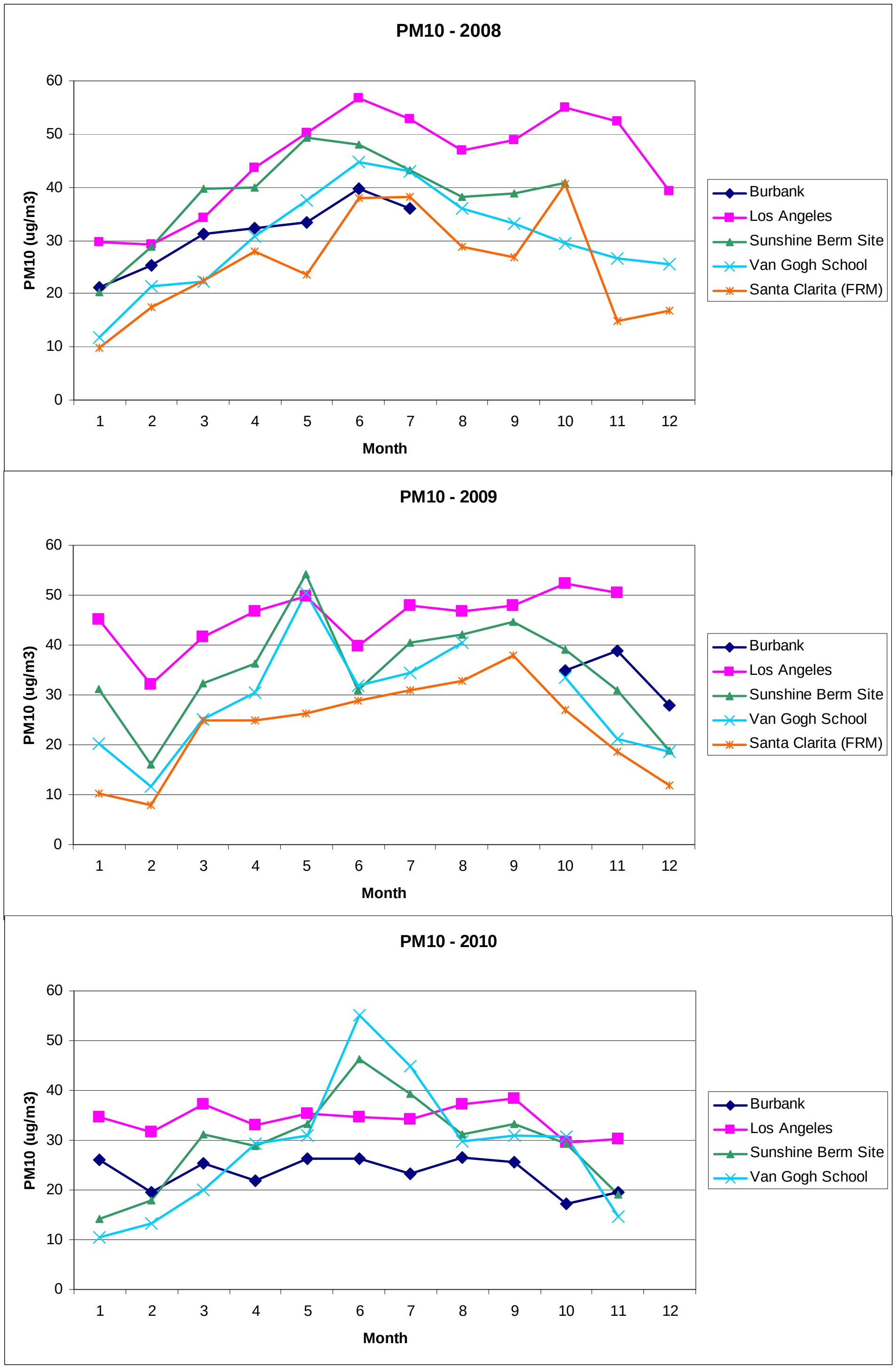


Figure 4-1. Monthly average PM_{10} concentrations for the Landfill and Community sites and three regional monitoring sites for 2008, 2009, and 2010.

There are two notable exceptions to this general pattern. In May 2009 and June/July 2010, both the Landfill and Community PM_{10} monthly average concentrations were notably higher than usual. In May 2009, both sites reported averages essentially equivalent to the Los Angeles location. A time series plot of the daily average PM_{10} concentrations for May 2009 (**Figure 4-2**) illustrates that the very high 24-hr concentration measured on May 6, 2009, at the Landfill site (257 $\mu g/m^3$) pushed the monthly average over 50 $\mu g/m^3$.

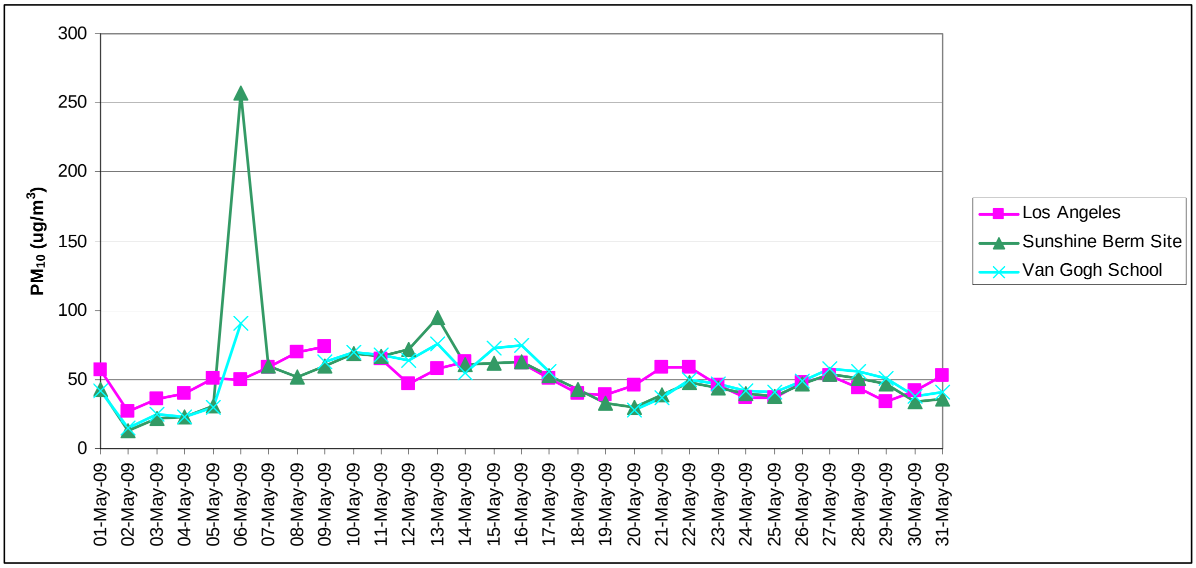


Figure 4-2. A time series of daily average PM_{10} concentrations for May 2009.

During the summer of the following year (2010), monthly averages at the two monitoring sites for June and July exceeded those of Los Angeles. **Figure 4-3** shows that the Landfill and Community monitoring sites during these two months were characterized by PM_{10} concentrations that were higher than the Los Angeles Main St. site on most days.

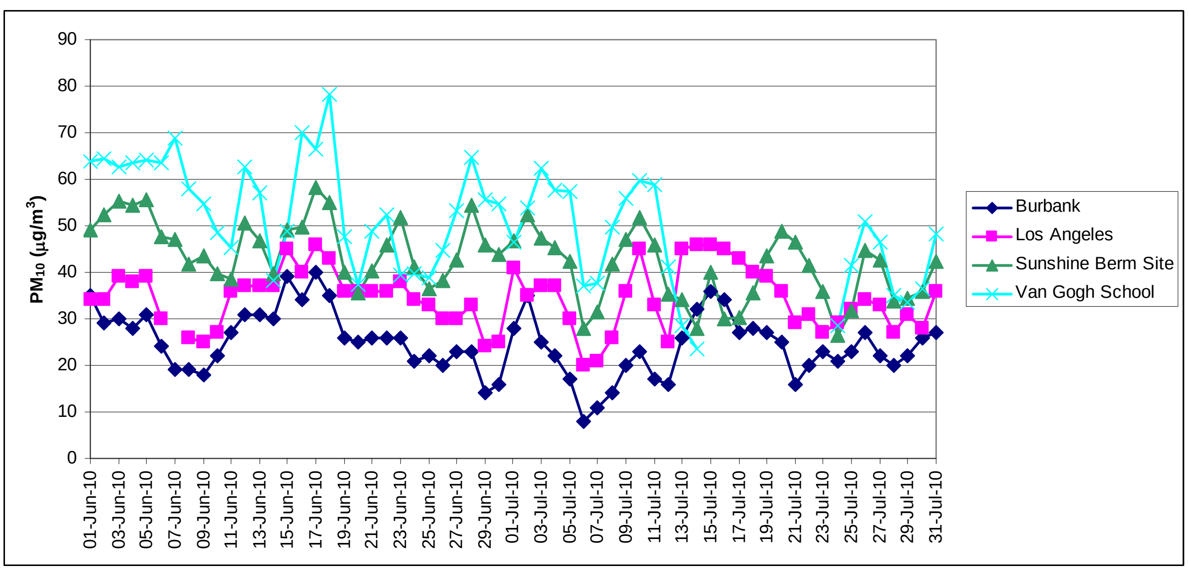


Figure 4-3. A time series of daily average PM_{10} concentrations for June and July 2010.

In this case, one may be inclined to conclude that the general increase in PM_{10} concentrations over a two-month period was due to activities at the landfill combined with meteorological conditions. Closer examination of the PM_{10} and meteorological data sheds doubt on this hypothesis. Summer months in the SoCAB are generally characterized by onshore wind flow patterns that carry pollutants northward from the SoCAB. **Figure 4-4** shows the hourly PM_{10} data (top panel) and the high-time-resolution wind data (bottom panel) from the Landfill site for June 2010. The dominance of southerly wind flow is evident. Also, a diurnal pattern in PM_{10} concentrations can be seen, presumably associated with regional daily PM_{10}-generating activities in the SoCAB. The occurrence of increased PM_{10} concentrations at the Landfill and Community monitoring sites, compared to the downtown Los Angeles site, suggests that PM_{10} in the upper portions of the atmospheric boundary layer may have been carried aloft to the downwind monitoring sites.

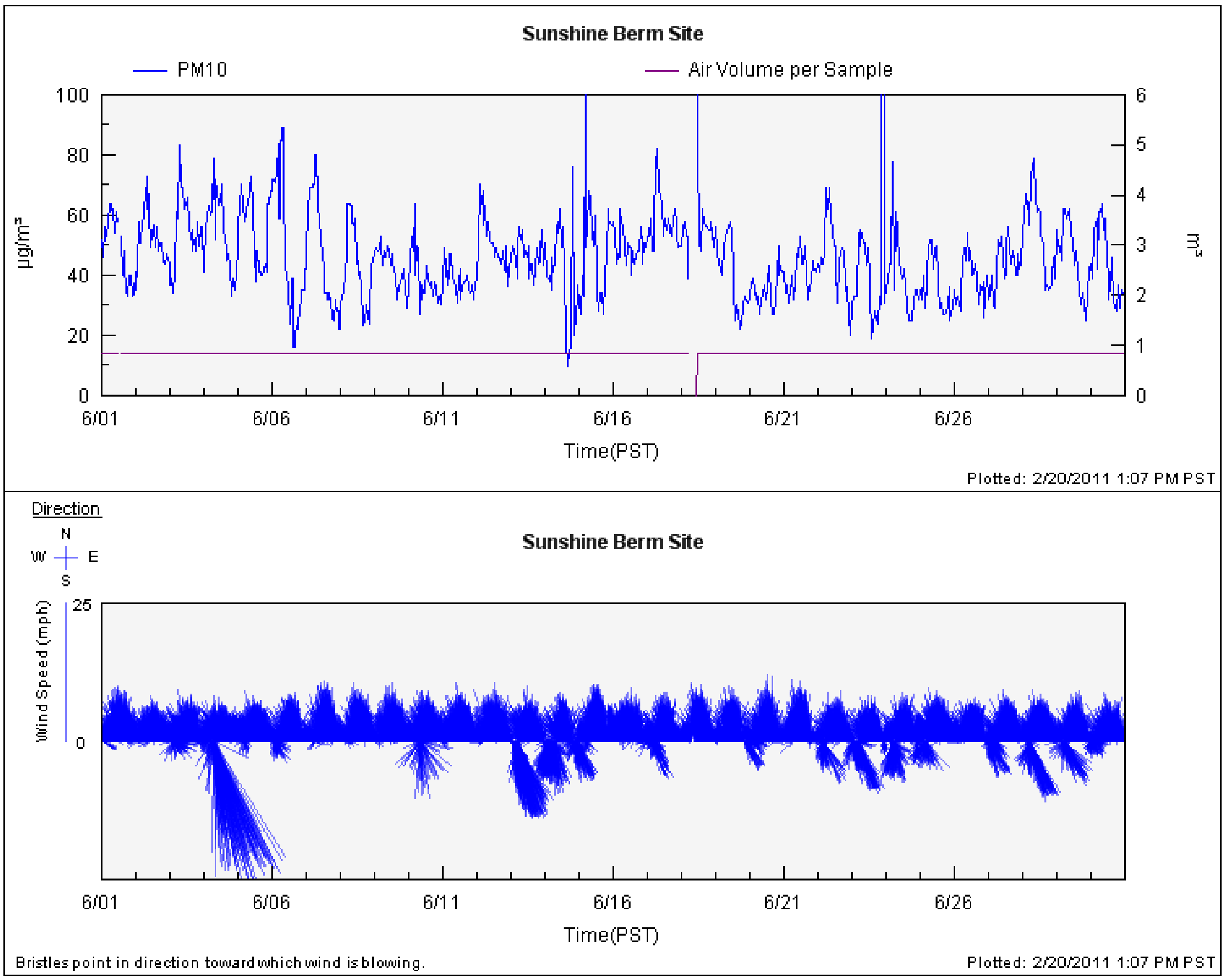


Figure 4-4. Hourly PM_{10} (top panel) and one-minute wind data (bottom panel) from the Landfill site for June 2010 indicate that during these summer months, southerly wind flow dominates (bristles pointing north indicate a southerly wind).

5. PM_{10} and BC: Effects of Wind Direction and Work Activity Levels

The statement that wind direction and landfill work activity levels affect PM_{10} and BC concentrations measured at the Landfill and Community monitoring sites is not unexpected: winds coming from the south, for example, will transport pollutants from densely populated areas of the SoCAB and have a major effect on local pollutant concentrations. Similarly, observations of landfill contributions to neighborhood-scale PM_{10} and BC concentrations are expected under northerly wind flow or under calm conditions, such as early morning, when downslope flows or airflow through canyons and around elevated landforms can have an impact. PM_{10} and BC concentrations would also be expected to vary diurnally, and from day to day, as source strengths increase and decrease with changing activity levels. These activity levels vary with different times of day (e.g., daytime versus nighttime) or between working days and holidays, both regionally and at the local (landfill operations) scale.

The three-year data archive is used here to compare, with long-term averaging, the concentrations of PM_{10} and BC that characterize the Landfill and Community monitoring sites under northerly and southerly wind flows and under differing activity levels. Activity levels are binned according to landfill working and non-working days and working and non-working hours.

5.1 Wind Direction Sectors for Categorizing Data

Data for this analysis were selected using a wind sector to represent the landfill source and areas to the north and a wind sector to represent the area from which pollutant concentrations travel from the SoCAB. **Figure 5-1** is an aerial image of the area showing the wind sectors representing the landfill source in black for the Landfill monitor and in green for the Community monitor. Hourly pollution data corresponding to hourly wind direction data that fall within the boundaries of these sectors are used to compute the pollution metrics for working and non-working days (hours). Note that the Landfill monitor's wind sector (greater than or equal to 303 degrees and less than or equal to 360 degrees from true north) is broader than the Community monitor's (greater than or equal to 325 degrees and less than or equal to 355 degrees from true north). The analysis is based only on direction, not on matching times between records. The underlying premise is that long-term averages calculated in this manner more accurately represent true average landfill-derived contributions than do those calculated from matched hourly records, because of the frequent poor wind direction correlation between the two sites. Thus, some hourly records included in an individual monitor's averages do not appear in the other monitor's averages. For average concentrations calculated from the wind sector targeting the SoCAB, both monitors are in the same sector (greater than or equal to 150 degrees and less than or equal to 210 degrees from true north, **Figure 5-2**).

Figure 5-1. Aerial image of the Sunshine Canyon Landfill and the surrounding area, showing the wind direction sectors representing the landfill source used for selecting data for analysis from the Landfill monitor (in black) and the Community monitor (in green).

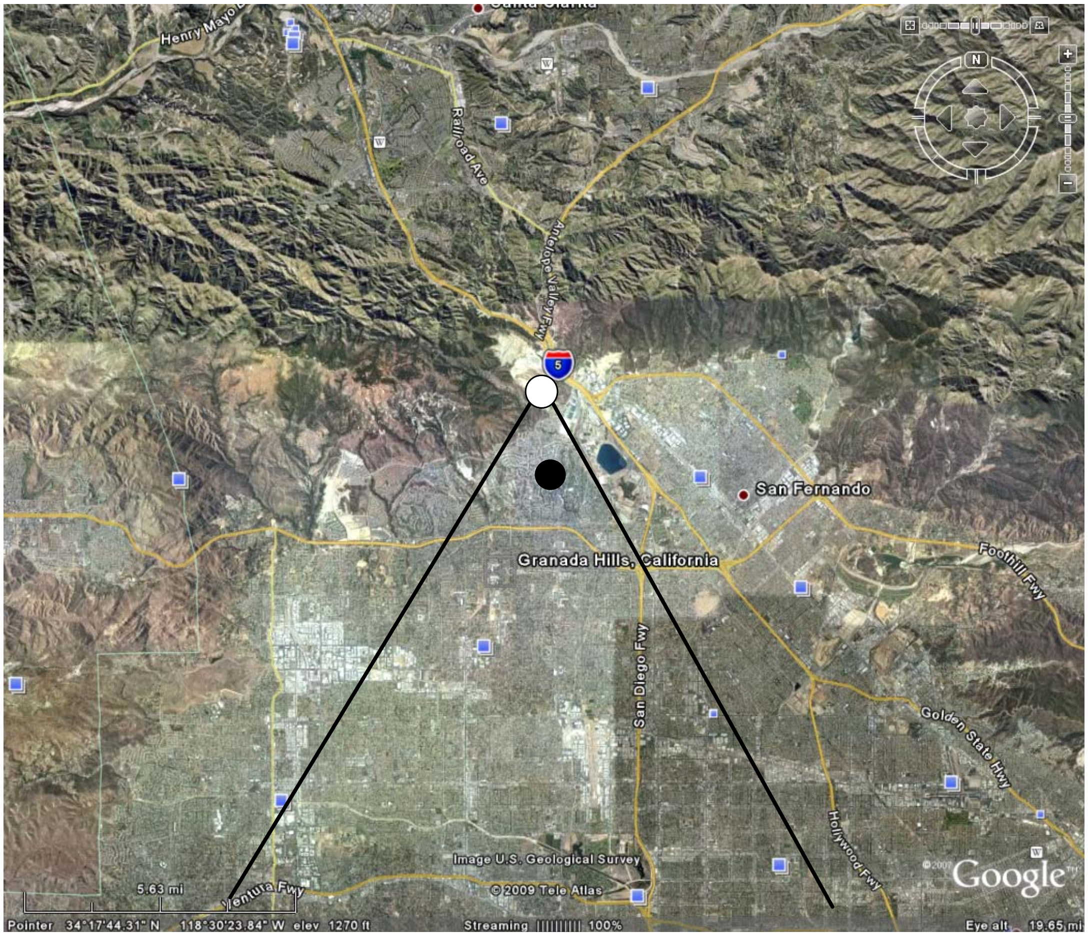


Figure 5-2. Aerial image of the Sunshine Canyon Landfill and the northern portion of the SoCAB, showing the wind direction sector representing the SoCAB source used for selecting data for analysis to compare with the landfill wind direction sectors depicted in Figure 5-1. The white dot represents the Landfill monitor, and the black dot represents the Community monitor.

5.2 Working and Non-Working Days and Hours for Categorizing Data

After the hourly data have been initially binned by the wind direction sectors described above, hourly PM_{10} and BC concentrations are categorized into landfill working and non-working days, and working and non-working hours within those days (based on landfill operations). Working days at the landfill are defined as Monday through Friday, excluding federal holidays. Non-working days are considered Sundays and federal holidays, including New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day; operations occurring on those days would confound the averages to an unknown degree. Additional non-Sunday holidays during which the landfill is closed, but operating, would similarly be incorrectly binned and thus slightly skew the resulting estimated concentration for that category. Saturdays are categorized "mixed use" at the landfill; thus, they do not fit easily into either category. The non-Sunday holidays and Saturdays are excluded from the analysis.

5.3 PM_{10} Concentrations

Figure 5-3 summarizes the 3-yr average PM_{10} concentrations for the northerly and southerly wind sectors for working and non-working days and for working and non-working hours within those days. The Landfill and Community monitors are represented on the bar graphs; the error bars represent the standard error of the 3-yr mean for each category.

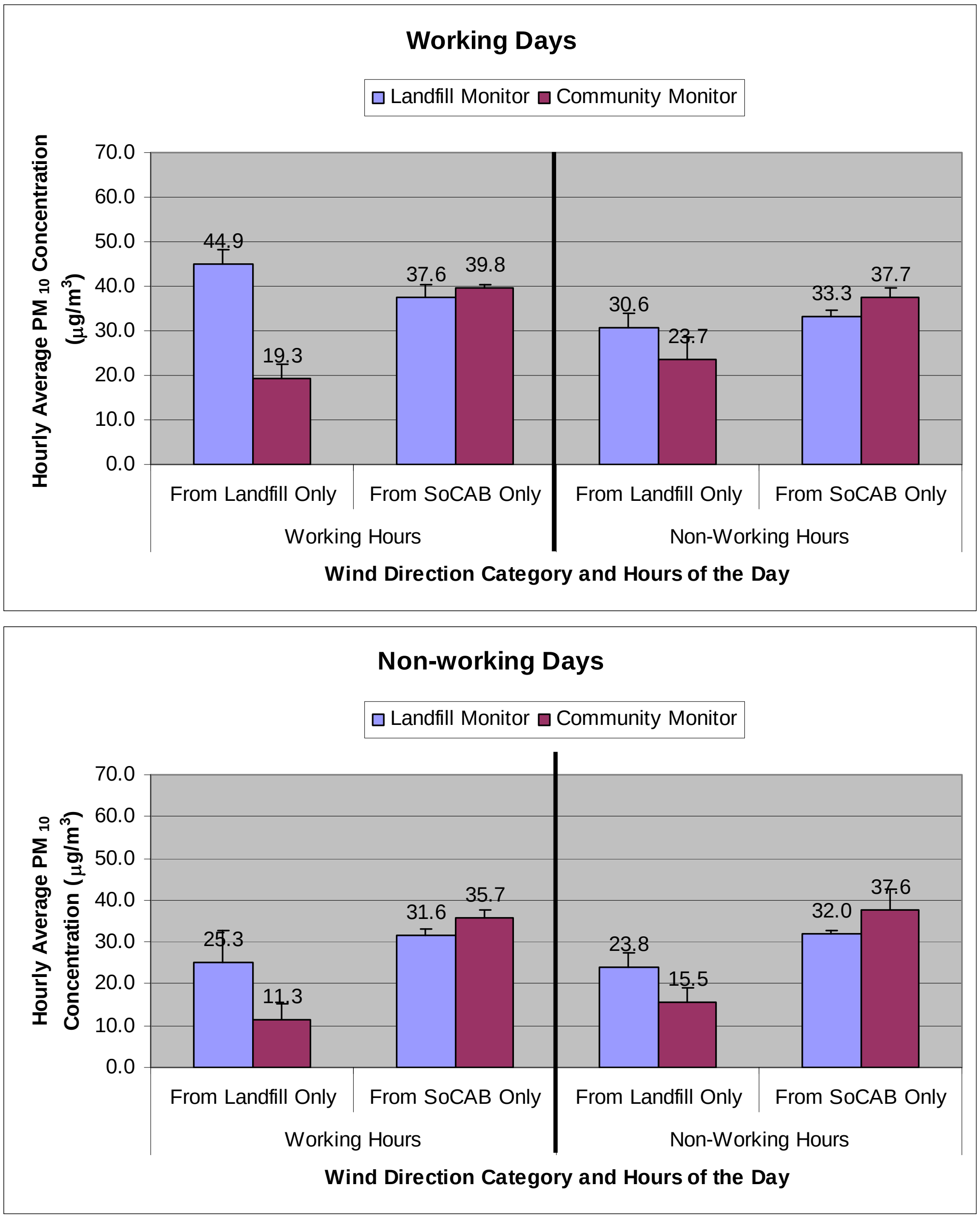


Figure 5-3. 3-yr average PM_{10} concentrations for northerly and southerly wind sectors for working and non-working days and for working and non-working hours within those days.

The following general conclusions are based on the average values presented in Figure 5-3.

- During the highest activity levels (working hours on working days, top panel, left side):
  - When the wind is from the SoCAB, the Landfill and Community monitors measure about the same average concentrations of PM_{10}.
  - When the wind is from the SoCAB, the average concentration of PM_{10} at the Community site is almost twice as high as when the wind is from the landfill.
  - When wind is from the landfill, PM_{10} concentrations at the Community site are about one-half of those measured at the landfill itself, suggesting that although the landfill-derived PM_{10} concentrations are significant, they remain mostly localized to the landfill.
- During the lowest activity levels (non-working days, lower panel):
  - Ambient concentrations of PM_{10} are lower on non-working days, but the extent of the decrease is influenced by wind direction.
    - Ambient PM_{10} concentrations in daytime (working hours) showed a greater proportional decrease on non-working days when wind direction was from the landfill (about 50% lower) than on non-working days when wind came from the SoCAB (about 15% lower), reflecting the larger regional PM_{10} influence of the SoCAB on non-working days.

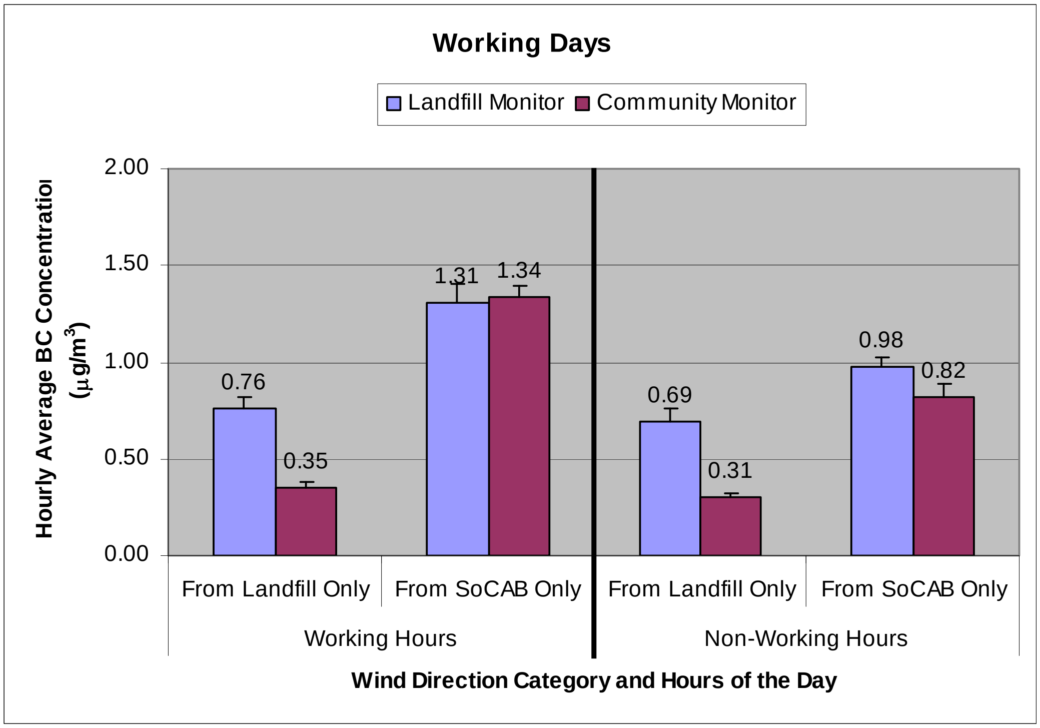
5.4 BC Concentrations

Figure 5-4 summarizes the 3-yr average BC concentrations for the northerly and southerly wind sectors during working and non-working days and during working and non-working hours within those days. The Landfill and Community monitors are represented on the bar graphs; the error bars represent the standard error of the 3-yr mean for each category.

The following general conclusions are based on the average values presented in Figure 5-4.

- During the highest activity levels (working hours on working days, top panel, left side):
  - When the wind is from the SoCAB, the Landfill and Community monitors measure about the same average BC concentrations.
  - When the wind is from the SoCAB, the Community monitor measures about three times the average concentration of BC as when the wind is from the landfill.
  - When wind is from the landfill, the Community BC levels are about one-half of the BC levels measured at the landfill itself.
- During the lowest activity levels (non-working days, lower panel):
  - Ambient concentrations of BC are lower on non-working days in all categories, but the extent of the decrease is influenced by wind direction:
    - The proportional decrease in BC concentrations on non-working days was larger than the decrease observed for PM_{10}. Compared to working hours, BC concentrations decreased by a factor of 2 (Community site) or 3 (Landfill site)

when winds were from the landfill, and by a factor of 2 when winds were from the SoCAB.



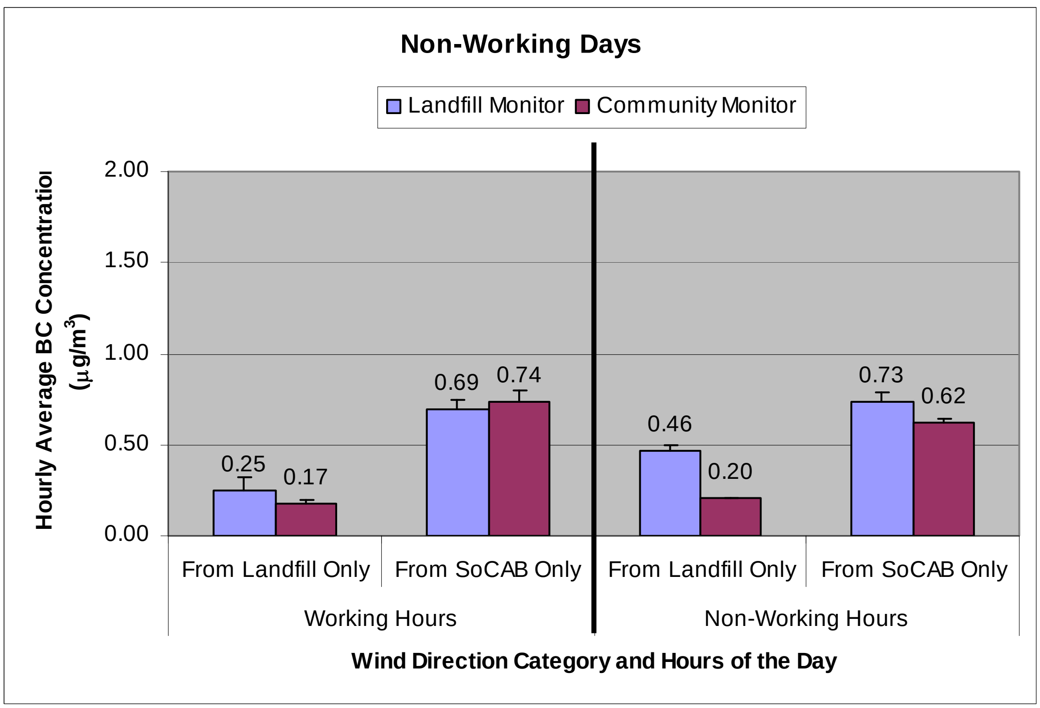


Figure 5-4. 3-yr average BC concentrations for northerly and southerly wind sectors for working and non-working days and for working and non-working hours within those days.

6. Quantitative Estimates of Landfill Impacts on Ambient Concentrations of PM_{10} and BC

Quantitatively estimating the impact of landfill operations on neighborhood-scale ambient air quality is required by the original Conditions of Approval (C.10.a) and the recently adopted (and nearly identical) County Condition 81. Specifically, the Conditions require determination of "whether air quality near the Landfill is consistent with the supporting environmental documentation for the City Project (i.e., the City's Final Supplemental Environmental Impact Report or 'FSEIR')." The FSEIR reported emissions estimates of pollutants likely to result from landfill operations, modeled by the Industrial Source Complex Short Term (ISCST3) regulatory model. Beginning with baseline year data (November 22, 2001–November 21, 2002) and continuing through 2008, no attempt was made to specifically address this requirement, presumably because there is no way to *directly* calculate an appropriate metric. The primary reason is that no pollutant monitoring data are gathered immediately upwind of the landfill to enable accurate estimates of the regional concentrations north of the landfill (and thus unaffected by landfill contributions). While the SCAQMD operates a BAM-1020 monitor at the Santa Clarita station, it is configured for $PM_{2.5}$ sampling. These $PM_{2.5}$ data are not directly comparable to the PM_{10} data provided by the BAM-1020 instruments currently deployed at the Landfill and Community monitoring sites. The Santa Clarita station does employ Federal Reference Method measurements of PM_{10} (integrated 24-hr samples on filters) on a 1-in-6 day schedule. While 24-hr averaged data from the Landfill PM_{10} monitor could be compared with the 24-integrated data from the FRM samples every sixth day, the low frequency sampling supports only minimal statistical power for calculation of upwind (background) PM_{10} concentrations. Additionally, the location of the Santa Clarita station relative to the landfill and nearby freeways further minimizes the potential for direct application of that data for calculation of landfill contributions of PM_{10}.

Beginning with STI's Second Annual Report[3] in 2009, a data analysis method to approximate landfill contributions to neighborhood-scale PM_{10} and black carbon (BC) concentrations, intended to address City Ordinance C.10.a and County Condition 81, was developed. The method was used to assess regional concentrations and provide estimates of landfill contributions above the regional contributions. It utilizes long-term averaging to maximize the sample size (hourly values) to be sufficiently representative. In 2009's Second Annual Report, rolling averages were used to maximize the sample size. In this Third Annual report, rolling averages are not used because a full three years of continuous data are available for calculation of the yearly averages used in the analysis. The results of the analysis have an undefined level of uncertainty because, in lieu of directly measured concentrations upwind of the landfill, regional pollutant concentrations are estimated from a southerly wind direction sector, isolating the SoCAB, to provide an estimate of regional pollutant levels during working days and non-working days.

[3] Vaughn D.L. and Roberts P.T. (2009) Second annual report of ambient air quality monitoring at Sunshine Canyon Landfill and Van Gogh Elementary School. Prepared for the Planning Department, City of Los Angeles, CA, by Sonoma Technology, Inc., Petaluma, CA, STI-907032.19-3671-AR, August.

The method involves the use of the same specific wind direction sectors and activity level bins for selecting the BC and PM_{10} data as described above for the annual average regional comparisons.

6.1 Justification of the Method

As illustrated in Section 5 above, when the wind is from the south, bringing pollutants northward from the SoCAB, the pollutant concentrations measured at the Community and Landfill monitoring sites are similar. When the wind is from the north, bringing pollutants southward, the pollutant concentrations measured at the two monitoring sites are much less similar. This observation provides the framework to

- Calculate regional pollutant concentrations not affected by contributions from the landfill.
- Calculate differences in regional pollutant concentrations between regular working days and non-working days. The data from non-working days provide estimates of baseline or background pollutant levels, and the data from working days provide estimates of any additional regional contribution associated with regular work days.
- Estimate regional contributions and use this estimate to assess landfill contributions to neighborhood-scale pollutant concentrations when winds are from the north (i.e., when landfill impacts, if any, would be measurable at both monitoring sites). In the absence of a monitor north of the landfill, the application of this estimate results in an undefined degree of uncertainty, since it is unknown how well this estimate of regional concentrations truly reflects the impact of concentrations from areas north of the landfill.

6.2 Specific Steps of the Method

Implementation of this analytical approach involves the following basic steps, using only validated and quality assured data:

- From the two monitoring sites, select the hourly pollutant concentration data for the analysis based on wind direction sectors, as described in Section 5.1.
- Categorize the data from the two sites into landfill-operating days (referred to as “working days”) and non-operating days (referred to as “non-working” days), as described in Section 5.2.
- Categorize the data from the two sites into working hours (chosen to reflect the main operating hours of the landfill) and non-working hours (non-operating periods), as described in Section 5.2.
- Calculate average pollutant concentrations for each data category.
- Using only the average concentrations derived from data attributed to the SoCAB, calculate the difference in regional concentrations between working days and non-working days.
- Compare the average concentrations measured on working days when the wind direction is from the landfill with the regional estimates and calculate an estimate of

landfill contributions. Under these sampling conditions, the working day concentrations are assumed to have three components:

(1) A regional contribution, estimated using data from non-working days when winds are from the landfill

(2) An additional regional contribution, estimated by multiplying the estimate in (1) above by the proportional increase in concentrations observed during times of southerly winds on working days compared to non-working days

(3) Average concentrations, measured when winds blow from the landfill on working days, in excess of the sum of (1) and (2) are attributed to the landfill. If average concentrations measured when winds are from the landfill increase proportionally with the regional increases associated with working days, no contribution from the landfill would result from this calculation.

The hours within each of these working and non-working day categories are additionally binned into working hours (defined as beginning at 0600 PST and ending at 1700 PST) and non-working hours. While the level of activity may vary within each timeframe, reliance on long-term averaging of pollutant concentrations will help to integrate the effect of these varying activity levels.

6.3 Estimates of Landfill Contributions of BC and PM_{10}

The results of the analyses are presented in two figures: **Figure 6-1** for PM_{10} and **Figure 6-2** for BC. The bar charts shown for each parameter depict the measured average concentration at both monitoring sites for working days during daytime hours, apportioned among three components: a component attributable to a background regional concentration estimated from non-working days, an additional regional component attributable to working days, and a component estimated as the landfill contribution on working days.

6.3.1 PM_{10} Impacts

Figure 6-1 shows the estimated apportionment of average PM_{10} concentrations to regional, non-working day levels; additional regional inputs on working days; and landfill contributions associated with working days (calculated by difference). The average PM_{10} concentrations noted for the first year are a few tenths of a $\mu g/m^3$ different from those reported in the Second Annual Report because the number of days assigned as holidays differed.

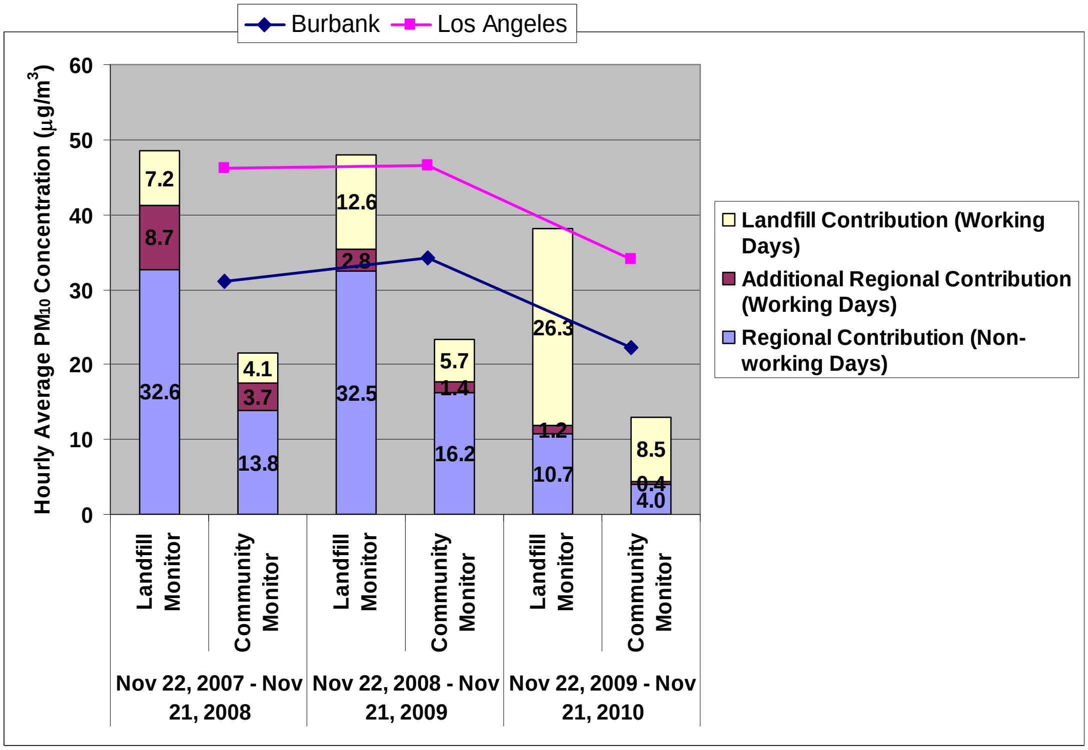


Figure 6-1. Summary of three consecutive years of quantitative estimates of the average regional contribution to ambient PM_{10} levels on non-working days (blue bars), the additional regional contribution associated with increased activity levels on working days (violet bars), and the average hourly landfill contribution on working days (yellow bars). Line graphs show annual averages for Los Angeles and Burbank (Jan-Dec).

The following comments are offered about the estimates of regional and landfill contributions of PM_{10} shown in Figure 6-1:

- Average PM_{10} concentrations at the Landfill and Community sites were similar for 2008 and 2009. Both sites exhibited decreased average annual PM_{10} concentrations in 2010. This pattern is similar to the annual averages shown for Los Angeles and Burbank. (Note: the annual averages shown by the line graphs are meant to illustrate the general agreement in regional trends of annual average PM_{10} concentrations between the SCAQMD sites and the two local monitoring sites. They are January through December averages, and thus not directly comparable to the November to November averages shown for the Landfill and Community monitoring sites.)
- The “background” PM_{10} concentration, estimated from non-working days when wind direction is from the landfill (blue bars), did not change substantially between 2008 and 2009. However, from 2009 to 2010, it decreased by factors of 3 (Landfill monitor) and 4 (Community monitor). The reasons for this large decline are unknown. The underlying hourly data are shown in Figure 6-2, which shows the distribution of hourly PM_{10} concentrations that yield the annual averages shown by the blue bars in Figure 6-1. The number above each box/whisker plot is the hourly sample count.

- The additional regional contribution of PM_{10} associated with working days (violet bars) decreased by about a factor of 3 in 2009 compared with 2008, with a further decrease between 2009 and 2010.
- The unchanged, or decreasing, background PM_{10} concentrations, coupled with diminished additional regional amounts of PM_{10} associated with working days, resulted in increasing estimates of landfill contributions on working days from 2008 to 2009 and again in 2010. This effect was most pronounced at the Landfill monitor. This magnitude of estimated increases in landfill contributions at the Landfill site is not reflected in a corresponding increase in landfill contributions at the Community site.
- At the Community monitor, estimates of average annual landfill contributions increased by 1.6 $\mu g/m^3$ from 2008 to 2009 and by 2.8 $\mu g/m^3$ from 2009 to 2010.
- The large increase in 2010 at the Landfill monitoring site may be associated with increased activity levels at the landfill and the tendency for those emissions to remain localized to the landfill area.
- The substantial increases in PM_{10} attributed to the landfill during 2009 and 2010, which are not duplicated at the Community monitor, suggest a local source that minimally impacts neighborhood- or regional-scale measurements.

6.3.2 Black Carbon Impacts

Figure 6-2 shows the estimated apportionment of average BC concentrations to regional, non-working day levels, additional regional inputs on working days, and landfill contributions associated with working days (calculated by difference). The average BC concentrations noted for the first year are a few hundredths of a $\mu g/m^3$ different from those reported in the Second Annual Report because the number of days assigned as holidays differed.

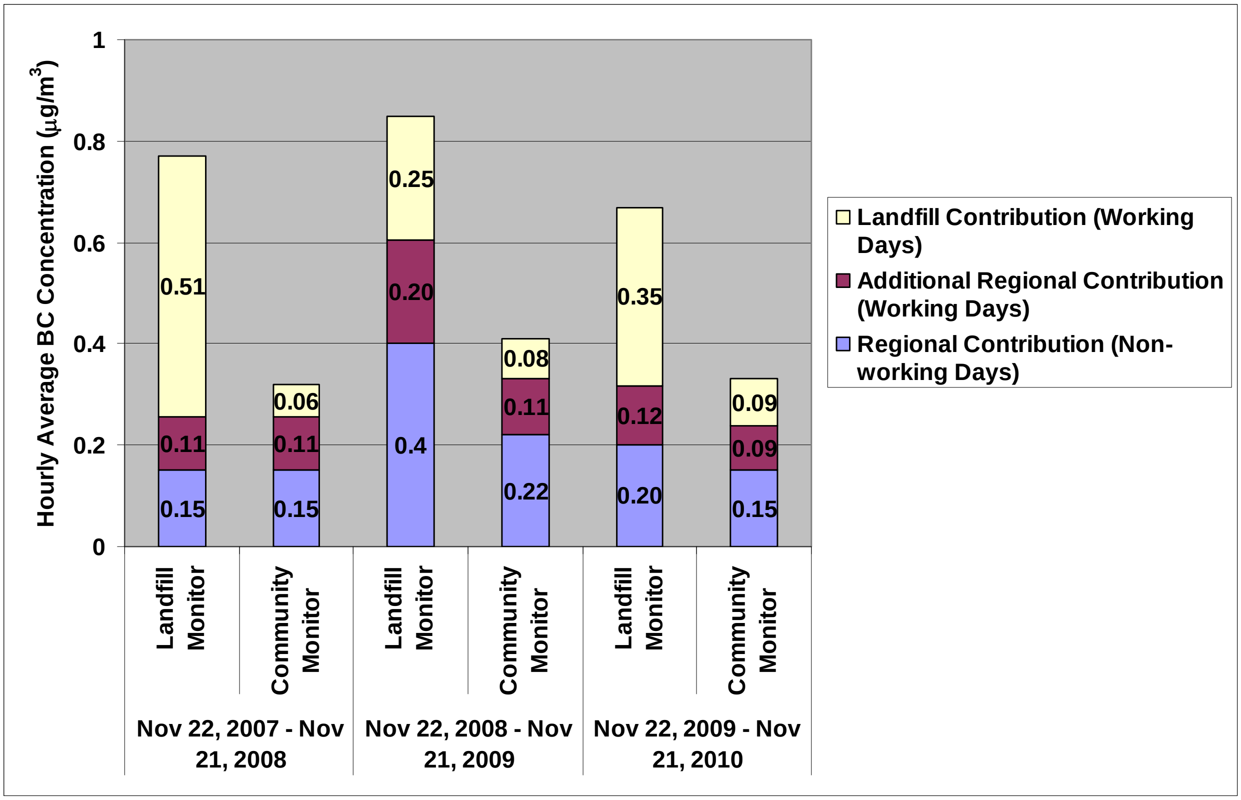


Figure 6-2. Summary of three consecutive years of quantitative estimates of the average regional contribution to ambient BC levels on non-working days (blue bars), the additional regional contribution associated with increased activity levels on working days (violet bars), and the average hourly landfill contribution on working days (yellow bars).

The following comments are offered about Figure 6-2:

- Average annual landfill contributions to ambient BC concentrations at the Community monitor have remained fairly stable for the last three years, contributing from 19% to 27% of the annual average.
- As measured at the Landfill BC monitor, the landfill contribution to ambient BC concentrations (yellow bar) declined by 50% from 2007 to 2008. Changes that can account for this decrease include the increase in regional contributions during non-working days at the Landfill monitor (blue bar), but this decrease may also reflect the application of DPM emission-control technologies to landfill diesel equipment and changes in fleet operations from diesel to natural gas.
- The increase in landfill contributions of BC from 2009 to 2010 are assumed to be associated with a general increase in landfill activities or scope of operations. No metric gauging that level of activity is provided, however.

7. Landfill Gas, Hazardous Air Pollutants, and Odors

This section of the three year summary report offers brief overviews of LFGs, hazardous air pollutants (HAPs), and odors. Most of the general information regarding LFGs presented here is taken from a publication from the Agency for Toxic Substances and Disease Registry (ATSDR)[4], and readers are directed to the web link in the footnote to obtain additional information. A brief review of HAPs, those compounds known to have carcinogenic, teratogenic, or other serious health effects, and the role that they play in the LFG sampling strategy, is given. The LFG sampling strategy and methodology which has been used over the last three years is described, and the results of the LFG sampling conducted to date are qualitatively summarized. Detailed quantitative data summaries of the LFG ambient air sampling are contained in the quarterly reports (12 to date) covering the periods when the samples were taken. A few examples (one typical, one less so) are presented in this report for illustrative purposes. Finally, a short discussion of odors is offered to help promote a general understanding of the problems associated with detecting and identifying the compounds that cause odors.

7.1 LFG Overview

While LFG can include literally hundreds of compounds, it is typically composed of 45% to 60% methane and 40% to 60% carbon dioxide. It may include small amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and non-methane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride.

Landfill gases are derived from three processes: bacterial decomposition, volatilization, and chemical reactions. Bacterial decomposition of organic matter proceeds through four phases, moving from aerobic, to anaerobic processes producing acidic compounds and carbon dioxide and hydrogen, to anaerobic methane production, and finally to a steady state where methane and carbon dioxide gas production remains more or less constant. This latest stage can last 20 years or more. Any or all of these stages may be proceeding simultaneously in different parts of the landfill. **Figure 7-1**, taken from the ATSDR publication, illustrates the gas production at each of the four stages of microbial degradation.

Volatilization is the process of a compound changing from a solid or liquid to a gaseous state. Some NMOCs can come directly from this process if chemicals are disposed of in a landfill. (Many chemicals are prohibited from being disposed of in landfills.) Chemical reactions can also produce NMOCs if chemicals are deposited and react with each other.

[4]Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services (2001) Landfill Gas Primer - An Overview for Environmental Health Professionals, available at http://www.atsdr.cdc.gov/HAC/landfill/html/intro.html

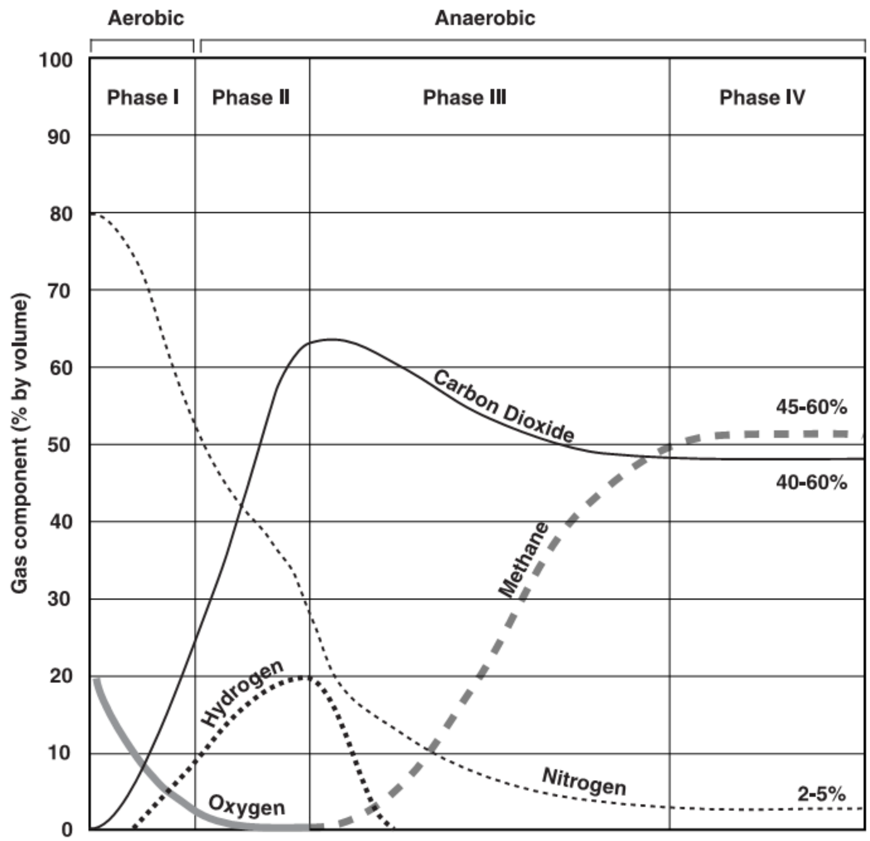


Figure 7-1. Generalized scheme of landfill gas production during the bacterial decomposition process in municipal landfills. Figure from ATSDR.

Site characteristics determine the rate and volume of gas production. The composition of the waste (the balance of organic matter and chemical compounds), the age of the refuse (fresh material produces more LFG than does older waste), the presence of oxygen (methane is produced only when no oxygen is available), the moisture content (increased moisture increases bacterial decomposition), and temperature are all critical factors that interact to influence the gas production.

The Sunshine Canyon Landfill likely has areas ranging from old sections in the equilibrated methane-producing stage to newly deposited refuse that is added daily and is in the aerobic stage of microbial degradation. The measurement and control of LFG from all these areas represents one of the major tasks of the landfill operators. Independent measurements of LFG are required by SCAQMD Rule 1150.1 and include integrated and instantaneous landfill surface monitoring and periodic ambient air sampling (nominally monthly) at landfill property boundaries. This monitoring is undertaken by an independent contractor and is separate from monitoring required by City Conditions of Approval C.10.a and County Condition 81. These latter two conditions govern the ambient air sampling conducted by Sonoma Technology at the southern edge of the landfill and in the neighboring community of Granada Hills.

7.2 Hazardous Air Pollutants

Some NMOCs are known to cause serious environmental and health effects and are known as HAPs. Some of the compounds associated with landfill emissions have been classified by the U.S. Environmental Protection Agency (EPA) as environmental and health hazards, and cancer and non-cancer health benchmarks have been established for many of them. A cancer benchmark means that exposure to concentrations at this level for 70 years would be expected to result in one additional case of cancer per million people. Concentrations below this level would result in a lower rate, and concentrations above, a higher rate. Non-cancer benchmarks are also based on a 70-year exposure, but the health effects are such things as asthma or neurological or reproductive effects

HAPs have many sources. They may occur in LFG as a result of the physical process of volatilization of chemicals deposited in the landfill, or they may be derived from chemical and biological reactions. Some HAPs are additionally classified as mobile source air toxics (MSATs) that are associated with motor vehicles (e.g., benzene, 1,3-butadiene, xylene, and toluene). Many industrial processes produce HAPs as byproducts. While most HAPs do not occur naturally, some do (1,2-dibromomethane produced by algae and kelp; ethylbenzene and xylenes in coal tar). Thus, the mere presence of a compound in a sample of ambient air does not indicate that it is derived from a landfill. Attributing ambient concentrations of NMOCs to landfill emissions requires care in sampling technique and information about the factors affecting transport, such as meteorology and topography. Worldwide ambient concentrations of methane are about 1.8 ppmV; thus, methane exists at these levels in most ambient air samples. Determining which compounds should be targeted in an analysis is one important aspect of sampling for LFG in ambient air.

7.3 LFG Sampling Strategy—When to Sample

LFG sampling in ambient air normally utilizes “grab sample” techniques. Using an appropriate collection mechanism (e.g., Tedlar bags, Summa canisters), air samples are acquired over a specific time period, ranging from several minutes to several hours. The duration of the sample period is dictated by the objective of the sampling. Typically, 24-hr average concentrations are used to assess seasonal variability or annual averages. Shorter duration samples (1- to 3-hr) are used to determine diurnal variability. Once the sampling objective and sample duration are determined, a sufficiently large number of samples must be obtained to assure statistical rigor. For example, 1-in-6- or 1-in-12-day samples of 24-hr duration on a continuing basis are sufficient to delineate seasonal differences. (It should be noted that continuous monitoring, on the scale of minutes to hours, of LFG is possible with automated gas chromatography, but such monitoring involves large investments in equipment and frequent site visits by trained personnel.)

The minimum sample frequency imposed by the Conditions of Approval precludes a statistically based LFG sampling strategy. Thus, sampling LFG only four times a year should target the “worst case scenario” by sampling during those times when the probability of landfill emissions influencing neighborhood-scale ambient concentrations is highest. Beginning in 2010, the LFG sampling strategy was changed to reflect patterns seen in the SCAQMD’s 2009 and 2010 registry of complaints attributed to landfill operations. These complaints tended to peak in the fall and winter months. This peak coincided with the seasonal change in prevailing wind patterns from onshore (southerly) to offshore (northerly) flow, and suggested strongly that it would be during these time frames that any impacts of LFG on the community would be most likely to be detected. Currently, all four LFG sampling periods fall within the fall and winter months.

Published accounts of diurnal variation in concentrations of air toxics may also help refine a sampling strategy targeted to measure maximum levels of LFGs. Recently, McCarthy et al (2007)[5] evaluated the temporal variability of selected air toxics in the United States. Sufficient data were available to analyze diurnal variability for 14 air toxics, and the authors were able to identify four diurnal variation patterns: invariant, nighttime peak, morning peak, and daytime peak. Carbon tetrachloride was the only air toxic fitting the invariant pattern. The nighttime and morning peak patterns were similar, with high evening/nighttime concentrations and low midday concentrations driven primarily by meteorology. Concentrations build up during the night because of lower mixing heights. As the sun rises and heating occurs, turbulence develops and results in dispersion and lower concentrations. The morning pattern has an additional mid-morning rush-hour peak attributable primarily to mobile sources. The daytime peak pattern is driven by photo-oxidation of other volatile organic compounds (VOCs). If the temporal variability of ambient LFG concentrations near the landfill is meteorologically driven, then the nighttime peak pattern may be the most applicable, suggesting that the best time to sample maximum concentrations may be the middle of the night. Sampling during this window would also minimize mobile source contributions.

The sample times for LFG samples collected to date were chosen on the basis of real-time wind data, coupled with anecdotal knowledge derived from reported odor complaints suggesting that transport to the community may be occurring during early morning hours. For each designated sample day, two samples are taken at each location. The first integrated sample is taken from 7 a.m. to 8 a.m. and is immediately followed by a second sample from 8 a.m. to 9 a.m.

7.4 LFG Sampling Strategy—How to Sample

Samples for NMOCs are collected in evacuated Summa canisters. A Summa canister is a stainless steel vessel which has had the internal surfaces specially passivated using a “Summa” process. This process combines an electropolishing step with chemical deactivation to produce a surface that is chemically inert. The canisters used for the ambient sampling undergo a 100% certification process that ensures no contamination in the canister. In combination with the canister is a flow controller with a critical orifice, calibrated specifically for the duration of the sample, to allow the can to fill gradually over the intended sample period so the sampled air represents a properly integrated sample. Flow controllers calibrated for 1-hr samples are currently being used for the Sunshine Canyon ambient LFG sampling.

[5] McCarthy M.C., Hafner H.R., Chinkin L.R., and Charrier J.G. (2007) Temporal variability of selected air toxics in the United States. *Atmos. Environ*. **41**(34), 7180-7194 (STI-2894). Available on the Internet at http://dx.doi.org/10.1016/j.atmosenv.2007.05.037.

On the designated sampling day, one STI staff person is located at each monitoring site to manually control the sample collection process. Once collected, the samples are immediately shipped to an independent lab for analysis.

7.5 LFG Sampling Strategy—Target Compounds

The list of NMOCs targeted in the laboratory analysis of collected samples includes those compounds that were sampled during the baseline study. This ensures continuity and allows direct comparison with the results of the baseline study should that be desired. The list also includes other NMOCs commonly associated with landfills, in particular those compounds specified in SCAQMD's Core Group of "Carcinogenic and Toxic Air Contaminants" listed in the District's Rule 1150.1. The ATSDR also provides a list of NMOCs commonly found in LFG, and a few of these compounds are included in the list as well.

In the baseline study, one objective was to identify compounds found in LFG but not typically found in background air, thereby allowing the identified compounds to act as tracers specific to the landfill. An analysis was performed on LFG collected directly from the onsite LFG collection and control system. The most prevalent components of LFG found in these landfill samples, in decreasing order of concentration, were xylenes, toluene, dichlorobenzenes, benzene, perchloroethene, dichloromethane, and vinyl chloride. The measured concentrations of these compounds were compared to the average concentrations reported by the California ARB for the SoCAB for the year 2001.[6] These ratios were used to help identify appropriate tracer compounds, based on the notion that compounds exhibiting the highest ratio would be the best marker compounds. Xylenes, benzene, and toluene were excluded as target compounds because they are found in motor vehicle exhaust, confounding the ability to pinpoint emission sources. Perchloroethene and dichloromethane were excluded because they exhibited low landfill gas-to-ambient air ratios.

The baseline study identified the three isomers of dichlorobenzene and vinyl chloride as the most appropriate target NMOC compounds. These compounds are included in the target list of compounds in the ongoing monitoring work so that direct comparisons to baseline concentrations can be made. However, it should be noted that the average concentration of the three isomers of dichlorobenzene reported for the SoCAB in 2001 (0.31 ppbv) in the Baseline Monitoring Report[7] does not agree with published California ARB data.[8] All Southern California stations with available data on any of the three isomers of dichlorobenzene had reported concentrations of 0.15 ppbv for the 2001 calendar year, which is one-half the Method Detection Limit (MDL) of 0.3 ppbv (1.8 $\mu g/m^3$). A value of one-half the MDL value is commonly used for reporting non-detect data.

[6] ENVIRON International Corporation (2003) Proposed landfill gas baseline ambient air monitoring protocol for the Sunshine Canyon Landfill. Report prepared for Browning-Ferris Industries of California, Inc., by ENVIRON International Corporation, Contract No. 03-9660A, March 27. Table 1.
[7] ENVIRON International Corporation (2003) Results of the baseline ambient air monitoring program for the Sunshine Canyon Landfill. Final report prepared for Browning-Ferris Industries of California, Inc., by ENVIRON International Corporation, Contract No. 03-9660A, June 6.
[8] California Air Resources Board (2008) Annual toxics summaries. Available on the Internet at http://www.arb.ca.gov/adam/toxics/statesubstance.html.

Several other NMOCs are included in the ongoing monitoring. Information about concentrations of other landfill-associated gases affords comparison with other NMOC data sets collected in the Los Angeles air basin or at other landfills. **Table 7-1** lists the compounds included in the ongoing monitoring and whether they (1) were included in the baseline study, (2) are listed in the Core Group of toxic substances in Rule 1150.1, or (3) are listed as a common constituent of landfill gas by the ATSDR. The table also contains information on the odor characteristics of the target compounds, and the odor threshold concentration, when available.

Two compounds are being assayed in the current sampling strategy that were not monitored in the baseline study and do not appear in either the SCAQMD's Core Group or the ATSDR's list of common LFGs. The compound 1,1,2,2-tetrachloroethane is not commonly found in ambient air samples, but it is one of the most commonly monitored air toxics because of its high toxicity. It was previously used as an industrial solvent or as an ingredient in paints and pesticides, but commercial production for these uses in the United States has ended. It is currently used only as an intermediate in production of other chemicals. A second commonly measured air toxic, 1,3-butadiene, was added not because of its strong association with municipal solid waste landfills, but because it serves as a good tracer for motor vehicles. Other compounds in the ongoing monitoring list can be attributable to either motor vehicles or to LFG (e.g., benzene, toluene, xylenes); if these compounds are detected in an LFG sample, but 1,3-butadiene is not, then the landfill is the most likely source of those species.

Table 7-1. A listing of the NMOCs included in the current monitoring program, the baseline monitoring program, SCAQMD's Core Group of air toxics from Rule 1150.1, and ATSDR's list of common LFGs. Odor characteristics and odor threshold concentrations from references as noted in table footnotes.

Compound	Ongoing Monitoring	Base-line	SCAQMD Core Group	ATSDR	Odor	Odor Threshold (mg/m^3)
1,1,2,2-Tetrachloroethane	✓				Sweet, chloroform-like	11.2[a]
1,1-Dichloroethane	✓		✓	✓	Mildly aromatic, similar to ether	523[a]
1,1-Dichloroethene	✓		✓		Sweet, mild, chloroform-like	811[a]
1,2-Dichlorobenzene	✓	✓	✓		Pleasant, aromatic	324[b]
1,3-Butadiene	✓				Mild, gasoline-like	3.8[a]
1,3-Dichlorobenzene	✓	✓	✓		Odorless	[c]
1,4-Dichlorobenzene	✓	✓	✓		Mothball-like	1.2[a]
Benzene	✓		✓	✓	Sweet	5.2[a]
Benzyl chloride	✓		✓		Pungent, unpleasant, irritating	0.25[a]
Carbon tetrachloride	✓		✓		Sweet, characteristic	67.7[a]
Chlorobenzene	✓		✓		Aromatic, almond-like	5.0[a]
Chloroform	✓		✓		Pleasant, non-irritating	447[a]
cis-1,2-Dichloroethene	✓			✓	Ether-like, slightly acrid	72.6[d]
Dichloromethane	✓		✓	✓	Sweet, mild, chloroform-like	767[a]
Ethylbenzene	✓			✓	Gasoline	10.8[a]
Ethylene dibromide	✓		✓		Slightly sweet, chloroform-like	82.7[d]
m- and p-Xylene	✓		✓	✓	Sweet, characteristic	5.1[a]
Methyl chloroform	✓		✓		Sweet, sharp, chloroform-like	705[a]
n-Hexane	✓			✓	Faint, peculiar	493[a]
o-Xylene	✓		✓	✓	Sweet, balsam-like, distinct	5.1[a]
Tetrachloroethylene	✓		✓	✓	Sharp, sweet	7.3[a]
Toluene	✓		✓	✓	Sweet, pungent	11.8[a]
Trichloroethylene	✓		✓	✓	Sweet; ether- or chloroform-like	162[a]
Vinyl chloride	✓	✓	✓	✓	Mild, sweet	8260[a]

[a]Technology Transfer Network Air Technical Website, U.S. EPA, http://www.epa.gov/ttn/atw/
[b]Spectrum Laboratories Inc., http://www.speclab.com/
[c]ATSDR - Toxprofile: Toxicological Profile Information Sheet, http://www.atsdr.cdc.gov/toxprofiles/index.asp
[d]http://www.osha.gov/SLTC/healthguidelines/

7.6 Summary of LFG Sampling

As stated previously, the LFG sampling that occurs under the auspices of City Condition c.10.a and County Condition 81 is limited in scope to four samples per year and is not statistically robust for making any general inferences. Sampling has been targeted at those times when meteorology and odor complaint registry records (anecdotal) indicate that landfill impacts may be most likely. Under this scenario, the LFG data collected to date has fit into one of three cases: (Case I) sampling problems or unidentified laboratory issues return methane concentrations below the global average concentration of 1.8 ppmV, and are thus suspect; (Case II) methane and NMOC concentrations fall within the historical range of Los Angeles and Ventura County values (the most common result); and (Case III) a few compounds above the 90^{th} percentile of historical concentrations have been detected in a few samples, but usually these compounds are also associated with mobile sources and not directly attributable to landfill operations.

Two recent examples are provided to illustrate cases (II) and (III) above.

7.6.1 Example of Case II: Typical LFG Sampling Results

Figure 7-2 depicts the LFG data collected on December 29, 2009. These results typify the most common range of LFG concentrations that have been observed over the last three years of sampling at the Landfill site and the Community site.

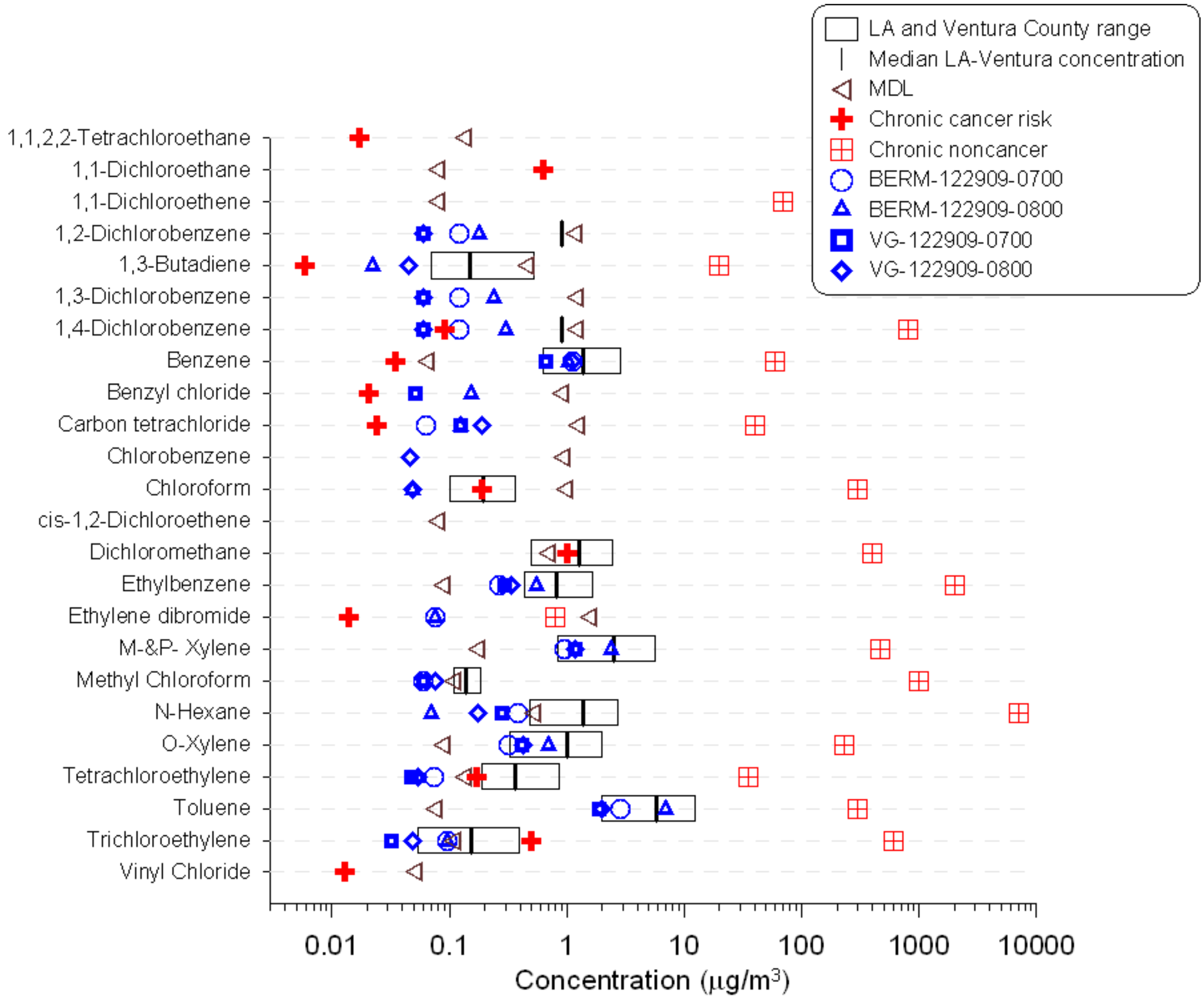


Figure 7-2. Illustration of a typical LFG sample data set. The plot depicts ranges of the 10th to 90th percentile quarterly averages and median values for available Los Angeles and Ventura County NMOC data from 2005 to 2009; concentrations determined from the December 29, 2009, samples collected at the Sunshine Canyon Landfill ("Berm") and Van Gogh School ("VG") sites; MDL; and chronic cancer risk and noncancer benchmarks. If data are not shown, the compounds were "not detected."

7.6.2 Example of Case III: Some Concentrations Above the Historical 90th Percentile

Since November 5, 2010, one additional sample was collected on November 18, 2010, but the lab results were not complete in time to include in the 12th Quarterly report, which spanned September 1, 2010, through November 30, 2010. The results from that sample are representative of the Case III scenario, in which some compounds are measured above the typical range of Los Angeles and Ventura County values, but the compounds are also associated with mobile sources and difficult to attribute to landfill operations. The results also contain one methane sample that is below the global average concentration and is thus suspect.

The methane levels reported for the November 18 samples are given in **Table 7-2**. The values are within the normal range. Global ambient concentrations are near 1.8 ppmV, so the 8:00 a.m. sample at the Landfill site is below background level. It is at the borderline of laboratory Quality Control failure (1.26 ppmV).

Table 7-2. Ambient concentrations of methane measured at the Landfill monitoring site and the Van Gogh School on November 18, 2010.

	Methane Concentration (ppmV)	
	7:00-8:00 a.m.	8:00-9:00 a.m.
Landfill Site	3.8	1.3
Community Site	2.5	1.9

Figure 7-3 presents the LFG NMOC analytical results from the samples collected on November 18, 2010. The two samples at the Community site both had high benzene, high hexane, and somewhat high xylenes and toluene. The concentration of 1,3-butadiene also looks high, but it is below MDL. As explained above, this might suggest landfill contributions, since 1,3-butadiene was added to the target list to help segregate out mobile sources. The concentrations at the Landfill, however, are at the low end of the expected range, suggesting that the landfill is not a contributor. No high concentrations were found at the Landfill monitoring location.

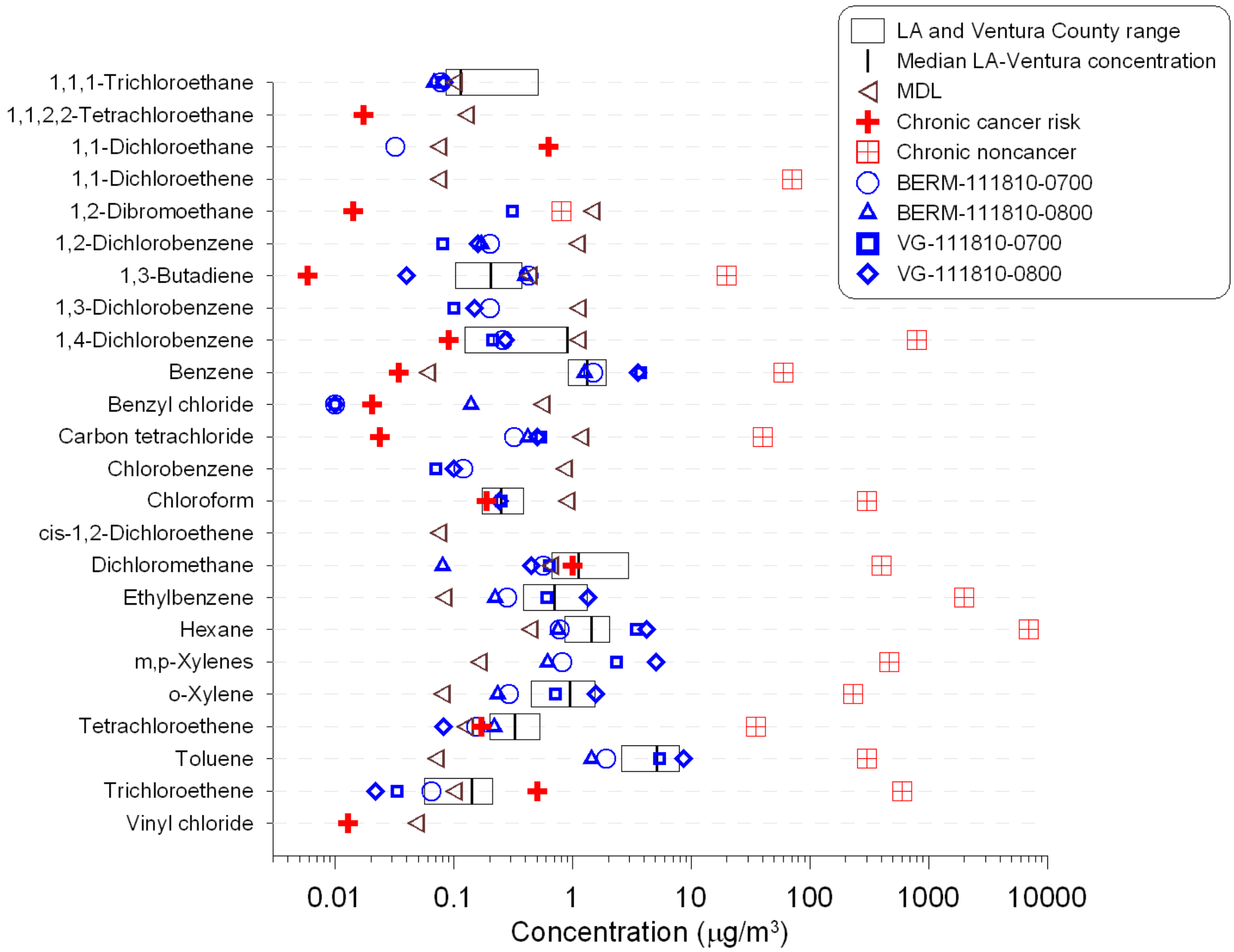


Figure 7-3. Ranges of the 10th to 90th percentile quarterly averages and median values for Los Angeles and Ventura county NMOC data from 2006 to 2009, as available; concentrations determined from the November 18, 2010, samples collected at the landfill site (BERM) and Van Gogh Elementary School site (VG); MDLs; chronic cancer risk; and chronic noncancer hazard levels. For the November 18 sample, any data not shown were not detected by the analytical laboratory. Data below MDL that were reported are shown.

7.7 Odors

One dominant issue with the residents of Granada Hills concerning the Sunshine Canyon Landfill has been odors. This has been especially true over the last two years, when the frequency of odor complaints to SCAQMD and to the landfill itself has increased substantially. Interested readers are referred to **Appendix A**, which is a paper from the Proceedings of Air and Waste Management Association (1998) about odor quantification methods and practices at municipal landfills. This paper presents a good summary of the issues involved with odor measurement and control.

Other generalized comments regarding odors:

- Odor characteristics of most compounds on the LFG target list (Table 7-1) are not typical of those commonly referred to in the SCAQMD odor complaint registry.
- Offensive odors are primarily the result of microbial degradation of organic matter, and there are likely hundreds of compounds that can contribute to odors.
- The offensive odors may occur in extremely low concentrations (parts per trillion range) that
  - Are detectable by human olfactory senses;
  - Are not easily detectable by common analytical methods;
  - May act in a synergistic fashion to intensify the degree of unpleasantness.

8. Field Operations

Field operations include regular visits to both monitoring sites, scheduled for every second week. Problems are usually detected quickly (within a day) and addressed remotely when possible. Occasionally, non-scheduled onsite visits by an STI technician are required and occur as soon as reasonably possible.

Each quarterly report contains tables with the dates and times of each site visit and a summary of activities that took place. Since the site infrastructure and equipment were upgraded in 2010, the continuity and reliability of the monitoring sites has improved.

Appendix A

Odor Quantification Methods and Practices at MSW Landfills

Odor Quantification Methods & Practices at MSW Landfills

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Proceedings of

Air and Waste Management Association
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ABSTRACT

The measurement of odors from municipal solid waste (MSW) landfills is usually a requirement for compliance monitoring, planning, site expansion and review of operational practices. Additional purposes for quantification of MSW landfill odors include trials and testing of topical and area dispersed odor counteractant sprays and other alternative practices.

Sources of odorous emissions are a challenge to control by MSW landfill management. When odors impact the surrounding community, regulators attempt to enforce compliance. Emission sources, that include hauling trucks, specific odorous materials (i.e. sludge), landfill gas, cell cover breaches and other on-site activities, are difficult to identify and to compare on a relative basis. Presenting the greatest challenge for odor control is the open working face of the MSW landfill.

Portable and laboratory gas monitoring sometimes lead to identifying an odorous source because of the chemical differences between the emissions. However, because of the many potential odorous sources and their chemical similarities or complexities, odor measurement is the direct way to compare and quantify the various source contributions. After all, it is the odors that impact the community. Specific odorous emissions can be collected from surfaces and from the ambient air. These samples, shipped to an odor laboratory, can be evaluated for odor concentration and odor quality (i.e. descriptors). However, many of the odors occurring at MSW landfills can not be collected for laboratory odor evaluation.

Field observation by operators, inspectors and citizens provide a cost effective means to quantify odors from MSW landfills. Using simple word intensity scales or butanol intensity scales with standard odor descriptor nomenclature, direct field observation is a dependable practice for quantification of odors from MSW landfills.

This paper presents specific methods and practices for quantification of odors from MSW landfills by regulators, operators and the community for purposes of monitoring, planning and testing.

INTRODUCTION

Communities and regulators readily know that municipal solid waste (MSW) landfill operations yield odorous emissions. MSW landfills can emit odors in varying degrees from many potential sources that may include[1]:

1) Arriving and queuing hauling trucks
2) On-site vehicles and heavy equipment
3) Biodegraded household waste
4) Sewage sludge
5) Working face
6) Fugitive odorous dust
7) Temporary cover
8) Capped cells
9) Access road construction
10) Leachate collection systems
11) Leachate treatment systems
12) Monitoring wells
13) Gas well construction
14) Gas wells and collection piping
15) Gas treatment systems
16) Gas flares
17) Associated landfill activities, ie. yard waste and composting.
18) Adjacent unrelated landfill activities and businesses

Each of these potential odorous sources varies in the following ways:

- ⇒ emission type (surface or point source)
- ⇒ emission rate ("odor units" per second)
- ⇒ odor strength (concentration and intensity)
- ⇒ odor persistence (dose-response relationship)
- ⇒ odor character (descriptors and Hedonic Tone)
- ⇒ frequency of occurrence (random or repeating)
- ⇒ duration of emission (episode or activity related)
- ⇒ circumstances (temporary condition, emergency release, construction, etc.).

Quantification of odors from MSW landfills is typically prescribed for the following purposes:

1. Compliance monitoring (compliance assurance)
2. Determination of compliance (permit renewal)
3. Determination of status (base line data for expansion planning)
4. Determination of specific odor sources (investigation of complaints)
5. Verification of complaints (notice of violation)
6. Monitoring daily operations (management performance evaluation)
7. Comparison of operating practices (evaluating alternatives)
8. Monitoring specific events or episodes (defensible credible evidence)
9. Determination of an odor counteractant's efficacy (scientific testing)
10. Determination of an odor counteractant's cost effectiveness (cost minimization)
11. Comparison of odor counteractants and other methods (cost accountability)
12. Verification of odor dispersion modeling (model calibration)

Each of these purposes dictates a need for dependable and reproducible methods and practices for odor quantification. The trend in the United States and internationally is toward a recognition that odor is a legitimate air pollutant and odor can be controlled. Therefore, regulators and operators of MSW landfills are faced with practical needs for odor quantification, whether the purpose is solely for complaint investigation (i.e. public relations) or for permit renewal (i.e. facility survival).

The **methods** of odor quantification address the purpose of the work (i.e. site specific criteria). The **practices** of odor quantification address the scientific procedures (i.e. ASTM Standard Practices). For example, a MSW landfill may need to conduct routine odor monitoring because of a permit condition. The purpose of the odor quantification demands a method that will satisfy the permit conditions. The *method* that would be selected might be a schedule of routine odor observations at specific locations around the property line and within the community. In this example, the odor quantification *practice* that would be selected might be the use of ASTM E544 (1988), Standard Practice for Referencing Suprathreshold Odor Intensity.

Site specific conditions often place significant limitations on the ability of regulators and MSW landfill operators to implement a program of odor quantification. Local terrain and local meteorology are common constrains that challenge method development and sometimes limit the choices of odor quantification practices.

METHODOLOGIES

Ten methods are commonly used by MSW landfills and regulators responsible for permitting. The term **"protocol"** is often applied to the method that is selected for a specific program or requirement. The following methods or protocols are presented in brief exemplary form as a guide.

(1) **Point Source Sampling** - The operations on a MSW landfill site may include leachate treatment, gas cleaning, enclosed transfer operations or other buildings or processes that have a specific point emission source. The point source may be a stack, roof exhaust or building side vent. The sampling of the potentially odorous point sources involves the collection of the air from the point source in a Tedlar gas sample bag using a vacuum chamber, sometimes called a sampling lung[2]. The bag is placed in the vacuum chamber with a Teflon tubing line placed in the exhaust stream. A pump is used to create a vacuum in the chamber, which causes the odorous air sample to flow into the bag. The bag is first partially filled, then emptied and finally filled with the sample. This method, called "conditioning the bag", is believed to minimize the loss of odor on the bag's inside surface. The odorous air sample is express shipped to an odor laboratory for evaluation of the odor parameters, ie. odor concentration and descriptors.

(2) **Surface Sampling** - A MSW landfill contains a number of surfaces that have the potential to emit odorous gases, i.e. daily cover, temporary cover or capped cells. The collection of odors from surfaces requires the use of a device called a flux hood[3]. A simple flux hood is a bowl inverted on to the surface that is to be sampled. Odor free air is supplied to the flux hood during sampling from the flux hood. Several methods of surface sampling have been used by investigators. One alternative method utilizes a portable wind tunnel[4]. Any of these methods are available for use at a MSW landfill and the choice will be dictated by the site specific conditions and the data requirement needs.

(3) **On-Site Monitoring** - Operators have the unique ability to monitor odors throughout the day. Operator monitoring can include odor observations of arriving materials (i.e. sludge), the working face, the leachate collection system and the gas wells. Monitoring on-site can also involve odor observations from selected predetermined locations. Sample locations might be at and around the working face, on closed cells and adjacent to leachate systems.

(4) **Complaint Response** - The use of "Odor Complaint Hot Lines" is a common method used by MSW landfills and communities. A "Hot Line" phone system provides citizens with direct access to register a "complaint" and other relevant information. A complaint response plan, with designated "on call" inspectors, produces opportunities for observing odor episodes and for tracking odors to the contributing sources.

(5) **Random Monitoring** - A frequently used method for odor monitoring is the "random inspection" approach. This method is also called the "unannounced inspection". The random monitoring method leads to a compilation of data that can be correlated with meteorological information and on-site activities. Regulators often find that random monitoring is the only cost effective method available for compliance determination.

(6) **Scheduled Monitoring** - Well planned scheduled monitoring can be limited to a daily drive around the MSW landfill site or a daily visit to several predetermined monitoring locations. The data from scheduled monitoring can be used to correlate the many parameters which potentially influence odor episodes. Meteorological conditions and on-site operating activities need to be recorded during the monitoring. The use of a versatile data base will facilitate the analysis of the data.

(7) **Citizen Monitoring** - The implementation of citizen monitoring can be part of an interactive community outreach program for a MSW landfill. The primary function of citizen monitoring is to obtain information, through accurate record keeping, that represents real conditions in the residential community. The citizens recruited would be trained to measure odors using an intensity scale and to assign standard odor descriptors. The citizen monitors can assist in determining prevalent times which odors occurs and prevalent weather conditions of odor episodes. Citizen monitors also help in understanding the odor intensity level at which an odor is considered a nuisance (i.e. first becomes a nuisance).

(8) **Citizen Jury** - Occasionally a citizen "jury" is impaneled to evaluate odors associated with a MSW landfill. A typical citizen jury would be gathered to observe odors at specific locations and asked to respond to the following question with a YES or NO: "In your opinion, do the odors witnessed at this location on this day and at this time have the intensity and character which would interfere with the normal conduct of business or cause material, physical discomfort to a person ?"

(9) **Intensive Odor Survey** - An in-depth evaluation of on-site odor generation and off-site odor impact might be needed for a MSW landfill in preparation for a permit review or facility expansion. Extensive data collection of odors, related meteorological conditions and site operations will identify which sources and operations cause odors and which ones that do not cause odors. All potential odor sources can be ranked and their relative odor contributions determined. Short term trials of odor counteractants also may require an intensive period of data collection using odor monitoring practices.

(10) **Plume Profiling** - Odor dispersion monitoring can be supplemented with odor plume profiling. Several inspectors spaced cross wind and down wind from the odor source can be assigned to measure odor intensity. Multiple plume profiles, during differing wind conditions, can be used to "calibrate" a dispersion model or verify model predictions.

STANDARD PRACTICES

Four standard practices directly applicable for quantification of MSW landfill odors are:

- ⇒ Odor Characterization by Descriptors
- ⇒ Word Scale Odor Intensity
- ⇒ Suprathreshold Odor Intensity
- ⇒ Odor Threshold Concentration
- ⇒ Odor Persistence

Characterization by Descriptors

The character of an odor is reported by an observer using "standard odor descriptors". Odor character is also known as "odor quality". Odor descriptors provide a referencing vocabulary or standard nomenclature for reporting, comparing and contrasting.

Numerous "standard" odor descriptor list are available to use as referencing nomenclature. One standard published by the International Association on Water Pollution Research and Control (IAWPRC) is a "flavor wheel" for natural waters[5]. An adaptation of this IAWPRC "flavor wheel" is a grouping of odor descriptors applicable for MSW landfills, as in Table 1.

A standard list of odor descriptors provides odor inspectors, monitors, operators and citizens with a common (i.e. similar) vocabulary for evaluation, reporting and communicating.

Word Scale Odor Intensity

Odor intensity is a measure of the relative strength of an odor above the threshold. Odor intensity can be assigned a word descriptor or a number on a "5" or "10" scale. A common word scale is:

0 No Odor
1 Very Faint
2 Faint
3 Noticeable
4 Strong
5 Very Strong

Intensity word scales are also used with only "end point" word descriptors, i.e.

Light	-------------------	-------------------	-------------------	**Strong**
1	2	3	4	5

The citizen odor monitor typically finds the word intensity scale easy to understand and use. A MSW landfill would best use the same intensity word scale in order to facilitate communication and summarizing of data.

Suprathreshold Odor Intensity

Odor intensity quantification can be accomplished using an "Odor Intensity Referencing Scale"[6] (OIRS). Odor intensity referencing compares the odor in the ambient air to the odor intensity of a series of concentrations of a reference odorant. A common reference odorant is n-butanol. The inspector, investigator, monitor or operator observes the odor in the ambient air and compares it to the OIRS[7]. The person making the observation must use a carbon filtered mask to "refresh" their olfactory sense between observations (sniffing). Without the use of a carbon filtered mask the observer's olfactory sense would become fatigued or would adapt to the odors in the surrounding ambient air.

Using the OIRS, the intensity of the observed air is expressed in "parts per million" of n-butanol. A larger value of butanol means a stronger odor. The OIRS serves as a standard practice to quantify the intensity of odors for documentation and comparison purposes.

Odor Threshold Concentration

The odor concentration is a number derived from a laboratory dilution of a sample odor[8]. Dilution of the odor is the physical process that occurs in the atmosphere down wind of the odor generating source. The "receptor" (citizen in the community) sniffs the diluted odor. The dilution ratio is an estimate of the number of dilutions needed to make the odor "non-detectable" (threshold).

Samples of ambient air that have been collected on-site and surrounding a MSW landfill can be evaluated at an odor laboratory using trained panelists (assessors). The odor panelists observe the sample using an instrument called an olfactometer. The testing procedure produces threshold values that are called "detection threshold" and "recognition threshold". The detection threshold represents the dilution ratio needed to make the sample "detection free". The recognition threshold represents the dilution ratio needed to make the sample "odor free". The differences between the detection threshold and recognition threshold may only be significant in odor dispersion modeling. However, when comparing sample results, one type of threshold must be used consistently.

In addition to the determination of odor thresholds, an odor laboratory can conduct evaluations for the following odor parameters:

- Odor Intensity using the n-butanol Odor Intensity Referencing Scale
- Odor Quality using Standard Character Descriptors
- Odor Hedonic Tone (Pleasantness verses Unpleasantness)
- Odor Persistency (Dose-Response)

A field procedure exists, known as the "Scentometer", for the estimating of ambient odor threshold[9]. The Scentometer, a small portable box device, has been in use since its development in 1959[10]. The Scentometer, when used by an experienced technician, estimates the odor concentration using a dilution threshold technique. Holes in the Scentometer box, specially sized, allows ambient air to enter through charcoal filters and directly to the user's sniffing ports. The Scentometer, a single user device, is limited primarily by wind conditions that affects the air entering the open holes in the sniffing chamber.

Odor Persistence

Persistency is a term used in conjunction with intensity. The intensity of an odor will change in relation to its concentration. However, the rate of change in intensity verses concentration is not the same for all odors. This rate of change is termed the persistency of the odor.

The persistency of an odor can be measured in an odor laboratory as a "dose-response" function. The dose-response function is determined from the intensity of an odor at full strength and at several dilution levels above the threshold level. The plotted values as logarithms of the intensity and dilution ratios makeup the dose-response function. In a simplified form for comparing two odors, i.e. odor with and without counteractant, the plots of the two samples might have different slopes. As illustrated in Figure 1, the odor with the flatter slope would have a greater persistency, i.e. greater "Hang Time" (slang) in the ambient air.

CONCLUSIONS

MSW landfill odor data collection and analysis address four basic questions:

1) **What** are the odors ? (Description)
2) **When** are the odors ? (Relation to time, activity, episode ...)
3) **Where** are the odors ? (In the Community)
4) **What does or does not cause** the odors ? (Sources, activity ...)

MSW landfill odors can be quantified using ten (10) site specific **methods** (protocols) for sample collection and direct observation.

1. Point Source Sampling
2. Surface Sampling
3. On-Site Monitoring
4. Complaint Response
5. Random Monitoring
6. Scheduled Monitoring
7. Citizen Monitoring
8. Citizen Jury
9. Intensive Odor Study
10. Plume Profiling

Standard **practices** for odor quantification at MSW landfills include: characterization by descriptors, intensity by word and butanol scales, threshold evaluation, and odor persistence.

MSW landfills have the opportunity to embrace standard methods and practices of odor quantification for purposes of self improvement, survival and growth. Proactive odor management strategies with ongoing monitoring and aggressive odor control will provide assurances of favorable public acceptance, regulatory compliance and informed management decision making.

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Table 1. Grouping of Odor Descriptors for MSW Landfills.

Group 1:	Earthy	Mushroom	Mouse-like
	Musty	Peat-like	Chalk-like
	Moldy	Grassy	Cork-like
	Musk	Herbal	Bark-like
	Stale	Ashes	Woody
Group 2:	Floral	Eucalyptus	Carnation
	Fragrant	Geranium	Rose
	Flowery	Violet	
	Perfume	Lavender	
Group 3:	Fruity	Apple	Vegetable
	Citrus	Pear	Honey Dew
	Orange	Strawberry	Cucumber
	Lemon	Pineapple	Celery
Group 4:	Spicy	Garlic	Vanilla
	Cinnamon	Onion	Almond
	Mint	Pepper	Maple
	Peppermint	Dill	Pine
	Anise	Cloves	Coconut
Group 5:	Fishy	Prawns/Shrimp	Amine (hair perm solution)

Table 1 (cont.). Grouping of Odor Descriptors for MSW Landfills.

Group 6:	Sewage	Garbage	Foul
	Septic	Rotten	Sour
	Putrid	Decayed	Vinegar
	Rancid	Raw Meat	Pungent
	Fecal	Blood	Burnt
	Urine	Cadaverous	Swampy
	Sulfurous	Rotten Eggs	Mercaptan
Group 7:	Medicinal	Chlorinous	Alcohol
	Disinfectant	Soapy	Ether
	Phenol	Caster Oil	Anesthetic
	Camphor	Ammonia	Menthol
Group 8:	Chemical	Petroleum	Tar
	Solvent	Car Exhaust	Oily
	Paint	Diesel	Pine Oil
	Aromatic	Gasoline	Plastic
	Varnish	Creosote	Vinyl
	Turpentine	Kerosene	Metallic

Figure 1. Odor Persistence Illustrated.