

Fugitive Dust Modeling with AERMOD for PM10 Emissions from a Municipal Waste Landfill

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ABSTRACT

This paper discusses issues and challenges addressed during a project to calculate and model fugitive dust and PM10 emissions from a large municipal solid waste (MSW) landfill located in eastern Oregon. The model selected for the study, which was completed in 2004, was AERMOD Version 02222. AERMOD Version 04300 was promulgated by USEPA as a regulatory model in the *Guideline on Air Quality Models*¹ on November 9, 2005.

To permit a planned facility expansion, the Oregon Department of Environmental Quality (ODEQ) required the facility to complete an air quality impact analysis for PM10 emissions. Total PM10 emission increases, including fugitive dust emissions from haul trucks on paved and unpaved roads and from landfill waste handling, were required to be included in an ODEQ (state-only) Prevention of Significant Deterioration (PSD) analysis.

Important project issues and challenges included utilizing appropriate methods to calculate fugitive PM10 emissions for input to modeling using USEPA AP-42 Section 13, selecting AERMOD source parameter inputs, and processing representative meteorological and site characteristic data inputs. An important up-front modeling data input issue was the PM10 emission calculation methodology. Given the planned large number of haul trucks entering the facility, PM10 emissions calculations, and thus modeled impacts, were highly uncertain and sensitive to roadway length, roadway silt content, proposed dust suppression techniques, and other assumptions employed.

Passing the PM10 PSD increment threshold values was challenging. Multiple project refinements and detailed justification was made in the Air Quality Modeling Report to show compliance with ODEQ standards. Refinements are discussed in detail in the paper.

Going beyond experience with the eastern Oregon landfill, this paper examines regulatory and technical issues associated with regulating fugitive dust emissions in air permits. The role of state agencies in applying dust control measures or requiring modeling is examined. Challenges of modeling fugitive PM10 emissions with AERMOD are discussed, including developing input source parameters (area and volume sources), establishing average hourly emission rates, issues with source and receptor elevation inputs, meteorological data processing, and use of deposition algorithms.

INTRODUCTION

This paper discusses the regulatory and technical issues with using AERMOD to model impacts from fugitive PM10 emission sources at municipal solid waste (MSW) landfills. In 2003 and 2004, SCS Engineers and BlueScape Environmental teamed to complete a challenging PM10 modeling study for a landfill located in eastern Oregon. Fugitive PM10 emission sources included paved and unpaved roads, storage piles and waste material handling operations. The specific facility is not named due to ongoing permit negotiations.

The landfill is a Title V facility, but is excluded from federal Prevention of Significant Deterioration (PSD) source applicability. Nonetheless, because planned emission increases would exceed PSD significance thresholds, the Oregon Department of Environmental Quality (ODEQ) cited authority under state air quality regulations to require a “state-only” PSD modeling study. The landfill was required to show compliance with the National Ambient Air Quality Standards (NAAQS) for PM10 which are equivalent to the Oregon Ambient Air Quality Standards (OAAQS). The facility was also not allowed to exceed the PSD PM10 increment thresholds.

At the time, ODEQ was in the forefront of state air agencies, in that AERMOD was already the regulatory model of choice. The project team expected the PM10 modeling study to be challenging from the outset. Many tons of fugitive PM10 emissions were calculated for haul roads located within 200 meters of the facility property line, or the location of “ambient air.” This situation is common, since entry and exit haul roads with the greatest traffic and PM10 emissions often run close to the facility boundary. As discussed in the paper, initial modeling results exceeding the 24-hour average PM10 increment threshold by more than four times, were reduced to below that threshold, using refinements and many AERMOD modeling iterations.

The first section of this paper presents an AERMOD case study, involving the eastern Oregon landfill. The second section provides details on current regulatory policies and technical issues regarding fugitive PM10 modeling and AERMOD. The focus of this paper is on mechanically generated PM10 emissions from haul roads. Uncertainty with using standard USEPA emission calculation methods, and use of AERMOD technical options to model these sources are described. The last section presents recommendations on how industrial facility staff, regulators, and modelers should assess potential impacts from proposed permitted fugitive PM10 emissions increases, and addresses the question - to control, model, or both?

MODELING FUGITIVE PM10 AT A LANDFILL - A FEW BAD DAYS

This section recounts experience using AERMOD to complete a fugitive PM10 modeling study. From the period September 2003 through September 2004, SCS Engineers and BlueScape Environmental completed the study for a MSW landfill located in eastern Oregon. The active landfill occupies 647 acres of a 2,000 acre property. The ODEQ was notified of increases in estimated facility fugitive Total Suspended Particulate (TSP) and PM10 emissions. The emissions were expected to increase due to a change in emission calculation methods and a proposed increase in waste intake.

The majority of total calculated PM10 emissions (80%) were from heavy truck traffic on paved and unpaved roads, and material handling activity in the main landfill area. Much of the those emissions, initially about 48 tons/year (68%), were estimated to be from trucks on the paved (PRD) and unpaved (MHR) sections of the Main Haul Road, and from “goats” that haul waste from railcars on the Main Haul Road to the Material Handling Area. PM10 emission estimates at the outset of the modeling project, and after completing emission calculation refinements are shown in Table 1.

Table 1. Summary of Landfill PM10 Emissions Before and After Refinement

Emission Source	Initial Estimates ¹		Refined Estimates ²		Difference (%)	
	PM10 (lb/day)	PM10 (tons/yr)	PM10 (lb/day)	PM10 (tons/yr)		
Paved Main Haul Road (PRD)	170.4	27.3	76.2	10.7	-55	-61
Unpaved Main Haul Road (MHR)	53.6	8.6	82.6	11.4	54	33
Unpaved Access Road (UPR)	10.7	1.7	12.9	1.8	21	6
Unpaved Railyard Road	74.6	11.9	33.4	4.8	-55	-60
Material Handling	48.7	7.6	74.6	11.6	53	53
Wind Erosion	16.3	2.5	32.5	5.9	99	136
Engines	5.6	0.7	5.1	0.7	-9	0
LFG Flare	55.2	10.1	85.2	15.6	54	54
Total	435.1	70.4	402.6	62.5	-7	-11

¹As submitted with the Modeling Protocol, September 2003.
²As provided in response to ODEQ comments on the Modeling Report, September 2004.

Figure 1 shows an aerial photograph of the landfill and select PM10 emission sources. Figure 2 shows a site plan and graphical rendition of modeled PM10 emission sources.

Figure 1. Aerial Photograph of the Eastern Oregon Landfill

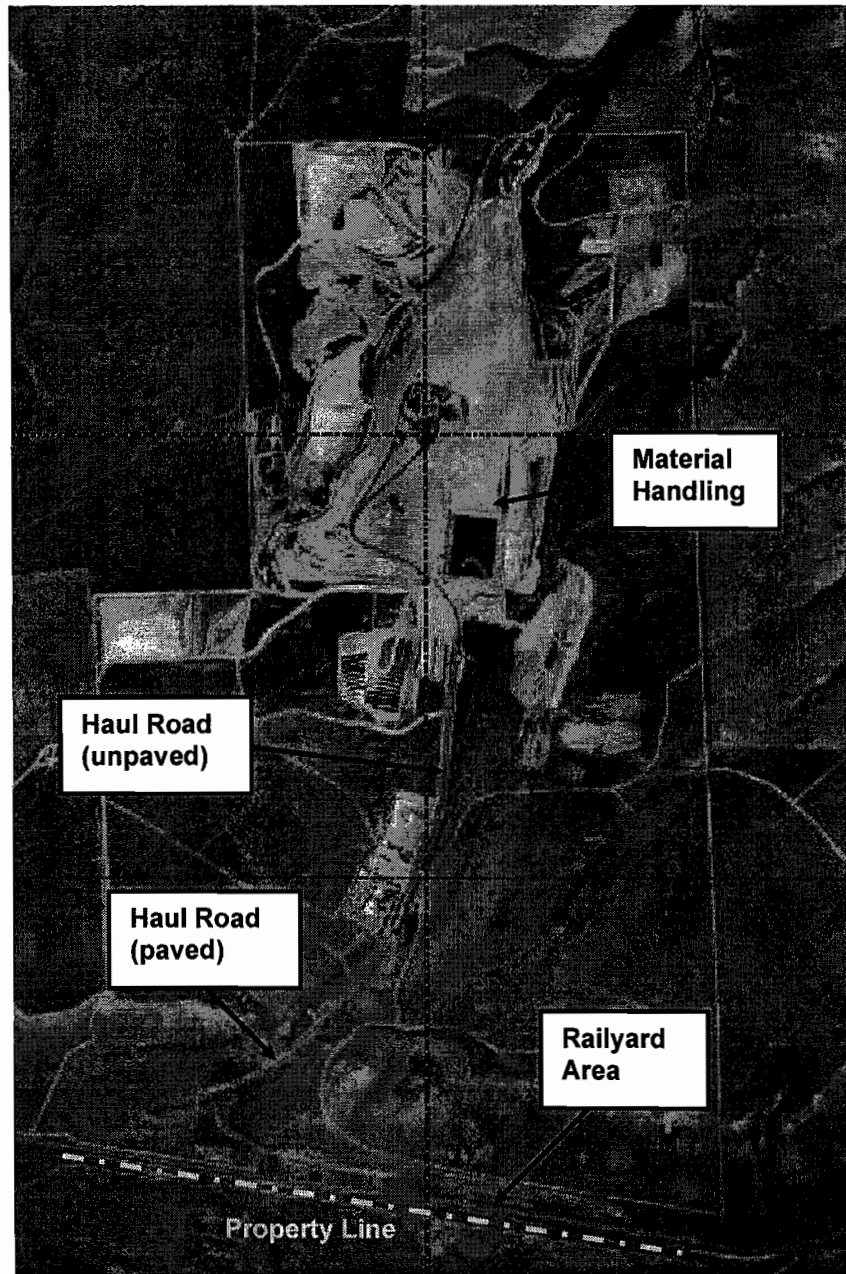
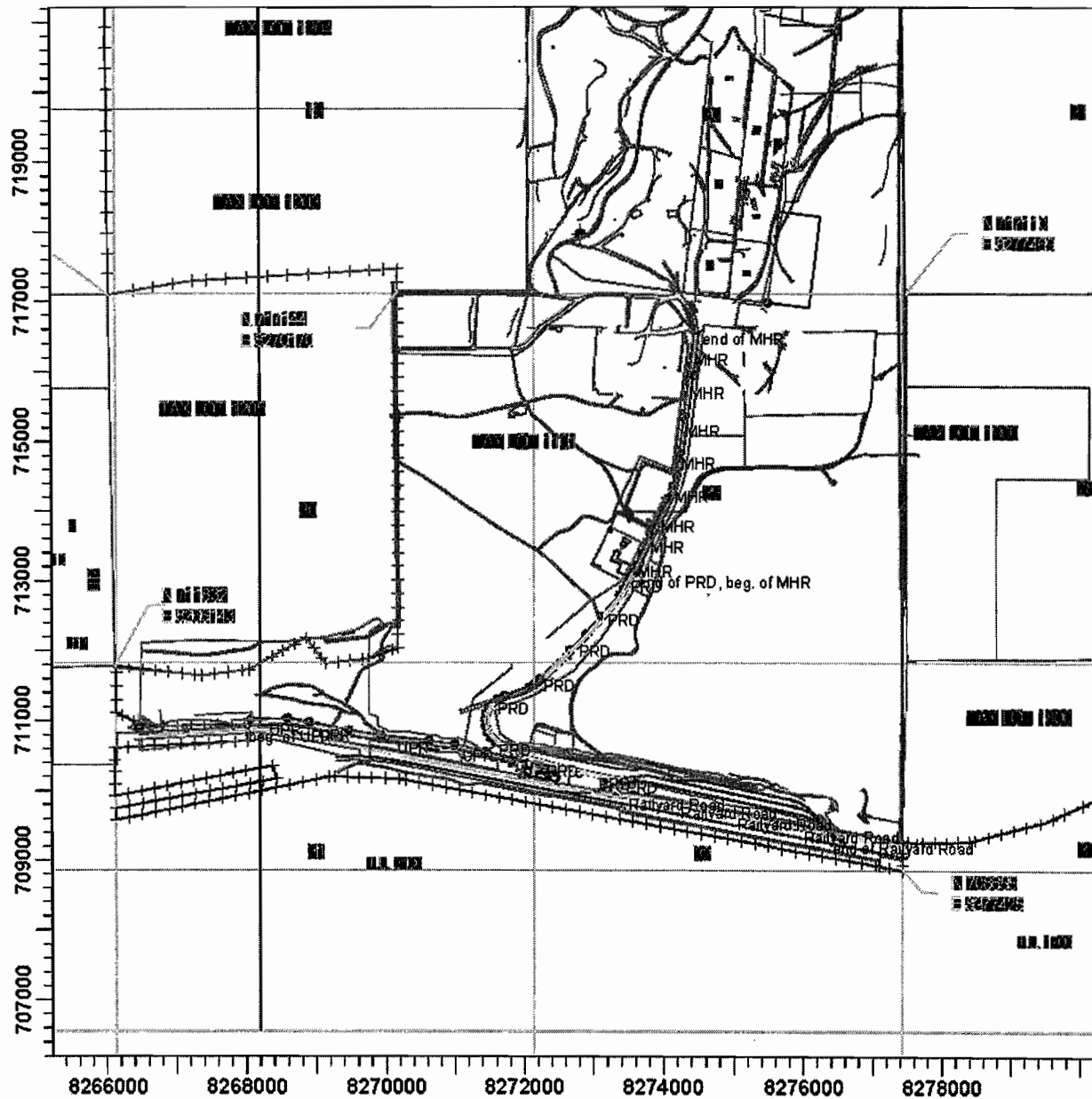


Figure 2. Map of Landfill Showing Modeled PM10 Emission Sources



Federal PSD modeling requirements were not triggered. MSW landfills are not one of the 28 source categories that must consider fugitive PM10 emissions increases for federal PSD applicability. Nonetheless, due to the fact permitted TSP and PM10 emissions were to increase substantially at a Title V facility, ODEQ required a “state-only” PSD modeling study. The facility was required to compare modeled impacts with the PM10 modeling significance thresholds, the OAAQS, which are equivalent to the NAAQS, and the PSD increments. A summary of these standards is provided in Table 2. As shown, the modeling significance levels requiring full impact modeling (*i.e.*, the significance thresholds that requires full modeling to

show compliance with the AAQS and increments) are a factor of 5 times lower in Oregon as compared to the federal levels. Generally, this would mean modeling fugitive emission sources would be more likely to trigger full impact modeling.

Table 2. Federal and Oregon PM10 Modeling Thresholds ($\mu\text{g}/\text{m}^3$)

Averaging Period	Federal			Oregon		
	Significance Threshold	Class II Ambient Standard	Increment Threshold	Significance Threshold	Class II Ambient Standard	Increment Threshold
24-hour	5.0	150	30	1.0	150	30
Annual	1.0	50	17	0.2	50	17

Because ambient PM10 impact modeling had not been completed for the facility, ODEQ required all PM10 emissions (not just the proposed increases) to be considered for the modeling study, including truck traffic on paved and unpaved roads, material handling storage piles, diesel engines, and a landfill gas flare.

PM10 emissions were calculated using default USEPA methods from AP-42 Section 13. Silt sampling was conducted at roads to provide for more accurate PM10 emissions estimates. Silt loading averaged about $4.1 \text{ g}/\text{m}^2$ on the paved road, and $54.9 \text{ g}/\text{m}^2$ on the unpaved Main Haul Road. Vehicle average truck weights, speeds and daily and annual vehicle miles traveled were estimated from a diverse fleet mix. Material Handling emissions were based upon estimates of total daily and annual waste disposal and earth movement amounts, with rainfall and wind data representative for the area. Paved Main Haul Road emissions were assumed to have 79% cumulative emissions control from watering and sweeping. Unpaved Main Haul Road emissions were assumed to have 88% cumulative emissions control from watering and chemical suppressants. Railyard Road emissions were assumed to have 80% cumulative control from watering and gravel coverage.

The modeling study utilized AERMOD Version 02222 that was current at the time. A Modeling Protocol was submitted to ODEQ in September 2003 and approved. Following ODEQ guidance, baseline modeling was complete using AERMOD and area sources for fugitive road, storage pile and material handling PM10 emission sources. The maximum baseline PM10 concentrations from modeling were in compliance with the NAAQS and OAAQS. The baseline modeling also showed compliance with the PM10 annual average increment threshold, $17 \mu\text{g}/\text{m}^3$.

However, the baseline maximum 24-hour average PM10 concentration, $125 \mu\text{g}/\text{m}^3$, exceeded the increment threshold, $30 \mu\text{g}/\text{m}^3$ by more than a factor of four. Examination of model results by source showed high impacts due to PM10 emissions from only a few segments of the paved and unpaved main haul road, and from the unpaved Railyard Road. These impacts occurred on only a few “bad” days, in a highly localized area extending for about 200 meters from the southern landfill property line. That property line is at the location of a remote county road with no local

residences or businesses along the road. On the maximum impact days, 24-hour average PM10 concentrations were dominated by notably high impacts during only a few one hour periods. The modeled one-hour average values ranged on the order of 200 to 500 $\mu\text{g}/\text{m}^3$. The high one-hour average impacts occurred during very stable atmospheric conditions with light winds. Low surface friction velocity and stable boundary layer (SBL) depth values were noted in the meteorological data file for these hours.

Sensitivity analyses were completed in earnest by updating emissions estimates and changing AERMOD input source parameters. At this point after many iterations, the refined maximum PM10 24-hour average concentration was reduced to 62 $\mu\text{g}/\text{m}^3$, still more than twice the increment threshold. The project team contacted ODEQ and provided initial modeling results. Given that dominant 24-hour average impact results from AERMOD occurred on only a few bad days in a localized area, the project team requested that ODEQ require only the annual average PM10 impacts to show compliance with the PSD increments. ODEQ refused this request, but recommended that the project team continue to work on refinements to the modeling study.

Following ODEQ direction, considerable work was continued to work with AERMOD to refine the 24-hour PM10 concentration values. The following techniques (and more) were considered:

- Modeled multiple line (volume) sources in AERMOD instead of area sources;
- Used ISCST3 instead of AERMOD;
- Increased the haul road effective source release height and dilution depth to account for vertical emissions dilution from moving trucks;
- Increased the haul road effective width to account for horizontal mixing;
- Refined emission estimates to account for greater dust suppression, refined the average number of truck trips and trip lengths, and used more accurate road length estimates;
- Refined the area source configuration for the Railyard PM10 emissions;
- Located the property line more accurately;
- Apportioned emissions throughout the day according to traffic volume, versus equal hourly emission rates for each hour of the 24-hour operations day;
- Refined receptor and source input elevations;
- Ignored modeled hours with measured precipitation as potential emission hours;
- Ran plume depletion from dry deposition using the beta version of AERMOD, Version 03273.

ODEQ was supportive of reasonable refinements. Although such techniques as using line sources and ISCST3 lowered impacts, lacking EPA guidance to change protocol, the project team decided to follow ODEQ guidance and stay with using area sources and AERMOD to model fugitive PM10 emission sources. Much of the modeling refinement that was completed was to recalculate fugitive PM10 source emissions. As shown in Table 1 above, emission estimates for the Paved Road and Railyard Road were reduced substantially, by about 55% to 60%. PM10 emission increases from the unpaved Main Haul Road, Material Handling and the landfill gas flare due to ODEQ comments did not have an appreciable impact on the study conclusions. Impacts were also lowered substantially by accounting for initial horizontal and vertical mixing of PM10 emissions on haul roads.

The final modeling study submitted to ODEQ showed compliance with the PM10 standards and thresholds, just passing the PM10 24-hour increment value with 28.6 µg/m³. The modeling report was submitted to ODEQ in June 2004.

FUGITIVE PM10 MODELING WITH AERMOD - REGULATORY POLICY ISSUES AND TECHNICAL CHALLENGES

This section discusses current regulatory policies, and technical challenges with using AERMOD to complete dispersion modeling for air quality impact analyses. The focus of this section is on fugitive PM10 emissions from paved and unpaved roads. However, much of the discussion can also be applied to storage pile and material handling emissions at landfills, as well as fugitive emission sources in other industries.

Regulatory Policies Regarding Fugitive Dust Control and Air Quality Modeling at Landfills

USEPA and state air agencies in the United States have long recognized that regional fugitive dust and PM10 emissions can contribute to health problems in the public at large. Many state and local air agencies have enacted rules or policies to control fugitive dust emissions. These rules or policies generally focus on the physical methods to reduce dust emissions generation. Agencies may term these methods as Best Available Control Methods (BACM) or Reasonably Available Control Methods (RACM).

Under federal and state new source review (NSR) rules, air quality modeling is commonly required to permit new or modified permit units. This is especially true for major sources. Fugitive PM10 emissions, especially generated by traffic at a stationary source, may or may not be included in permits. Thus, modeling requirements for fugitive sources will vary by agency jurisdiction.

The following are possible instances where dispersion modeling for fugitive PM10 sources may be required by a state or local agency:

1. The agency requires a Title V or major NSR source to show compliance with the federal or state PM10 AAQS and increment thresholds, including the possible impact from nearby background and competing emission sources;
2. State guidelines require air dispersion modeling for emission increases (including roadway emissions) from minor sources;
3. An air toxic health risk assessment is required, to consider potential community exposure to metals in fugitive dust emitted by a facility;
4. An agency requires an ambient air quality impact analysis for an environmental impact report (EIR) completed under the California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA);
5. A facility operator chooses not to follow BACM to control dust emissions, but rather, opts to show compliance with the ambient air quality standards using modeling.

Many municipal waste landfills in the United States are categorized as Title V facilities, although they do not meet the definition of a federal major source. This is due to the fact that the NSPS for Municipal Solid Waste Landfills (40 CFR Part 60, Subpart WWW) also triggers Title V applicability. As stated previously, for MSW landfills, the Part 70 Title V rules exclude fugitive emissions from major applicability. Nonetheless, state air agencies can have jurisdiction and the discretion to require air quality modeling when significant expansion and increase in PM10 emissions above current permit limits is expected. Regulatory air quality modeling requirements for major source and minor source projects are more likely to be triggered in attainment areas where states are striving to maintain good air quality.

In the more serious PM10 nonattainment areas, such as in Phoenix, Arizona, the South Coast Basin in Southern California, Clark County, Nevada and the San Joaquin Valley in California, agencies have set stringent fugitive dust emission control requirements. Interestingly, these agencies do not require stationary source facilities such as landfills to show compliance with the AAQS. Rather, these agencies utilize implementation of BACM as the best way to reduce PM10 emissions and to achieve compliance with the AAQS on a jurisdiction-wide basis. Examples include San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) Rule 8061 for paved and unpaved roads, and South Coast Air Quality Management District (SCAQMD) Rules 403 and 1186 for fugitive dust and roads.

EPA AP-42 Sections 13.2.1 (paved roads) and 13.2.2 (unpaved roads) list methods for controlling particulate emissions generation and dispersion from haul roads to off-site areas. These sections can be found at <http://www.epa.gov/ttn/chief/ap42/ch13/index.html>. Some of the methods include:

- Covering truck loads;
- Paving;
- Vacuum sweeping and broom sweeping;
- Water flushing or applying chemical suppressants;
- Installing berms and planting vegetation along roads;
- Limiting the number of vehicles, vehicle weight, distance or speed traveled.

The emission control efficiencies from these techniques can vary widely. AP-42 states that the commonly used watering technique can reduce emissions from unpaved roads by up to 100% by keeping the soil saturated. However, such control requires a tremendous amount of a precious resource (water) and fuel for watering trucks. Applying chemical suppressants can be costly and also have an environmental impact. If an agency will support modeling to show compliance with ambient air quality standards and/or protection of increments, then modeling might be more attractive than controls. By its very nature, an active landfill will expand in size and capacity with population growth. Landfill operators will generally not want to take operational restrictions

In Texas, a combination of BACM and air quality modeling may be employed to control fugitive PM10 emissions from fugitive sources, depending upon the stationary source type. The Texas Commission on Environmental Quality (TCEQ) *Modeling Guidelines* specifically state that road emissions should not be included in permit modeling analyses for short-term averaging periods,

that is, less than the annual averaging period². Annual modeling should not be completed if the emissions cannot be accurately quantified, or if best management practices are used to control emissions. TCEQ states, “combined with worst-case operating scenarios, the modeling tool [referring to ISCST3] will overpredict concentrations, particularly in the vicinity of the source, and may incorrectly identify road emissions as the major cause of air pollution at a site. Often the use of control measures and best management practices are the most effective means to address off-property impacts from road sources.” TCEQ developed a factor, 0.6, to be applied to ISCST3 and SCREEN3 model results to reduce the potential for overprediction³. As for use of AERMOD for fugitive PM10 emissions modeling, the TCEQ website states that this adjustment factor is not allowed, since AERMOD has better treatment of stability parameters than ISCST3. However, the website does not currently have guidance on implementation of AERMOD for these sources.

Regulatory Use of AERMOD for Fugitive PM10 Emissions Modeling

Dispersion modeling to show compliance with regulatory standards is generally completed using regulatory models following EPA’s *Guideline on Air Quality Models*¹ and written state guidelines or policy memoranda. Until December 9, 2005, ISCST3 was the regulatory model of choice in the United States. ISCST3 has a tendency to overestimate impacts from low-level PM10 emission releases. A study completed for the coal mining industry has shown that ISCST3 overestimates impacts by at least a factor of two⁴. A study referenced in that document submitted to the National Stone, Sand and Gravel Association (NSSGA) showed that ISCST3 predicted PM10 concentrations in the range of 0.87 times to 5 times monitored values.

According to USEPA, AERMOD is a better regulatory model than ISCST3 for a number of reasons⁵. For example, AERMOD has better treatment of vertical plume dispersion. For point and volume sources, the accounting for plume meander is a significant improvement. However, for low-level emission plumes, AERMOD has not been evaluated extensively by USEPA for performance against measured data, nor compared to ISCST3 modeling results. AERMOD will treat emission plumes from roadways as uniform for a given hour, when in actuality, these plumes are quite transient. While AERMOD may perform well as a regulatory model for source scenarios evaluated to date, AERMOD may or may not be reliable for modeling fugitive emission impacts. More formal evaluation by USEPA is needed.

Challenges of Modeling Fugitive PM10 Impacts with AERMOD

In modeling fugitive PM10 emission impacts with AERMOD, there will be assumptions made, uncertainties realized, and challenges faced. A number of questions might arise. How will PM10 emissions be calculated and what emission control techniques (at what control efficiency) must be considered for the emissions? Are these control techniques BACM, RACM, or optional, and what are the costs? When employing emission controls, should the agency waive modeling requirements for 24-hour average or annual average PM10 impacts? What is your justification, if this is your proposal? Does the state air agency have authority to decide that you must conduct modeling? How will you input emissions data and source parameters into AERMOD in a manner that will be technically accurate and not overly conservative? How will you properly characterize the meteorological data and surface characteristics that effect low-level dispersion?

Should you consider PM10 monitoring to verify that PM10 emissions do not cause the problems shown by modeling? Why not just conduct PM10 monitoring rather than modeling?

Challenge #1 – Characterizing Fugitive PM10 Emissions Modeling Inputs

To model fugitive PM10 emission impacts, AERMOD requires input average PM10 emission rates. Landfill owners and consultants faced with calculating fugitive PM10 emissions typically use USEPA AP-42 Section 13 calculation methods. For landfills, the most relevant sections are Section 13.2.1 (Paved Roads), Section 13.2.2 (Unpaved Roads), and Section 13.2.4 (Aggregate Handling & Storage Piles)⁶. These sections are currently under revision to update the emission calculation methods for PM2.5.

For MSW landfills, the focus is likely on PM10 emissions from paved and unpaved haul roads. Relatively high traffic volumes are common. For emissions per vehicle mile traveled (lb/VMT), the key inputs are average vehicle weight, distance traveled, surface silt content, particle size factor, and emissions from break and tire wear. Note that the paved road PM10 emission equations do not build in an assumption for average vehicle speed, even though greater speeds would be expected to generate higher emissions. The unpaved road empirical emission equations do require the mean vehicle speed and also the surface material moisture content.

A good degree of uncertainty exists with these empirically derived emissions calculation methods. The calculations are sensitive to silt loading (mass of silt-sized material per unit area of travel surface). Silt loading is site-specific and even road-specific, and thus, often requires site measurements to provide a realistic value. Uncertainty is also introduced when calculating average vehicle weights and speeds. Municipal waste trucks and on-site waste haul trucks (“goats”) vary widely in size and loaded weight entering landfills. On return trips, the average vehicle weights will be much less than fully loaded weights. Vehicle traffic volume can vary widely during a 24-hour day, which can impact the hourly PM10 emissions profile. The fully-loaded vehicle speeds would be expected to be much less than the unloaded vehicle speeds, especially when vehicles climb up a landfill slope. Thus, the average vehicle weights and emissions generation per square meter per day for haul roads must take into account this variability. Daily and hourly emissions are estimated based upon fleet averages.

Challenge #2 – Developing AERMOD Source Parameter Inputs

AERMOD was recently promulgated as the new regulatory model to replace ISCST3. While the plume transport equations have been improved, modeling source parameter input requirements for fugitive (non-point) sources have changed little. AERMOD will be widely applied and required for all types of emission releases including low-level fugitive PM10 emission releases. The modeler must understand how AERMOD model source parameter inputs will have bearing on impact study results.

To properly apply AERMOD and develop model inputs, one must understand the physical situation modeled. Take, for example, mechanically generated fugitive PM10 emissions from a haul road. As a large truck passes, a cloud of dust emissions will be picked up behind the truck and dispersed downwind for a brief period. Some of that cloud will consist of PM10 emissions.

The plume will have some initial vertical depth and lateral spread behind the truck. Heavier material will fall out quickly due to gravity, Brownian motion, and interaction with surface features. The plume centerline will descend toward the ground, at a rate that depends upon the atmospheric stability, soil composition and other factors. Smaller particles such as PM10 will be deposited further downwind from the source.

Area Versus Volume Source Configuration for Haul Roads

For haul roads and other fugitive emission sources, an important choice to make is whether the source should be modeled as an area or volume source. Written state air agency modeling guidelines may require that haul roads be modeled either way. Missouri, Nebraska, Nevada, Utah, South Carolina, and Vermont recommend that haul roads be modeled as area sources⁷. New Mexico, South Carolina, North Carolina, Oklahoma, and Texas suggest that haul roads be modeled as volume sources. Louisiana recommends modeling roads as a series of point sources. In the case of Oregon, ODEQ has shown preference for modeling roads as area sources. The *Guideline on Air Quality Models 5.2.2.2(e)*¹ states that roads can be modeled as either line, area, or volume sources. Where published guidelines or policies do not state a preference, the modeler will have some flexibility to state an approach. State guidelines will no doubt be updated as air agencies become more familiar with AERMOD.

To develop AERMOD inputs for a haul road as a series of area sources, the emissions flux in g/sec-m², source release height above ground, horizontal dimensions (x and y), and initial vertical plume dilution (σ_z) are required⁸. The *AERMOD User's Guide* recommends that an area source length be no greater than 10 times the area source width. For a long haul road, this can require many area source inputs and long model run times. AERMOD inputs for volume sources (or a line source consisting of adjacent volume sources) include the emissions rate in g/sec, source release height above ground, and the initial lateral (σ_y) and vertical (σ_z) plume dimensions.

Little guidance can be found from state agencies on how to develop the lateral and vertical source parameter inputs, σ_y and σ_z . For haul roads, the TCEQ recommends that volume sources have a source depth equal to two times the height of the vehicle generating emissions, with a source release height at half of that depth². TCEQ recommends that the adjusted width of a haul road be the actual width plus 6 meters. A study prepared for the National Stone, Sand and Gravel Association (NSSGA) titled *Modeling Fugitive Dust Sources* recommends that haul roads be modeled as area sources or volume sources with initial plume depth equal to two times the height of the vehicle generating the emissions, with source release height one half that depth⁷. In that study, the recommended adjusted road source width is the haul road width plus 9.75 meters. The (σ_z) parameter would be calculated as the initial plume depth divided by 4.3.

The *AERMOD Implementation Guide*⁹ states that the modeler should exercise caution when using the area source algorithm with low-level emission sources. Plume meander has not been included for area sources to date due to issues with excessive run times. The guidance states that concentrations from area sources may be overestimated during very light wind conditions. This was likely the case with the eastern Oregon landfill modeling study, which was completed prior to inclusion of plume meander in AERMOD. The guidance recommends that volume sources be

used instead of area sources for light wind conditions. If area sources must be used, the guidance recommends consulting the regulatory agency about possibly excluding high concentration hours as missing data.

Operating Schedule, Emissions Inputs and Hour-of-Day Scaling Factors

The minimum concentration averaging time in AERMOD is one hour. The 24-hour average concentrations are calculated from one-hour average concentrations. PM10 emissions from haul roads at landfills are variable. The emissions can vary by time-of-day, by season, and within each hour. The emissions profile will change as the landfill surface changes, as haul roads and material handling areas change location. On unpaved roads, vehicle speeds might vary over different lengths of a haul road.

The simplest modeling approach would be to divide all average daily or annual emissions calculated for haul road sources equally into the area or volume sources that represent that road. For planning purposes, and to more closely match emissions to daily peak periods and meteorology, a refinement would be to use hour-of-day or seasonal scaling factors. If a landfill only operates during daytime hours, the hour-of-day scaling factors with only daytime emission inputs would be appropriate since emissions cannot occur at night.

Source and Receptor Terrain Elevations

When fugitive PM10 sources such as haul roads are relatively close to modeled receptors, AERMOD results may be very sensitive to relative source-receptor elevation differences. State agencies often require source and receptor terrain elevations to be included in modeling. However, this requirement may not make sense for fugitive PM10 emission releases near ground level.

Under higher wind speeds and unstable atmospheric conditions, a fugitive dust plume might maintain appreciable height above ground and be dispersed rapidly downwind. These are seldom the conditions that will drive maximum modeled impacts. Under low wind speeds and stable conditions, dust plumes are likely to “hug” the ground and interact closely with ground features.

One must consider whether relative elevations have an important, and possibly unrealistic, impact on the modeling study results. The *AERMOD Implementation Guide*⁹ suggests that, if terrain is included, AERMOD might underestimate concentrations in gently downsloping terrain. Similarly, AERMOD might overestimate concentrations in upsloping terrain for certain source configurations. In both cases, modeling may not accurately account for interaction of the plume with surface features such as vegetation, berms and fences (see below for more discussion). On a case-by-case basis, modeling using a flat terrain assumption may be the most appropriate procedure.

Meteorological Input Data and Surface Characteristics

AERMOD requires input meteorological data and description of surface characteristics. Surface characteristics include surface roughness (z_0), albedo, and Bowen ratio. Atmospheric stability parameters are calculated from AERMET for input to AERMOD from the input surface meteorological data, upper air data, and surface characteristics.

A number of papers have been published stating the sensitivity of AERMOD modeling results to the surface roughness parameter. Surface roughness can be estimated for an area from USGS land use land cover (LULC) files, referenced from the *AERMOD User's Guide*, or measured at the site. When using AERMOD for fugitive PM10 emission releases, the user must consider whether the surface roughness value adequately accounts for the microscale interaction of the plume with features such as vegetation, walls, fences, and berms that commonly exist along facility property lines and near haul roads. Raising the surface roughness factor relative to the overall background surface roughness may be appropriate.

Surface wind speed data are typically obtained from the 10-meter tower level, with data extrapolated to source emissions level using the wind profile equation. Under stable, light wind conditions, there can be considerable uncertainty in the wind speed values extrapolated to near ground level. Data from a two-meter tower might be more appropriate. This level was used to evaluate AERMOD performance with Prairie Grass data for a low-level point source release¹⁰. Model results occurring under hours with light winds and very low calculated surface friction velocity (u_*) values should be viewed skeptically. It may be appropriate to remove hours with relatively high concentration values from the modeling study, and from the reported 24-hour average concentration impacts. The modeler should also look at the meteorological data file, and consider whether modeled hours with precipitation and saturated conditions can be removed from consideration.

Deposition

Deposition is an important effect that can lead to rapid concentration depletion in a fugitive PM10 emissions plume. The PM10 deposition velocity is about 0.3 cm/sec, which means that PM10 will deposit out of a plume located one meter above ground in about 1 kilometer with a 3 meter/second wind speed¹¹. The effect of deposition on plume depletion is an obvious technical refinement that should be considered.

However, there are issues associated with using deposition in AERMOD. First, the dry and wet deposition algorithms are considered draft in AERMOD Version 04300 and optional. There is uncertainty associated with determining a representative particle density for the particulate emissions plume including the PM10 portion.

The author's experience is that only marginal concentration reduction will result from using dry deposition when sources are close to receptors. Experience with the eastern Oregon landfill study showed only a 5% to 10% reduction in the PM10 plume concentration. Wet deposition with AERMOD was not available during the case study.

RECOMMENDATIONS AND CONCLUSIONS: CONTROL, MODEL, OR BOTH?

This section provides recommendations and conclusions applicable to fugitive PM10 modeling using AERMOD for a municipal waste landfill. Recommendations are organized by regulatory policy issues, and AERMOD technical considerations.

Regulatory Policy and Fugitive PM10 Modeling

From a regulatory policy standpoint, facility operators and agency staff should carefully consider the potential effect of proposed fugitive PM10 emission increases on ambient air quality. While emissions may have a high impact at off-site areas termed ambient air, impacts will usually be highly localized. The actual impacts will drop off rapidly within a short distance from the property line.

Employment of Best Available Control Measures or Reasonably Available Control Measures may be the best option to regulate and control the emissions, whether or not the facilities are located in PM10 nonattainment areas. The control measures include such techniques as watering, sweeping, use of chemical suppressants, and installing fences and vegetation along haul roads. Facility owners in PM10 attainment areas (both major and minor sources) that would prefer not to employ these control measures, might be required by agencies to conduct modeling to show compliance with the PM10 ambient air quality standards and increments.

If a regulatory agency requires fugitive PM10 modeling and impacts are problematic, facility and agency staff should look carefully at the model results and understand whether they are realistic. On a case-by-case basis, AERMOD could overpredict short-term PM10 concentrations. It would not make sense to limit a facility's operations based upon a few bad days or hours. Perhaps only annual average concentration modeling should be required, or facility and agency staff could explore AERMOD technical refinements that might be appropriate for the site.

AERMOD Technical Considerations for Fugitive PM10 Emissions Modeling

The following conclusions and recommendations are provided concerning use of AERMOD for fugitive PM10 modeling:

- Before completing modeling with AERMOD, spend time refining fugitive PM10 emission estimates, especially for sources such as haul roads located close to property line locations. Refinements should account for site-specific silt loading, average vehicle weights, actual average miles traveled, and reasonable, physical techniques to control dust emissions;
- Paved and unpaved road roads can be modeled in AERMOD as line, volume, or area sources. For stable, low wind-speed conditions, use of line or volume sources is preferred to account for plume meander. Line of volume sources will cause significantly less model runtime;

- Account for initial plume dilution from mechanically generated PM10 sources by increasing the effective source dilution depth and width, and calculating appropriate source release parameters for input to AERMOD;
- Consider the actual emissions profile over the operational day. Hour-of-day emission scaling factors in AERMOD can be used to apportion variable daily emissions;
- When the source-receptor distance is close, consider that inclusion of source terrain might either overestimate or underestimate modeled impacts. The appropriate assumption may be to model terrain as flat in AERMOD;
- The surface roughness value used for modeling with AERMOD should reflect the microscale interaction of low-level fugitive PM10 plumes with surface features. Consider using a higher surface roughness value than area background to account for this interaction;
- Surface wind speed data should reflect the elevation of plume release. Wind speeds extrapolated by AERMOD from higher measurement levels above ground may lead to underestimated wind speeds;
- Wet and dry deposition can be used with plume depletion in AERMOD to reduce calculated PM10 concentrations. The method is currently considered draft and optional;
- The modeler should closely review source impacts and meteorology on worst-case 24-hour PM concentration days. A few unrealistically high hours can dominate 24-hour concentration impacts, and the impacts might be overestimated by AERMOD in hours with low-wind speeds, highly stable atmospheric conditions, and precipitation.
- Given the potential for agencies to place restrictive permit and operational limits on facilities due to fugitive PM10 emissions, USEPA should conduct more extensive AERMOD model evaluation for fugitive sources, and provide better modeling guidance to the regulated community.

This paper should be used as a guide for open discussions between staff at facilities that generate fugitive PM10 emissions and regulatory agency staff. The goal for any modeler facing the uncertain task of using AERMOD to show compliance with regulatory standards should be to have a proactive understanding of the local regulatory policy regarding appropriate fugitive dust control techniques and modeling requirements. If modeling is required, it is incumbent on the modeler to understand the effect that model inputs will have when using AERMOD.

ACKNOWLEDGMENTS

The authors thank Gabrielle Fourie of SCS Engineers for her dedication and hard work running many iterations of landfill TSP and PM10 emissions estimates, and Laurence S. Reider of BlueScape Environmental for his efforts in completing the landfill AERMOD modeling work.

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KEYWORDS

Air dispersion modeling
AERMOD
Fugitive dust
PM10
ISCST3
Area Source
Volume Source
Landfill