URBAN INFILLING IMPACTS ON FLORIDA SOLID WASTE FACILITIES

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ABSTRACT

Increasing urbanization in the US is leading to development or re-development of lands adjacent to solid waste facilities and these lands are being considered for residential communities and commercial projects. Thus, the potential for nuisance complaints against the pre-existing solid waste facility operations has become an increasing reality. The objective of this study was to develop a methodology to gather scientific and quantifiable data related to potential nuisances caused by landfills to determine setbacks and buffer zones near landfill and transfer station operations. Appropriate recommendations for these setbacks were made from case studies conducted at two landfills in Florida. The study involved measurements related to odor, noise, litter and dust. Impact on housing prices was also evaluated by analyzing publicly available house price data. In this study volatile organic compound (VOC) concentration was used as a surrogate measure for gaseous impacts.

The mass flux of VOCs was measured on the landfills using the dynamic flux chamber method. The ultimate purpose of flux measurements was to provide input data for dispersion modeling to analyze the extent of odor impact around the landfills, which is outside the scope of this study. Ambient measurements were also made around Landfill A for validating the dispersion model. Although there are no significant health and odor impacts caused by the landfill, higher background concentration extend 1.2-1.5 km from the active landfill cell center on the southeast side of the landfill. Litter from roadsides around the landfills was collected and catalogued based on size and material type. Litter count per site obtained for both landfills was less than the 2001 and 2002 state-wide counts. The difference was statistically significant. Noise measurements were made at landfills during waste-to-energy (WTE) operations and landfilling. Based on average measurements obtained at various distances from WTE facility and landfilling activity, and considering EPA recommended noise level of 55 dB(A) for a quiet neighborhood, a set back distance of 1.6-1.9 km was recommended. Impact on house prices near the landfills was evaluated for four landfills in Florida. Analysis showed that three out of four landfills significantly impacted the house prices within 0.6-0.8 km from the edge of the landfill cell. Dust measurements were made at Landfill B using particulate samplers, quantifying the dust associated with landfilling. Measured values were below National Ambient Air quality Standard (NAAQ) for PM_{10}. Finally, recommendations were developed to mitigate some of these nuisances.

INTRODUCTION

As the nation becomes more urbanized, sites once considered remote are now located in areas increasingly ripe for development or re-development. In order to site solid waste facilities, local governments have installed public works infrastructure such as roads and utilities, reducing the costs for owners of adjacent parcels. Consequently, land adjacent to solid waste facilities is being considered for development such as residential communities and commercial and industrial projects. Thus, the potential for nuisance complaints against the existing solid waste facility operations has increased in many areas of the nation. The most widely used measure of the magnitude of a facility nuisance problem is the number of complaints it receives. Most of the nuisance complaints received by the landfills are related to odor, noise, litter and birds. These issues are a function of distance from the landfill and in reality most of these complaints are received from the people living very near to the landfill. People living near the landfill are mainly concerned about the change in their property values compared with the properties farther away from the landfill.

There have been some instances in recent years where public and private owners/operators of solid waste facilities have been forced to close their facilities prematurely because of urban infilling, resulting in loss of valuable solid waste capacity and increased cost for solid waste disposal (Rogoff et al, 2006). Development of properties adjacent to solid waste facilities will become a significant problem for solid waste managers in the years ahead. Therefore the objective of this research was to develop methodology to gather scientific and quantifiable data to support setback distance and buffer zones near landfills. As an example of this recommended approach, appropriate recommendations for these setbacks were made from two case studies.

BACKGROUND

Most of the research on nuisance issues near landfills is related to evaluating the overall impact caused by the landfill. In many studies overall impact was evaluated by conducting a community survey in the neighborhood of the landfill and analyzing the results statistically.

Furuseth and Johnson (1988) studied the attitudes of people living within five kilometers of a sanitary landfill in North Carolina. The primary goal of this study was to assess the role distance to a landfill played in individual perception and concern. Among the impacts cited noise, landfill traffic, litter from garbage trucks, appearance of the landfill, and property devaluation raised the greatest concerns. Approximately 35% of respondents was concerned about the traffic problem, 31% about garbage truck litter, and 21% about traffic noise problem. About one third of the respondents felt that the landfill adversely impacted the value of their property. Further analysis showed that the effects which were sensory related such as landfill noise, odor, litter and dust were strongly influenced by the distance from the landfill. Property devaluation was the only non-sensory effect influenced by the distance from the landfill. Finally, this study recommended better understanding of these effects around the landfill so that buffer distances can be more appropriately defined and efficient local decisions can be made that are fair to citizens and land use planners.

Odors from landfills are of particular concern for residents living near landfills and have been the subject of several studies. Bedogni and Resola (2002) developed a methodology to evaluate odor impact of a solid waste landfill in the northern part of Italy. The methodology integrates two different approaches: monitoring data and modeling to simulate the impact of odor emissions. In this study, the CALPUFF dispersion model was used to carry out the evaluation. The validation compared the gas and odor concentrations measured at five points outside the landfill with the corresponding values estimated by the model. The results of the validation procedure showed a good agreement with the experimental data concerning methane emissions but overestimated the concentration of odorous gases. Finally, this study focused on methodology used and its importance as a decision tool for odor impact situations.

Nicolas et al (2005) studied the estimation of odor emission rates from landfill areas using the sniffing team method. The odor was detected by the sniffing team at various points around the landfill by moving in a zigzag manner around the plume axis. The meteorological situation was simultaneously recorded. Then, a bi-Gaussian model was used to simulate the perception of the odor. McGinley (1998) studied the various odor quantification methods and practices at MSW landfills. In this study ten methods were reviewed that were commonly used by MSW landfills and regulatory authorities.

Reichert et al (1991) studied the impact of five municipal landfills on surrounding residential property values in Cleveland, Ohio. In this study, a total of 2243 market sales was analyzed using regression analysis and the results were mixed. In a similar study done by Schulze et al (1986) three different California city housing markets were analyzed for potentially hazardous landfill effects. The study found significant results for one region for houses within 300 m of the landfill site.

Materials and Methodology

The methodology adopted involved measuring various quantifiable parameters related to nuisance complaints typically received by landfills at two sites (Landfills A and B) in Florida. The quantifiable parameters that were measured were volatile organic compounds (VOC) mass flux rate, noise, litter, and dust.

Landfill A is located in one of the most densely populated counties of the state. Approximately 800 to 1000 vehicles arrive at Landfill A each day and in 2006 the landfill received approximately 284,800 Mg of solid waste. This facility consists of a Waste-to-Energy (WTE) facility, an ash processing facility, a municipal solid waste (Class I) landfill and a construction and demolition debris (Class III) landfill. Ash from the ash processing facility is used as landfill cover.

When the area was chosen for construction of a solid waste facility, the surrounding land was undeveloped. The landfill began its commercial operation in 1979 and construction of the waste-to-energy plant started in 1980. During this time, over the objection of the county, the city in which the landfill is located approved the zoning for construction of a residential community containing several hundred homes directly west of the active landfill. Also during the 1980s and 1990s, as permitted by the zoning regulations, the surrounding area continued to develop commercially.

Landfill A started logging complaints related to odor, noise, litter and birds, in 2004 from the residential community west of the landfill. The number declined during later years. All the complaints were received from the houses which are nearest to the landfill.

Landfill B is located in the central part of Florida and started its operations in 1978. It has a total footprint of 0.98 km^2. It is a Class I inward-gradient landfill with a natural clay liner and has a total design capacity of 34,405,000 m^3. Gas recovery and leachate removal systems were installed. In 2006, the landfill received 308,500 Mg of solid waste and 48,300 Mg of yard waste. Landfill B is surrounded with highly dense tree growth and the nearest residential housing is at least 600 m away from the landfill. Therefore, they have never received complaints related to any of the nuisance issues.

VOC Flux Measurement: People in communities near landfills are often concerned about odors emitted from landfills. Potential sources of landfill odors include sulfides, ammonia, and certain Non-Methane Organic Compounds (NMOCs), if present at sufficiently high concentrations. A landfill system has a strong potential to produce and release an excessive amount of organic compounds into the atmosphere (Zou et al., 2003). Also, Kim et al (2005) characterized malodorous sulfur compounds in landfill gas and found that H_2S is the main odor causing component; further, they found a strong correlation between H_2S and VOCs for several of the landfill sites. VOCs are composed of methane and some non-methane volatile organic compounds (NMOCs) (Kreith, 1995). NMOCs include saturated and unsaturated hydrocarbons, acidic hydrocarbons, organic alcohols, halogenated compounds, aromatic compounds and sulfur compounds (Keller, 1988). Although NMOCs account for less than 1% of total VOCs, they can cause significant health impacts (Zou et al., 2003), and alkyl benzenes, limonene, certain esters and organosulfur compounds are responsible for undesirable odor. Hence, in this study, VOC concentration was used as a surrogate measure for gaseous impacts.

The mass flux of VOCs was measured on the landfill using the flux chamber method. The concentration of VOCs in the exit gas from the flux chamber was measured using a flame ionization detector (FID). In this methodology, the dynamic flux chamber method was used since it is the most accurate method for determining emission rates from the landfill (Cooper et al, 1992). The ultimate purpose of flux measurements is to provide input data for dispersion modeling to analyze the extent of odor impact around the landfill, which is outside the scope of this study.

The operational procedure was adopted from Walker (1991), Rash (1992) and Eun (2004). Random sampling points were selected on the landfill to place the flux chamber. The flux chamber was sealed along the edges using a bentonite slurry and a flow meter was connected to the inlet. Air was supplied at a constant flow rate into the flux chamber. A portable MicroFID from Photovac Inc. (Waltham, Massachusetts, US) was used to measure the concentration of VOCs. The MicroFID uses a hydrogen supply and the oxygen from the sample air to support combustion. Measurements were made at the exit port using the MicroFID at constant intervals until steady-state condition was achieved. At steady-state, the concentration of VOCs at the exit port was recorded. The emission rate at the sampling point was calculated using equation 3.

$$F = \frac{(C(mg/L) \times Q)}{A} \tag{3}$$

Where: F is the emission flux rate measured for sampling point (mg/m^2-min), C (mg/L) is exit VOC concentration in mg/L as carbon, Q is the flux chamber sweep air flow rate in L/min, and A is the enclosed surface area (0.19 m^2).

Litter Survey: Most litter surveys are focused on roadsides because they are easy to access and measurements are straightforward. The methodology followed for the litter survey around Landfills A and B was similar to that developed by the Florida Center for Solid and Hazardous Waste Management (FCSHWM 2002). The primary goals of the litter survey around Landfills A and B were to quantify the litter and identify the composition of the litter.

At both Landfills A and B, litter is collected five days per week as part of their daily operations. Roads around the landfills were selected which are accessed daily by trucks and trailers carrying waste to the landfill. Litter is collected on a selected road and when the collection is completed, litter collection on another selected road will be started.

For Landfill A, litter collection is done on the selected roads around the landfill in five days and the procedure is repeated every week. Litter collection around Landfill A for this survey started on April 16, 2007. Litter collected on different roads was stored in bags with name tags identifying where they were collected. Collection of litter was completed by 20th April 2007. Overall, 40-45 bags of litter were collected and litter was counted and catalogued on 20th April 2007. The procedure was repeated the next week when 35-40 bags were collected. Collected litter was counted again on 27th April 2007.

Landfill B has only one approach road and litter collection on this road is done three to four times every week by landfill personnel. Each time four to six bags of litter is collected on this approach road. Similar to Landfill A, collected litter near Landfill B was counted and catalogued. Since litter is removed continuously from the selected roads around each landfill, this approach captures the steady-state litter that has accumulated between the scheduled collections.

Litter collected on the roadsides around the landfills was counted and categorized based on material type. Similar to the methodology followed by FCSHWM (FCSHWM 2002), litter was first categorized by size as small litter (area < 26 cm^2) and large litter (area > 26 cm^2) and then based on material type as paper, plastic, glass, aluminum, steel, mixed and composite. This classification allowed comparison of the litter count values obtained around Landfills A and B to the values obtained by the FCSHWM in state-wide surveys, which would represent background litter. FCSHWM state-wide surveys measured litter that had accumulated over relatively long period of time. The FCSHWM surveys capture a steady-state condition balancing litter accumulation and degradation. In this study the amount of litter present on road segments represents a steady state established between accumulation and regular litter collection by landfill personnel.

Impact on House Prices: The effect of certain land uses on residential property values has long been of interest in the public policy arena. In the real estate market, people are willing to pay higher prices for sites that are not affected by nuisances than for sites affected by nuisances (Crecine et al, 1967). Past research showed mixed results regarding impact of landfill on nearby residential property values (Reichert et al, 1991). Statistical approaches were adopted in previous studies to analyze the impact of landfill on house prices.

In this study, impact on house prices near the landfill was evaluated using market price data available from a public website, http://www.zillow.com. In order to evaluate the impact, data regarding 10-year (1997-2007) percentage change in house prices was analyzed. It is recognized that there are some limitations to this public source, however we believe that the trends are consistent and worth reporting. A more accurate assessment could be made using local tax records.

Noise and Dust Measurements: These studies were performed by the UCF CEE Community Noise Lab. Typical daily sounds range from 40 dB(A) (very quiet) to 100 dB(A) (very loud). The U.S. EPA states a goal for community noise levels of 55 dB(A). Sound level meters Cesva 310 from Scantek Inc. (Columbia, Maryland) and Metrosonic dB308 (Norcross, Georgia) were used to measure noise. A receiver height of 1.5 meters was used at all microphone locations. All receivers were located at least 3.5 meters from any reflecting source such as a building or wall. Key, or reference, receivers were located as close as possible to avoid unwanted interferences.

At Landfill A, the first set of measurements involved measuring noise levels associated with typical WTE facility activity and the second set of noise levels associated with landfilling of unburned waste was made when the WTE facility was down for maintenance. For both cases, background noise levels were measured by setting up sound level meters far away from the source. Landfill B noise measurements were mainly made to capture the noise levels associated with equipment used on the landfill and then measurements were made to capture the noise levels at various locations on the landfill.

Dust measurements were also made on Landfill B. Dust is generated from the landfill mainly from landfilling activity and from trucks/trailers traveling around the landfill while moving the waste. Measurements were made by setting up particulate samplers in upwind and downwind locations relative to the landfilling activity. Particulate samplers were designed to collect particulate matter smaller than 10 microns. A 38-elemental break down and analysis of the dust samples collected was done by Chester LabNet (Oregon).

Results and Discussion

VOCs Mass Flux Results: Flux measurements for Landfills A and B were conducted from December 2006 to June 2007. Most of the trips were made when the forecasted weather was partly cloudy. Occasionally adverse weather conditions were encountered during the measurements, such as rain and heavy wind, and the measurements were stopped. Most of the flux measurements were made between 11 am and 5 pm. The site weather conditions and landfill visit dates are recorded in TABLE 1. According to EPA users guide (Kienbusch, 1986) the minimum number of samples to be measured is given by equation 4.

$$N_k = 6 + 0.1 \times (Area(m^2))^{0.5} \qquad (4)$$

Using the GPS and ArcGIS software, the calculated area available for measuring the gas emissions on Landfill A was 137000 m^2. Based on the area available and equation 4, the minimum number of samples required was approximately 40.

Calculation of available area on Landfill B was difficult because of its irregular surface profile, however since the footprints were similar; it was assumed that the area available for measurements was also similar. To confirm this similarity, the same distance between the samples was maintained for Landfill B.

Flux data were collected at Landfill A from December 2006 to April 2007. All the measurements were made using the dynamic flux chamber method. Overall, 38 measurements were made on Landfill A out of which 14 measurements were below detection limit. Locations of flux measurements are show on Figure 1. Emission rates measured on Landfill A ranged from BDL to 47 mg/m^2-min and a mean emission rate of 2.37 mg/m^2-min (TABLE 22) was obtained.

TABLE 1. LANDFILL VISIT DATES AND WEATHER CONDITIONS

	Visit Date	Weather
Landfill A	29-Dec-06	79 F, Clear
	4-Jan-07	81 F, Partly Cloudy
	12-Jan-07	75 F, Partly Cloudy
	19-Jan-07	86 F, Partly Cloudy, Heavy winds
	28-Feb-07	81 F, Partly Cloudy
	9-Mar-07	90 F, Clear
	14-Mar-07	79 F, Clear, Heavy winds
	15-Mar-07	81 F, Clear
	Visit Date	**Weather**
Landfill A	10-Apr-07	82 F, Partly Cloudy
Landfill B	11-May-07	95 F, Partly Cloudy
	16-May-07	113 F, Clear
	25-May-07	81 F, Partly Cloudy
	30-May-07	86 F, Partly Cloudy, Heavy winds
	7-Jun-07	79 F, rainy
	8-Jun-07	99 F, Partly Cloudy

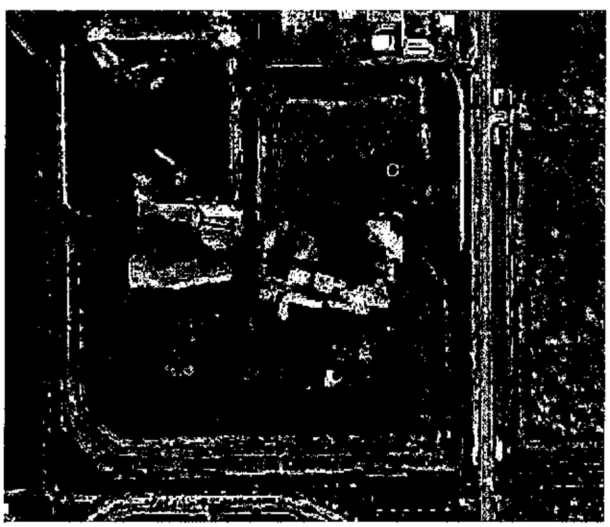

FIGURE 1. LANDFILL A VOC MEASUREMENTS

Flux data were collected at Landfill B from May 2007 to June 2007. Similar to Landfill A, measurements were made using the dynamic flux chamber method. A total of 36 measurements was made on the landfill, out of which 18 measurements were below detection limit. Locations are shown on Figure 2. Emission rates measured on Landfill B ranged from BDL to 40 mg/m^2-min and a mean emission rate of 4.59 mg/m^2-min (

TABLE 22) was obtained. The flux from most of the locations where measurements were made that had intermediate cover consisting of a mixture of mulch and dirt was BDL. Areas with soil cover only had emissions in the range 15 to 40 mg/m^2-min.

FIGURE 2. LANDFILL B VOC MEASUREMENTS

TABLE 22 provides a comparison of VOC measurements conducted on Landfills A and B. It can be observed from TABLE 22 that Landfill B has 94% higher emissions than Landfill A. TABLE 22 also presents the other characteristics of Landfills A and B VOC emissions.

TABLE 2. SUMMARY OF VOC MASS FLUX MEASUREMENTS AT LANDFILLS A AND B

Characteristics	**Landfill A**	**Landfill B**
# of Flux Measurements	38	36
Area of active landfill (km^2)	0.3	0.38
# of locations Below Detection Limit	14	18
Arithmetic Mean Flux (mg/m^2-min)	2.37	4.59
Standard Deviation of VOC Flux (mg/m^2-min)	7.79	9.99
Total Emissions (Mg/yr)	**375**	**933**

A number of researchers (Barry, 2003; Borjesson et al., 2000; Cardellini, 2003; Paladugu, 1994; Rash, 1992; and Walker, 1991) have reported methane flux rates. These rates ranged from 0.253 to 4300 mg/m^2-min. VOCs measured by the MicroFID are composed of methane and NMOCs. In the absence of site-specific data, the value recommended for NMOC concentration by US EPA is 8,000 ppmv (0.8 % by volume) (EPA, 1999) and for methane 50 % by volume (EPA, 1997). As can be seen, methane to VOC concentration and the mean flux rates of methane on Landfills A and B are within the range of emission rates reported in the literature.

It is important to note that the flux rates measured were assumed to be constant over time. However in reality, not only the total concentration of VOCs but also the relative composition of various components of VOCs will vary with time (Kim et al 2005).

Ambient measurements were made around Landfill A on February 9, 2007. These measurements will be used to validate dispersion model results by

concentration is significantly greater than NMOC concentration. Therefore for the purpose of this evaluation methane concentration is assumed to be approximately equal

comparing the model results with ambient data. Weather data were also collected during the same time on the surface of the landfill. FIGURE 33 shows the contour map with ambient measurements and Table 3 provides the concentration range.

The ambient measurements were made around the landfill using the MicroFID. One minute averaging time was used for measuring the concentrations. The prevailing wind direction during the measurements was from northwest. As would be expected, highest off-site concentrations were observed southeast of the landfill as shown in FIGURE 3.

FIGURE 3. GIS CONTOUR MAP WITH AMBIENT MEASUREMENTS (PPM)

TABLE 3. AMBIENT MEASUREMENTS AROUND LANDFILL A

Location	Peak Conc. Range (ppm)
Residential neighborhood(West)	0
Commercial neighborhood(south)	0.4-6.7
East side of landfill	0-4.7

Some of the NMOC constituents such as alkylbenzenes and limonene along with H_2S are dominant odor sources (Zou et al, 2003). Although there are negligible health impacts caused by the VOC emissions from the Landfills A and B, the constituents of NMOCs and H_2S can be responsible for causing offsite odors. To evaluate offsite odor impacts, NMOCs and H_2S were estimated from VOC data.

The highest VOC concentration, 6.7 ppm, was observed on the southeast side of the landfill. VOCs measured by the MicroFID are composed of methane and NMOCs. In this analysis NMOC to VOC ratio is considered equal to NMOC to methane ratio. Therefore, the ratio of NMOC to VOC concentration in landfill gas is 0.016. Using this ratio of NMOC to VOC, the highest NMOC concentration would be 0.11 ppm. Most of the NMOC gas components have odor detection thresholds higher than 0.11 ppm (ATSDR, 2001) except dicholoroethylene which has an odor threshold of 0.085 ppm. Hence it is unlikely that there were offsite odor impacts due to VOCs.

Using a typical concentration of H_2S of 35.5 ppmv (EPA, 1990); the ratio of H_2S concentration to methane concentration in landfill gas is 8×10^{-5}. Again, since VOCs are mainly composed of methane, H_2S to VOC ratio is assumed to be 8×10^{-5} as well. Therefore, the highest H_2S concentration obtained would be 0.5 ppb which is less than the odor threshold for H_2S (0.5-10 ppb). Hence it is unlikely that offsite odor impacts occur due to H_2S.

Although there are no significant health or odor impacts caused by the emissions from the landfill, it can be observed from FIGURE 34 that ambient concentrations of VOCs on southeast side of the landfill are higher than the background (northwest) concentration. These higher concentrations extend 1.2 to 1.5 km from the active landfill cell center on the southeast side of landfill. Ambient air measurements could not be made around Landfill B because of the dense tree growth around the landfill.

Litter Survey Results: Litter surveys were performed around Landfills A and B following a procedure similar to Florida Center for Solid and Hazardous Waste Management (FCSHWM) (FCSHWM 2002). Accumulated roadside litter was collected around the landfill and counted after sorting was done based on size and material. The length of the roads from which litter was collected was obtained using ArcGIS software. Similar to FCSHWM methodology (FCSHWM 2002), counts per site were obtained by finding the litter count per 100 meters of road length.

TABLE 4. LITTER SURVEY RESULTS FOR LANDFILL A

Roads	**Length (meters)**	**Average Litter count (Large)**	**Average Litter count (Small)**
1	2700	153	24
2	4500	295	62
3	1600	293	68
4	1400	92	31
5	4000	485	73
6	1800	20	0
7	1100	253	28
8	1100	231	58
9	1500	170	29
10	1100	474	88

Litter was collected on ten selected roads in five days around Landfill A by the landfill personnel and the procedure is repeated every week. In this study, collected litter on all selected roads was counted and categorized for two collection rounds. Litter count obtained was normalized to road length. Average litter count values were obtained by averaging the values obtained in two collect rounds. TABLE 4 presents the results of the litter survey around Landfill A.

The average values of litter count normalized to road length for the roads around the landfills are less than the FCSHWM 2001 and 2002 state-wide surveys as shown in FIGURE 14. The coefficient of variation (COV) for Florida Centers 2001 and 2002 state-wide surveys was in the range of 8.5-9% (Florida Litter Study 2002). The COV for the data collected around landfill A was relatively high (70-90%). In this study, the maximum litter that accumulates around the landfill was measured and was found to be less than the FCSHWM 2001 and 2002 state-wide surveys. Analysis showed that the difference between the litter count values obtained from FCSHWM 2002 state-wide survey and around Landfill A was statistically significant at 5% level of significance.

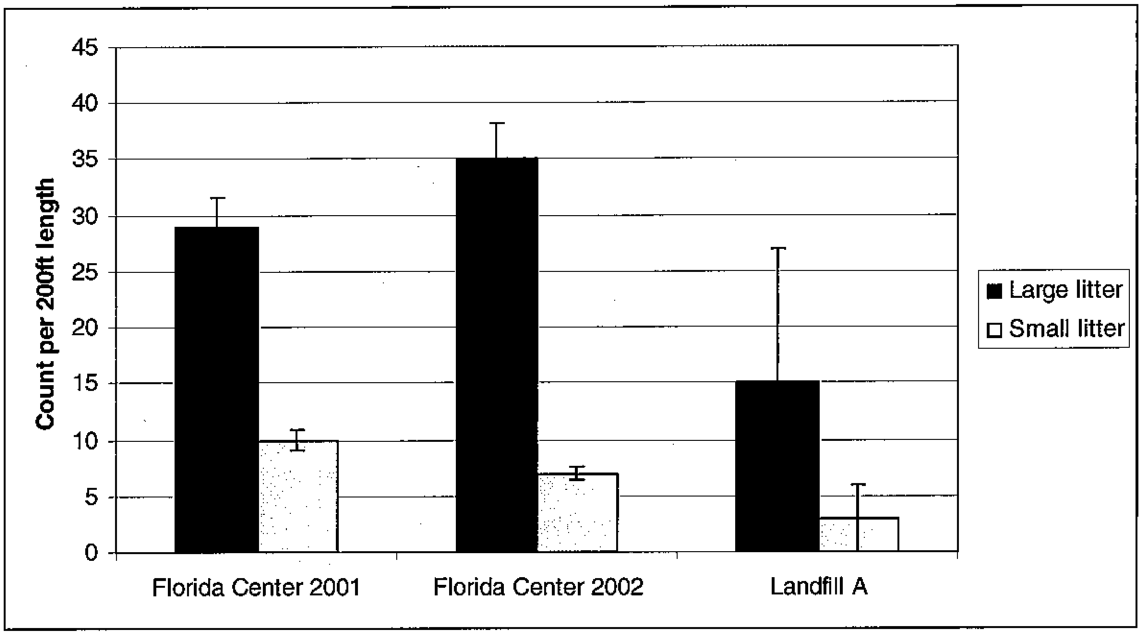

FIGURE 1. LITTER SURVEY AROUND LANDFILL A

Collected litter around Landfill A was also categorized based on material type. Results are shown in TABLE 55. From TABLE 55 it can be observed that paper and plastic constituted more than 80% of the total large litter items. Paper and plastic are the material categories which have lower density compared to other material categories. Hence higher percentage of paper and plastic might be due to litter blowing from the trucks and trailers arriving at the landfill. Occasionally, on some of the roads near the landfill, trash bags filled with household waste were collected which presumably fell from the trucks carrying waste to the landfill.

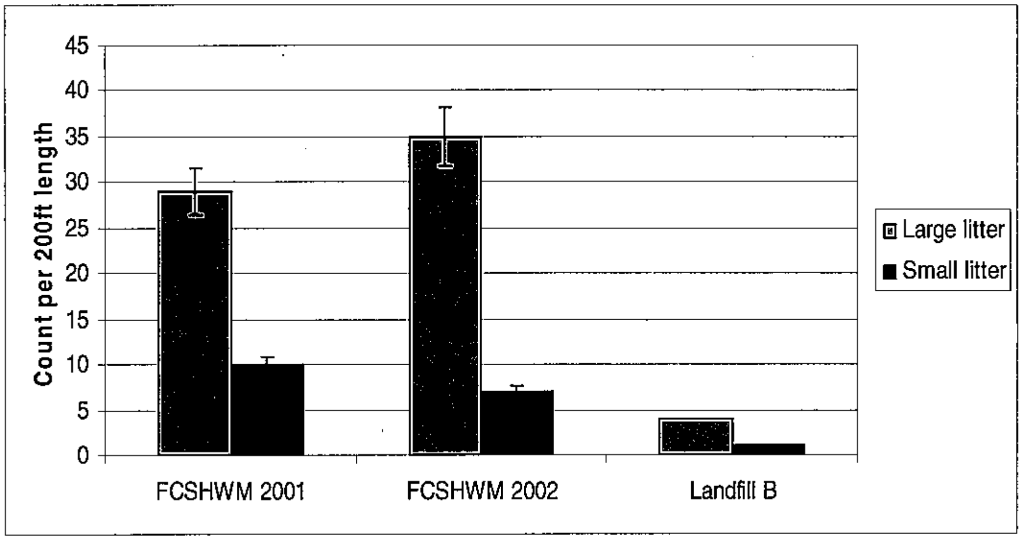

FIGURE 5. LITTER SURVEY AROUND LANDFILL B

There is only one approach road for landfill B which is accessed by trucks and trailers carrying the waste to the landfill. Collected litter on this approach road by the landfill personnel was counted and categorized. The procedure was repeated two times and average values of large and small litter counts were obtained. It can be seen from FIGURE 55 that for Landfill B the accumulated litter is negligible compared to FCSHWM 2001 and 2002 state-wide surveys. Statistical analysis has not been done for Landfill B because of small number of counts. For this purpose, a t-test was done to compare means.

Large litter collected on road segments around Landfill B was classified based on material type and compared with the FCSHWM state-wide surveys as shown in TABLE 55. It can be observed from TABLE 55 that, in the state-wide litter surveys conducted by FCSHWM, mixed and paper were more than 50% of total large litter; whereas, in the litter surveys around Landfill B, paper and plastic constituted more than 80% of total large litter. Similar to Landfill A, higher percentage of paper and plastic might be due to litter blowing from the trucks and trailers arriving at the landfill.

TABLE 5. CLASSIFICATION OF LARGE LITTER BY MATERIAL TYPE (% OF TOTAL COUNT)

Material	**FCSHWM 2001**	**FCSHWM 2002**	**Landfill A**	**Landfill B**
Mixed	35	36	8	2
Paper	25	24	49	27
Plastic	24	24	37	66
Aluminum	11	11	4	3
Glass	5	4	1	3
Steel	0	0	0	0
Composite	0	0	0	0

Property Values Results: Landfill A is located in one of the most densely populated counties in Florida. The area was chosen in 1975 for construction of a solid waste management facility when the surrounding land was vacant. The surrounding land was zoned in the County's comprehensive plan for light industrial and commercial use only. Construction of a waste-to-energy plant began in 1980 and during this time, construction of a residential community directly west of active landfill was approved. The effect of the landfill on residential property values was analyzed.

Houses at a particular distance from the edge of the landfill active cell were selected and the 10-year percentage change in the house price was obtained from a public website, http://www.zillow.com. An average value of 10-year percentage change of house prices was obtained for all the houses at a given distance from the edge of the active landfill cell and this procedure was repeated for various distances from the landfill.

Similar analysis was done for three additional landfills in Florida which have residential development near the landfill. It can be seen from FIGURE6 that the percentage change in house prices increased significantly 600 m to 800 m (2000 ft to 2600 ft) from the landfill cell boundaries.

Statistical analysis was done using MS EXCEL to examine the significance in difference of means of percentage change in house prices at various distances. Initially an F-test was performed to evaluate whether variances of sample data at various distances are statistically different. For Landfill A, house data at distances below 400 m were combined and compared with the combined data at distances above 800 m. The initial F-test obtained p-value was significantly greater than 0.05. Hence, it can be concluded that the variances of the two samples are statistically the same at 95% confidence interval. Further, a t-test was performed assuming equal variances and a p-value significantly less than 0.05 was obtained. This shows that the mean value of data below 600 m is statistically different than the data above 800 m. Similar analysis for Landfills C and D showed that the mean of the house data below 600 m is statically different from the mean of the house data above 800 m. However, for Landfill E there was no statistical difference in means at distances less than 600 m and greater than 800 m.

Hence, based on this analysis, a setback distance of 800 m to 1200 m from active landfill cells is recommended to minimize the impact on residential property values. TABLE 66 compares setback distances recommended in this study and other studies conducted on impact of landfills on housing prices. Since the impact caused by the landfills is a function of many parameters such as operational characteristics and landfill age, the difference in the spatial impact observed around the landfill is expected.

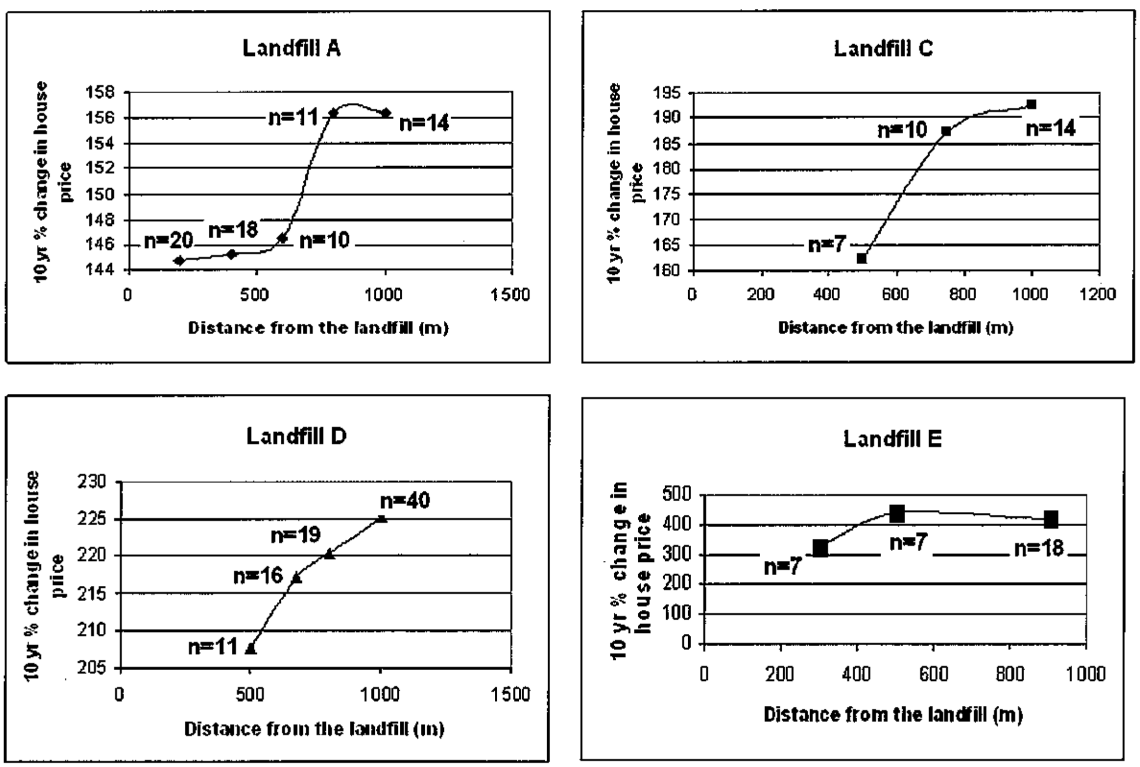

FIGURE 6. EFFECT OF LANDFILL ON PROPERTY VALUES

TABLE 6. COMPARISON OF SETBACK DISTANCES

Source	State	Setback distance from the landfill (km)
Schulze et al (1986)	California	0.3

Nelson et al (1992)	Minnesota	3-4
Gamble et al. (1982)	Pennsylvania	1.6
Present study	Florida	0.8 to 1.2

Noise Measurements: Noise measurements at Landfill A were made in July 2006 (during typical WTE activity) and October 2006 (during landfilling of unburned waste). FIGURE 77 shows the locations of stationary meter measurements during typical WTE activity. A stationary meter located directly in front of the WTE facility Bay 4, Location 4, captured the noise levels associated with the trucks coming and going from the WTE facility, backup beepers, and crane operations. This site recorded a L_{eq} of 64.2 dB(A) and an L_{max} of 76.4 dB(A) and a standard deviation of 2 dB(A). L_{eq} (Equivalent Sound Level) is a steady-state sound which has the same A-weighted sound energy as that contained in the time varying sound in the measurement period and L_{max} is the highest noise level during the measurement period. The L_{eq} and L_{max} values obtained at locations 1, 2, 3 and 4 (FIGURE 77) are shown in TABLE7 along with the standard deviation values.

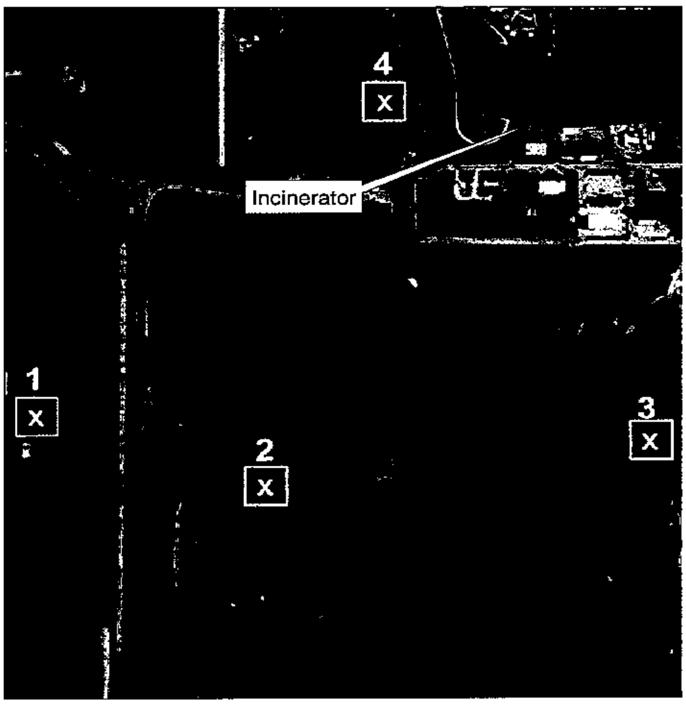

FIGURE 7. NOISE MEASUREMENTS DURING TYPICAL WTE ACTIVITY

TABLE 7. NOISE MEASUREMENTS ON LANDFILL A DURING WTE ACTIVITY (DB(A))

Location	L_{eq}	L_{max}	St. dev
1	58	66.3	4.3
2	58.3	63.7	3.7
3	62.4	65.9	3.9
4	64.2	76.4	2

A roving meter was used to take recordings even closer to the WTE facility and on all four sides of the operations. These sites helped determine a background noise level associated with the landfill during WTE operation, as well as the sound levels associated with the WTE facility directly.

A second set of measurements were made on Landfill A in October 2006 when the WTE facility was shut down for maintenance. During this period all incoming waste was sent to the landfill directly. Measurements were made directly in front of the WTE facility Bay 4 as shown in FIGURE8.

In order to record sound levels (TABLE8) associated with garbage collection trucks, dump trucks, and transfer trucks arriving at the landfill, a microphone setup was deployed, 10 meters (25 feet) and 15 meters (50 feet) from the landfill access road.

TABLE 8. NOISE MEASUREMENTS DURING WTE FACILITY SHUTDOWN

Site Description	**L_{eq}**	**L_{max}**	**St. Dev**
Across from Inactive WTE	63.6	81.6	4.1
15 m from access road 90 m from landfill	67.7	76.0	5.6
10 m from access road 85 m from landfill	71.3	84.2	3.4

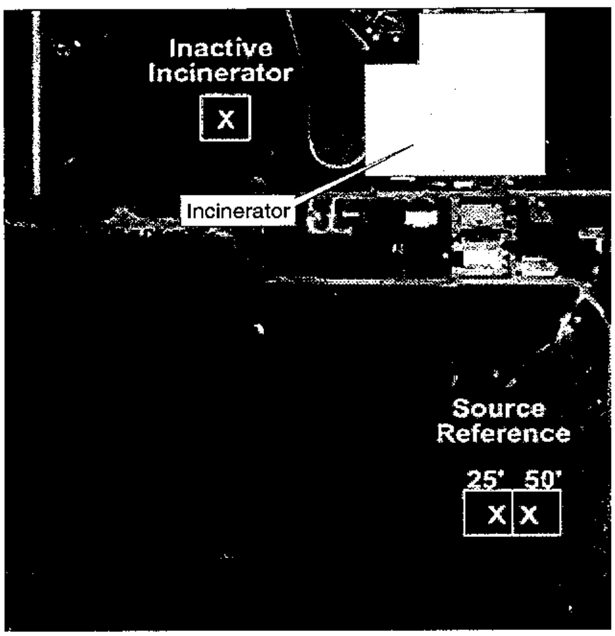

FIGURE 8. NOISE MEASUREMENTS DURING WTE FACILITY SHUTDOWN

Noise measurements were made on Landfill B during March and April 2007. Landfilling was the only source of noise from this landfill. Hence, measurements were made to capture the noise levels associated with landfilling activity.

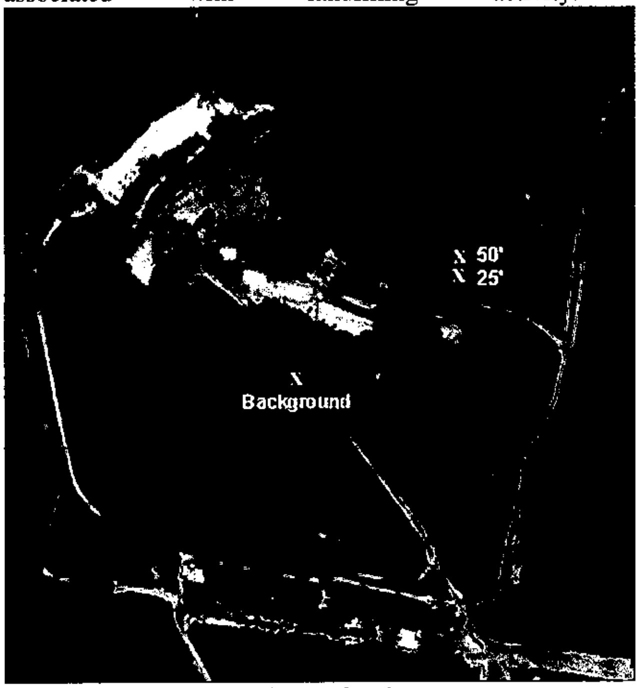

FIGURE 9 shows locations of noise measurements on Landfill B. Background measurements were taken 200 meters from the active landfill zone and, similar to Landfill A, measurements were made at 10 and 15 meters from the landfill access road (**Error! Reference source not found.**9).

TABLE 9. NOISE MEASUREMENTS ON LANDFILL B (DB(A))

Site Description	L_{eq}	L_{max}	**St. Dev**
Background Site 200 m from landfill	54	73.7	5.2
15 m from access road 100 m from landfill	59.4	70.0	3.6
10 m from access road 80 m from landfill	60.3	76.8	4.5

TABLE10 shows a summary of noise measurements made at Landfills A and B. Based on field measurements at both landfills it can be observed from

TABLE10 that to achieve EPA recommended values of 55 dB(A) for quiet neighborhood, a setback distance of 1.6 to 1.9 km should be maintained around the landfill if no shielding occurs.

TABLE 10. SUMMARY OF NOISE MEASUREMENTS AT LANDFILLS A AND B

Distance (Meters)	**Location**	**L_{eq} dB(A)**	**desired L_{eq} dB(A)**	**d2 for L_{eq} (miles)**
100	Landfill A	64.2	55	0.5
100	Landfill B (or Landfill A with WTE inactive)	69.4	55	0.9

FIGURE 9. NOISE MEASUREMENTS ON LANDFILL B

It can be observed from TABLE8 and **Error! Reference source not found.**9 that Landfill A recorded higher measurements than Landfill B. The distances recommended in

TABLE9 do not account for ground effects and other topological factors that affect the sound wave propagation between the source and the receptor. Also, it is important to note that the noise measurements recorded may vary when there is a change in the location of landfilling activity.

Dust Measurements: Dust measurements were made at Landfill B over a 48-hour period. Two particulate samplers, known as Mini Vols, were set up on Landfill B as shown in FIGURE 1010. The choice of locations for the Mini Vols was somewhat limited due to sensitivity of the equipment and the layout of the active cell.

The first Mini Vol was located about 200 meters off the access road in a inactive area (Figure 10). This site was upwind of the active landfill in a relatively secluded area, and provided background dust levels. The second Mini Vol was located in the active cell area, 50 meters from where the bulldozers were moving waste (FIGURE 1010). This downwind location was selected to collect the particulate matter directly associated with landfilling activity. It is important to note that in an attempt to avoid filter clogging the equipment was located away from traffic that would stir up large amounts of dust. Each location used two 24-hour filters while on location. A 38-elemental break down and analysis of the dust samples collected was done by Chester LabNet (Oregon). TABLE11 gives the net concentration (downwind-upwind) of the ten highest elemental concentrations coming from the landfilling activity. Increase in concentration of all major analytes were observed

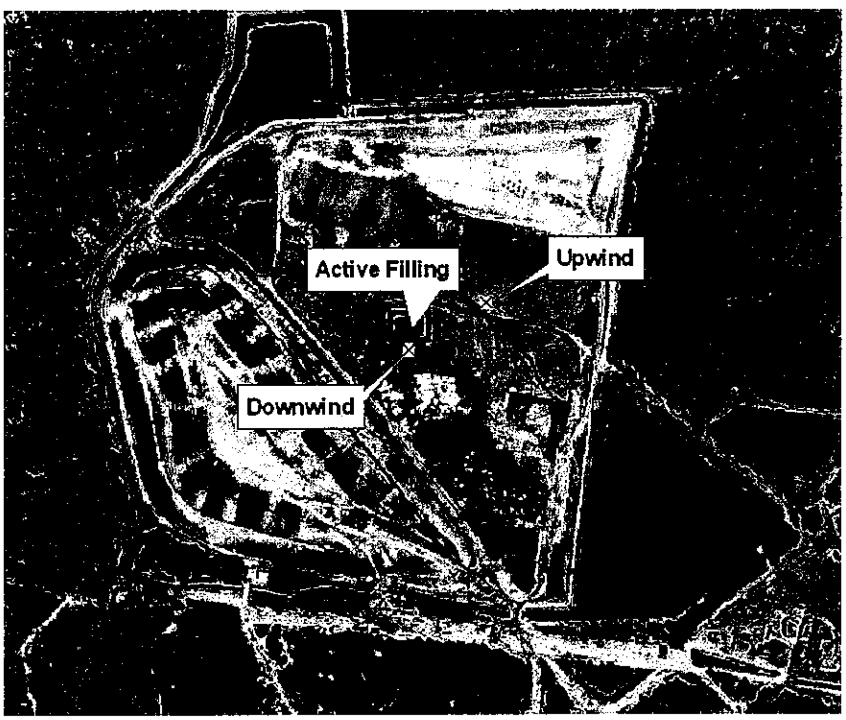

FIGURE 10. DUST MEASUREMENTS ON LANDFILL B

TABLE 11. NET CONCENTRATION OF HIGHEST ELEMENTAL CONCENTRATIONS UPWIND AND DOWNWIND OF LANDFILL B

Day 1		Day 2	
	μg/filter		μg/filter
Ca	3.493	Na	1.2586
Si	1.407	S	0.126

Al	0.793	Si	0.0791
Na	0.675	Sn	0.0735
S	0.299	Ti	0.0475
Fe	0.177	Ni	0.0452
K	0.061	Sb	0.0339
Cl	0.042	Al	0.0249
Cd	0.037	Ag	0.0238
Ti	0.036	Fe	0.0158

The Mini Vol located in the upwind location collected a total mass of 110 mg in 24 hours (14.9μg/m^3) and the second Mini Vol located in the downwind direction collected a total of 136 mg in 24 hours (18.4μg/m^3). Both of these values are below National Ambient Air Quality Standards (NAAQS) of 150μg/m^3 for PM_{10} (US EPA 1997).

Conclusions and Recommendations

This study investigated a methodology to gather scientific and quantifiable data and recommend setback distances from landfills to minimize nuisance impacts. Based on the results obtained, the impact distances recommended for Landfill A are shown in

TABLE 1212. Because of Landfill B's remote location, VOC, house price, and visual impact could not be evaluated, and only noise impact distance values would apply.

TABLE 12. OBSERVED IMPACT DISTANCES FROM ACTIVE CELLS

Nuisance	**Impact Distance (km)**
Noise	1.6-1.9
VOCs	1.2-1.5
House prices	0.8-1.2
Complaints/Visual	0.45-0.5
Litter	No Impact

It can be observed from

TABLE 1212 that noise is the most significant off-site impact. Since the nuisances caused by the landfill are function of landfill characteristics including landfill age, operating conditions and equipment used, the value of impact distances and the order of importance of nuisances are expected to be site specific.

VOC concentrations were measured and the concentrations of odorous compounds were obtained by using the default concentration ratios of gases present in the landfill gas due to study budget. Better estimation of gaseous impacts can be done by directly measuring the concentration of various odorous gases present in landfill gas. Also, this study did not consider the traffic impact caused by the landfill. Traffic impact can be evaluated by calculating the volume of traffic on the roads near the landfill and comparing with the standard traffic conditions. Visual impacts and bird nuisances can be minimized by maintaining a line of tree growth around the landfill. Also, operational changes such as active gas collection and minimizing exposed active area which would reduce the gas emissions from the landfill are important to reduce offsite impacts.

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- Integrated Solid Waste Systems
- Public/Private Partnerships
- Human Resource Issues
- Waste-to-Energy Options

TECHNICAL PROGRAM

S.C. = SWANA Certified

DAY 1

Monday, June 9, 2008

8:00 A.M. - 5:00 P.M.

Registration Open

8:00 A.M. - 9:00 A.M.

Continental Breakfast

9:00 A.M. - 10:30 A.M.

Keynote Presentations

Welcome and Introduction

Stephanie Hinson, *Landfill Management Division Director, S.C.*

John Carlton, *Planning & Management Division Director, P.E.*

Keynote Presentation

Greenhouse Gas Issues and the Solid Waste Management Industry

Frank Caponi, *Los Angeles County Sanitation Districts, Calif.*

10:30 A.M. - 11:00 A.M.

Break

11:00 A.M. - 12:30 P.M.

Plenary Presentation & Panel Discussion

Greenhouse Gas Credits from Landfill Gas Collection Provides Other Environmental Benefits

Michael L. Leonard, *Sr., SCS Engineers, Calif.*

Building Community Relations - Panel Discussion

Establishing a working relationship with your community is essential to ensuring an efficiently operated solid waste system. Whether you are siting a new landfill, expanding an existing landfill, operating a waste to energy facility or managing a transfer station, maintaining a strong relationship with your community is extremely important. This session discusses ways you can build your relationship with your community and improve your facility's image.

12:30 P.M. - 2:00 P.M.

Lunch

SWANA's Landfill Management Division worked all year to produce four high-quality, peer-reviewed landfill papers. The two Monday afternoon sessions in the Landfill Technical Session Track feature these four papers. Do not miss this rare opportunity to hear these presentations and to ask these landfill industry experts questions.

2:00 P.M. - 3:00 P.M.

Landfill Management Track

Peer Reviewed Research: Urban Infilling & Landfill Reclamation

Urban Infilling Impacts on Florida Solid Waste Facilities

Dr. Debra Reinhart, *University of Central Florida, Fla.*

City of Clovis Landfill Reclamation and Reconstruction Project

Luke Serpa, *City of Clovis, Calif., S.C.*

Planning & Management Track

Human Resource Issues

Kenneth Baylor, *Republic Waste Services, Inc.*

Mr. Baylor will discuss important issues all solid waste managers have to deal with on a regular basis, including: new hire training, succession planning, employee retention and motivation, behavioral issues and communication. This session looks at successful strategies for managing and maintaining a highly motivated and productive work force through site-specific examples and general-management theory.

3:00 P.M. - 3:30 P.M.

Break

3:30 P.M. - 4:30 P.M.

Landfill Management Track

Peer Reviewed Research: GHG Issues and Post-Closure Care

Landfill Gas and Greenhouse Gas Emissions: An In-Depth Assessment

Tej Gidda, *Conestoga-Rovers & Associates*

Post-Closure Care-Expect the Unexpected

Robert Schoenberger, *Chester County Solid Waste Authority, Pa.*

Planning & Management Track

Extended Producer Responsibility - Panel Discussion

Many local governments do not have the resources to effectively manage the hard-to-recycle products in the waste stream. This has lead many local governments to establish producer responsibility for these products. Through this panel discussion you will learn how local government councils have formed to accomplish this goal.

4:30 P.M. - 5:30 P.M.

Landfill Management Division Meeting

(Open to All)

6:00 P.M. - 8:00 P.M.

Welcoming Reception and Table Top Trade Fair

Sponsored by:

DAY 2

Tuesday, June 10, 2008

7:30 A.M. - 8:30 A.M.

Continental Breakfast

7:30 A.M. - 5:00 P.M.

Registration Open

8:30 A.M. - 9:30 A.M.

Landfill Management Track

Landfill Covers

Design and Construction of an Enhanced Evapotranspirative Cover in Southeast Texas

Dr. Beth Gross, *Geosyntec Consultants*

Performance Assessment of the Kiefer Landfill Alternative Cover Pilot Test

Jason Smesrud, *CH2M HILL*

Planning & Management Track

Carbon Credit Trading Platforms - Panel Discussion

This discussion features experts from different carbon credit trading platforms discussing the specifics of buying and selling offsets in the carbon market. This session will describe the origin of emission offset credits, or carbon credits, and will explain the differences between various trading platforms. This session will help solid waste managers fully understand the options available for trading carbon credits, and will review available markets.

9:30 A.M. - 10:00 A.M.

Break with Exhibitors

10:00 A.M. - 11:30 A.M.

Landfill Management Track

Leachate Challenges

Challenges of a Leachate Sump Riser Replacement

Michael Abberton, *Sanborn, Head & Associates*

New Approach to Landfill Leachate Removal Systems

Te-Yang Soong, *CTI and Associates, Inc.*

Closed Loop Leachate Management Using Engineered Wetlands and a Phyto-Cap

Carrie Pendelton, *Geosyntec Consultants*

Planning & Management Track

Solid Waste Management - Business vs. Service

This session will discuss the different management models used to run your solid waste operation; will it be run as a business or service? Examine the differences in which you conduct your daily activities depending on how you operate and discuss the advantages and disadvantages inherent in each system. This sessions goal consists of having a productive discussion on the merits of running your solid waste operation as a business versus as a service.

11:30 A.M. - 1:00 P.M.

Lunch in Exhibit Hall

1:00 P.M. - 2:30 P.M.

Landfill Management Track

Groundwater Remediation

Landfill Closure Enhancements and Groundwater Remediation to Protect Water Quality in Biscayne Bay

James A. Nissen, *Brown & Caldwell*

Groundwater Contamination and Remediation - Essex County Landfill Site No. 2 - A Case Study

Todd R. Pepper, *Essex-Windsor Solid Waste Authority, Ontario*

Innovative Investigation Techniques of VOC Vapor Impacts to Groundwater and Confirmation of Hydrogeologic Model

Mark Verwiel, *Waste Management*

Planning & Management Track

Public/Private Partnerships - Panel Discussion

This session looks at public/private partnerships and discusses how these partnerships can be beneficial to your solid waste operation. The discussion will focus on different ways to form partnerships and key stakeholder issues while highlighting how the public can benefit from a well-conceived partnership. This session's goal is to identify benefits and risks inherent in public/private partnerships, common obstacles to overcome and ways to strengthen existing partnerships.

2:30 P.M. - 3:00 P.M.

Break

3:00 P.M. - 4:30 P.M.

Landfill Management Track

Closure Case Studies

Tacoma Landfill White Goods Facility Brownfield Redevelopment - A Case Study on Mitigating Differential Settlement Impacts on a Closed Landfill

Lewis Griffith, *City of Tacoma, Wash.*

A Tale of Two Seasons: Closure at the Campbellsville Landfill

Gordon Parish, *Malcolm Pirnie, Inc., P.E., CPG*

Trash to Treasure: Lantana Landfill Becomes Championship 18-Hole Golf Course

Anika Crawford, *CDM*

Planning & Management Track

The Resurgence of Waste-to-Energy and Conversion Technologies - Panel Discussion

This session examines the many different WTE options and the progression of facility expansion and construction around the country, with an emphasis on discussing why different options make sense for different communities. This session's goal includes attendees discussing the available WTE options and gaining information on the latest developments in the WTE industry.

4:30 P.M. - 5:30 P.M.

Planning & Management Division Meeting

(Open to All)

4:30 P.M. - 5:30 P.M.

Landfill Bioreactor Committee Meeting

(Open to All)

DAY 3

Wednesday, June 11, 2008

7:30 A.M. - 8:30 A.M.
Continental Breakfast

7:30 A.M. - 12:00 P.M.
Registration Open

8:30 A.M. - 9:30 A.M.
Landfill Management Track
Landfill Expansion and End Use

Leachate Trends, End Use, and the Sustainable Landfill
Jeremy Morris, *Geosyntec Consultants*

Innovative Technologies for Landfill Expansion
Cami Van Abel, *R.W. Beck*

Planning & Management Track
Estimating and Reducing Greenhouse Gas Emissions

The New World of Greenhouse Gas Emissions for Landfills
Patrick Sullivan, *SCS Engineers*

A Carbon Neutral Landfill
Jen Lavoie, *Sperling Hansen Associates*

9:30 A.M. - 10:00 A.M.
Break

10:00 A.M. - 11:30 A.M.
Landfill Management Track
Bioreactors

Performance of an Anaerobic Digester for Biodegradation of Green Waste
Ramin Yazdani, *Yolo County Department of Public Works, Calif.*

Design of the Aeration System in Aerobic Landfill Systems
Dr. M. Sinan Bilgili, *Yildiz Technical University*

Steam Injection Landfill Bioreactors
Reg Renaud, *STI Engineering*

Planning & Management Track
Integrated Solid Waste Management Planning

Collier County, FL: A Case Study in Integrated Solid Waste Management
Daniel Dietch, *CH2M Hill*

Evolution of Integrated Solid Waste Management Systems – Enhanced with Municipal Utilities and Green Energy Production
Paul Hauck, *CDM*

Weathering Broward County's Perfect Storm
Sandy Gutner, *Malcolm Pirnie*

12:00 P.M. - 5:00 P.M.
FACILITY TOUR
(separate fee, lunch provided)

Lamb Canyon Landfill, Riverside County, California

DAY 4

Thursday, June 12, 2008

7:00 A.M. - 5:00 P.M.
Training Registration Open

8:00 A.M. - 5:00 P.M.
Landfill Operational Issues Workshop
(separate fee, continental breakfast and box lunch included)

8:00 A.M. - 5:00 P.M.
Landfill Fires Workshop
(separate fee, continental breakfast and box lunch included)