

GEOTEXTILE SEPARATORS FOR
DUST SUPPRESSION ON GRAVEL ROADS

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By

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DUST SUPPRESSION ON GRAVEL ROADS

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ABSTRACT

Dust can be a health concern because of its potential to contain respirable particles. The US Environmental Protection Agency (EPA) designates particulate matter of 10 microns or less in diameter (PM₁₀) as the point of regulatory concern. Dust can also be a nuisance issue for residents living in the vicinity of gravel roads. The US EPA and state environmental agencies developed and implemented a reporting system for the amount of particulate (PM₁₀) derived from various sources including gravel roads. An annual fee is assessed to the roadway owners based on the estimated level of particulate generated from the roadway per year. Dust control treatments such as watering the gravel road or applying a dust suppressant reduce the annual fee. Although numerous techniques are used in attempts to control the dust generated from gravel roads, all have limitations and the search for more effective means of reducing dust levels from gravel roads continues. Geotextile separators offer the potential to reduce dust while providing enhanced driving characteristics and reduced maintenance of the roads.

A field demonstration program was initiated to quantitatively document the dust suppression effect of geotextile separators on unpaved, gravel-surfaced roads. Active monitoring systems were used to collect and quantify dust volumes and particulate size distributions along with distance of transport and vehicular characteristics. The test site was located in Boone County, Missouri and was approximately 180 m in length by 15 m in width. It included two, 100-m nonwoven geotextiles (AASHTO Class 2) test sections and a 100-m control

section (fresh gravel with no geotextile). One geotextile was spun bonded and the other was needle punched.

Six sampling events were taken to evaluate the effectiveness of using geotextiles as a dust suppressant. Two sampling events were taken before the geotextiles were installed and are identified as pre-geotextile sampling events. Four sampling events were taken after the geotextiles were installed and are identified as post-geotextile sampling events.

Results indicated that the dust collected on the downwind side were always significantly higher than the dust collected on the upwind side. Initially, dust collected on the control section was 70 to 80% less than the pre-geotextile dust levels, for the downwind side. Over a five month period the dust levels in the control section increased and the range was 80% to 230% of the pre-geotextile dust levels. Dust levels from the spun bonded geotextile section ranged from 10% to 310% of that from the control section; while dust from the needle punched geotextile section ranged from 20% to 190% of that from the control section. Analyses were conducted on the surface aggregate. Results indicated that the aggregate used to surface the road was readily soluble.

The objective of this research was to determine the effectiveness of geotextile separators on reducing dust from gravel roads. Installing a geotextile on unpaved roads was determined to be beneficial in reducing the dust. A direct relationship was observed between the amounts of fines in the surface aggregate to the use of geotextiles. Comparing the control section to the geotextile sections indicated that there was an increase in the amount of fines in the control section,

this increase in fines was likely due to the fines coming from the subbase material.

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Chapter 1 - Introduction

1.0 Introduction

Dust is a health concern because of its potential to contain respirable particles (PM10 or PM2.5). It can also be a safety issue and a nuisance for residents living in the vicinity of gravel roads (Figure 1.1). Numerous techniques (chlorides, resins, natural clays, asphalts, soybean oil, and others) are used in attempts to reduce the dust generated from gravel roads. All have limitations and the search for more effective means of reducing dust levels from gravel roads continues (Skorseth and Selim 2000).



Figure 1.1 Gravel road located at the City of Columbia landfill.

Anecdotal evidence suggests that dust from gravel roads is reduced for roads that incorporate a geotextile separator (Marienfeld 2005). Geotextile separators offer the potential to reduce dust while providing enhanced driving characteristics and reduced maintenance of the roads. The latter is well documented (Amoco Fibers 2005); however, the dust reduction function is not. The concept is that the dust particulate originates from the fines of the subgrade

which migrate upward into the gravel surface over time. Vehicular traffic causes the fines in the gravel to be mobilized into the atmosphere. It is well recognized that geotextile separators limit the migration of fines into the overlying aggregate and also the intrusion of aggregate into the subgrade (Figure 1.2) (Holtz et al. 1997; Koerner 1998). Thus, adding a geotextile separator will reduce the amount of fines in the aggregate layer and therefore should decrease the dust generated from a gravel road. Quantitative information is needed to determine if indeed a geotextile does reduce the amount of dust and if so, what the level of effectiveness is.

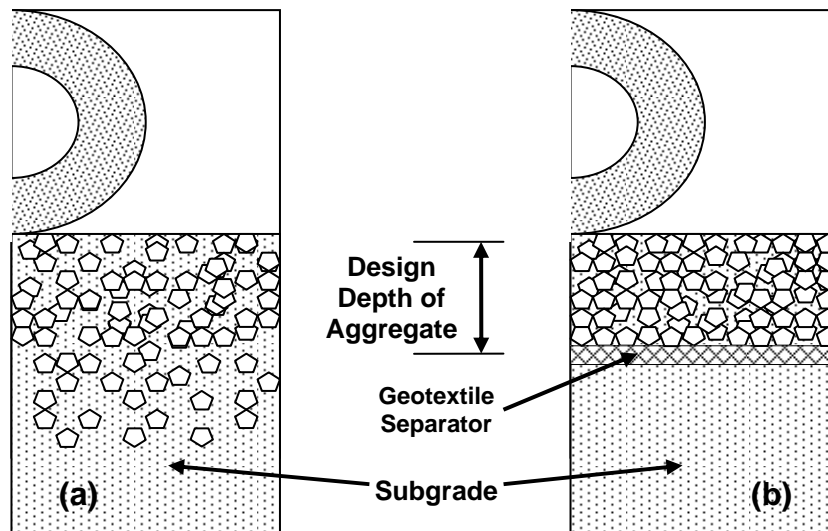


Figure 1.2 Unpaved road (a) without and (b) with a geotextile separator.

1.1 Objective and Tasks

The objective of the research reported herein was to develop a system to quantify the effectiveness of geotextile separators in reducing the dust generated from gravel roads and to collect data from field test sections.

1.2 Scope

Initially background (pre-geotextile) monitoring was conducted to determine the amount of dust a particular test section generated. After the pre-geotextile data had been collected the surface aggregate was graded and geotextiles were placed on the subbase then covered with new aggregate.

Post-geotextile monitoring of the test sections was conducted periodically to determine the effect the geotextile had on the dust generated. Monitoring included:

- Dust collection via containers filled with water and performing total suspended solids tests;
- Measuring moisture contents;
- Sampling aggregate and performing grain size analysis.

The scope of this research is limited to one test site located at the City of Columbia landfill in Columbia, MO. Installation of the geotextile occurred in September of 2005 and post-geotextile monitoring took place in October 2005, January, February, and March of 2006. Two nonwoven, geotextiles were used, one spun bonded and the other needle punched.

1.3 Layout of Thesis

Chapter 2 contains a literature review on issues concerning dust on gravel roads and the typical use of geotextiles. Described in Chapter 3 are the materials and methods incorporated to quantify dust. The data collected from the

landfill site located in Columbia, MO, and analyses of the data are presented in Chapter 4. Presented in Chapter 5 are the conclusion and recommendation sections of the thesis and Chapter 6 presents the references used throughout the thesis. Following Chapter 6 are appendices that contain material that has been referenced throughout the thesis.

Chapter 2 - Literature Review

2.0 Introduction

Dust can be a nuisance for residents and a health concern. Dust, from gravel roads, contains particulate matter of 10 microns (PM10) or less in aerodynamic diameter (EPA 1998). Health concerns associated with PM10's include breathing problems, coughing, decreased lung function; children, the elderly, and people with lung problems, i.e., asthmatic persons are more sensitive to respirable particulate (California Air Research Board 2003). Federal (EPA) and state (MDNR) agencies regulate the amount of PM10's that are emitted and prescribe an annual cost to owners of gravel roads for each pound of PM10 emitted. To reduce this cost, owners use control methods such as water, chlorides, resins, natural soils, and soybean oil for dust control (Skorseth and Selim 2000). This research investigates how a geotextile would provide an effective dust control method. Presented in this chapter are the typical control methods, how they work, and how a geotextile is used and how it can work to reduce dust from unpaved roads.

2.1 In-Practice Control Methods

Counties and cities combat dust from gravel roads using several different methods. Emission Factor Documentation for AP-42 identified three categories of emission control technology: source extent reductions, surface improvements, and surface treatment (EPA 1998). Source extent reductions limit the number of

vehicles that travel the road, surface improvements include paving the road, and surface treatment include dust control techniques (EPA 1998). An advantage to dust control is that the amount of aggregate lost per year and maintenance/upkeep of the roads can be significantly reduced (Skorseth and Selim 2000).

Typically water, chlorides, resins, natural soils, and soybean oil are used as stabilizers for dust control (Skorseth and Selim 2000). Calcium and magnesium chlorides are considered the most popular and work by attracting the moisture in the air to keep the dust down (Skorseth and Selim 2000). Control efficiency for watering depends on application rate of the water, time between applications, traffic volume during the period, and the meteorological conditions (EPA 1998). Control efficiency for magnesium chlorides is similar to that of watering but also depends on the dilution rate, application rate, time between applications, and traffic volume (EPA 1998).

According to Public Works Officials in Boone County, Cole County, and Callaway County Missouri, the preferred dust control method is a magnesium chloride solution. Magnesium chloride is applied once a year and observations have been made that the performance of treated roads increases with increasing applications of magnesium chloride. Discussions with Ms. Kelly Peyton of Scott Wood Industries (Peyton 2006) indicated that the dust performance of the road does increase with increasing applications of magnesium chloride. Peyton indicated that the increased performance is based on a build up of residual of magnesium chloride.

Peyton stated that Scoot Wood Industries supplies Boone County and Callaway County with magnesium chloride (brand name is DustGard^R). Most counties centrally located use magnesium chloride since the product is stored in Jefferson City, Missouri. Calcium chloride is stored in St. Louis, which affects the price of the calcium chloride (Peyton 2006). In discussions with Peyton she indicated that in 2005 a major supplier of calcium chloride went out of business, the hurricanes that affected the southwest region of the United States destroyed some of the major calcium chloride producing plants, which have led to higher prices for calcium chloride and the reduction of the use of calcium chloride.

The EPA created the Environmental Technology Verification (ETV) program that has tested several dust suppressant methods to determine their control efficiency (ETV 2005). Test sites were located in Fort Leonard Wood, Missouri and Maricopa County, Arizona. Provided in Table 2.1 is a comparison of dust suppressants that the ETV tested and their control efficiencies. Reported herein are the control efficiencies taken as the average PM₁₀ from testing that occurred in October and May of 2003 for the Fort Leonard Wood, Missouri site. Control efficiencies were determined using a mobile sampler (ETV 2003).

Table 2.1 Dust Suppressants and Recommended Cost

Manufacturer	Control Method	Material	EPA Control Efficiency (%)	Reference
City of Columbia Landfill	Water	Water on Site	50	Landfill Operator (2006)
Midwest Industrial Supply, Inc.	EK35	Contains Resins and synthetic organic fluid	85	ETV 2005
Midwest Industrial Supply, Inc	EnvironKleen	Organic, synthetic fluid	94	ETV 2005
North American Salt Company	DustGard ^R	Hygroscopic product made of Magnesium Chloride	99	ETV 2006
SynTech Product Corporation	PetroTac	Emulsion that bonds with road aggregate	86	ETV 2005
SynTech Product Corporation	TechSuppress	Integrates water-emulsified resins with wetting agents, surfactants, and emulsifiers	60	ETV 2005

The most cost effective forms of dust control as described in Table 2.1 are water and DustGard[®]. Presented in Table 2.2 are advantages and disadvantages of each method of dust control.

Table 2.2 Advantage and Disadvantages of Specific Dust Control Methods

Method	Advantages	Disadvantages
Water	Water available on site Inexpensive	Watered daily during the dry season
EK35	Obtain and maintain the design control efficiency	A minimum of two applications per season and may increase for drier season
EnvironKleen	Obtain and maintain the design control efficiency	A minimum of two applications per season and may increase for drier season
DustGard [®]	Reduced number of applications (applied annually) as time increases; build up of residuals over several years will provide better dust control efficiencies	Takes several years to build up resins, not as effective in drier seasons. Annual application or more
PetroTac	Obtain and maintain the design control efficiency	Application rate is significant; every 28 days. Cost is high to maintain design control efficiency
TechSuppress	NOT RECOMMENDED BY MANUFACTUROR	

2.2 Geotextiles Background

Geotextiles are made from polymers, formed into fibers or yarns and then manufactured as a woven or nonwoven fabric (Koerner 2005). There are various types of geotextiles and they can be designed based on cost and availability,

specification, and function (Koerner 2005). Presented in Table 2.3 are the AASHTO M288 specifications as identified by Koerner (2005).

Table 2.3 AASHTO M288 Geotextile Strength Property Requirements (Koerner 2005)

	Test Methods	Units	Geotextile Classification ⁽¹⁾					
			Class 1		Class 2		Class 3	
			Elongation <50% ⁽²⁾	Elongation ≥ 50% ⁽²⁾	Elongation <50% ⁽²⁾	Elongation ≥ 50% ⁽²⁾	Elongation <50% ⁽²⁾	Elongation ≥ 50% ⁽²⁾
Grab strength	ASTM D4632	N	1400	900	1100	700	800	500
Sewn seam strength ⁽³⁾	ASTM D4632	N	1200	810	900	630	720	450
Tear strength	ASTM D4533	N	500	350	400 ⁽⁴⁾	250	300	180
Puncture strength ⁽⁵⁾	ASTM D4833	N	500	350	400	250	300	180
Permittivity	ASTM D4491	sec ⁻¹	Minimum property requirements for permittivity, AOS, and UV stability are based on geotextile application.					
Apparent opening size	ASTM D4751	mm						
Ultraviolet stability	ASTM D4355	%						

Notes

- (1) Required Geotextile classification is designated in additional tables based on indicated application discussed by Koerner (2005)
- (2) As measured in accordance with ASTM D4632. Note: Woven geotextiles fail at elongations (strains) <50%, while nonwovens fail at elongation (strains) >50%
- (3) When sewn seams are required. Overlap seam requirements are application specific.
- (4) The required MARV tear strength for woven monofilament geotextiles is 250 N.
- (5) Puncture strength will likely change from ASTM D4833 to ASTM D6241 with approximately five times higher values.

Geotextiles in roadway applications have typically been used as separators, reinforcement, filtration, and drainage.

- Geotextile separation: the placement of a flexible porous textile between dissimilar materials so that the integrity and functioning of both materials can remain intact or be improved (Figure 2.1) (Koerner 2005).

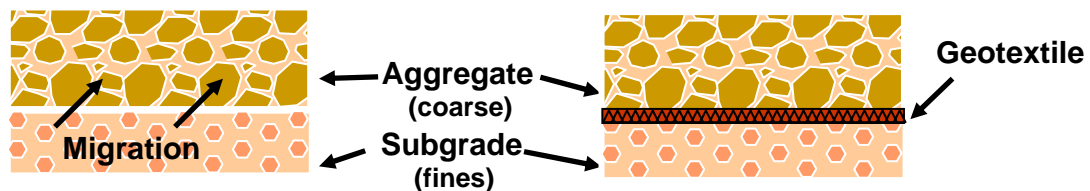


Figure 2.1 Separation function of a geotextile.

- Geotextile reinforcement: the synergistic improvement of a total system's strength created by the introduction of a geotextile (good in tension) into a soil (good in compression but poor in tension) or into other disjointed and separated material (Koerner 2005).
- Geotextile filtration: the equilibrium soil-to-geotextile system that allows for adequate liquid flow with limited soil loss across the plane of the geotextile over a service lifetime compatible with the application under consideration (Koerner 2005).
- Geotextile drainage: the equilibrium soil-to-geotextile system that allows for adequate liquid flow with limited soil loss within the plane of the geotextile over a service lifetime compatible with the application under consideration (Koerner 2005).

As described by the South Dakota LTAP in the Link publication, the benefits of using a geotextile in unpaved low volume roads include (South Dakota LTAP 2005):

- Reduced maintenance costs;
- Reduction of the depth of the structural section required to carry the load;
- Reduced initial construction costs;
- Possibility of reclaiming aggregate used in temporary roads;
- Structural section life is prolonged and maintenance costs reduced because soil intermixing between layers is restricted; and
- Cost effectiveness, approximately 33% reduction in aggregate required in the initial design of unpaved structural sections.

In reference to the research conducted the geotextile was used to provide separation. Separation will prevent the subgrade from migrating into the surface aggregate and vice versa. An additional benefit to using a geotextile for separation is that rutting will be reduced (Figure 2.2).

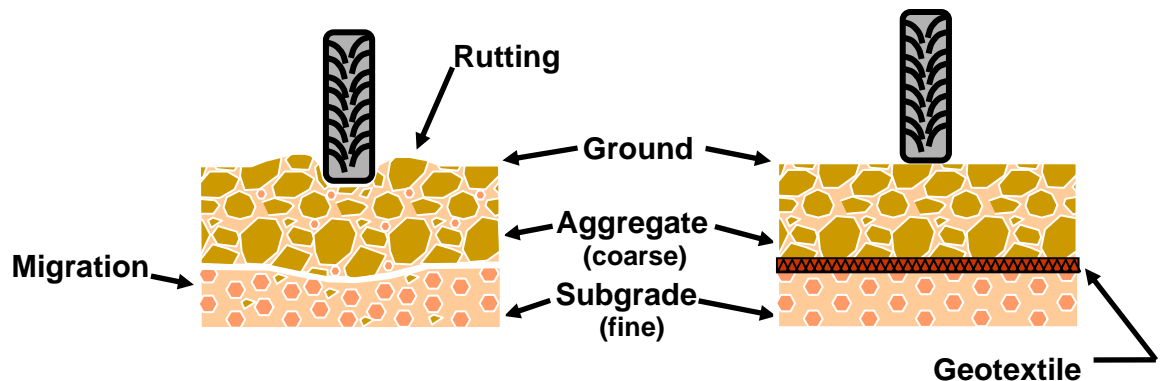


Figure 2.2 Separation function of a geotextile and reduced rutting.

2.3 Geotextiles as Dust Control

Anecdotal evidence suggests that using a geotextile between the aggregate and subgrade layer on a low volume unpaved road will reduce the amount of dust. The concept is that, as traffic uses a road, the fines from the subgrade migrate upward and emit dust into the air. A geotextile will separate the subgrade layer from the surface aggregate and maintain the fines in the subgrade layer, therefore reducing dust emitted into the atmosphere during traffic conditions.

In 1987 to 1989 the US Federal Highway Administration (FHWA), along with the Oklahoma Center for Local Government installed 19 geotextiles across six counties in Oklahoma to determine the effectiveness for separation and stabilization (Amoco Fabrics 2005). During the investigation, Mr. John Hopkins, with the Federal Highway Administration (FHWA), visually observed that the dust appeared to be reduced when geotextiles were used, although no quantifiable measurements were made.

2.4 Summary of Dust Control

Dust can be a nuisance for residents and a health concern. Dust, from gravel roads, contains particulate matter of 10 microns or less (PM10). Counties and cities combat dust from gravel roads using several different control methods. Typically water, chlorides, resins, natural soils, and soybean oil are used as stabilizers for dust control (Skorseth and Selim 2000). However geotextiles might provide a new method for dust control. Geotextiles have long been used as

separators in unpaved roads and there ability to provide reduced structural section, reduced maintenance, and prolonged life has been well documented. There ability to effectively reduce dust needs to be quantified with field performance data.

Chapter 3 – Materials & Methods

3.0 Introduction

A field monitoring plan was implemented to determine the effectiveness of geotextiles in reducing dust from gravel roads. Laboratory analyses were performed to determine the characteristics of the surface and subbase materials. During the first stages of research a preliminary field monitoring plan was implemented to determine the pros and cons of the dust measurement methods. Once geotextiles were installed, the final field monitoring plan was implemented and applied to every site. Presented herein is the preliminary field monitoring plan, the field monitoring plan implemented at the test site, and a description of the materials used and laboratory tests performed.

3.1 Field Monitoring Plan

A field monitoring plan was determined based on hands-on experimentation. Provided below are the methods and steps used to develop the field monitoring plan.

3.1.1 Preliminary Field Monitoring Plan

A preliminary field monitoring program was implemented to determine the quantity, characteristics of dust generated at gravel road sites, and to determine the best practices for collecting dust. The program consisted of using collection pans, plastic sheeting, and an Anderson Cascade Impactor to collect the dust. The Anderson Cascade Impactor was used to determine the particle

characteristics of the dust while the pans and plastic sheeting were used to determine the quantities of dust.

Two gravel road sites were selected to implement the preliminary field monitoring plan. One site was an alley that ran west to east and was located between Clark St. and Lewis St. (runs north/south streets), and 2nd and 3rd Street (runs west/east) in Rocheport, Missouri (Figure 3.1). The second site was located at the City of Columbia landfill in Columbia, Missouri. The road runs north-south and provides access to the administration building and the recycle center.

A preliminary field monitoring plan was implemented at the Rocheport, Missouri site on July 11, 2005. The alley was approximately 2.4 m wide by 74 m long (8 ft wide by 242 ft long). Plastic sheeting, a drop cloth, and two types of collection pans were used in the preliminary field monitoring plan (Figure 3.2). The tin pan was located approximately 1 m (3 ft) from the edge of the road while the plastic pan was located approximately 2 m (6 ft) from the edge of the road. Dimension of the pans are described in Table 3.1 and shown in Figure 3.3 (a) and (b). Both collection pans were filled with approximately 250 ml of distilled water. The water was collected from the collection pans by transferring the water into 500 ml (16 oz) water bottles with funnels. Plastic sheeting and the drop cloth were placed vertically by attaching them to fence posts and securing them to the fence post using duct tape (Figure 3.2 and 3.4 (a) and (b)). The fence posts were located approximately 1 m (3 ft) from the edge of the road.

Once the dust collection apparatus were set up, a two-axle 2,100 kg (4,600 lb) truck was driven across the alley to generate dust. This was referred to as Active Monitoring. Additional vehicles that traveled the road during testing were included in the number of passes. Vehicle speeds were kept constant at approximately 32 kmh (20 mph). Twenty-five passes, where one pass is equal to traveling one-way on the road, were made to generate dust.

Implementation of the preliminary field monitoring plan presented the following determinations:

- Tin pans were preferred based on the visibility of the dust collected. The dust collected was not visible in the plastic pans. More pans were needed.
- Determining the amount of dust or visual observations of dust, using the drop cloth, was not feasible due to the color of the drop cloth; since it was white it was difficult to make visual observations. Therefore, this method was not used for future samplings.
- Using the plastic sheeting to collect dust appeared to be feasible due to visual observations, though determining the quantity of dust collected was difficult. Initial weights of the plastic sheeting were taken prior to installation and final weights were taken after sampling. Difficulties in collecting accurate dust quantities came about when trying to dismantle the sheeting and trying to secure the plastic sheeting for transport to the lab for measurement. Dust was lost when transferring the plastic sheeting.

- In future practice, funnels were used to transfer the water from the collection pans to the water bottles.

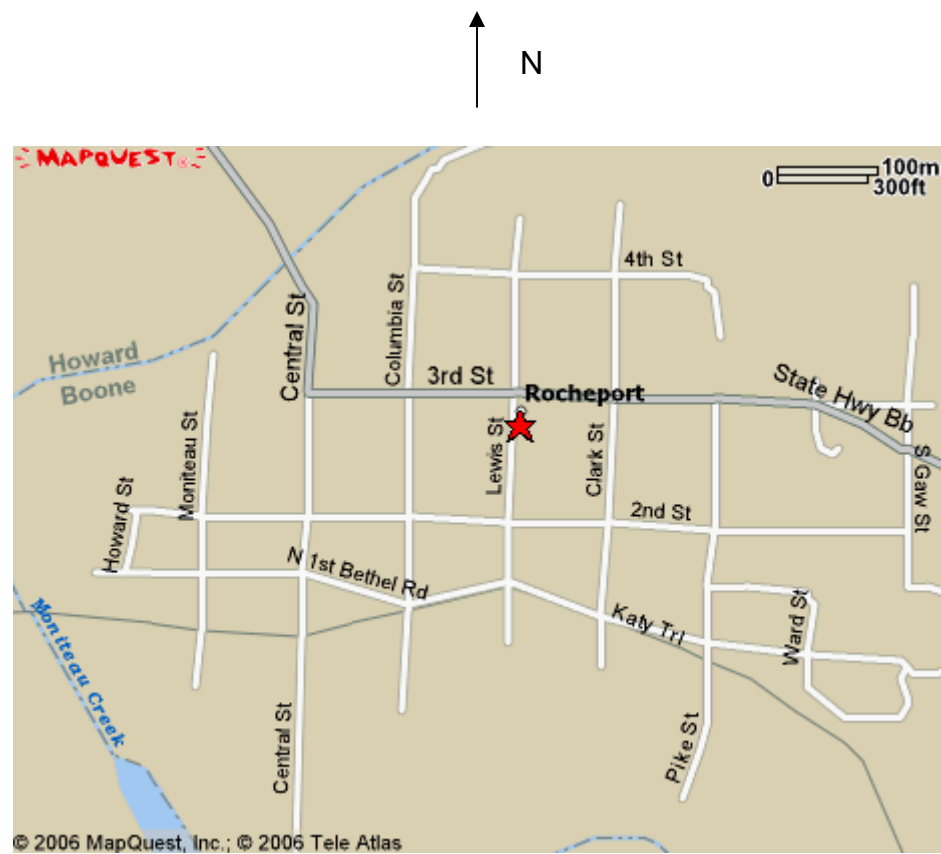
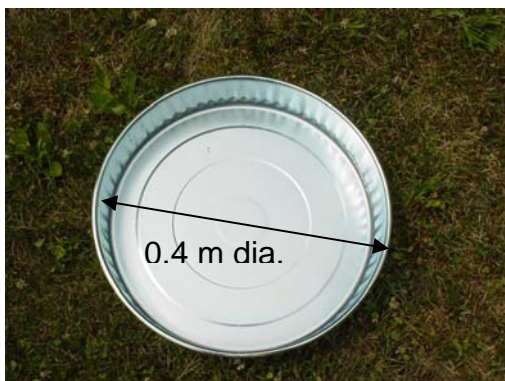


Figure 3.1 Location of the Rocheport, Missouri site (Mapquest 2006).



Figure 3.2 Preliminary monitoring at Rocheport, Missouri on July 11, 2005.



(a)



(b)

Figure 3.3 Pans used to collect the dust (a) and (b).



(a)



(b)

Figure 3.4 Plastic sheeting and drop cloth used to collect dust (a) and (b).

Table 3.1 Monitoring Techniques and Dimensions.

Monitoring Technique	Dimensions
Tin Pans (Figure 3.1 (a))	0.4 m diameter and 0.08 m in depth (16 inches in diameter and 3 inches in depth)
Plastic Pans (Figure 3.1 (b))	0.26 m in diameter and 0.1 m in height (10 inches in diameter and 4 inches in height)
Nalgene HDPE 500 ml Bottles (16 oz)	0.2 m in height and 0.09 m in diameter (6.5 inches in height and 3.5 inches diameter)
Multipurpose construction & Agriculture Grade Plastic Sheeting (4 mil thickness) and fence posts	Minimum 1 m in height spaced 1 m apart (40 inches by 40 inches).
Gotcha ^R Covered Absorbent Drop Cloth and fence posts	Minimum 1 m in height spaced 1 m apart (40 inches by 40 inches). Drop cloth size was 2.4 m by 3.7 m (8 ft by 12 ft)
Anderson Cascade Six Stage Impactor (New Star Environmental 2004)	Height 0.2 m (8 inches) Diameter 0.1 m (4 inches)
Kestrel 3000 Pocket Weather Meter (www.benmeadows.com)	Measures wind speed, temperature, wind chill, relative humidity, heat stress and dew point

3.1.2 Revised Field Monitoring Plan

Lessons learned from the preliminary field monitoring plan, taken on July 11, 2005, were used and implemented to make a revised field monitoring plan. The revised field monitoring plan incorporated a field monitoring layout that specified the placement of the pans and plastic sheeting in a manner that would best capture the dust (Figure 3.5). It was implemented in the July 25, 2005 and August 3, 2005 sampling events at the City of Columbia landfill, Columbia, Missouri (pre-geotextile sampling events). The north arrow in Figure 3.5 represents the north direction at the landfill site. To collect the dust, ten tin pans were used and plastic sheeting was used in locations indicated in Figure 3.5.

Once the dust collection apparatuses were set up, the same 2,100 kg, two-axle truck used at Rocheport, Missouri was driven across the road to generate dust. Additional vehicles that traveled the road during testing were included in the number of passes. Vehicle speeds were kept constant at approximately 32 kmh (20 mph). Three samplings were taken. Samplings 1 and 2 consisted of 15 passes, where one pass was equal to traveling one-way, in the center of the road. Sampling 3 consisted of making 15 passes, where one pass was equal to traveling both directions, keeping the vehicle to the side of the road.

Implementation of the revised field monitoring plan presented the following determinations:

- From the July to the August, 2005 sampling events the tin pans had started to rust. Samples collected in the August 2005 sampling

event were contaminated with rust. Therefore, in future sampling events the tin pans were replaced with plastic containers.

- Improvements were made for collecting the dust from the plastic sheeting. Wet cloths were used to collect the dust from the plastic sheeting. Initial weights of the cloths (when dry) were taken then the final weight of the cloths after wiping the plastic sheeting and drying the cloths was taken. This method was also deemed unsatisfactory for accurately collecting the dust quantities from the plastic sheeting. Therefore, the plastic sheeting was not used in future sampling events.

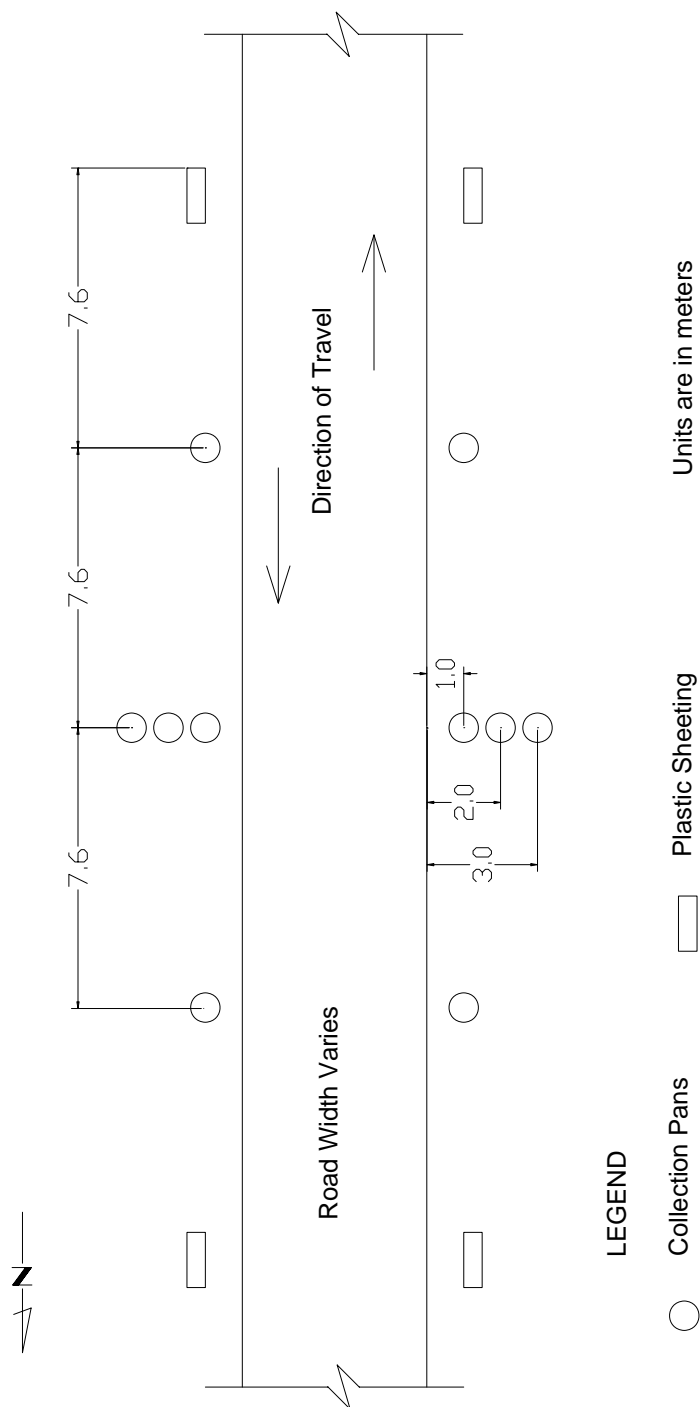


Figure 3.5 Plan view of field instrumentation program (all distances in meters).

3.1.3 Final Field Monitoring Plan

During pre-geotextile testing (i.e. sampling events on July 25 and August 3 of 2005) it was determined that the dust collected from the plastic sheeting and drop cloth was inconclusive and therefore these methods were discontinued (see previous discussions). An additional observation was that the tin pans tended to rust. Therefore the tin pans were replaced with plastic containers that had areas of 980 and 900 cm² (Figure 3.6). Placement of each type of collection pan was recorded for each sampling event, except for the sampling event on January 19, 2006 (Type A collection pan had a length of 38 cm (15 in) and width of 26 cm (10 in); Type B collection pan had a length of 38 cm (15 in) and width of 24 cm (9 in)). During the January 19, 2006 sampling event an average of the two types of collection pans were used (average length of 38 cm and width of 25 cm) due to the fact that the locations of the collection pans were not taken.

A modification was made to the placement of the collection pans for the final field monitoring plan. The length of the road increased to 183 m (600 ft) and three test sections were implemented for the final field monitoring. Therefore, the distance between plastic containers was increased to approximately 15.2 m from 7.6 m (Figure 3.7). The three test sections incorporate one control section and two sections that had two different types of geotextiles (Figure 3.7). Each test section was approximately 60 m (200 ft) in length. Ten collection pans were placed within the control section, five on each side of the road, and each geotextile section, for a total of 30 collection pans at the site.

In addition to collecting dust, the lift thickness of the gravel was measured at each sampling event. By measuring the lift thickness it was determined if the aggregate was spreading over the road or staying in place. Aggregate samples were collected at each sampling event. The aggregate was evaluated to determine if the aggregate deteriorated over time.

One other modification was made, which included reducing the number of sampling events from three to two per site visit. The results from two sampling events were then averaged to determine the quantities of dust.

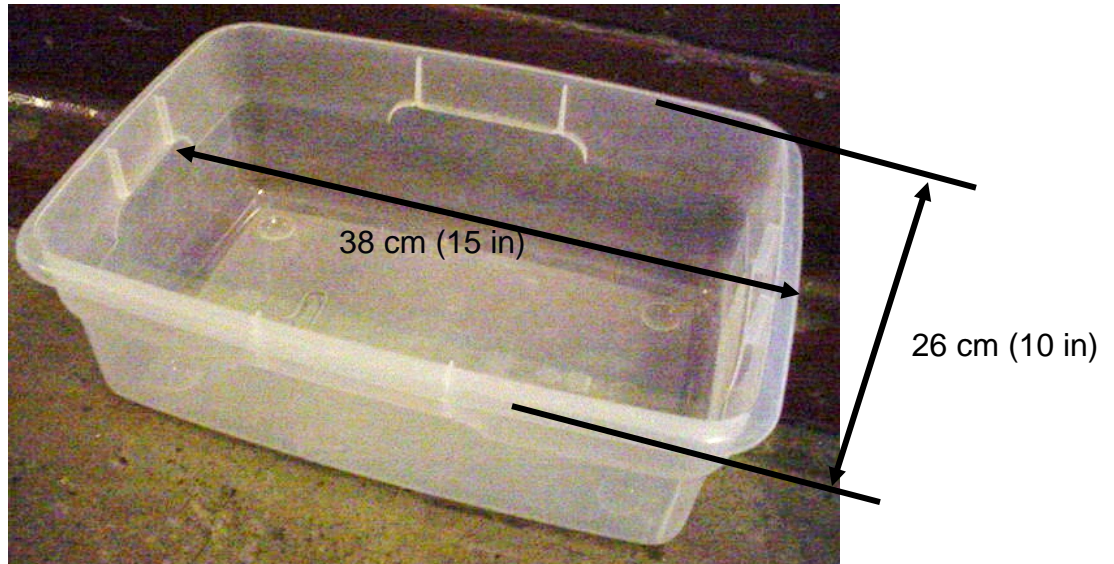


Figure 3.6 Plastic collection pans implemented in final monitoring plan.

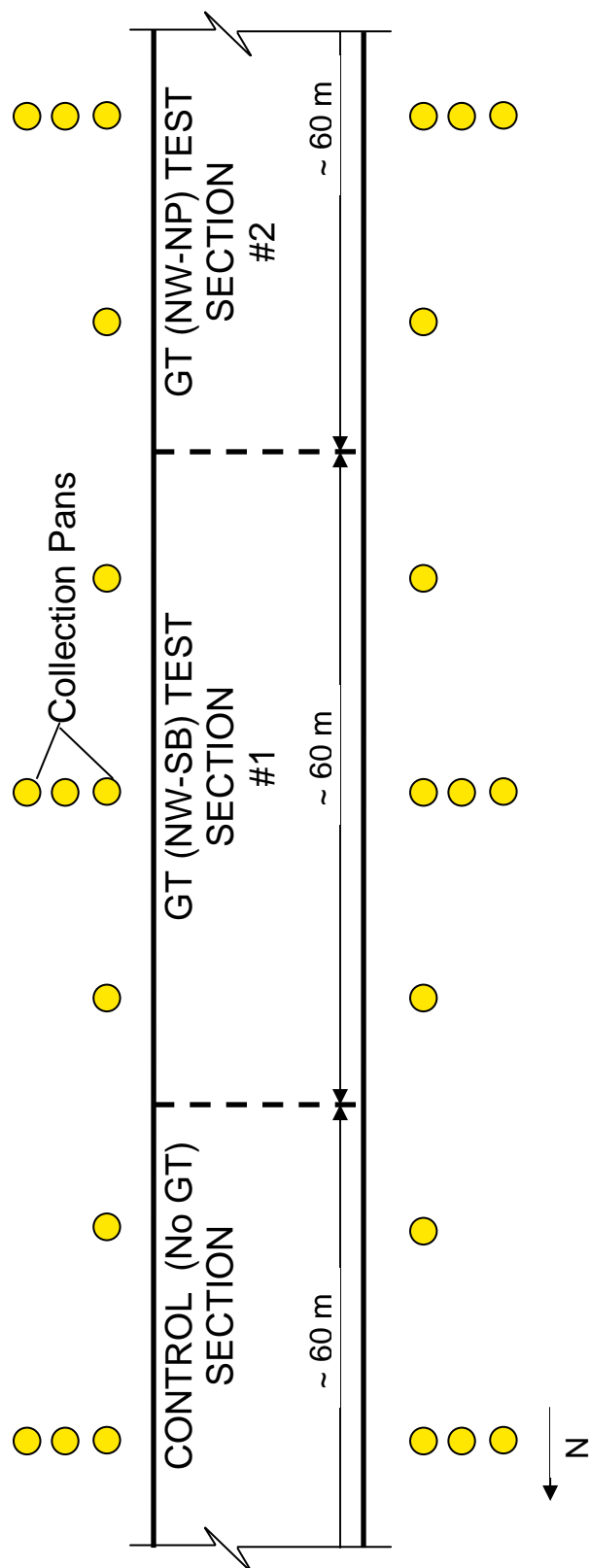


Figure 3.7 Modified field layout

3.1.4 Anderson Cascade Impactor

Implementation of the Anderson Cascade Impactor (ACI) occurred on August 11, 2005 at the Rocheport, Missouri site. It was used again during the October 5, 2005 sampling event. The ACI works by applying a vacuum and air flows through the top of the ACI and then filters downward. Particles are collected on the six different stages using Petri dishes (Figure 3.8). The Petri dishes are weighed previous to sampling and then after sampling. The difference in weight was used to determine the particles collected.

To take a sample using the ACI, a generator, vacuum pump, and flow meter were implemented in the field. The ACI was connected to the flow meter using 9.5 mm outer diameter and 6.4 mm inner diameter (3/8 inch outer diameter and 1/4 inch inner diameter) plastic (polyethylene) tubing. The flow meter had a 6.4 mm (1/4 inch) ball valve (Swagelok B-42S4) assembled to the influent which was connected to the vacuum pump (Figure 3.9). The generator was manufactured by Homelite and had a capacity of 2500 Watts (Serial No. HL2550383 and Model No. EH2500HD). The vacuum pump had a brand name of ROC-R and manufactured by GAST (Serial No. 0388 and Model No. ROA-P131-AA). Gilmont Instruments, a division of Barnant Company, manufactured the flow meter. It was a shielded flow meter GF-2060 or/and GF-2560 Size number 13. To effectively use the ACI, the vacuum on the apparatus must be maintained at a flow of 28.3 lpm (1 CFM) (New Star Environmental 2004). This flow was obtained by using a valve and set up as discussed previously and shown in Figures 3.9 and 3.10.

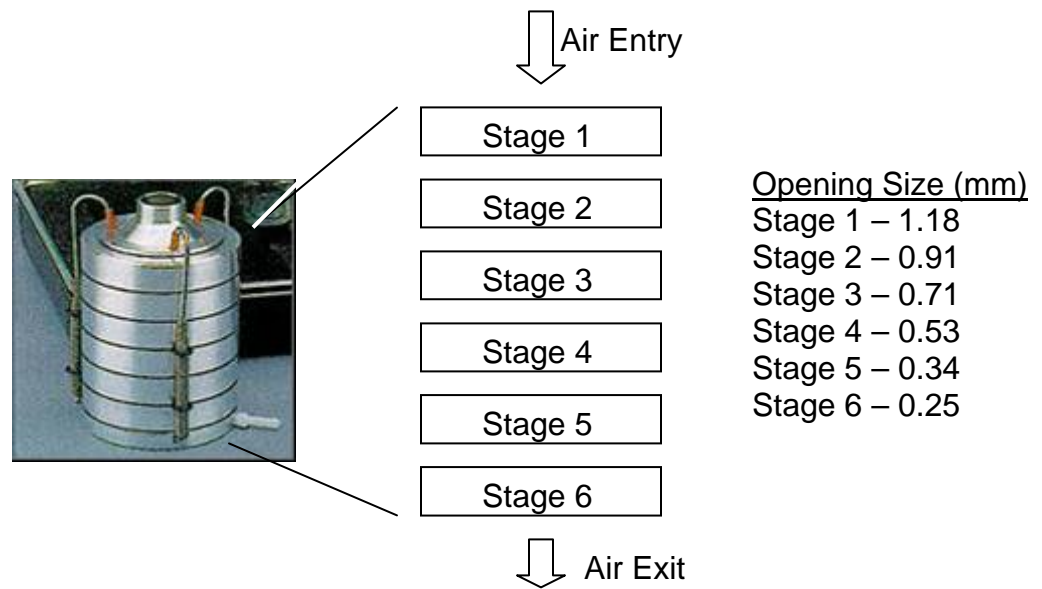


Figure 3.8 Six Stage Anderson Cascade Impactor for dust mass and particle size determination (New Star Environmental 2004).



Figure 3.9 ACI set up in the field.



Figure 3.10 A view of the ACI including the valve and vacuum pump.

3.2 Active Monitoring

For each site, a two-axle 2,100 kg (4,600 lb) truck was driven across the sections to generate dust; this is referred to as Active Monitoring. Additional vehicles that traveled the road during testing were included in the number of passes. Vehicle speeds were kept constant at approximately 32 kmh (20 mph). Two to three sampling events were made consisting of 15 passes (round trip = 1 pass) each, alternating between keeping the vehicle in the middle of the road and to the sides of the road. The average of the two or three sampling events was used to determine the amount of dust generated.

3.3 Geotextile Installation

The test site located at the City of Columbia landfill in Columbia, Missouri was used to install geotextiles. Two types of geotextiles were used. A non-woven, needle punched (NW-NP) and a non-woven, spun bonded (NW-SB), both AASHTO Class 2 geotextiles. The NW-NP geotextile was a 200 g/m² (6oz/yd²) PROPEX 4551 and was provided by Propex Fabrics, Inc. The NW-SB geotextile was a 140 g/m² (4 oz/yd²) TYPAR 3501 and was provided by BBA Fiberweb. Presented in Table 3.2 are the properties for each geotextile.

At the time of the geotextile installation three test sections were developed along the 183 m (600 ft) of road. One test section consisted of the control section, without a geotextile, and was approximately 60 m (200 ft) long. Test section 1, also 60 m (200 ft) long, consisted of the Typar fabric and Test section 2, again 60 m (200 ft) long, incorporated the Propex fabric (Figure 3.7). To

construct the test section, the top surface of old aggregate was graded, the geotextile was placed on the subgrade, and new gravel was then placed on the geotextile (Figure 3.11-3.13). The width of the road was measured to be approximately 11 m (36 ft); the geotextiles come in 5 m (15 ft) widths and the width of the in-place geotextiles was 9 m (30 ft) (Table 3.3). Therefore, the geotextiles were overlapped approximately 0.3 m (1 ft).

Table 3.2 Geotextile Properties

Property	Test Method	Propex 4551		Typar 3501	
		Minimum Average Roll Value (English)	Minimum Average Roll Value (Metric)	Minimum Average Roll Value (English)	Minimum Average Roll Value (Metric)
Grab Tensile	ASTM-D-4632	160 lbs	0.711 kN	160 lbs	0.710 kN
Grab Elongation	ASTM-D-4632	50%	50%	60%	60%
Mullen Burst	ASTM-D-3786	310 psi	2135 kPa		
Puncture	ASTM-D-4833	90 lbs	0.400 kN	56 lbs	0.250 kN
Trapezoidal Tear	ASTM-D-4533	65 lbs	0.285 kN	60 lbs	0.27 kN
UV Resistance	ASTM-D-4355	70 % at 500 hrs	70 % at 500 hrs	70 % at 500 hrs	70 % at 500 hrs
AOS ⁽¹⁾	ASTM-D-4751	70 sieve	0.212 mm	70 sieve	0.200 mm
Permittivity	ASTM-D-4491	1.1 sec ⁻¹	1.1 sec ⁻¹	0.5 sec ⁻¹	0.5 sec ⁻¹
Flow Rate	ASTM-D-4491	82 gal/min/ft ²	3340 L/min/m ²	50 gal/min/ft ²	2050 L/min/m ²



Figure 3.11 Scraping of the surface, prior to installation of the geotextiles.



Figure 3.12 Installation of the geotextiles.



**Figure 3.13 Installation of the aggregate after placement of the geotextiles.
(Note: End dumping of aggregate from trucks to keep trucks off of GT.)**

Table 3.3 Dimensions of the Width of the Road and Geotextile at Installation

Location	Length of Road m (feet)	Length of Geotextile m (feet)
Control Section	11 (37)	9 (30)
Test Section #1 (NW-SB)	11 (37)	9 (30)
Test Section #2 (NW-NP)	10 (34)	9 (28)
Average	10.9 (36)	9 (30)

3.4 Laboratory Testing

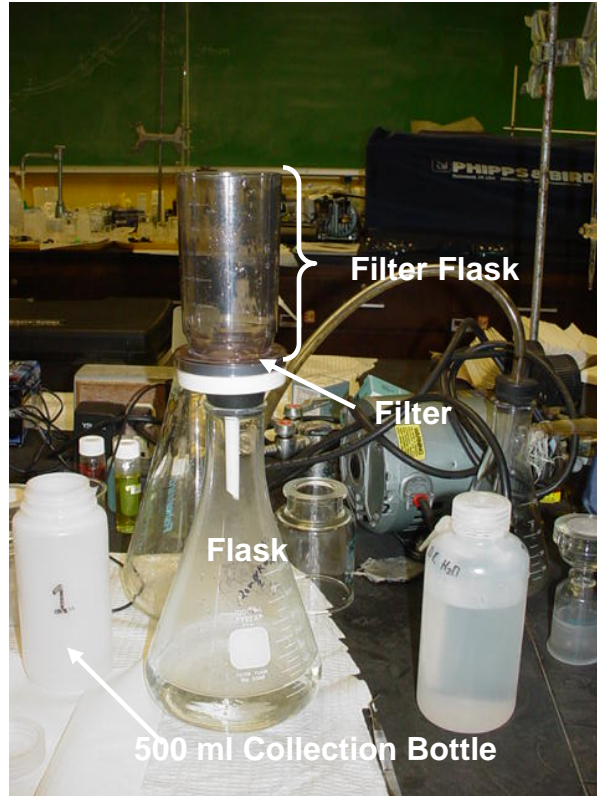
To determine the quantity of dust collected during the sampling events, the 500 ml (16 oz) bottles used to collect the dust-laden water samples, from the collection pans, were transported to the laboratory and a total suspended solids (TSS) test was performed. The amount of dust collected from the TSS was then divided by the area of the collection pan to normalize the dust collected.

In addition to collecting dust samples, aggregate samples were collected at the time of each dust sampling event. Site characterization of the subgrade and surface materials consisted of performing natural moisture contents (ASTM D 2216), Atterberg limits (ASTM D 4318), grain size distributions (ASTM D 422), and field measurements of the gravel lift thickness. Before performing the grain size analysis, a wash sieve (ASTM D 1140) was performed on all surface aggregate samples. The soil was classified, using the wash sieve and grain size results, according to the Unified Soil Classification System (USCS).

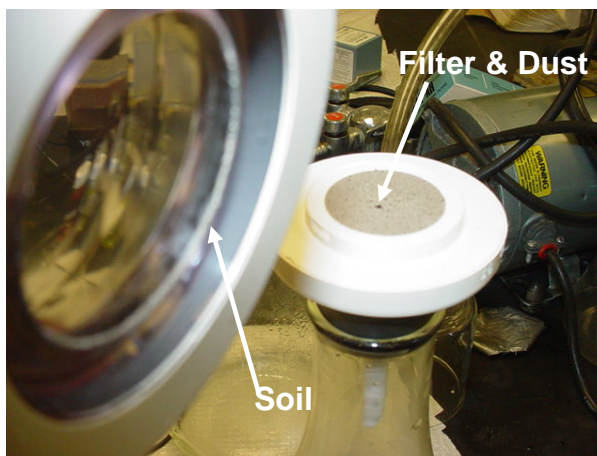
3.4.1 Total Suspended Solids

The TSS tests were performed according to ASTM 2540 D (Figure 3.14 (a)). Water samples, from the 500 ml (16 oz) bottles, were poured into the filter flask. Once the sample was in the filter flask the vacuum pump was turned on and provided a vacuum to push the water through the filter and collect in the flask (Figure 3.14 (a)). Dust was collected on the filter. Filters used to perform the TSS tests were Whatman 47 mm diameter glass microfiber filters with an opening size of 1.5 μm (Cat. No 1827 047).

It had been observed that a small amount of soil (dust) collected around the edge of the filter flask when it was removed from the flask (Figure 3.14 (b)). A sensitivity analysis was performed to determine how much soil (dust) was lost during transfer of the water samples in the collection pans to the 500 ml (16 oz) collection bottles and then performing the TSS test.



(a)



(b)

Figure 3.14 TSS apparatus (a) and observation of loss of soil (b).

A sensitivity analysis was performed by placing a known amount of soil (1 g, 0.1 g, and 0.01 g) in the collection pans with approximately 250 ml of water to represent the actual sampling practice. Next, the sample was funneled into the 500 ml water bottles and finally a TSS test was performed. A comparison of the measured mass of soil to that collected after the TSS test was performed is presented in Table 3.4. The test was performed three times for each amount of soil; Table 3.4 represents the average of the three tests. The relationship between recovered mass and actual mass is presented in Figure 3.15. An average ratio of recovered mass to actual mass was approximately 96%. Therefore, the collection procedure to collect the quantities of dust was deemed acceptable.

Table 3.4 Sensitivity Test Results for the TSS Test

Target Mass (g)	Actual Mass (g)	Recovered Mass (g)	Recovered/Actual
1	1.014	0.9613	0.960
0.1	0.1017	0.0934	0.918
0.01	0.0127	0.0125	0.984

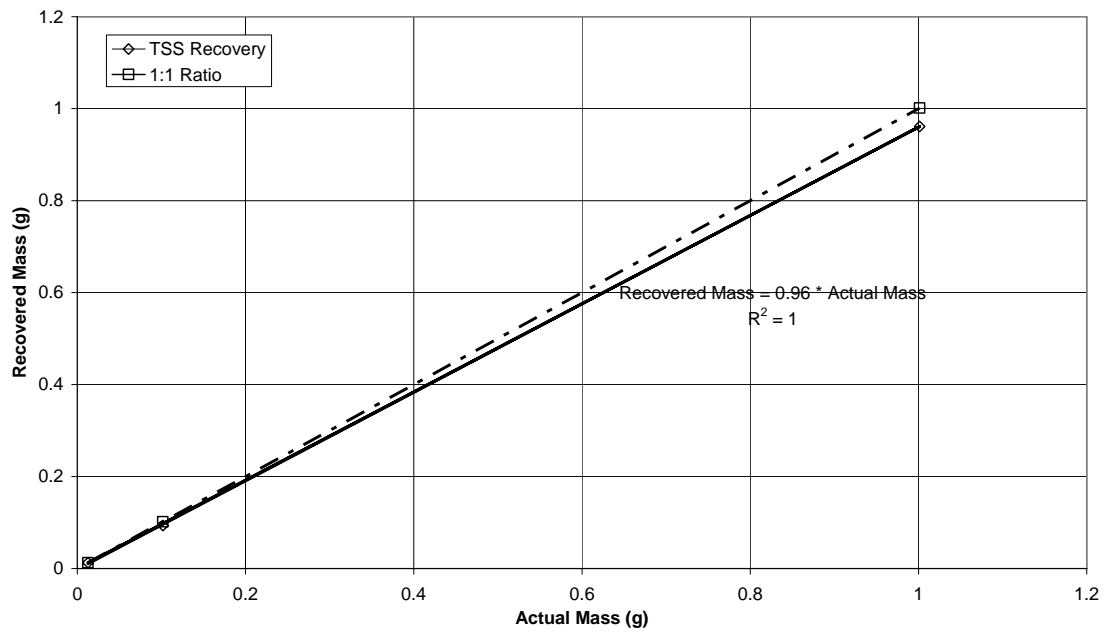


Figure 3.15 Comparison of actual mass to recovered mass.

3.4.2 Surface Aggregate

Samples of surface aggregate and subgrade soils were collected at the City of Columbia landfill site. Surface aggregate samples were collected periodically and typically correspond to the sampling events. Moisture contents, wash sieves, grain size distribution, and Atterberg limits were performed on the samples as appropriate. The soils and aggregates were classified using the Unified Soil Classification System (U.S.C.S.) (ASTM D 2487). The coefficient of curvature (C_c) and coefficient of uniformity (C_u) was determined for each aggregate sample where:

$$C_u = \frac{D_{60}}{D_{10}} \quad \text{Equation 3.1}$$

$$C_c = \frac{(D_{30})^2}{D_{10} * D_{60}} \quad \text{Equation 3.2}$$

And D_{10} = grain diameter (in mm) corresponding to 10% passing;

D_{30} = grain diameter (in mm) corresponding to 30% passing;

D_{60} = grain diameter (in mm) corresponding to 60% passing by weight

(Holtz and Kovacs 1981).

The aggregate used at the City of Columbia landfill test site was a 25 mm (1 inch) clean aggregate obtained from Boone Quarry. Laboratory tests were performed on the aggregate to determine its properties.

3.4.2.1 Properties of Aggregate

A hardness test, “scratchability”, was conducted on the aggregate (% retained above 2 mm (#10) Sieve). The range of hardness for this material is between 3 and 5.5 (Leet and Judson 1971). The aggregate could not be scratched by a penny but could be scratched by a knife.

Hydrochloric acid (HCL) was applied to the larger samples of aggregate. The aggregate reacted with a slight amount of steam coming off and small bubbles. This indicated that the aggregate was readily soluble limestone. According to the Geological map of Boone County, the rock in the area is limestone from the Mississippian System and Osagean Series of the Paleozoic Era (CARES 2006).

3.4.2.2 Durability Testing

Carbonate aggregates were used to surface the roads. Laboratory durability testing was performed to evaluate how quickly the aggregates deteriorate when exposed drying and wetting cycles with abrasion (ASTM D4644). Durability testing was also performed on the geotextiles to determine the effects of deterioration of the aggregate when geotextiles are added. To perform these durability tests a modified slake durability test was performed. The test was performed based on the slake durability test according to ASTM D4644. The modifications made to the slake durability test were: 1) there was only one drying and wetting cycle (ASTM D4644 specifies two wetting and drying cycles);

2) The amount of time the test was performed was increased from 10 minutes to 1, 6, 12, and 24 hours.

Two sets of tests were performed; one set of tests (i.e. 1, 6, 12, and 24 hour tests performed) determined the durability of the aggregate and the second set of tests determined the durability of the aggregate with geotextiles. To perform the aggregate modified slake test the following procedures were used:

- Aggregate was prepared by performing a sieve on the material and retaining the material that collected on and above the 2 mm sieve (#10 sieve). A wash sieve was then performed to eliminate any fines. The samples were then oven dried.
- Each drum (there were four drums total) was filled with 600 g (1.3 lbs) of the prepared aggregate and then oven dried for 24 hours (Figure 3.16).
- Mass of the oven dried aggregate and drum was taken before the test was performed
- Drums were placed in the trough and distilled water was added to a line specified by the ASTM D4644 (Figure 3.16).
- The motor was turned on and the test was performed for 1 hour (Figure 3.16).
- After 1 hour the motor was turned off and the drums with aggregate were oven dried for 24 hours.
- Mass of the oven dried aggregate and drum was taken.

- Lastly, the mass of specimen lost was determined and the slake durability index was calculated (mass of specimen after test/mass of specimen before test).

The procedures described above were repeated for each time period of 6 hours, 12 hours, and 24 hours. Different times were used to examine how the aggregate deteriorates when exposed to longer wetting and drying cycles.

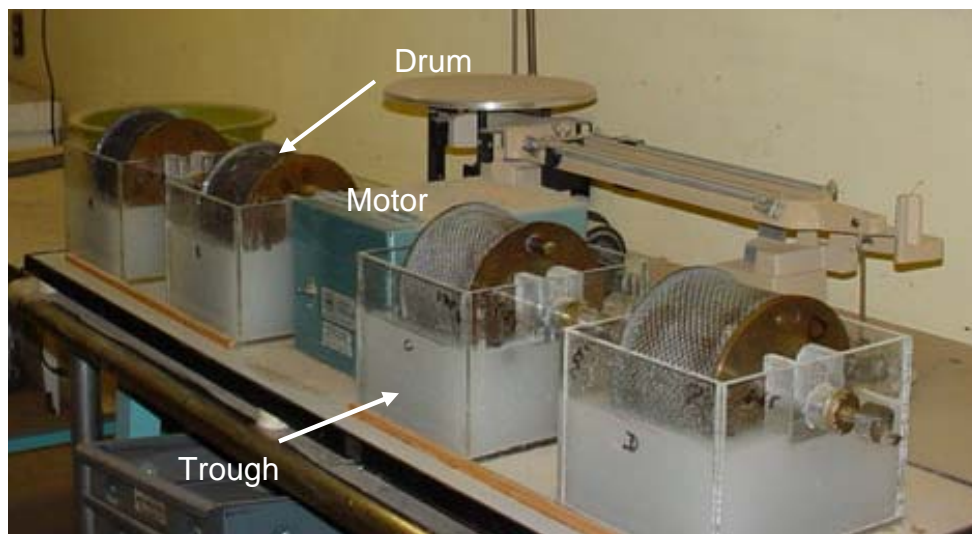


Figure 3.16 Slake durability apparatus.

The second set of tests examined the durability of the aggregate with geotextiles using the slake durability apparatus. Both of the nonwoven geotextiles were used (spun bonded and needle punched). Each geotextile was cut to 470 mm long by 100 mm wide, weighed, wrapped along the inside of the drum, and secured to the drum walls with bailing wire (Figure 3.17 and 3.18). Then the procedures described above were followed. After each test was performed, the geotextile was removed from the drum; the fines were shaken from the geotextile and then the geotextile was weighed.

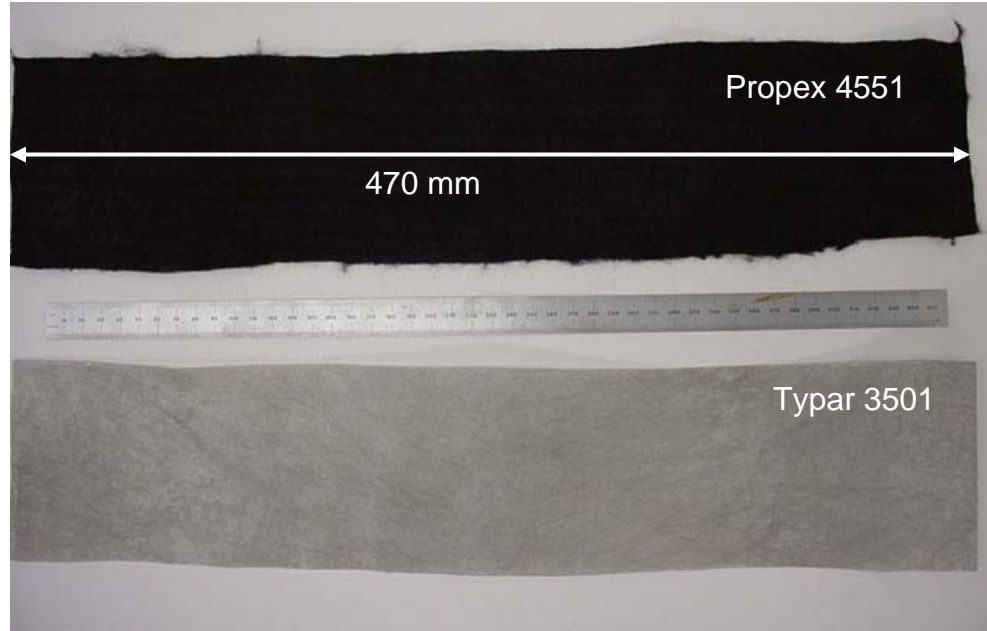


Figure 3.17 Geotextiles cut to size to fit into the drum.

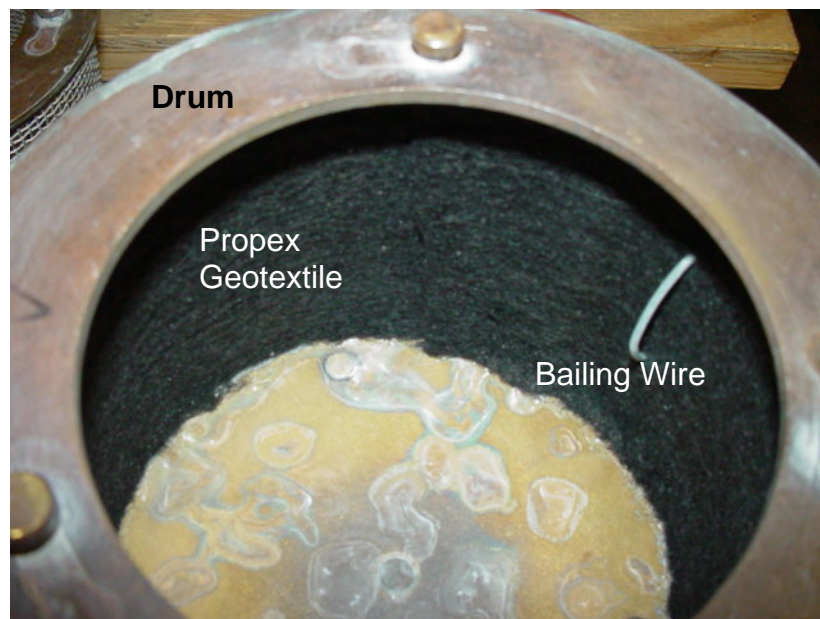


Figure 3.18 Slake durability drum with geotextile and bailing wire.

3.5 Summary

Preliminary field monitoring plans were used to determine the testing apparatuses that worked best to collect dust. The final field monitoring plan incorporated plastic collection pans, collecting surface aggregate samples, and performing field measurements. Thirty collection pans were used, ten per test section (Control, Test Section #1, and Test Section #2). Two nonwoven (a needle punched and a spun bonded) geotextiles were used.

Laboratory tests were performed to quantify the amount of dust collected and determine the performance of the surface aggregate. The tests consisted of performing total suspended solids (TSS) tests, grain size distributions, moisture contents of the aggregate, and measuring the aggregate thickness in the field.

Chapter 4 – Landfill Gravel Road Site

4.0 Introduction

A test section was identified in Boone County, Missouri, USA to determine the effectiveness of geotextiles in reducing dust from gravel roads (Figure 4.1). The test section is a gravel road located at the City of Columbia landfill (Landfill) and is 183 m (600 ft) long. The road runs north-south and provides access to the administration building and the recycle center. Presented herein are the site characteristics of the test section, a description of the geotextile test sections, and background and post-geotextile installation dust quantities. In addition, the estimated dust emissions the test section produces are examined.



Figure 4.1 Map of Missouri (cares.missouri.edu 2006).

4.1 Site Characterization

The gravel road test section is located at the border between the glaciated high plains and the transition to the Ozark Plateau (Missouri State Highway Commission 1962). The geographic area is in the drainage basin of the Missouri river and is characterized most recently as a humid climate with an annual average precipitation of 1.0 m (40 inches). The surficial soils are primarily loess (a wind deposited silt that can be highly erodible) with some areas of glacial till (Young et al. 2001).

4.2 Precipitation

Central Missouri's climate has most recently been identified as a humid climate with an annual average precipitation of 1.0 m (40 inches) (Midwestern Regional Climate Center 2006). At the landfill, precipitation data was collected using a manual rain gauge. The precipitation recorded at the landfill was compared to the precipitation recorded at surrounding weather stations within a 85 km (53 mile) radius of the landfill (averaging the rain data from the following weather stations: Columbia Regional Airport, University of Missouri Campus, California, Boonville, New Franklin, and Moberly, Missouri) (Appendix A). For 2005, the landfill recorded an annual precipitation of 1.2 m (47 inches) and the average of the surrounding weather stations recorded an annual precipitation of 1 m (38 inches) (Figure 4.2).

It is uncertain why there was a discrepancy between the landfill weather station and the surrounding weather stations. The landfill may lie in a geological

area that experiences extreme events. To reconcile this discrepancy, in the summer of 2005 the landfill installed an electronic rain gauge that collects and records the rain data. To date the rain gauge has not worked properly, it has been sent to the manufacturer for repair, and been re-installed but no new rain data have been collected.

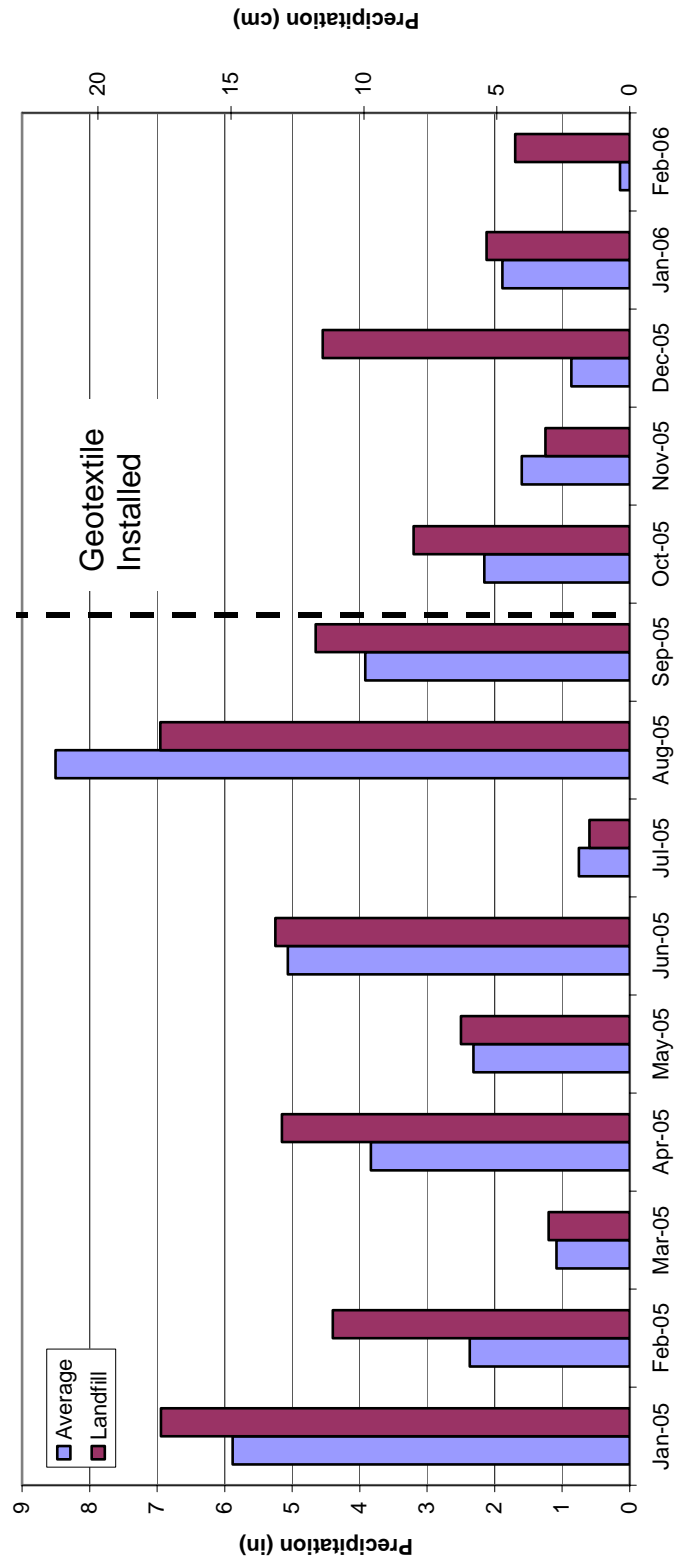


Figure 4.2 Precipitation data for 2005 Boone County, Missouri.

4.3 Traffic Flow

It is typical for recycle bin roll-off trucks (both single and tandem axle), two-axle cars and trucks, and other landfill maintenance vehicles to use the gravel road including the test section. Presented in Table 4.1 are the types of vehicles, weights of the vehicles, and the estimated number of passes each vehicle travels the road. The traffic information was provided by the City of Columbia Public Works and the estimated number of passes was based on actual numbers for a three week time period, from January 8, 2006 to January 28, 2006, which were averaged to determine the weekly number of passes each vehicle type makes.

4.4 Estimated Emissions

Each year the landfill operator must submit an Emission Inventory Questionnaire (EIQ) to the Missouri Department of Natural Resources (MDNR). The EIQ includes a procedure to estimate the amount of particulate matter (PM) no greater than 10 μm A (microns in aerodynamic diameter) generated from unpaved roads (EPA 1998). An annual fee is assessed based on the quantities of PM₁₀ calculated from the EIQ procedures.

The PM₁₀ Emission Factor was determined using the equations in the EIQ Form 2.7 Haul Road Fugitive Emissions Worksheet, the traffic information presented in Table 4.1, the 183 m (600 ft) length of test section, and MDNR default values described in Form 2.7 (Appendix B). The equation used was as follows and is based on the EPA's AP-42 equation for determining PM₁₀:

$$\text{PM}_{10} = 2.6 * \left(\frac{s}{12} \right)^{0.8} \left[\frac{(U + L)}{6} \right]^{0.4} \left(\frac{365 - p}{p} \right)^{0.3} \left(\frac{SW}{0.2} \right)^{0.3} \quad \text{Equation 4.1}$$

Where:

PM₁₀ = PM₁₀ Emission Factor

s = Silt Content (%)

U = Unloaded Truck Weight (tons)

L = Average Loaded Truck Weight (tons)

p = number of days with at least 0.01 inches of precipitation per year

SW = Surface Material Moisture Content (%)

To determine the PM₁₀, MDNR specifies a default value for the silt content and moisture content of the surface aggregate. These default values are 8.3% and 0.2% respectively. The effect of changing the default values on the resulting PM₁₀ estimation is examined in Section 4.8.

The PM₁₀ for the gravel road test section (183 m or 600 ft of length) located at the landfill was estimated to be 50 lbs of PM₁₀/VMT (VMT, annual vehicle miles traveled) (Appendix C). Once the emissions were calculated, Form 2.0 Emission Point Information was used to determine the effects that controls provide (Appendix B). Presented in Table 4.2 are the types of controls listed in Form 2.7 and the associated fees if controls are used, which was determined by using Form 3.0 (Appendix B). In Table 4.2, a column was designated for geotextiles as a control.

Table 4.1 Vehicle Type and Estimated Number of Passes

Vehicle Type	Passes		Estimated Average Weight, kg (lb)
	Monday-Friday (passes/5 days)	Saturday (passes/day)	
Small Cars/Trucks	60	10	1,400 (3,000)
Roll-Off, Tandem Axle	4	0	25,000 (55,000)
Roll-Off, Single Axle	30	0	13,600 (30,000)
Mini Roll-Off, Tandem Axle	6	0	8,200 (18,000)
Split-Hopper, Tandem Axle	29	0	18,100 (40,000)

Table 4.2 Annual Emission Fees and Associated Costs for 183 m (600 ft) Gravel Road at the City of Columbia Landfill. (Note: Annual cost was calculated to be \$1,275.)

Control Method	Efficiency Factor (%)	% of Untreated Cost
None	0	100
Water	50	50
Water Documented	>50	<50
Surfactant Spray	90	10
Geotextile	Unknown – To be determined	Unknown

4.5 *Pre-Geotextile Dust Quantities*

To determine the quantities of dust that were being generated on the landfill test section, dust sampling events were conducted before and after the geotextile sections were installed. Presented in Figure 4.3 is the monthly precipitation values, occurrences of sampling events, date of geotextile installation, and the cumulative estimated number of traffic passes since the geotextile installation.

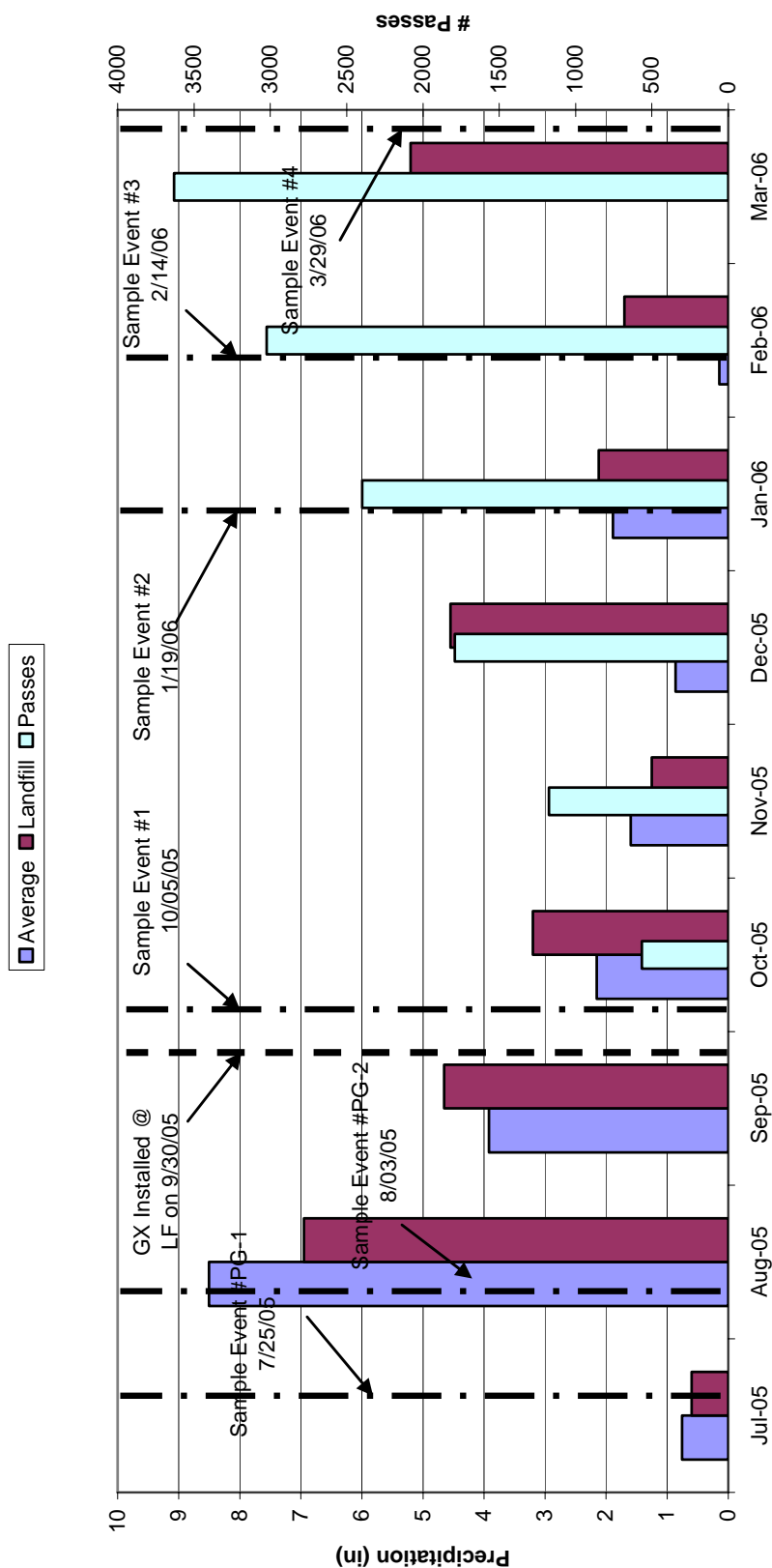


Figure 4.3 Precipitation data, sampling event occurrences, and traffic passes for the landfill gravel road test section.

4.5.1 Pre-Geotextile Sampling Events

Two dust sampling events were taken prior to the installation of the geotextiles and these are referred to as pre-geotextile sampling events with old gravel. The first pre-geotextile sampling event occurred on July 25, 2005 and the second pre-geotextile sampling event took place on August 3, 2005 (Figure 4.3). According to the record the landfill operator maintains, the existing surface aggregate was placed in June 28, 2005 approximately one month before pre-geotextile sampling events.

4.5.1.1 July 25, 2005 Sampling Event

At the first sampling event, at the Columbia landfill (July 25, 2005), approximately 30 m (100 ft) of the road that runs north-south and provides access to the administration building and the recycle center was used. Weather conditions during the time of sampling were taken with the Kestrel 3000 Pocket Weather Meter and the results are presented in Table 4.3. To collect the dust, eight tin pans were used and plastic sheeting was placed as indicated in Figure 3.5. The third row of pans (furthest from the road) was excluded from this test.

Table 4.3 Climate Conditions for Landfill Gravel Road Sampling Event 7-25-05.

Current Wind Speed (mph)	5	7	kmh
Max. 3-sec Gust Max. (mph)	10	17	kmh
Average Wind Speed (mph)	5	7	kmh
Average Temperature (°F)	92	33	°C
Wind Chill (°F)	-----	-----	°C
Relative Humidity (%)	59	-----	
Heat Stress (°F)	108	42	°C
Dew point (°F)	74	23	°C
Predominant Wind Direction	Southwest to Northeast		

Three samplings were taken to provide an average dust collected. Approximately 250 ml of water was placed in each pan per sample event. After the sample event was completed, the pans of water were funneled into 500 ml bottles. Total suspended solids (TSS) tests were performed on the water samples collected. The amount of dust per unit area was determined based on the area of the pans and amount of dust measured in the TSS tests.

Sampling 1 and 2 consisted of 15 passes, where one pass is equal to traveling one-way, in the center of the road. A two-axle truck, weighing 2,100 kg (4,600 lbs), was driven across the test section to generate dust. This vehicle was used for every sampling event. The average vehicle speed for sampling 1 and 2 was 30 and 33 kmh, respectively. Sampling 3 consisted of making 15 passes, where one pass is equal to traveling both directions, keeping the vehicle to the side of the road. The average vehicle speed for sampling 3 was 32 kmh (Appendix D).

Comparison of the two different methods to generate dust was investigated (Figure 4.4 and 4.5). Taking the average of samplings 1 and 2 and comparing to the amount of dust collected from sampling 3 indicates that:

West Side

- Average of samplings 1 and 2 was 100 to 540% of sampling 3.

East Side

- Average of sampling 1 and 2 was 24 to 53% of sampling 3.

A combination of having the truck travel in the center of the road and to the side of the road better represents the flow of traffic and traffic pattern. Therefore, in future sampling events, the truck was altered between traveling on the side of the road and in the center. Averaging of all three events to compare to future sampling events was deemed satisfactory due to the variability in how actual traffic uses the road. Presented in Figures 4.4 and 4.5 is the average from sampling event 1 and 2 with the maximum and minimum values represented.

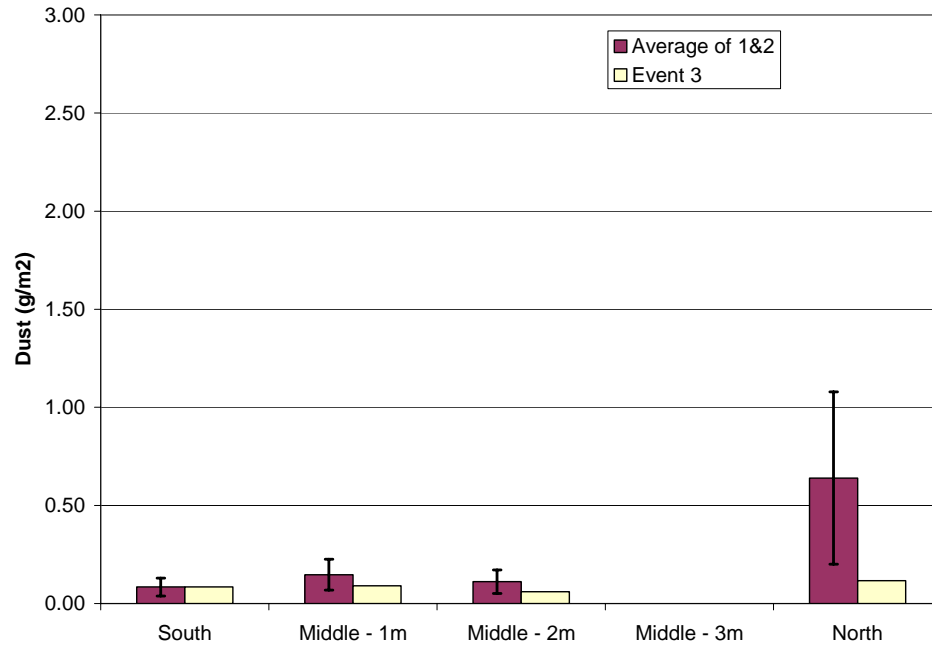


Figure 4.4 Average Samplings of 1 and 2 (15 passes in center of road) vs. Sampling 3 (15 roundtrip passes on edges of road) on the west side (upwind) of the road on 7/25/05.

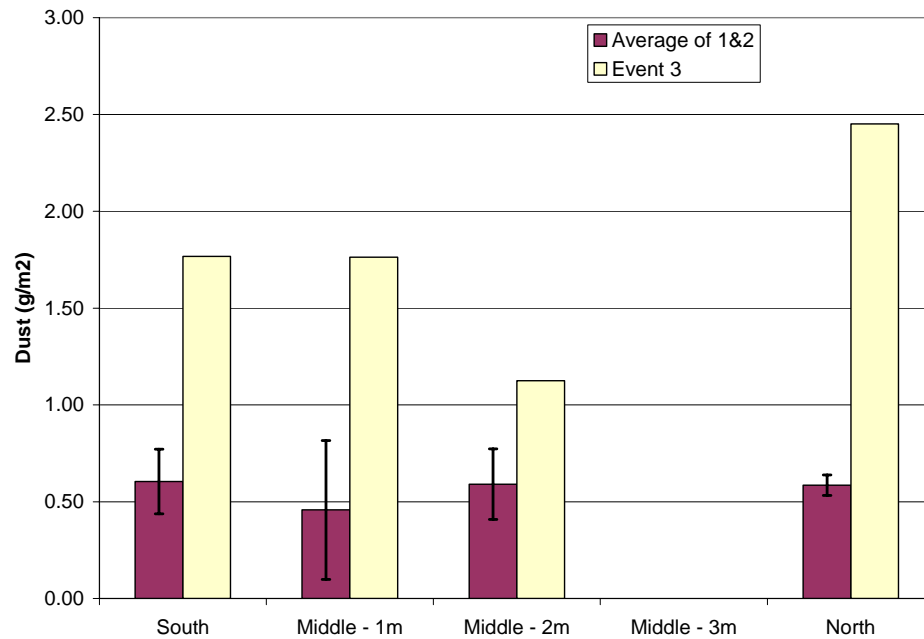


Figure 4.5 Average Samplings of 1 and 2 (15 passes in center of road) vs. Sampling 3 (15 roundtrip passes on edges of road) on the east side (downwind) of the road on 7/25/05.

To normalize the amount of dust that was collected, the mass of dust collected was divided by the area of the collection pan (diameter of the pan = 40.7 cm with an area of 1300 cm²). Presented in Figure 4.6 and 4.7 are the mass per unit area of dust collected during the July sampling event. The x-axis represents the location of the dust pans along the test section.

Dust collected on the east side of the road ranged from 3 to 12 times higher than the dust collected on the west side. The wind direction was predominately from the southwest to the northeast. An additional observation was the dust collected in the pan located 2 meters (6 feet) from the road contained less dust. Also, dust collected in the north pan was higher than that of the south pan, which is likely due to the predominate wind direction. Dust quantities obtained from the plastic sheeting were inconclusive since it was difficult to control the amount of dust lost during transferring.

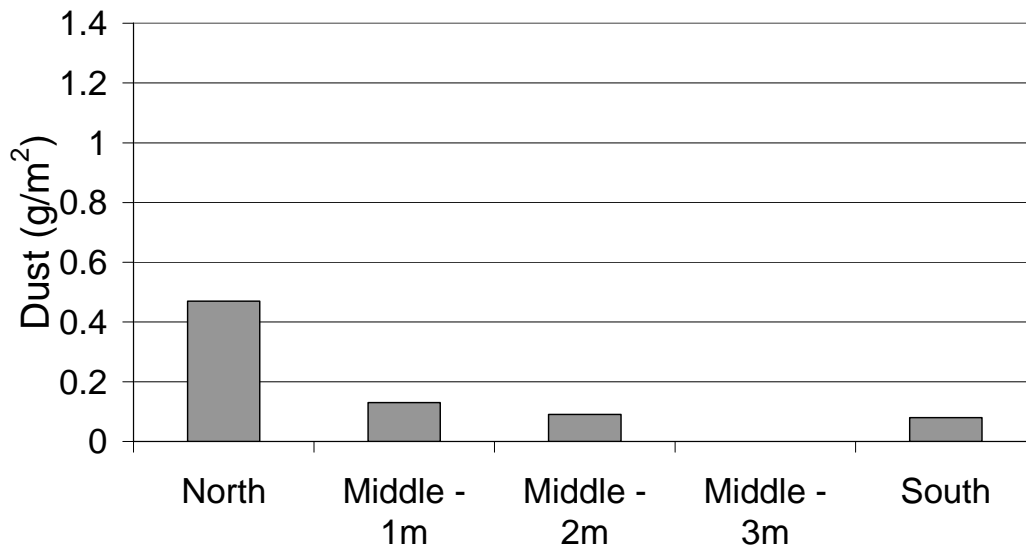


Figure 4.6 Dust collected for the west side (upwind) of the road on 7/25/05 (pre-geotextile).

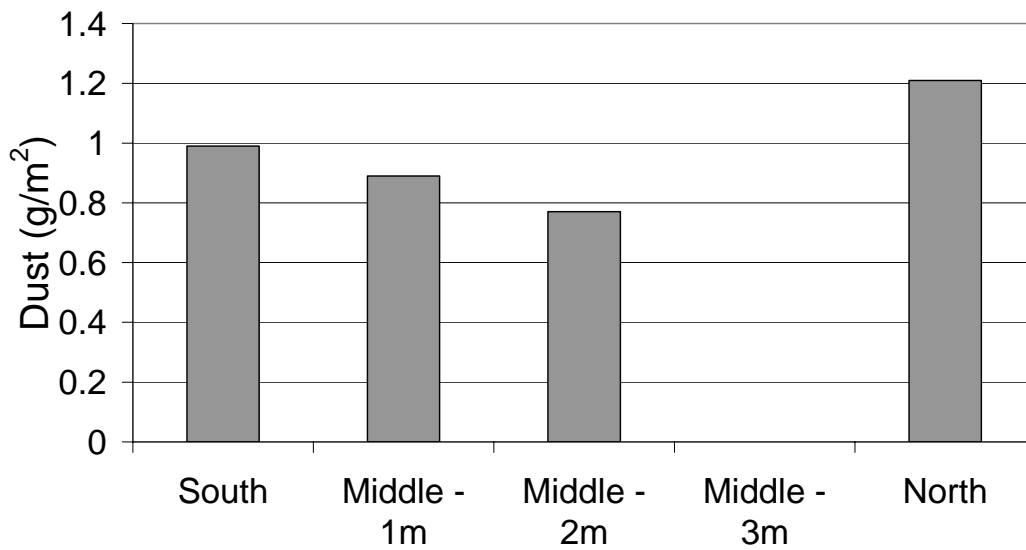


Figure 4.7 Dust collected for the east side (downwind) of the road on 7/25/05 (pre-geotextile).

4.5.1.2 August 3, 2005 Sampling Event

During the second sampling event at the Columbia landfill (August 3, 2005), ten pans were used and plastic sheeting was placed as indicated in Figure 3.5. The test section was the same section as used in the July sampling event.

As in the July sampling event, three samplings were taken and the weather conditions at the time of sampling are presented in Table 4.4. Each event consisted of 15 passes, where one pass is equal to traveling both directions (round trip), half the passes were completed in the center of the road and the remaining passes were conducted by keeping the vehicle to the side of the road. This later method better represents the actual use of the road. The same two-axle truck was used to generate dust.

Table 4.4 Climate Conditions for Landfill Gravel Road Sampling Event 8-03-05.

Current Wind Speed (mph)	-----	-----	kmh
Max. 3-sec Gust Max. (mph)	5	8	kmh
Average Wind Speed (mph)	2	4	kmh
Average Temperature (°F)	86	30	°C
Wind Chill (°F)	-----	-----	°C
Relative Humidity (%)	64	-----	
Heat Stress (°F)	96	36	°C
Dew point (°F)	73	23	°C
Predominant Wind Direction	Southwest to Northeast		

This site was very active and additional vehicles that traveled the road during testing were included in the number of passes and were typically counted as a one-way pass. Average vehicle speeds during each sampling 1, 2, and 3 were 34, 33, and 32 kmh, respectively (Appendix D).

An average of the three samplings was taken to determine the amount of dust collected on August 3, 2005. As in the July sampling event, the mass of dust collected was divided by the area of the collection pan to normalize the dust quantities (diameter of the pan = 40.7 cm with an area of 1300 cm²). The mass per unit area of dust collected during this sampling event is presented in Figures 4.8 and 4.9. The x-axis represents the location of the collection pans.

Dust collected on the east side of the road ranged from 2 to 5 times higher than the dust collected on the west side. As in July, the wind direction was dominantly from the southwest to the northeast. Dust in the collection pans located 1 and 2 meters (3 and 6 feet) from the road contained roughly the same amount of dust; however, the dust collected in the pan located 3 meters (9 feet) from the road was slightly less. Also, as in the July sampling event, the north collection pan contains more dust than the south pan. This was expected due to the wind direction. Since the July sampling, a modification was made to the plastic sheeting; however, the modification still hindered the dust collected on the plastic sheeting as inconclusive and difficult to control the mass of dust lost during transferring. Therefore plastic sheeting was discontinued after the August sampling event.

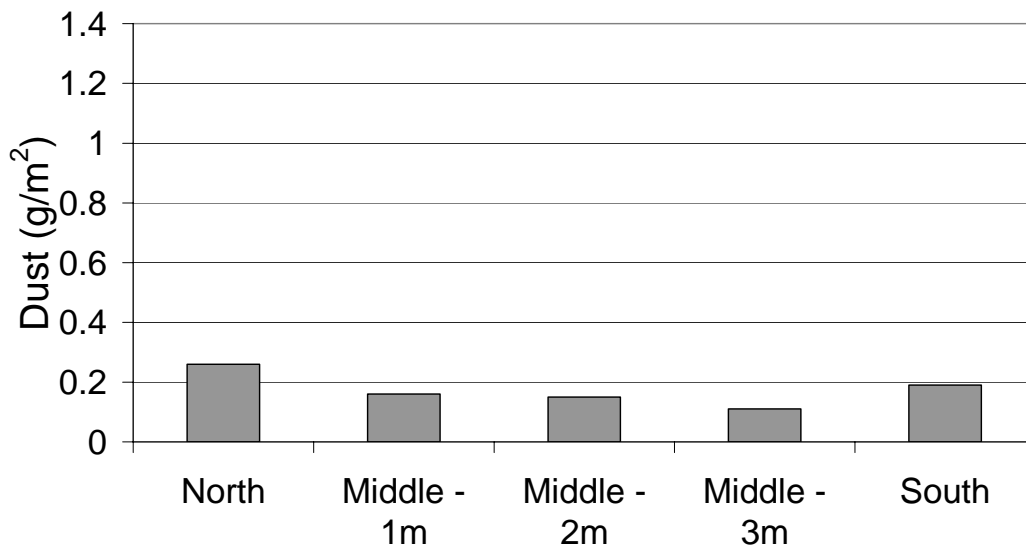


Figure 4.8 Dust collected for the west side (upwind) of the road on 8/03/05 (pre-geotextile).

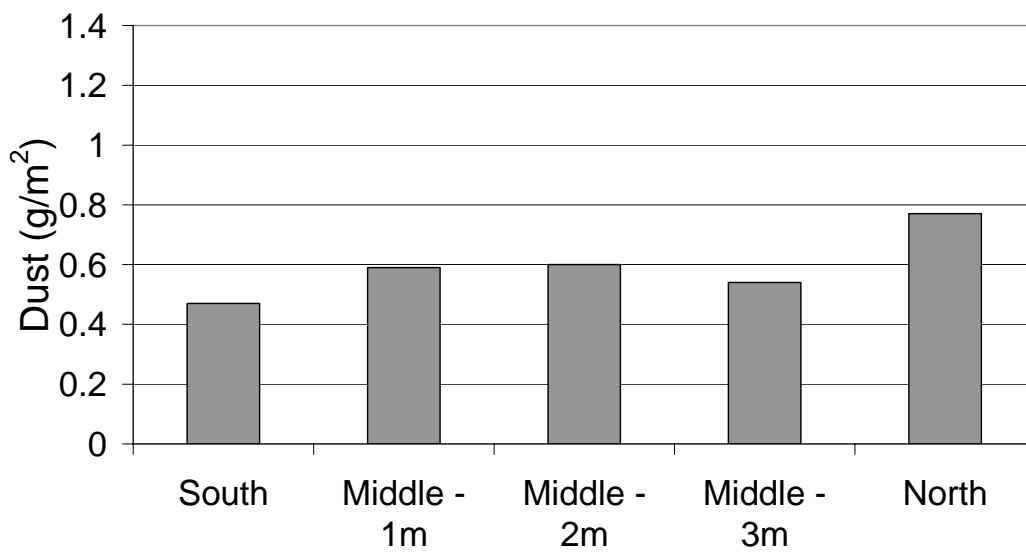


Figure 4.9 Dust collected for the east side (downwind) of the road on 8/03/05 (pre-geotextile).

4.5.1.3 A Comparison of Pre-Geotextile Dust Quantities

A comparison of the July and August sampling events indicate the following:

- Dust quantities ranged from 0.08 to 1.21 g/m².
- Dust collected on the west side (upwind) was 8 to 40% of that of the east side (downwind).
- As the collection pans moved further away from the road (1, 2, and 3 m collection pans), the amount of dust collected decreased (Figure 4.10).
- The collection pan located in the North position always had higher levels of dust.
- There had been one day of precipitation between the sampling events. The rainfall during the precipitation event was 13 mm (0.5 in).

From these sampling events, the dust collected on the east side (downwind) of the road and the north collection pan were expected to have higher levels of dust; this is due to the fact that the wind direction is dominantly from the southwest to the northeast. Dust quantities collected in July were typically higher than the dust quantities collected in August. This is likely due to the fact that there had only been 1.5E-2 m (0.6 inches) of rain during the month of July (Figure 4.3). The road experienced approximately 0.18 m (7.0 inches) of rain during the month of August.

The average dust quantities obtained from the July 25 and August 3, 2005 tests were used as pre-geotextile dust quantities. These pre-geotextile dust quantities were used to compare the dust levels prior to the installation of the geotextiles to the control section once geotextiles were installed. Presented in Figure 4.11 and 4.12 are the pre-geotextile dust quantities, or average dust quantities from the July and August sampling events, for both the west (upwind) and east (downwind) side of the road. The y-error bars indicated the maximum and minimum measured dust and represent the variability in the test data. These error bars will be used in the proceeding figures and always represent the minimum and maximum dust measured.

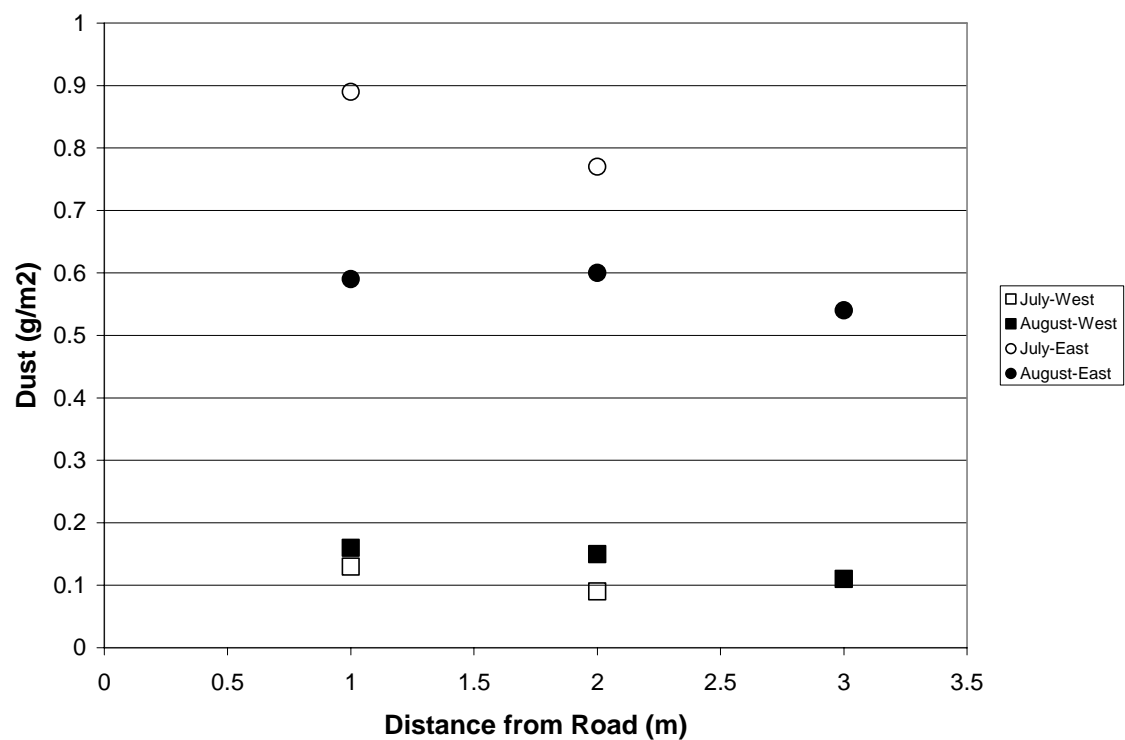


Figure 4.10 Dust collected from the collection pans located 1, 2 and 3 m from the edge of the road.

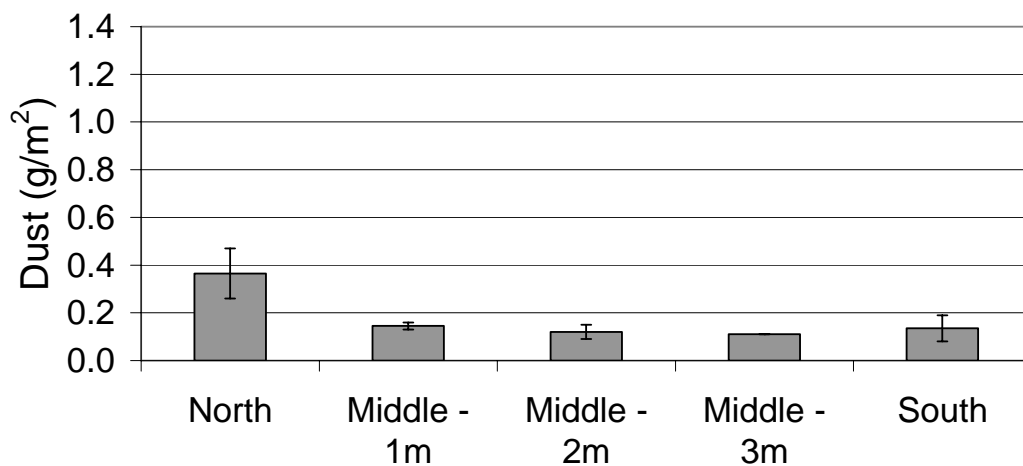


Figure 4.11 Average of pre-geotextile dust collected for the west side (upwind) of the road (7/25/05 and 8/3/05 events).

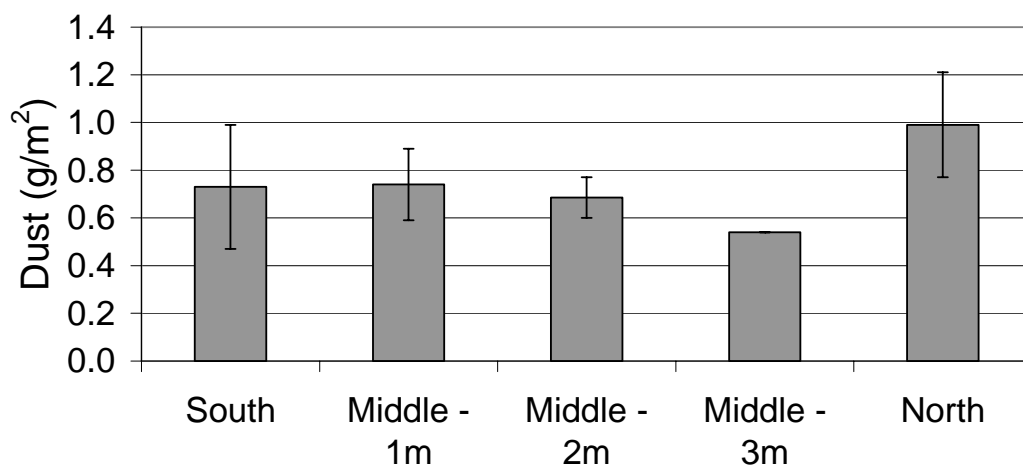


Figure 4.12 Average of pre-geotextile dust collected for the east side (downwind) of the road (7/25/03 and 8/3/05 events).

4.6 *Post-Geotextile Placement Sampling Events*

Four dust sampling events were taken after the geotextiles were installed. Installation of the geotextiles is discussed in detail in Chapter 3. Post-geotextile sampling events took place on October 5, 2005, January 19, 2006, February 14, 2006, and March 29, 2006 (Figure 4.3). Approximately 180 m (600 ft) of the road that runs north south and provides access to the administration building and the recycle center was used for each post-geotextile sampling event. This length of road has three sections, a Control Section and Test Sections 1 and 2, each about 60 m in length as described in Chapter 3.

Sampling was conducted in a similar manner to that of the pre-geotextile sampling events. Modifications were made based on equipment and experienced gained from the pre-geotextile sampling events as described in Chapter 3. The final field monitoring plan was implemented to collect the post-geotextile samplings.

4.6.1 October 5, 2005 Post-Geotextile Sampling Event

The first post-geotextile sampling event, at the Columbia landfill, took place on October 5, 2005 one week after installation of the geotextiles. No precipitation events had occurred between the installation of the geotextiles and this sampling event. However, rainfall did occur on the day of the sampling event of approximately 18 mm (0.7 inches). Weather conditions, during the time of sampling, were taken with the Kestrel 3000 Pocket Weather Meter and are

presented in Table 4.5. The average vehicle speed for each sampling was 33 kmh and 32 kmh (21 and 20 mph) (Appendix D).

Table 4.5 Climate Conditions for Landfill Gravel Road Sampling Event 10-05-05.

Current Wind Speed (mph)	5	8	kmh
Max. 3-sec Gust Max. (mph)	9	15	kmh
Average Wind Speed (mph)	3	5	kmh
Average Temperature (°F)	85	29	°C
Wind Chill (°F)	85	30	°C
Relative Humidity (%)	72	-----	
Heat Stress (°F)	96	35	°C
Dew point (°F)	79	26	°C
Predominant Wind Direction	Southwest to Northeast		

An average of the two samplings was taken to determine the amount of dust collected on October 5, 2005. Presented in Figure 4.13 and 4.14 are the quantities of dust collected during this sampling event. The x-axis represents the location of the collection pans.

Dust quantities collected on the west side (upwind) of the road are described as:

- Dust collected ranged from 0.11 to 0.26 g/m² with an average of 0.17 g/m².
- Control section was 40 to 150% of the Pre-Geotextile dust levels.
- Nonwoven Needle Punched (Propex) geotextile ranged from 10 to 50% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 20 to 30% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 60 to 180% of the control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 70 to 190% of the control section

Dust quantities collected on the east side (downwind) of the road are described as:

- Dust collected ranged from 0.11 to 0.38 g/m² with an average of 0.20 g/m².
- Control Section was 20 to 30% of the Pre-Geotextile dust levels.

- Nonwoven Needle Punched (Propex) geotextile ranged from 30 to 50% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 20 to 30% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 90 to 310% of the control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 60 to 170% of the control section

The wind direction was dominantly from the southwest to the northeast. Typically the dust collected on the east side was greater than the dust collected on the west side; ranging from 40% to 300% of the west side. There was a reduction in dust when the geotextile and new gravel was placed compared to the Pre-geotextile dust collected, as noted by the 20 to 30% reduction in dust on the east (downwind) side. Rainfall in September and October of 2005 was 0.09 to 0.13 m (3 to 5 inches) whereas the rainfall in August was 0.18 m (7 inches) (Figure 4.3). It is proposed that the decrease in dust is possibly due to the aggregate being new.

Investigating the dust collected in the collection pans located at 1, 2, and 3 m from the road typically indicated that the dust decreased as the distance from the road increased (Figure 4.15). This occurred every time with the exception of the collection pan located on the east (downwind) side for the Control section, where an increase in dust as the collection pans moved farther away from the

road was observed. An increase was observed in the collection pan located 3 m from the road for Test Section 2 (Propex).

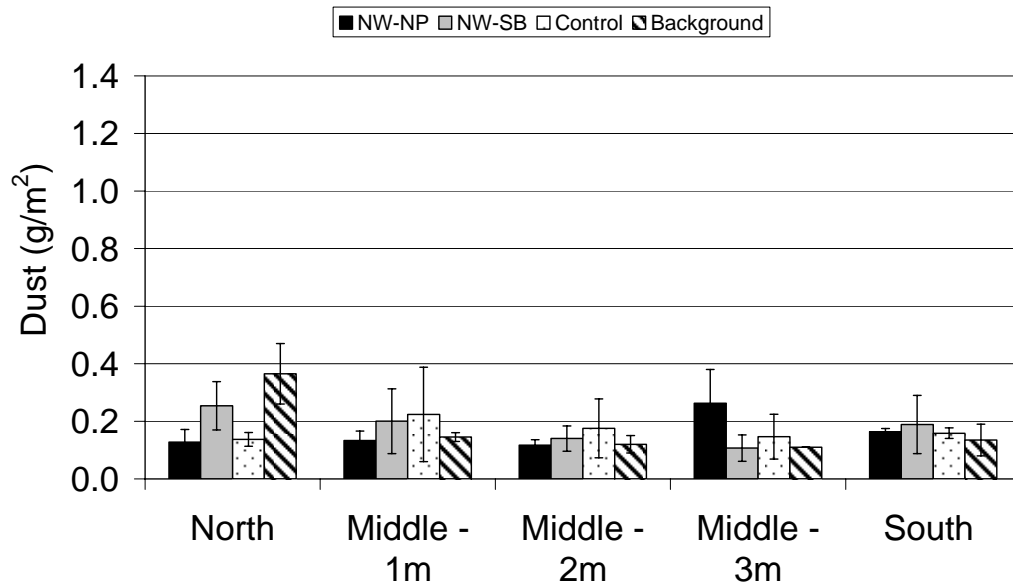


Figure 4.13 Post-geotextile dust collected for the west side (upwind) of the road on 10/5/05.

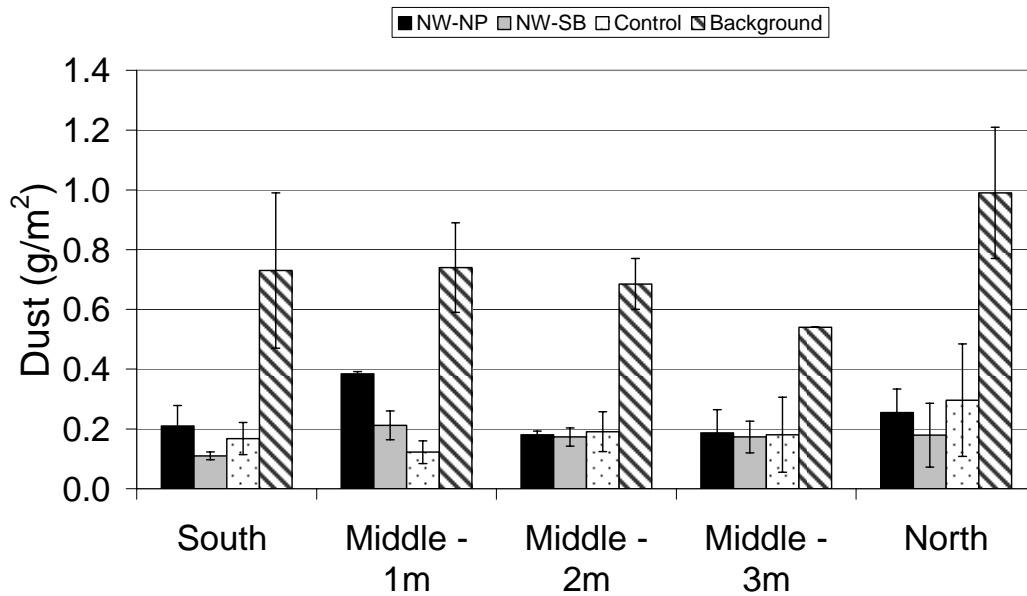


Figure 4.14 Post-geotextile dust collected for the east side (downwind) of the road on 10/5/05.

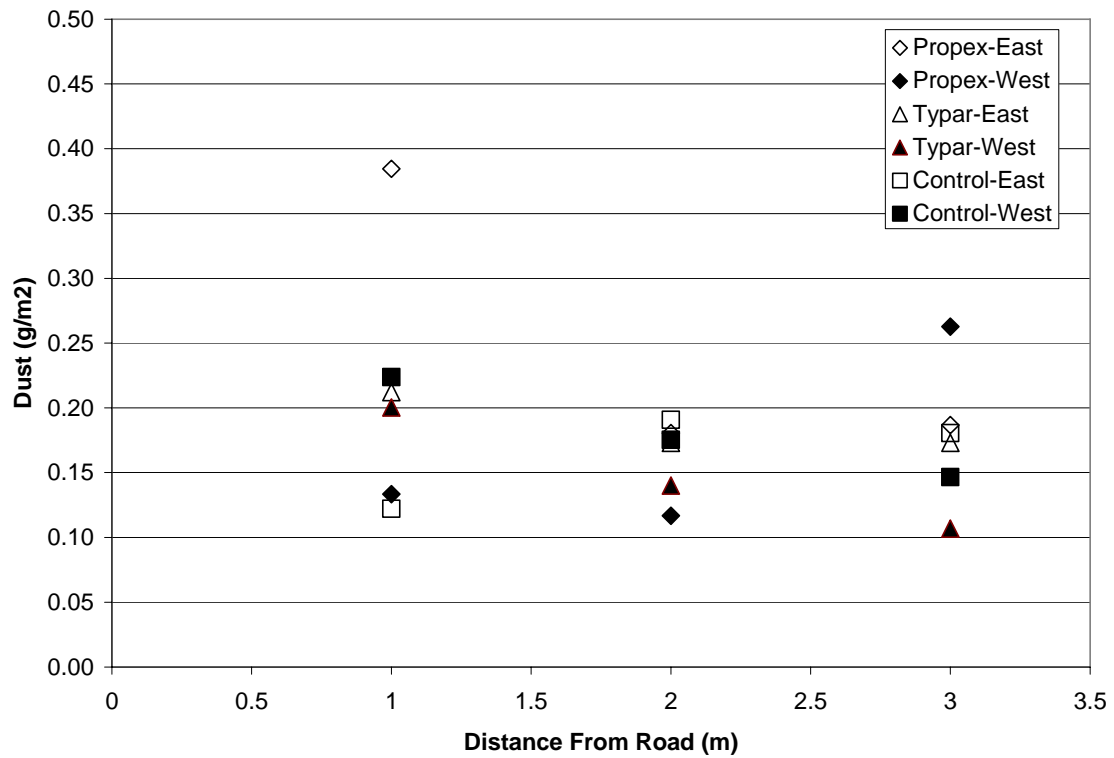


Figure 4.15 Dust collected from the collection pans located 1, 2 and 3 m from the edge of the road on October 5, 2005.

4.6.2 January 19, 2006 Post-Geotextile Sampling Event

The second, post-geotextile, sampling event, at the Columbia landfill took place on January 19, 2005. Weather conditions, during the time of sampling, were taken with the Kestrel 3000 Pocket Weather Meter and are presented in Table 4.6. The average vehicle speed for each sampling was 32 kmh and 36 kmh (20 and 23 mph) (Appendix D).

Table 4.6 Climate Conditions for Landfill Gravel Road Sampling Event 1-19-06.

Current Wind Speed (mph)	12	19	kmh
Max. 3-sec Gust Max. (mph)	14	22	kmh
Average Wind Speed (mph)	8	13	kmh
Average Temperature (°F)	64	18	°C
Wind Chill (°F)	66	19	°C
Relative Humidity (%)	40	-----	
Heat Stress (°F)	63	17	°C
Dew point (°F)	39	4	°C
Predominant Wind Direction	Southwest to Northeast		

An average of the two samplings was taken to determine the amount of dust collected on January 19, 2006. Presented in Figure 4.16 and 4.17 are the quantities of dust collected during this sampling event. The x-axis represents the location of the collection pans.

Dust quantities collected on the west side (upwind) of the road are described as:

- Dust collected ranged from 0.07 to 0.76 g/m² with an average of 0.37 g/m².
- Control section was 40 to 150% of the Pre-Geotextile dust levels.
- Nonwoven Needle Punched (Propex) geotextile ranged from 10 to 80% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 10 to 40% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 10 to 300% of the control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 20 to 130% of the control section

Dust quantities collected on the east side (downwind) of the road are described as:

- Dust collected ranged from 0.63 to 1.96 g/m² with an average of 1.12 g/m².
- Control Section was 60 to 700% of the Pre-Geotextile dust levels.

- Nonwoven Needle Punched (Propex) geotextile ranged from 90 to 210% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 90 to 190% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 50 to 90% of the control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 60 to 80% of the control section

The wind direction was predominately from the southwest to the northeast. Typically the dust collected on the east side was greater than the dust collected on the west side; ranging from 100% to 1000% of the west side. Dust collected in January was 3 to 14 times higher than the dust collected in October, for the east (downwind side). Values of dust collected for the west (upwind) side ranged from 0.3 to 5 times higher than the October sampling event. Rainfall in January of 2006 was 0.05 m (2 inches) over seven precipitation events whereas the average rainfall from August to October was 0.13 m (5 inches) and from October to December rainfall averaged 0.08 m (3 inches) (Figure 4.3). Therefore, the increase in dust is likely due to the lower amounts of rainfall and the degradation of the aggregate.

Investigating the dust collected in the collection pans located at 1, 2, and 3 m from the road indicated that the dust decreased as the distance from the road increased on the east (downwind) side of the road (Figure 4.18). For the west (upwind) side this generally occurred with the exception of the collection pan

located 1 m from the road for the Control section, where an increase in dust as the collection pans moved farther away from the road was observed. This may indicate that the control section has smaller particles than the other sections. The smaller particles will likely weigh more and therefore settle out further away from the edge of the road.

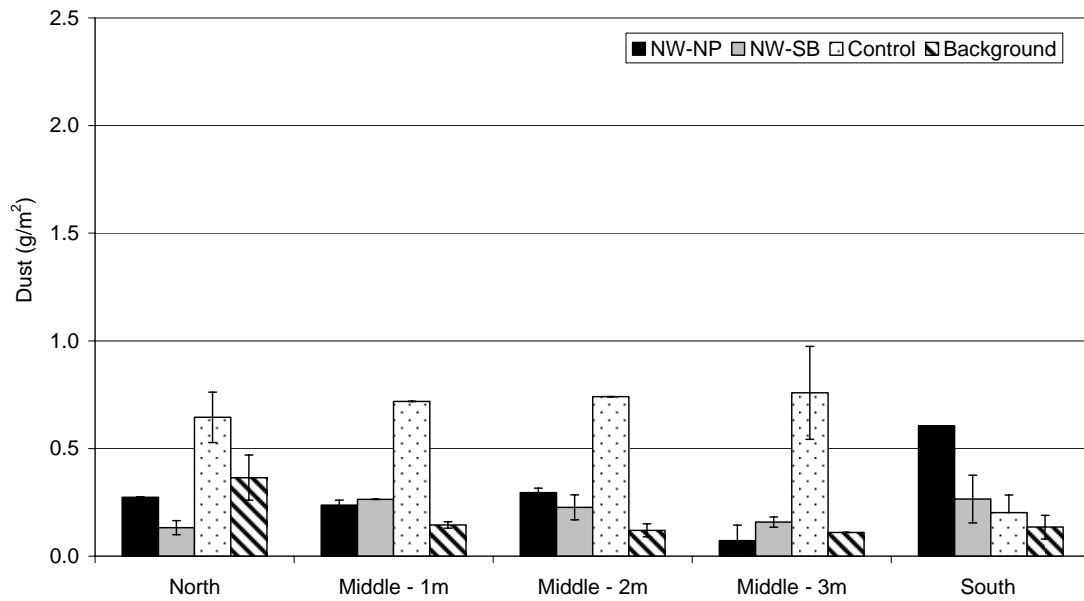


Figure 4.16 Post-geotextile dust collected for the west side (upwind) of the road on 1/19/06.

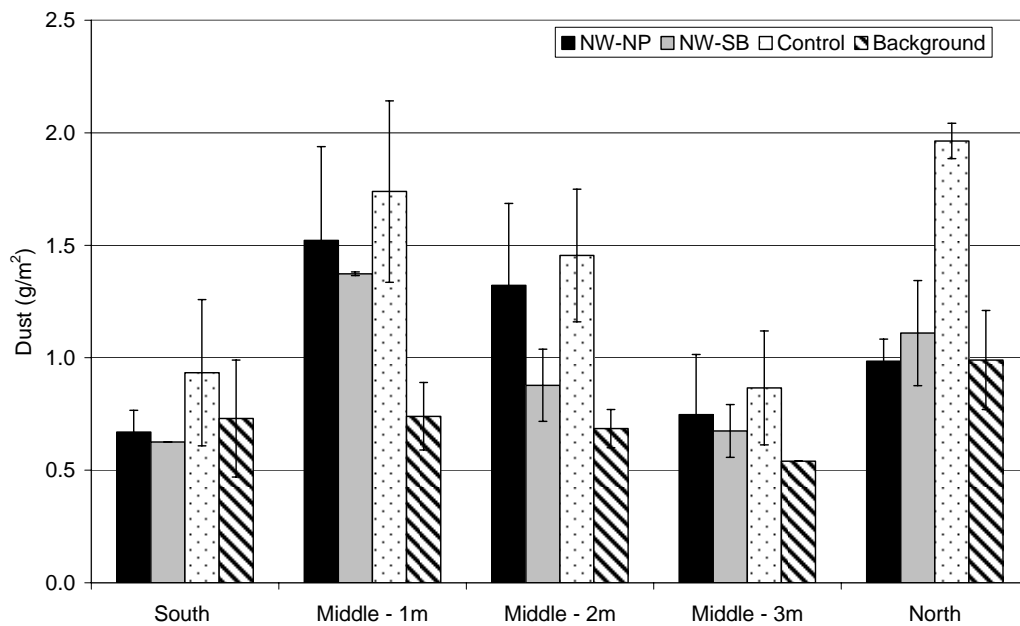


Figure 4.17 Post-Geotextile dust collected for the east side (downwind) of the road on 1/19/06.

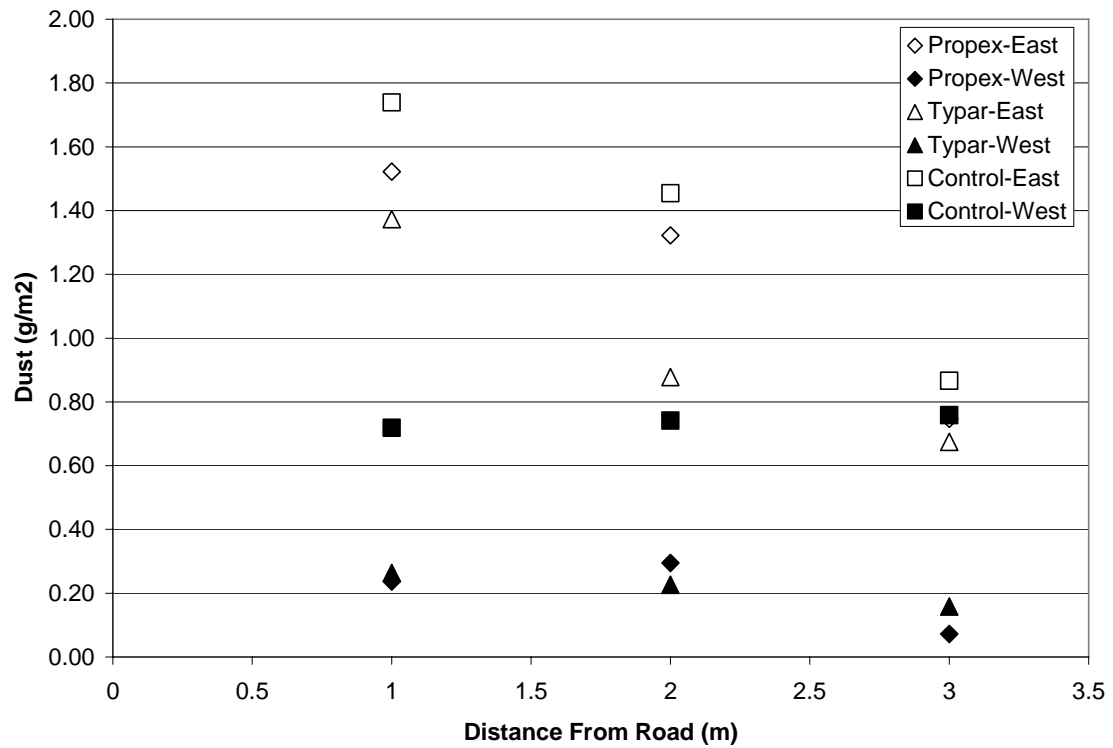


Figure 4.18 Dust collected from the collection pans located 1, 2 and 3 m from the edge of the road on January 19, 2006.

4.6.3 February 14, 2006 Post-Geotextile Sampling Event

The third, post-geotextile, sampling event, at the Columbia landfill took place on February 14, 2006. Weather conditions, during the time of sampling, were taken with the Kestrel 3000 Pocket Weather Meter and are presented in Table 4.7. The average vehicle speed for each sampling was 32 kmh and 33 kmh (20 and 21 mph) (Appendix D).

Table 4.7 Climate Conditions for Landfill Gravel Road Sampling Event 2-14-06.

Current Wind Speed (mph)	9	15	kmh
Max. 3-sec Gust Max. (mph)	15	23	kmh
Average Wind Speed (mph)	7	11	kmh
Average Temperature (°F)	58.4	14.7	°C
Wind Chill (°F)	55.3	12.9	°C
Relative Humidity (%)	37	-----	
Heat Stress (°F)	55	13	°C
Dew point (°F)	34	1	°C
Predominant Wind Direction	Southwest to Northeast		

An average of the two samplings was taken to determine the amount of dust collected on February 14, 2006. Presented in Figure 4.19 and 4.20 are the quantities of dust collected during this sampling event. The x-axis represents the location of the collection pans.

Dust quantities collected on the west side (upwind) of the road are described as:

- Dust collected ranged from 0.1 to 0.71 g/m² with an average of 0.4 g/m².
- Control section was 130 to 630% of the Pre-Geotextile dust levels.
- Nonwoven Needle Punched (Propex) geotextile ranged from 30 to 90% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 10 to 110% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 50 to 170% of the control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 20 to 90% of the control section

Dust quantities collected on the east side (downwind) of the road are described as:

- Dust collected ranged from 0.66 to 2.81 g/m² with an average of 1.35 g/m².
- Control Section was 80 to 180% of the Pre-Geotextile dust levels.

- Nonwoven Needle Punched (Propex) geotextile ranged from 150 to 470% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 100 to 160% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 150 to 270% of the Control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 60 to 150% of the control section

The wind direction was predominately from the southwest to the northeast. Typically the dust collected on the east (downwind) side was greater than the dust collected on the west side; ranging from 110% to 1100% of the west (upwind) side. Dust collected in February ranged from 0.4 to 3.4 times higher than the dust collected in January, for the east (downwind side). Values of dust collected for the west (upwind) side ranged from 0.4 to 5 times higher than the January sampling event. Comparing the February dust collected to that collected in October indicated that the dust levels were 3 to 14 times higher for the east (downwind) side and 0.5 to 6 times higher for the west (upwind) side. Rainfall in February of 2006 was 0.04 m (1.7 inches) over three precipitation events (and five trace events) whereas January of 2006 was 0.05 m (2 inches) over seven precipitation events and the average rainfall from August to October was 0.13 m (5 inches) and from October to December rainfall averaged 0.08 m (3 inches) per month (Figure 4.3). Therefore, the increase in dust is likely due to the lower amounts of rainfall and the degradation of the aggregate.

Investigating the dust collected in the collection pans located at 1, 2, and 3 m from the road the dust is expected to decrease as the distance from the road increased. However in the February sampling the dust collected in the pan located 3 m from the road collected more dust than the pan located at 2 m from the road (Figure 4.21). This occurred in every sampling location except for the collection pans located on the west (upwind) side for the Control section. For the Typar and Control section (west side) the dust increased as you moved further from the road and the Propex section slightly decreased. This may indicate that there is an increase in smaller dust particles, hence the increase in dust at locations further from the road, for the Typar and Control sections than for the Propex section. Since the smaller dust particles are likely to travel through the air further than the larger dust particles which are more likely to settle more quickly due to their mass.

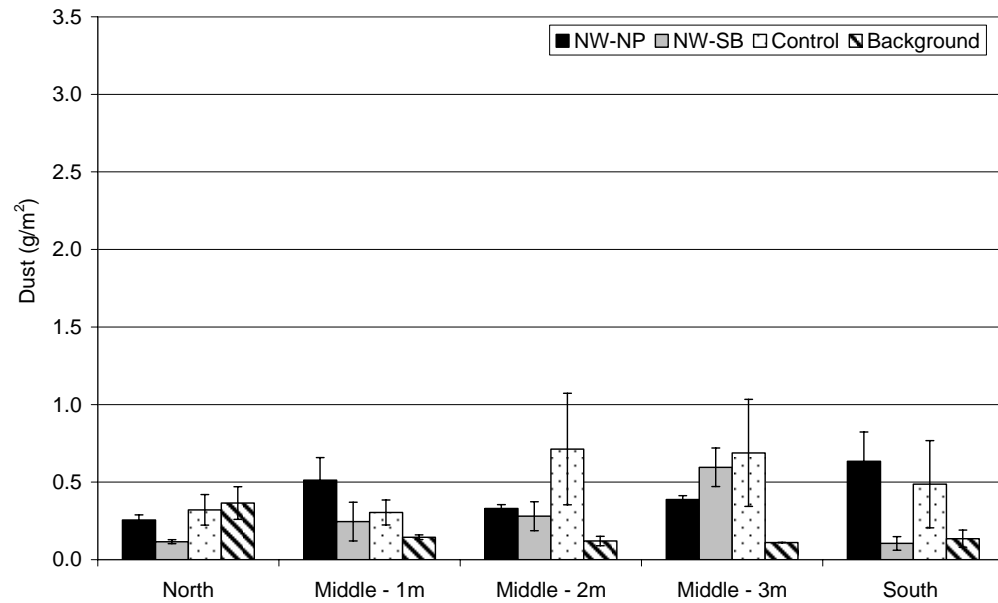


Figure 4.19 Post-geotextile dust collected for the west side (upwind) of the road on 2/14/06.

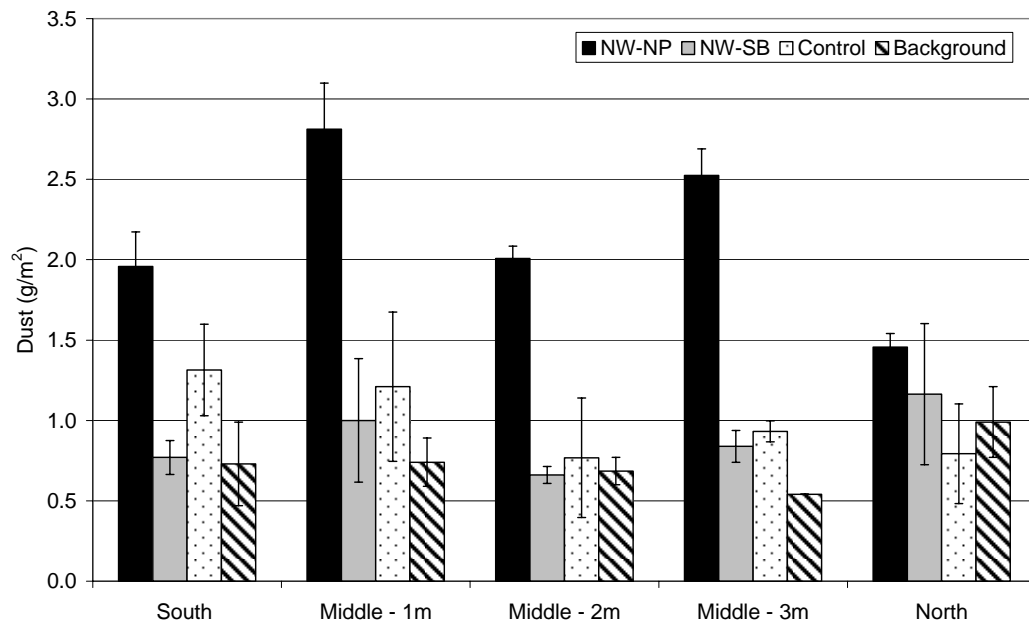


Figure 4.20 Post-geotextile dust collected for the east side (downwind) of the road on 2/14/06.

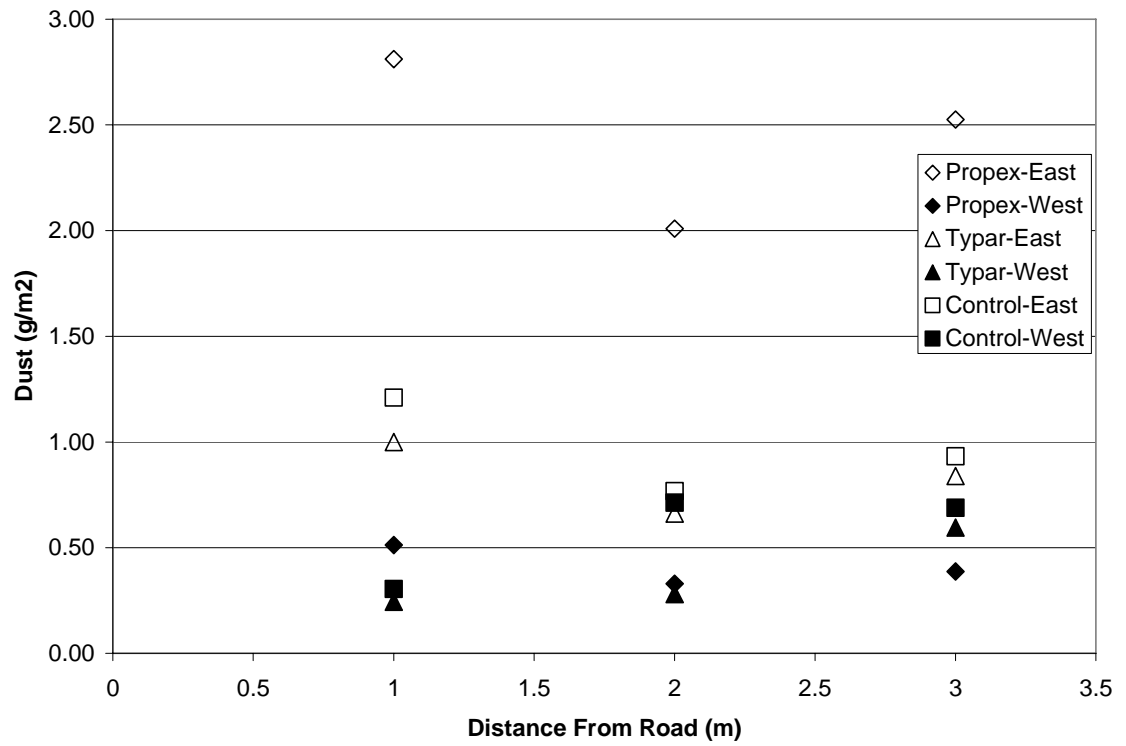


Figure 4.21 Dust collected from the collection pans located 1, 2 and 3 m from the edge of the road on February 14, 2006.

4.6.4 March 29, 2006 Post-Geotextile Sampling Event

The fourth, post-geotextile, sampling event, at the Columbia landfill took place on March 29, 2006. Weather conditions, during the time of sampling, were taken with the Kestrel 3000 Pocket Weather Meter and are presented in Table 4.8. The average vehicle speed for each sampling was 35 kmh and 33 kmh (22 and 21 mph) (Appendix D).

Table 4.8 Climate Conditions for Landfill Gravel Road Sampling Event 3-29-06.

Current Wind Speed (mph)	6.7	11	Kmh
Max. 3-sec Gust Max. (mph)	7.9	13	Kmh
Average Wind Speed (mph)	5	8	Kmh
Average Temperature (°F)	64.3	17.9	°C
Wind Chill (°F)	64.4	18.0	°C
Relative Humidity (%)	56.4	-----	
Heat Stress (°F)	63.1	17.3	°C
Dew point (°F)	50	10.0	°C
Predominant Wind Direction	Southeast to Northwest (Note: Change in direction from other sampling events.)		

An average of the two samplings was taken to determine the amount of dust collected on March 29, 2006. Presented in Figure 4.22 and 4.23 are the quantities of dust collected during this sampling event. The x-axis represents the location of the collection pans.

Dust quantities collected on the west side (downwind) of the road are described as:

- Dust collected ranged from 0.4 to 1.3 g/m² with an average of 0.72 g/m².
- Control section was 220 to 730% of the Pre-Geotextile dust levels.
- Nonwoven Needle Punched (Propex) geotextile ranged from 80 to 170% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 60 to 100% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 60 to 170% of the Control section
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 50 to 120% of the control section

Dust quantities collected on the east side (upwind) of the road are described as:

- Dust collected ranged from 0.02 to 0.15 g/m² with an average of 0.07 g/m².
- Control Section was 4 to 30% of the Pre-Geotextile dust levels.
- Nonwoven Needle Punched (Propex) geotextile ranged from 0 to 20% of the pre-geotextile measurements
- Nonwoven Spun Bonded (Tytar) geotextile ranged from 0 to 10% of the pre-geotextile measurements
- Nonwoven Needle Punched (Propex) geotextile ranged from 20 to 160% of the Control section

- Nonwoven Spun Bonded (Tytar) geotextile ranged from 10 to 120% of the control section

The wind direction was predominately from the southeast to the northwest. Note that the wind direction has switched from the previous sampling events, where the wind direction was southwest to northeast. Due to the change in wind direction the dust collected on the east (upwind) side was lower than the dust collected on the west side; ranging from 4% to 20% of the west (downwind) side. Dust collected in March ranged from 0.6 to 8.1 times the dust collected in February for the west (downwind side). Values of dust collected for the east (upwind) side ranged from 0.01 to 0.2 times the February sampling event. Comparing the March dust collected to that collected in October indicate that the dust levels were 2 to 9 times higher for the west (downwind) side and 0.1 to 1 times the dust for the east (upwind) side.

Rainfall in March of 2006 was 0.13 m (5.2 inches) over seven precipitation events (and one trace event) whereas February and January of 2006 averaged approximately 0.05 m (2 inches) (Figure 4.3). The average rainfall from August to October was 0.13 m (5 inches) and from October to December was 0.08 m (3 inches) (Figure 4.3). Therefore, the dust collected in March should be similar to the amount of dust collected in October, if the amount of dust collected is limited to rainfall, since the rainfall amounts are similar. However, the higher amounts of dust experienced on the downwind side are likely due to the further degradation of the aggregate. As mentioned in Chapter 3, durability tests were performed on the surface aggregate that indicated after 24 hours there was a reduction in mass

of 20%; indicating that the aggregate is readily soluble. Degradation of the aggregate is expected due to the aggregate being exposed to rainfall and traffic use.

Investigating the dust collected in the collection pans located at 1, 2, and 3 m from the road the dust is expected to decrease as the distance from the road increased. In the March sampling the dust collected on the west side (downwind) did decrease as the pans were located further from the road, except in the control section (Figure 4.24). However, for the east side (upwind) no clear trend was observed. As mentioned previously, the increase in the amount of dust as the collection pans moved further away from the edge of the road, for the control section, indicates that there is a higher amount of smaller particles in the control section.

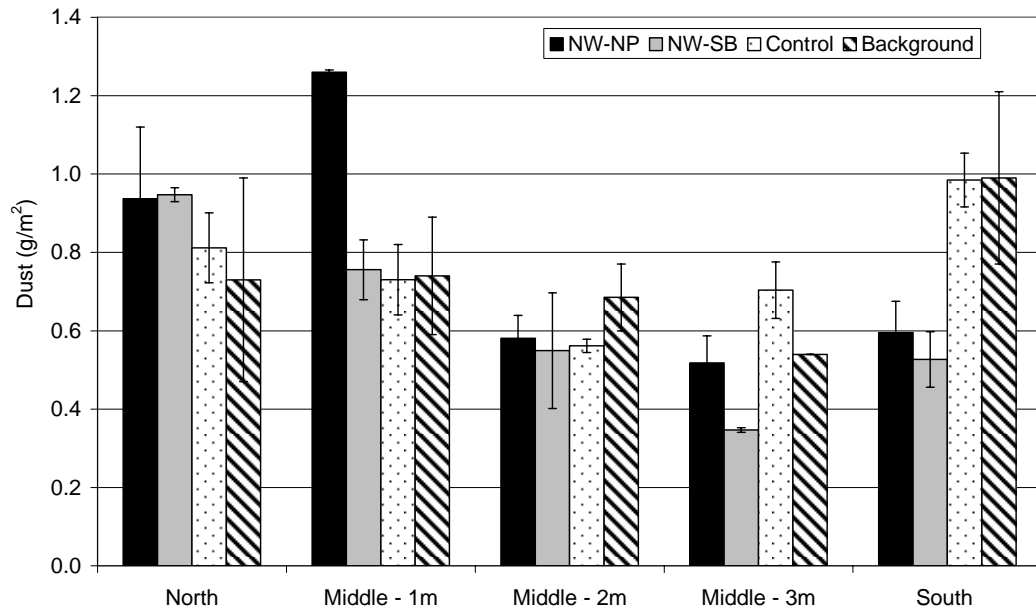


Figure 4.22 Post-geotextile dust collected for the west side (downwind) of the road on 3/29/06.

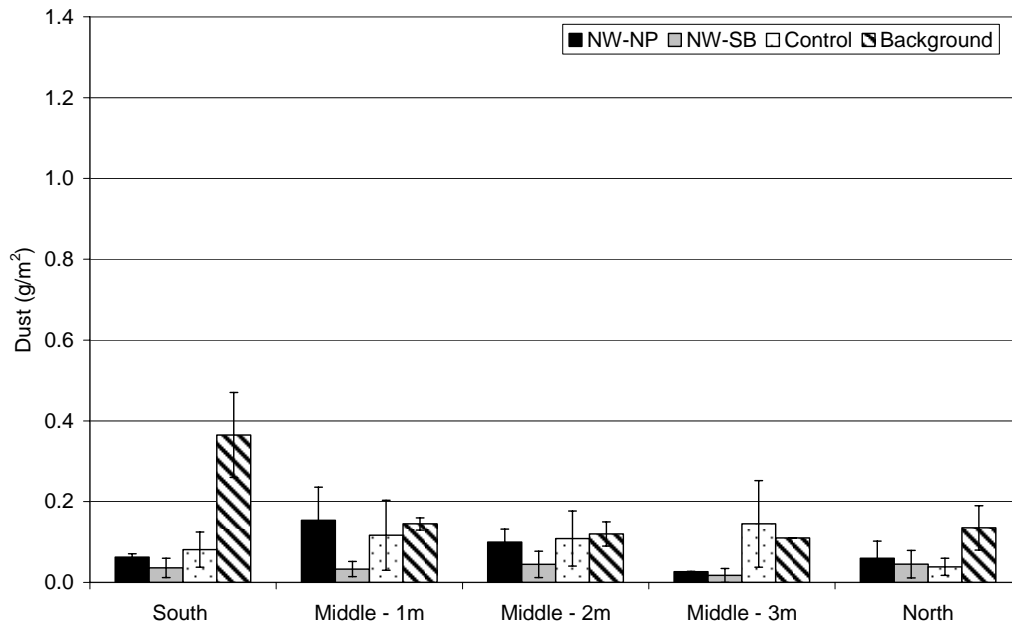


Figure 4.23 Post-geotextile dust collected for the east side (upwind) of the road on 3/29/06.

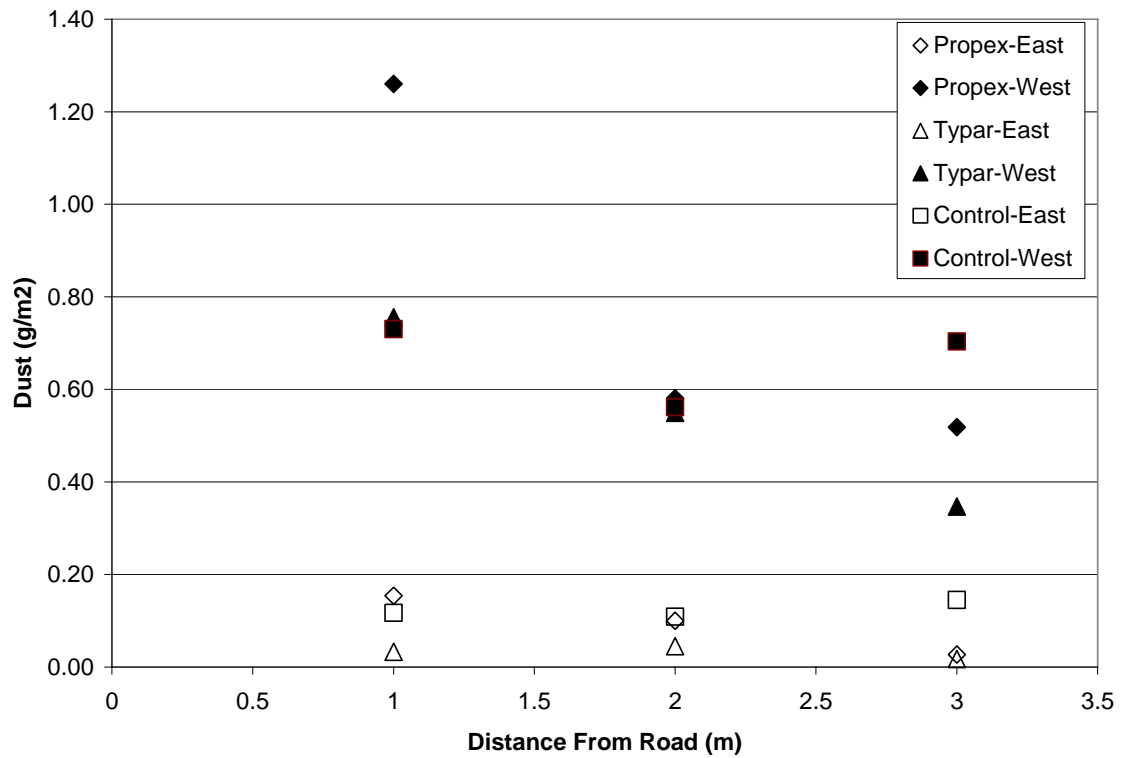


Figure 4.24 Dust collected from the collection pans located 1, 2 and 3 m from the edge of the road on March 29, 2006.

4.6.5 Overall Post-Geotextile Sampling Events

Presented in Figures 25 and 26 is a summary of all the dust sampling events. The average amount of dust collected on the geotextile sections (Typar and Propex) and average dust collected on the control section, for each sampling events, is represented. The y-error bars represent the maximum and minimum amounts of dust collected.

Examining the geotextile sections to the control sections indicate that the dust collected was similar for downwind and upwind sides of the road. Initially, the October sampling event indicated the amount of dust, for the downwind side of the road, was 70 to 80% less than the pre-geotextile sampling event. Further sampling events, i.e. January, February, and March events, indicate that the dust levels were similar to the pre-geotextile levels on both sides of the road.

For the downwind side, the February sampling event, indicated that the dust measured on the geotextile sections were higher than the control sections. However, for the January and March events, the geotextiles measured slightly less dust. For the upwind side, all sampling events had lower measured dust on the geotextile sections than the control section.

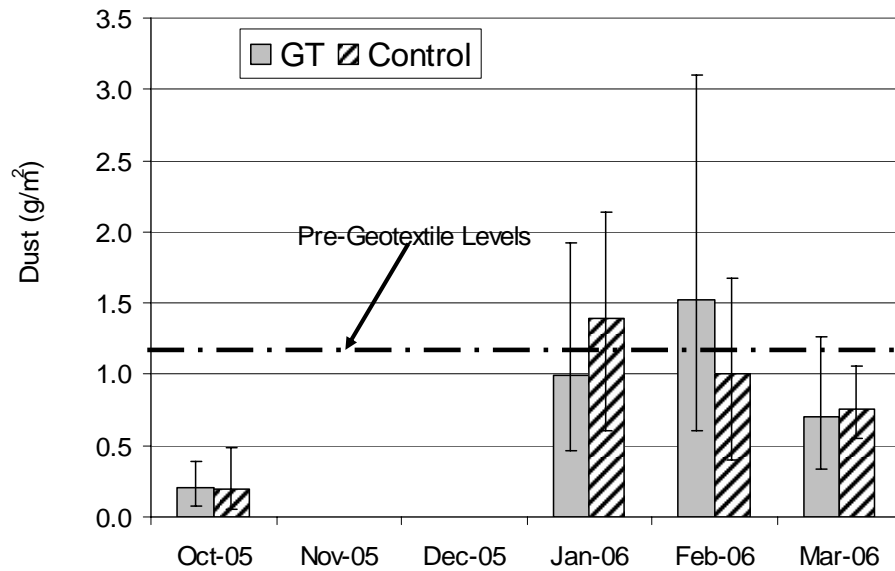


Figure 4.25 Post-geotextile dust collected for the downwind side of the road.

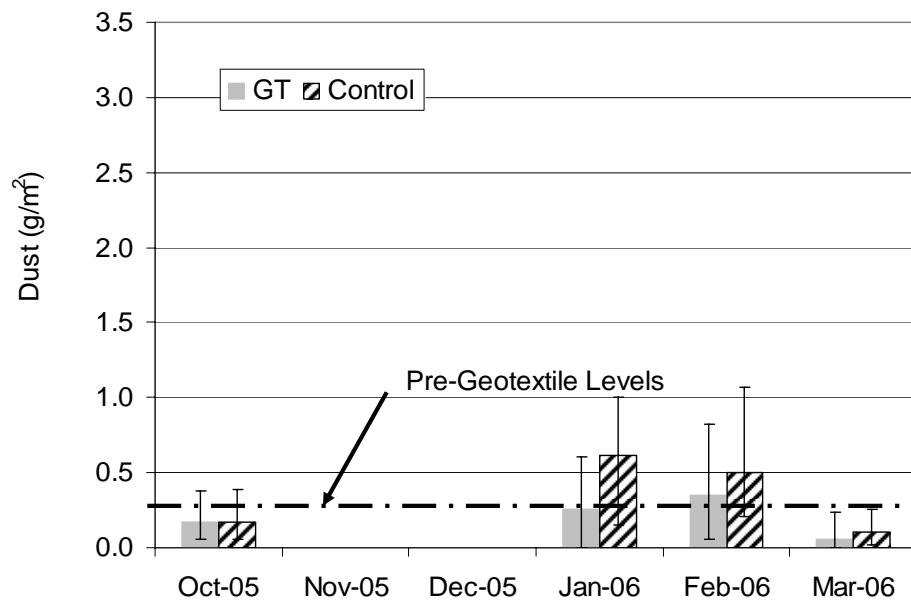


Figure 4.26 Post-geotextile dust collected for the upwind side of the road.

4.7 Surface Aggregate

Samples of surface aggregate and subbase soils, from the City of Columbia landfill test site, were collected at each sampling events. Grain size distribution, wash sieve, and Atterberg limits tests were performed on the samples as appropriate. The soils and aggregates were classified using the Unified Soil Classification System (USCS) (ASTM D 2487).

4.7.1 Grain Size Distribution

Surface aggregate was collected at each dust sampling event. An additional surface aggregate sample was collected prior to geotextile installation. This sample was taken on July 27, 2005 (pre-geotextile). According to the landfill operator the gravel had been placed on June 28, 2005. Also, a surface aggregate sample was taken at the time of installation on September 29, 2005 (post-geotextile). Sieve analyses were performed on each aggregate sample according to ASTM D 422.

Presented in Table 4.9 is the percent passing (by weight) for particle sizes equal to and less than 4.5 mm (#4 sieve) for the aggregate samples collected at the landfill. In Table 4.9, the column for average is the average of fines collected on the geotextile sections. Fines collected at Boone Quarry and in September are similar; however, the fines collected for the Pre-Geotextile are 3 times higher. Records obtained from the landfill operator indicate that new aggregate had been placed on the test section on June 28, 2005; therefore, the pre-geotextile aggregate sampling had been in place for about one month. This indicates that

fines in new aggregate are less and fines increase over time due to traffic use and degradation of the aggregate (Figure 4.27).

The fines observed in the January aggregate sample (3.5 months old) are similar to the fines observed in the pre-geotextile aggregate sample (one month old) for the aggregate located in the geotextile sections. Fines in the February aggregate sample were less than the pre-geotextile, January, and March samples, there does not appear to be an apparent reason for this. The rainfall in February was less than either March or January. Fines collected from the March sample were slightly higher than the January sample and both the January and March fines were higher than the pre-geotextile fines. Samples of aggregate taken from the control section indicate that the fines collected in these samples are twice as much as the fines collected from the geotextile sections. This indicates that the aggregate may deteriorate at a slower rate when a geotextile is used and may indicate that the control section includes fines that have migrated from the subbase.

Grain size distributions were performed on all the samples identified in Table 4.9 (Figure 4.27). Aggregate samples were classified according to USCS (Table 4.10 and 4.11). New aggregate samples (samples from Boone Quarry and September sampling) classified as poorly graded gravel (GP, fines passing the 0.075 mm sieve were less than 5%). As time increased, the classification changed to dual classification for the aggregate samples taken from the geotextile sections, poorly graded gravel and silty gravel (GP-GM), due to the increase in the amount of fines (between 5 to 12 % passing the 0.075 mm sieve).

Aggregate samples collected on the control section classified as silty gravel after approximately 4 months, the fines increased to greater than 12% passing the 0.075 mm sieve (Figure 4.27). This increase in fines is likely due to the degradation of the surface aggregate (see Chapter 3 regarding the durability of the aggregate) and the migration of fines from the subbase. To investigate this apparent degradation of the aggregate durability testing was performed as described in Chapter 3.

Table 4.9 Degradation of Surface Aggregate on Gravel Road at Landfill test site.

Grain Size	% Passing								
	Boone Quarry	9/29/2005	1/19/2006		2/14/2006		3/29/2006		Pre-Geotextile
	Aggregate	(New Aggregate)	(Average)	(Control)	(Average)	(Control)	(Average)	(Control)	(Old Aggregate)
4.75	4	6	30	-----	18	43	28	36	22
2	3	4	18	-----	11	35	21	28	17
0.42	3	4	12	-----	8	29	14	21	12
0.075	3	3	8	-----	6	24	9	15	8

Note: Average represents the average percent passing for both geotextiles.

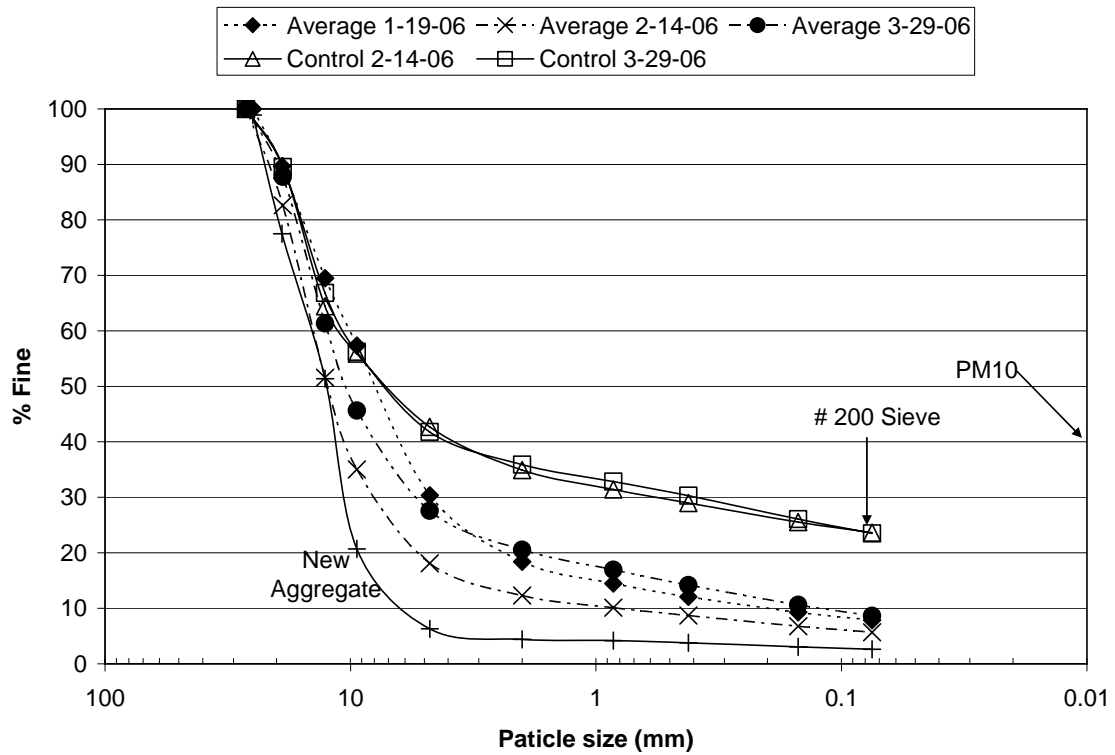


Figure 4.27 Grain size distribution of the surface aggregate taken from Boone Quarry and on July 27 and September 29, 2005.

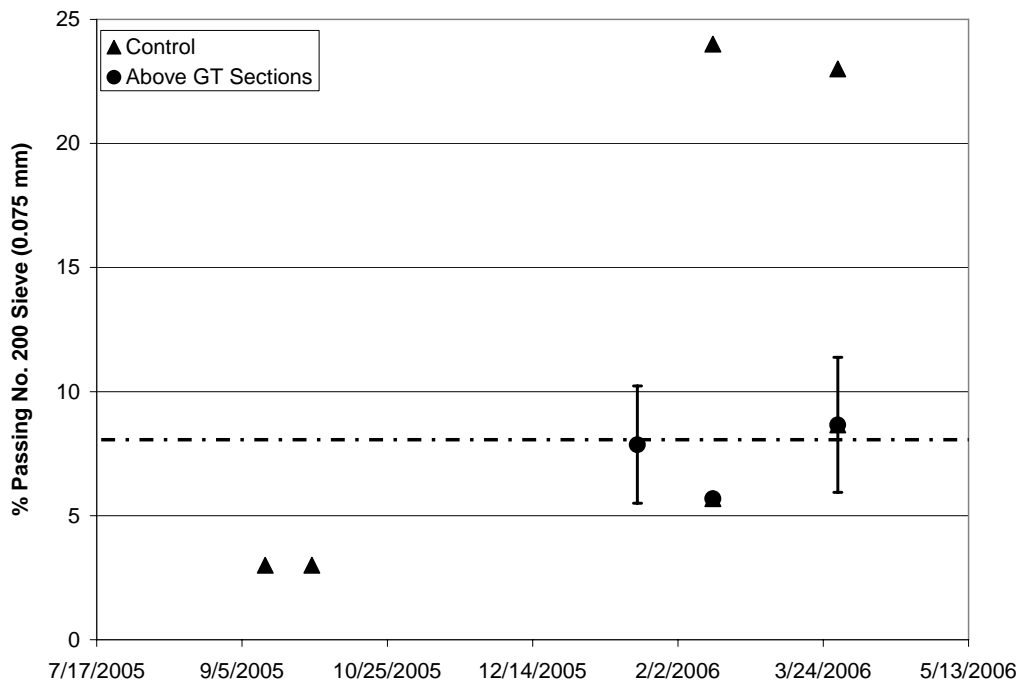


Figure 4.28 Percent passing the number 200 sieve vs. the date of sampling.

Table 4.10 Surface Aggregate Classification

Sample Date	Boone Quarry	7/27/2005 (Old Aggregate)	9/29/2005 (New Aggregate)
Grain Size Diameter	-----	-----	-----
D ₁₀	8.00	0.24	6.00
D ₃₀	10.20	7.10	10.10
D ₆₀	10.60	10.20	10.60
Cu	1	43	2
Cc	1	21	2
USCS	GP	GP-GM	GP

Table 4.11 Surface Aggregate Classification Continued

1/19/2006		2/14/2006			3/29/2006		
Test Section #1	Test Section #2	Control Section	Test Section #1	Test Section #2	Control Section	Test Section #1	Test Section #2
0.07	1.60	0.01	1.80	0.41	0.01	0.08	1.20
2.90	6.50	0.60	9.10	7.00	0.42	1.90	9.00
8.00	10.30	10.10	10.50	10.50	10.00	9.40	10.60
111	6	1010	6	26	1000	125	9
15	3	4	4	11	2	5	6
GP-GM	GW	GM	GP-GM	GP-GM	GM	GP-GM	GP-GM

4.7.2 Results of Durability Testing

The aggregates used to surface the roads were determined to be limestone and easily soluble (Chapter 3). Laboratory durability testing was performed to evaluate how quickly the aggregates deteriorate when exposed drying and wetting cycles with abrasion (ASTM D4644). Durability testing was also performed on the geotextiles to determine the effects of deterioration of the aggregate when geotextiles are added and to investigate how the geotextiles perform.

Presented in Figure 4.29 are the results from the durability testing. The aggregate, aggregate plus Typar geotextile, and aggregate plus Propex geotextile were tested. Durability of the aggregate indicates that after 24 hours the aggregate has a mass reduction of 20% or Durability Index of 78. Once the geotextiles were added the Durability Index was 78 and 80 for the Propex (NW-NP) and Typar (NW-SB) respectively. The geotextiles had little to no effect on the durability of the aggregate. The Propex geotextile gained mass after each test (1, 6, 12, and 24 hour test) and fines were visible within the fabric. However, for the test completed over 6 hours, for the Typar geotextile, mass was lost and visual observations indicated that the surface of fabric tended to ball up (side exposed to the rock). After the 24 hour test, the Typar geotextile had visual loss of fabric. Test completed at and below 6 hours indicated a gain in mass, for the Typar geotextile.

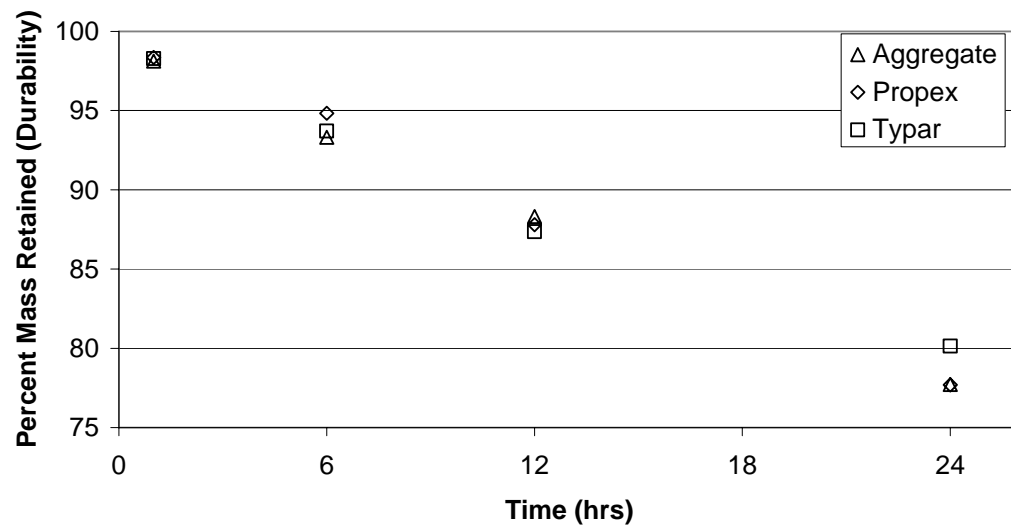


Figure 4.29 Durability index for aggregate and geotextile.

4.7.3 Moisture Contents

Surface aggregate was sampled at each dust collection event. Moisture content tests were performed on each sample of surface aggregate (ASTM D2216). Presented in Table 4.12 are the moisture contents measured from each sampling date and the locations. The average moisture content of the surface aggregate is 2%. Throughout the sampling events the moisture content remained relatively constant. Moisture contents of the subbase were taken at the time of installation of the geotextiles. Three subbase samples were taken, one for each section (i.e. control, test section #1, etc.). The average water content for the subbase was 3.8%. Moisture contents of the subbase were higher than the surface aggregates, the moisture contents were measured on 9/29/05 and averaged 4% (average taken from three subbase measurements located across the test site).

Table 4.12 Moisture Content (%) of Surface Aggregate

Sample Date	Control Section	Test Section #1	Test Section #2
7/27/2005	2.0		
9/29/2005	2.0		
1/19/2006	-----	2.6	1.8
2/14/2006	2.4	1.6	1.7
3/29/2006	2.7	2.9	2.4

4.8 Parametric Analysis of Dust (PM10) Generated

The dust emissions (PM10) determined in Section 4.4 can be re-evaluated using measured silt content and moisture contents. The measured silt content (S), which is defined as the percentage passing the 0.075 mm (#200) sieve, of the surface aggregate, ranged from 2.6% to 24%, with an average of 10%. As discussed in the previous section, the average in-situ gravimetric moisture content for the surface aggregate was 2%. Based on these values a parametric study was performed to determine the effect of varying the silt content and surface water content has on the amount of PM10 generated. To perform the analysis the surface water content was varied from 0.2% to 3% and the silt content was varied from 2 to 25% (Figure 4.30).

As can be observed in Figure 4.30, the relationship between PM10's and silt content are fairly linear. PM10 expected at the landfill site would be 29 lb/VMT, based on a moisture content of 2% and a silt content of 10% for the surface aggregate. Using the default values the PM10 value would be 50 lb/VMT, this is a reduction of 42%.

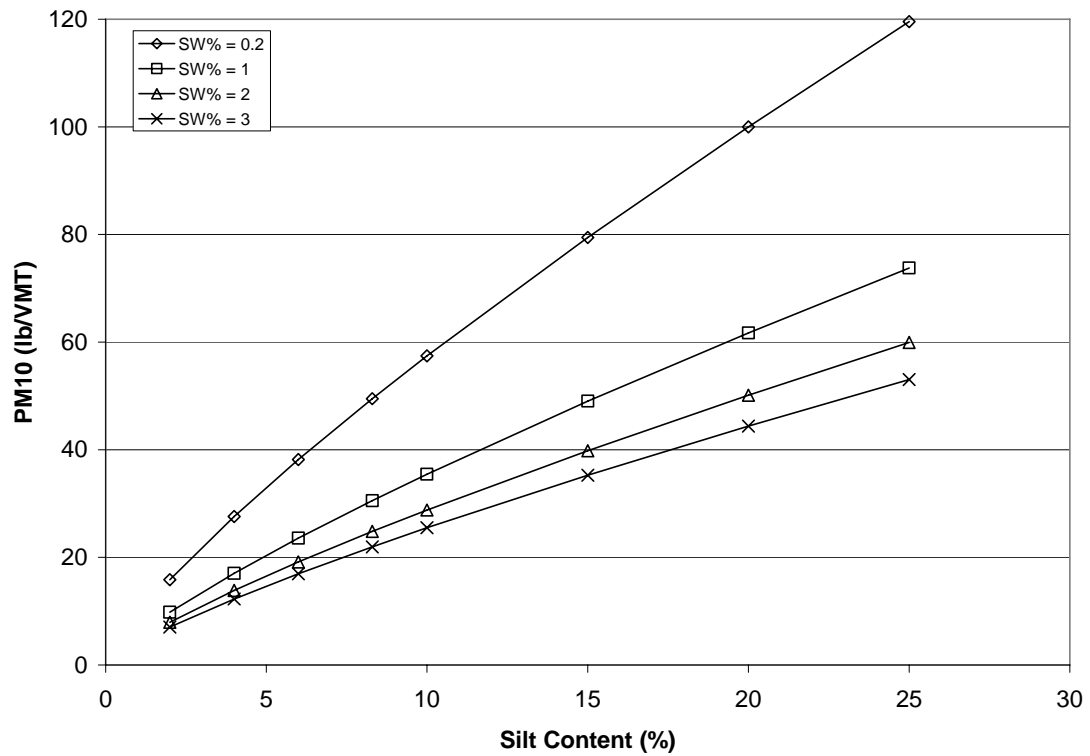


Figure 4.30 Dust (PM10), in pounds per vehicle miles traveled, for landfill gravel road test section versus silt content for various surface water contents (SW) generated using USEPA formulas.

Presented in Table 4.13 and Figure 4.28 are the silt contents for the surface aggregate at the landfill site at different times. The silt content for the control section was 2 to 4 times greater than that of either section with geotextile. However, the fines within the geotextile sections also increase with time, which are approximately 2 times higher than the fines in the new aggregate at time zero. The difference between the control section and the geotextile section may indicate that the subbase is migrating up in the control section therefore resulting in higher fines. There is also a trend of increasing silt content with time. Figure 4.31 was developed to graphically demonstrate the trend of silt content increasing with time and how that affects the dust emissions based on a moisture content of 2% (which was relatively constant). The emissions, in pounds per vehicle mile traveled, were calculated using equation 4.1 presented in section 4.4, and using the percent passing the 0.075 mm sieve (#200 sieve).

Table 4.13 Chronological Development of Silt Content at the Gravel Road at the City of Columbia Landfill (Percent Passing the 0.075 mm Sieve (#200 Sieve)).

7/27/2005	9/29/2005 & Boone Quarry		1/19/2006	2/14/2006	3/29/2006
Pre- Geotextile	New Aggregate	Control	-----	23.62	23.50
6.5	2.5 to 2.6	Test Section #1 (Tylar)	10.23	5.54	11.38
		Test Section #2 (Propex)	5.50	5.83	5.94

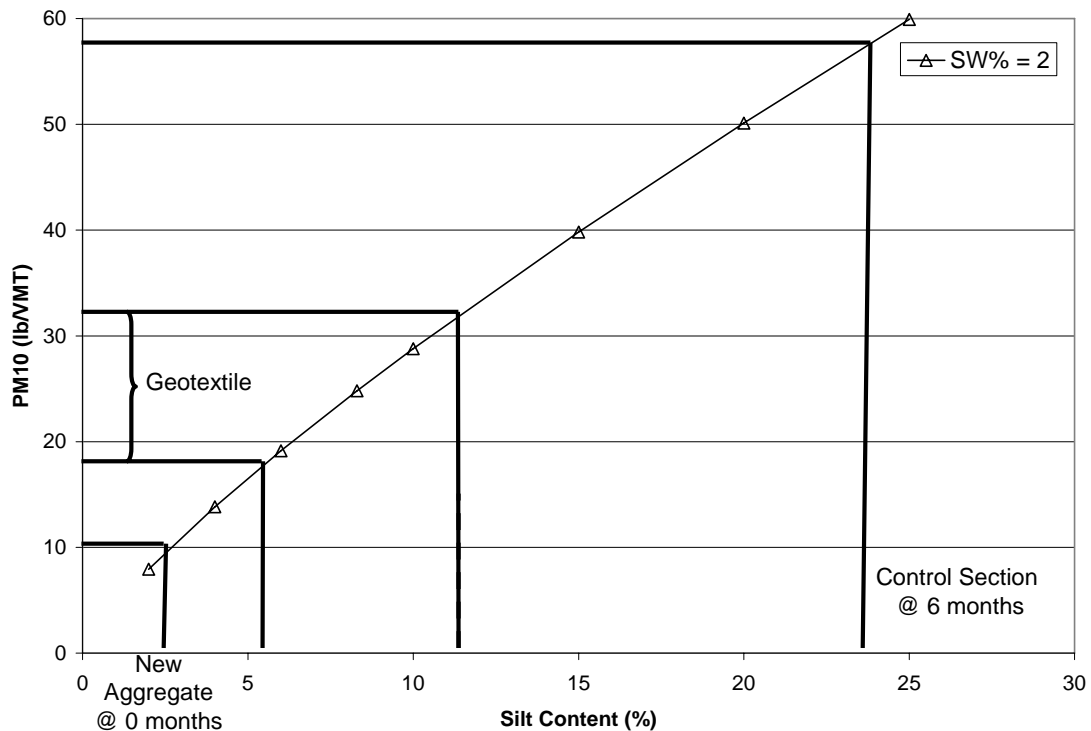


Figure 4.31 Range of dust (PM10) generated for the landfill gravel road test sections.

A PM10 of 10 lb/VMT were determined when the silt content for the new aggregate was placed (aggregate placed at the time of the installation of the geotextiles on September 29, 2005). As the time increased from the time of installation, the amount of fines (percent passing the 0.075 mm sieve (#200 sieve)) increased, therefore increasing the amount of PM10's calculated. The control section at 6 months indicated an increase of PM10's to approximately 58 lb/VMT, which is 6 times the amount of PM10's from placement of new aggregate. PM10's calculated for the geotextile sections ranged from 18 to 32 lb/VMT, which is an increase from the placement of new aggregate of 2 to 3 times but a reduction from the control section of 30 to 50%. Based on the

average silt content collected from January to March 2006, for the control section compared to the geotextile sections, PM10 reduction factors were developed.

Test Section #1, Typar, has a reduction factor or control efficiency of 56%. Test Section #2, Propex, has a reduction factor or control efficiency of 75%.

Differences in the control efficiency for each type of fabric may be contributed to the difference in permittivity and flow rate (Table 3.2). The permittivity for the Propex fabric is higher (1.1 sec⁻¹) than the Typar fabric (0.5 sec⁻¹). Also, the flow rate for the Propex fabric was 3340 L/min/m² (82 gal/min/ft²) versus 2050 L/min/m² (50 gal/min/ft²). However, the apparent opening size of the Propex fabric was slightly larger than the Typar fabric (0.212 mm vs. 0.200 mm, respectively).

4.9 Cost To Road Owner

As mentioned in Chapter 2, there are several methods to control the dust on gravel roads. A cost analysis was investigated for the road located at the landfill. The estimated cost, design control efficiency, and application rate were obtained from the manufacturers and are based on the landfill road that is 183 m (600 ft) long by 15 m (40 ft) wide with the characteristics of the landfill site (i.e. traffic pattern, weight of vehicles, aggregate type, etc as discussed in Section 4.3) (Table 4.14). The cost associated with the installation of the geotextile compares favorable to other dust treatment methods.

Table 4.14 Dust Suppressants and Recommended Cost

Manufacturer	Control Method	Material	EPA Control Efficiency (%)	Design Control Efficiency (%)	Application Rate	Estimated Cost (\$)	Reference
City of Columbia Landfill	Water	Water on Site	50	-----	Daily	75	Landfill Operator (2006)
Midwest Industrial Supply, Inc.	EK35	Contains Resins and synthetic organic fluid	85	85	1 gallon/34ft ² Applied twice (@ time zero and again 5 months later)	5,250	ETV 2005
Midwest Industrial Supply, Inc	EnvironKleen	Organic, synthetic fluid	94	85	1 gallon/38ft ² Applied twice (@ time zero and again 6 months later)	4,725	ETV 2005
North American Salt Company	DustGard ^R	Hygroscopic product made of Magnesium Chloride	99	90	0.6 gallon/yd ² Applied twice (once in the spring and once in the fall)	1,424	ETV 2006
SynTech Product Corporation	PetroTac	Emulsion that bonds with road aggregate	86	90	Initially - 1 gallon/64ft ² Then 1 application every 28 days at a rate of 1 gallon/96ft ²	8,410	ETV 2005
SynTech Product Corporation	TechSuppress	Integrates water-emulsified resins with wetting agents, surfactants, and emulsifiers	60	90	Not Recommended		ETV 2005
BBA Fiberweb	Nonwoven Spun Bonded GT	Polypropylene	Unknown	56	Once	1,750	Bill Hawkins (2006)
Propex	Nonwoven Needle Punched	Polypropylene	Unknown	75	Once	2,270	Mark Marienfeld (2006)

4.10 Summary

A test section was identified in Boone County, Missouri, USA to determine the effectiveness of geotextiles in reducing dust from gravel roads. Two pre-geotextile and five post-geotextile sampling events were conducted periodically to determine the effect the geotextiles had on the dust generated.

Initially, the October sampling event indicated that the amount of dust measured was 70 to 80% less than the pre-geotextile sampling event. As time increased the amount of dust increased which was more noticeably for the control section, however the measured dust was similar to the pre-geotextiles levels.

In addition to investigating and collecting the dust, the surface aggregate was monitored to determine how the fines of the aggregate behaved. By measuring the fines and moisture contents, a parametric analysis was performed to determine the effects on the amount of dust (PM10) that was generated by the road. There was a noticeable increase in the amount of fines measured in the surface aggregate with time. However, the fines measured within the geotextile sections were less than the fines measured within the control section. One reason for this decrease in fines from the geotextile sections was likely due to the geotextiles limiting the amount of fines that could migrate upwards from the subbase. This directly affects the amount of PM10 that was generated by the road. Comparing the measured fines within the geotextile sections to the control section indicates that the fines were 30 to 50% less.

Chapter 5 – Conclusions

The objective of the research reported herein was to quantify the effectiveness of geotextile separators in reducing dust generated from gravel roads. To determine if dust was reduced, background (pre-geotextile) monitoring was conducted to determine the amount of dust the particular test section generated. After the pre-geotextile data had been collected the surface aggregate was graded and geotextiles were placed on the subbase then covered with new aggregate. A control section (new aggregate but no geotextile) was also constructed. The test section was located at the City of Columbia, Missouri landfill.

Four post-geotextile sampling events (October 2005, January, February, and March of 2006) were conducted to determine what effect the geotextile had on the dust generated. Initially, the October sampling event indicated that the amount of dust measured was 70 to 80% less than the pre-geotextile dust levels. The measured dust quantity from each geotextile compared to the control section indicated that the NWSB (Tytar) geotextile measured less dust (ranging from 50 to 170% of that from the control section) while the NWNP (Propex) geotextile measured dust ranging from 50 to 310% of that from the control section. As time (and vehicular traffic) increased the amount of dust increased and it was especially greater for the control section.

The dust emissions (PM₁₀) were evaluated using measured silt content and moisture contents. Measured silt content (S), of the surface aggregate, ranged from 3% to 24%, with an average of 10%. New aggregate, freshly placed

and for the entire test section, had a silt content of 3%, while the aggregate that had been in place for 6 months and without a geotextile (i.e. control section) had a silt content of 24%. Sections of the road that had a geotextile placed measured average silt content of 8%. The average in-situ moisture content for the surface aggregate was 2% (which remained relatively constant).

A PM10 of 10 lb/VMT were determined when the silt content for the new aggregate was placed (aggregate placed at the time of the installation of the geotextiles on September 29, 2005). As the time increased from the time of installation, the amount of fines (percent passing the 0.075 mm sieve (#200 sieve)) increased, therefore increasing the amount of PM10's calculated. The control section at 6 months indicated an increase of PM10's to approximately 58 lb/VMT, which is 6 times the amount of PM10's from placement of new aggregate. PM10's calculated for the geotextile sections ranged from 18 to 32 lb/VMT, which is an increase from the placement of new aggregate of 2 to 3 times but a reduction from the control section of 30 to 50%. Based on the average silt content collected from January to March 2006, for the control section compared to the geotextile sections, PM10 reduction factors were developed. Test Section #1, Typar, has a reduction factor or control efficiency of 56%. Test Section #2, Propex, has a reduction factor or control efficiency of 75%

Installing a geotextile on unpaved roads was determined to be beneficial in reducing the dust. A direct relationship was observed between the amounts of fines in the surface aggregate to the use of geotextiles.

Chapter 6 – Recommendations

The objective of the research reported herein was to quantify the effectiveness of geotextile separators in reducing the dust generated from gravel roads. Through completing this research several recommendations are made that may help in future research to provide a better measure of quantifiable dust.

6.1 Sampling Equipment

A mobile sampling method was used by the EPA to determine the control efficiency for DustGard, EnvironKleen, EK35, Petrotech, and TechSuppress. When conducting future monitoring it would be beneficial to implement the sampling device used by the Environmental Technology Verification (ETV) Program (ETV 2003). Also, to collect a large dust sample, which could be used to investigate the mineralogy of the dust, the plastic sheeting connected to fence posts would be most beneficial. Another suggestion for collecting dust would be to set the collection pans at varying heights above the ground.

During sampling the Anderson Cascade Impactor (ACI) was never implemented properly due to the inability to control the vacuum adequately to secure the proper flow to the impactor. Investigations should be made to better control the vacuum. In addition, the eight stage impactor should be investigated and may be more applicable to this type of research (New Star Environmental 2004).

An observation was made when installing the geotextiles. If the roadway is wide enough to have side by side layers of geotextiles then it is important to

provide a minimum of 0.3 m (1 ft) of overlap and secure the overlap with duct tape or a staking device. Also, if back dumping aggregate, be sure to dig a small trench at start of geotextile along the width of the road, place geotextile inside the trench and backfill to hold geotextile in place while placing aggregate.

6.2 Site Selection

It would be beneficial to increase the number of sites used to test the geotextiles. Increasing the number of sites and varying the conditions of the sites would provide addition verification when obtaining dust control efficiencies for the geotextiles and analyzing the source of the dust. Suggestions on ways to vary the site would be:

- Soft subbase – placing the geotextile over soft spots on unpaved roads would help to verify the source of the dust (i.e. whether the dust is coming from the subbase or surface aggregate). The site obtained for this research had a strong subbase and the materials in the subbase were similar to the surface therefore limiting the researcher's ability to classify the source of the dust.
- Increase the length of the test section – the dust being generated from one section may have blown into another section. Increasing the length of the road from 60 m (100 ft) to 183 m (200ft) per section (i.e. test section #1, test section #2, and control section) may limit this effect.
- Surface aggregate material – varying the surface aggregate such that the aggregate is a less soluble material may reduce the amount of dust

measured and help to quantify the source of the dust either from the surface aggregate or from the subbase.

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APPENDIX A
Precipitation Data

A.1 Precipitation Data for the Surrounding Missouri Weather Stations within an 85 km (53 mile) Radius.

	City of Columbia Landfill	Columbia Regional Airport	MU Campus	California	Higbee 4S	Boonville	New Franklin	Moberly	Average Precipitation
Date	Monthly rainfall (in)								
Jan-05	6.94	5.94	6.87	7.24	5	5.18	6.4	4.53	5.88
Feb-05	4.4	1.94	2.44	2.21	2.45	3.13	2.39	2.02	2.37
Mar-05	1.2	0.92	0.92	1.69	1.5	0.73	0.86	0.99	1.09
Apr-05	5.15	4.33	3.94	7.15	3.25	2.79	2.61	2.76	3.83
May-05	2.5	2.01	3.2	1.74	3.2	1.54	1.79	2.74	2.32
Jun-05	5.25	4.66	5.11	3.93	3.16	6.2	7.28	5.12	5.07
Jul-05	0.6	0.62	0.6	0.65	0.95	0.64	0.77	1.05	0.75
Aug-05	6.95	10.19	8.38	11.67	7.8	8.47	8.08	4.93	8.50
Sep-05	4.65	5.6	6.03	5.76	1.5	4.32	2.82	1.39	3.92
Oct-05	3.2	2.97	2.25	4.09	1.95	1.82	1.58	0.43	2.16
Nov-05	1.25	1.08	2.21	1.69	1.9	-----	1.19	1.53	1.60
Dec-05	4.55	0.95	0.96	0.54	0.9	-----	0.65	1.19	0.87
Jan-06	2.12	1.91	2.1	1.53	2.2	0	1.72	1.86	1.89
Feb-06	1.7	0.11	0.07	0.42	-----	0.06	0.07	-----	0.15
Mar-06	5.2	0	0	0	-----	0	0	-----	0.00

APPENDIX B
MDNR Emission Forms
(<http://www.dnr.mo.gov/forms/index.html>)



STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES
AIR POLLUTION CONTROL PROGRAM
1101 RIVERSIDE DRIVE, P.O. BOX 176
JEFFERSON CITY, MISSOURI 65102-0176

**EMISSIONS INVENTORY QUESTIONNAIRE (EIQ)
FORM 2.0 EMISSION POINT INFORMATION**

FACILITY NAME				FIPS COUNTY NO.		PLANT NO.		YEAR OF DATA	
[1] POINT IDENTIFICATION									
POINT NO.		POINT DESCRIPTION			SIC CODE		NUMBER OF SCCs USED WITH THIS POINT		SEG. NO.
SOURCE CLASSIFICATION CODE (SCC)				SCC DESCRIPTION					SCC UNITS
DO THE EMISSIONS FROM THIS EMISSION POINT FLOW THROUGH A STACK? <input type="checkbox"/> Yes <input type="checkbox"/> No							POINT ACTIVITY STATUS		
ARE THE EMISSIONS FROM THIS POINT FUGITIVE? <input type="checkbox"/> Yes <input type="checkbox"/> No					IF FUGITIVE, WHAT PERCENTAGE?		<input type="checkbox"/> Active <input type="checkbox"/> Inactive <input type="checkbox"/> Dismantled		
[2] OPERATING RATE/SCHEDULE									
ANNUAL THROUGHPUT				UNITS		MAXIMUM HOURLY DESIGN RATE		UNITS/HR	
HOURS/DAY		DAYS/WEEK	WEEKS/YEAR	TOTAL HOURS PER YEAR	JAN-MAR (%)	APR-JUN (%)	JULY-SEP (%)	OCT-DEC (%)	
DOES THIS PROCESS INCLUDE ANY MAXIMUM HOURLY DESIGN RATE RESTRICTIONS? <input type="checkbox"/> Yes <input type="checkbox"/> No									
[3] EMISSIONS CALCULATIONS									
SOURCE OF EMISSION FACTOR : (List below in Column [6])					(1) CEM (2) STACK TEST		[4] AP 42/OTHER REFERENCE		[5] LIST OTHER WORKSHEETS
(3) MASS BALANCE (4) AP-42 (4F) FIRE (5) OTHER (EC) ENG CALC (TK) TANKS									
Or identify worksheet number (i.e.: (27) Haul Road Worksheet)									
AIR POLLUTANT	[6] SOURCE OF EMISSION FACTOR	[7] EMISSION FACTOR (LBS/UNIT)	[8] EMISSION FACTOR CONTROL STATUS	[9] ASH OR SULFUR (%)	[10] OVERALL CONTROL EFFICIENCY (%)	[11] ACTUAL EMISSIONS (TONS/YR)	MAXIMUM HOURLY (LBS/HR)	POTENTIAL CONTROLLED (TONS/YR)	POTENTIAL UNCONTROLLED (TONS/YR)
PM10									
SOx									
NOx									
VOC									
CO									
LEAD									
HAPs									
PM2.5									
NH3									

MO 780-1621 (9-05)

DUPLICATE THIS FORM AS NEEDED.



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EMISSIONS INVENTORY QUESTIONNAIRE (EIQ)
FORM 2.7 HAUL ROAD FUGITIVE EMISSIONS WORKSHEET

FACILITY NAME		FIPS COUNTY NO.	PLANT NO.	YEAR OF DATA
PLEASE NOTE: If the sum of all Vehicle Miles Traveled (VMT) for all haul roads and trucks is less than 100 VMT, then the PM10 emissions for all the haul roads do not need to be reported on these forms. However, if the emissions are not reported, documentation on the actual annual VMT figures for the facility must be provided.				
[1] HAUL ROAD INFORMATION				
POINT NO.	SOURCE CLASSIFICATION CODE (SCC)	SEG. NO.	TYPE OF DUST CONTROL (CHECK ONE)	CONTROL EFF %
LENGTH OF ROAD (MILES)	SILT CONTENT (%) DEFAULT = 8.3%	SURFACE MATERIAL OF ROAD	<input type="checkbox"/> SURFACTANT SPRAY	90
			<input type="checkbox"/> WATER SPRAY DOCUMENTED	> 50
			<input type="checkbox"/> WATER SPRAY	50
			<input type="checkbox"/> NO CONTROLS	0
			<input type="checkbox"/> OTHER (SPECIFY): _____	
SURFACE MATERIAL MOISTURE CONTENT (%) (MUST REFERENCE DRY, WORST-CASE CONDITIONS DEFAULT = 0.2%)		DAYS OF RAIN WITH AT LEAST 0.01" PER YEAR (DEFAULT = 105)		
[2] HAUL TRACK INFORMATION				
MAKE/MODEL				
AVERAGE WT OF MATERIAL PER LOAD (TONS)		UNLOADED TRUCK WT (TONS)		
AVERAGE TRUCK SPEED (MPH)		AVERAGE LOADED TRUCK WT (TONS)		
[3] MATERIAL HAULED				
TYPE OF MATERIAL(S) HAULED		LIST ANY PERMIT CONDITIONS LIMITING THE AMOUNT HAULED		
ANNUAL AMOUNT HAULED (TONS)		MAXIMUM HOURLY AMOUNT HAULED (TONS)		
[4] CALCULATION OF ANNUAL VEHICLE MILES TRAVELED (VMT)				
ANNUAL VMT = 2 X {LENGTH OF HAUL ROAD} X {ANNUAL AMOUNT HAULED} / {AVERAGE WT OF MATERIAL PER LOAD}				
ANNUAL VMT	REPORTABLE LEVEL = THE SUM OF ALL ROAD VMTS > 100	MAXIMUM HOURLY VMT		
[5] CALCULATION OF HAUL ROAD EMISSION FACTOR				
PM10 EMISSION FACTOR = $2.6 \times \left\{ \left(\frac{\text{SILT CONTENT (\%)}}{12} \right)^{0.8} \times \left[\left(\frac{\text{UNLOADED TRUCK WT}}{\text{AVERAGE LOADED TRUCK WT}} \right) + 6 \right]^{0.4} \times \left[\frac{365 - \text{DAYS OF RAIN}}{365} \right] \times \left[\left(\frac{\text{SURFACE MATERIAL MOISTURE CONTENT (\%)}}{0.2} \right)^{0.3} \right]$ * IF AVERAGE TRUCK SPEED IS <15 MPH, MULTIPLY THE EQUATION BY (AVERAGE TRUCK SPEED / 15)				
PM10 EMISSION FACTOR		LBS PM10/VMT		
<p>The PM10 emission factor for the haul roads can be calculated using the equation from the AP 42 section on Unpaved Haul Roads (section 13.2.2) provided in Block 5 of this worksheet. When using these equations, PM10 emission factors should be calculated for each separate haul road and type of haul truck. The Stone Quarrying SCC number (3-05-020-11) should be used as the SCC number on Form 2.0. The calculated PM10 emission factor should be entered in the PM10 Box in Section 3, Block 7 on Form 2.0.</p> <p>A more detailed discussion on dust control method and the resulting Control Efficiency (%) can be found in the AP 42 section 13.2.2. The appropriate dust control method should be checked in Block 1 and the control efficiency should be entered in the PM10 Box of Section 3, Block 10 on Form 2.0.</p>				
ALTERNATE METHODS TO ESTABLISH THE HAUL ROAD PM10 EMISSION FACTOR				
Instead of using this form to calculate the PM10 emission factor for haul roads, the Source Classification Code (SCC) For Stone Quarrying and Processing Haul Road Emissions (3-05-020-11) may be used as a default SCC number. The PM10 emission factor to use with this SCC number is 6.2 lbs of PM10 per VMT.				

MO 780-1445 (8-05)

DUPLICATE THIS FORM AS NEEDED.

STATE OF MISSOURI
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1101 RIVERSIDE DRIVE, P.O. BOX 176
JEFFERSON CITY, MISSOURI 65102-0176

EMISSIONS INVENTORY QUESTIONNAIRE (EIQ)
FORM 3.0CK EMISSIONS FEE CALCULATION

FACILITY NAME		FIPS COUNTY NO.			PLANT NO.			YEAR OF DATA		
[1] POINT NO.	Use one row to list the emissions from one emission point. Sum the emissions in the page total box at the bottom of the column. If more than one page is needed, use the first row of the duplicated page to list the page totals from this page. Express emission figures in tons per year and round to two [2] decimal places.									
SCC	AIR POLLUTANT									
	PM10	SOx	NOx	VOC	CO	LEAD	HAPs	PM2.5	NH3	
PAGE TOTALS										
NOTE: FILL OUT THE LOWER PORTION OF THIS FORM ONE TIME ONLY.										
[2] ACTUAL EMISSIONS (Make sure to use the sum of ALL page totals for each pollutant for the actual emission figures below.)										
Please report emissions to two decimal places.	PM10	SOx	NOx	VOC	CO	LEAD	HAPs	PM2.5	NH3	
Copy the actual emissions from [2] to the appropriate box(s) in the Total Plant Emissions section of Form 1.0										
[3] CHARGEABLE EMISSIONS (Maximum 4,000 Tons/Yr Cap per Pollutant)										
					NO FEES FOR CO			NO FEES FOR PM2.5	NO FEES FOR NH3	
[4] SUM OF EMISSIONS										
Round figure to nearest ton per year.					TONS/YR					
[5] TOTAL ANNUAL EMISSIONS FEE					\$					
Facilities which produce charcoal from wood are exempt from fees.										
[6] Include a check for the amount in Box 5, payable to the Missouri Air Pollution Control Program. Mail the check for the emissions fee to the State Air Agency listed at the top of this form.										
[7] Send the completed questionnaire and any supporting documentation to the agency listed at the top of Form 1.0.										
Facilities within local air program jurisdiction only need to include copies of Forms 1.0, 3.0, and 4.0 along with the emissions fee check.										

APPENDIX C
Example Emission Calculations
Using Default Values

C.1 Example of Emission Calculations using Default Values for the City of Columbia Landfill Test Site.

Length of Road (miles)	0.114	Days of Rain	105						
Silt Content (%)	8.3	Surface Water Content (%)	0.2						
Residential Recycling/Yard Waste Collection Vehicles	WT OF MATERIAL (ton)	TAREWT (ton)	Passes in 3 Weeks	Passes/WK	Annual Passes	Annual Amt. Hauled (ton)	Max. Hourly Amt. Hauled	Max. Hourly VMT	PM10
1010	4.35	16.55	3	1	52	226	588120	30826	2.87
1019B	2.62	17.53	1	0.3	17	45	118075	10275	2.88
1612B	2.39	20.89	10	3	173	414	1077093	102752	3.06
1628B	2.53	21.21	16	5	277	702	1824299	164403	3.09
1629B	3.44	22.12	2	1	35	119	310059	20550	3.16
1645B	2.71	21.44	18	6	312	846	2198352	184954	3.10
1646B	3.24	21.72	4	1	69	225	584064	41101	3.13
1815B	2.83	21.17	3	1	52	147	382616	30826	3.09
1838B	3.27	21.84	15	5	260	850	2210520	154128	3.14
1839B	2.99	21.39	13	4	225	674	1751741	133578	3.11
1878B	3.41	15.53	1	0.3	17	59	153677	10275	2.78
1879	1.59	15.68	1	0.3	17	28	71656	10275	2.73
Average (tons)	2.9	20	29	344	Total PM10	36.13			
Drop Off Collection Vehicles (Mini Roll-off Tandem)	WT OF MATERIAL (ton)	TAREWT (ton)	Passes in 3 Weeks	Passes/WK	Annual Passes	Annual Amt. Hauled (ton)	Max. Hourly Amt. Hauled	Max. Hourly VMT	PM10
1830	0.49	10.11	8	3	139	68	176661	82202	2.26
1616	0.66	8.23	10	3	173	114	297440	102752	2.10
Average (tons)	0.575	9.17	6	71	Total PM10	4.36			

C.2 Example of Emission Calculations using Default Values for the City of Columbia Landfill Test Site (continued).

Drop Off Collection Vehicles (Roll-off Single)	WT OF MATERIAL (ton)	TAREWT (ton)	Passes in 3 Weeks	Passes/WK	Annual Passes	Annual Amt. Hauled (ton)	Annual VMT	Max. Hourly Amt. Hauled	Max. Hourly VMT	PM10
1436	1.16	16.67	19	6	329	382	75	993269	195229	2.78
1810	0.86	16	14	5	243	209	55	542603	143853	2.72
1832	0.98	12.44	56	19	971	951	221	2473259	575411	2.47
Average (tons)	0.92	15	30	30	352	352	352	Total PM10		7.97
Cars/Trucks	WT OF MATERIAL (ton)	TAREWT (ton)	Passes in 3 Weeks	Passes/WK	Annual Passes	Annual Amt. Hauled (ton)	Annual VMT	Max. Hourly Amt. Hauled	Max. Hourly VMT	PM10
1436	0.2	1.3	180	60	3120	624	711	1622400	1849536	1.02
								Total PM10		49.48

APPENDIX D
Vehicle Type and Speeds for Each Sampling Event

D.1 Vehicle Type and Speed, for the City of Columbia Landfill Test Site, on July 25, 2005 for Sampling 1.

Road Name: Landfill

Sampling Date: 7/25/2005 Sampling Event: 1 of 3

Pass #	Vehicle Type	Vehicle Speed	Pass #	Vehicle Type	Vehicle Speed
0.5			1	MU-Truck	20
1.5			2	MU-Truck	20
2.5			3	MU-Truck	20
3.5			4	MU-Truck	20
4.5			5	MU-Truck	20
5.5			6	MU-Truck	20
6.5			7	MU-Truck	20
7.5			8	MU-Truck	15
8.5			9	MU-Truck	20
9.5			10	MU-Truck	20
10.5			11	Roll-Off	10
11.5			12	Truck	15
12.5			13	Roll-Off	20
13.5			14	Roll-Off	20
14.5			15	Roll-Off	20
				Average (mph)	19
				Average (kmh)	30

D.2 Vehicle Type and Speed, for the City of Columbia Landfill Test Site, on July 25, 2005 for Sampling 2.

Road Name: Landfill

Sampling Date: 7/25/2005 Sampling Event: 2 of 3

Pass #	Vehicle Type	Vehicle Speed	Pass #	Vehicle Type	Vehicle Speed
0.5			1	MU-Truck	20
1.5			2	MU-Truck	20
2.5			3	MU-Truck	22
3.5			4	MU-Truck	22
4.5			5	MU-Truck	20
5.5			6	MU-Truck	20
6.5			7	MU-Truck	22
7.5			8	MU-Truck	20
8.5			9	MU-Truck	22
9.5			10	MU-Truck	20
10.5			11	Truck	20
11.5			12	MU-Truck	20
12.5			13	Roll-Off	20
13.5			14	MU-Truck	20
14.5			15	MU-Truck	20
Average (mph)					21
Average (kmh)					33

D.3 Vehicle Type and Speed, for the City of Columbia Landfill Test Site, on July 25, 2005 for Sampling 3.

Road Name: Landfill

Sampling Date: 7/25/2005 Sampling Event: 3 of 3

Pass #	Vehicle Type	Vehicle Speed	Pass #	Vehicle Type	Vehicle Speed
0.5	Roll-Off	20	1	Roll-Off	20
1.5	MU-Truck	20	2	MU-Truck	20
2.5	Roll-Off	20	3	MU-Truck	20
3.5	Truck	20	4	MU-Truck	20
4.5	MU-Truck	20	5	MU-Truck	20
5.5	MU-Truck	20	6	MU-Truck	20
6.5	MU-Truck	20	7	MU-Truck	20
7.5	MU-Truck	20	8	MU-Truck	20
8.5	MU-Truck	20	9	MU-Truck	20
9.5	MU-Truck	20	10	MU-Truck	20
10.5	MU-Truck	20	11	Truck	20
11.5	MU-Truck	20	12	MU-Truck	20
12.5	MU-Truck	22	13	Roll-off	22
13.5	MU-Truck	20	14	MU-Truck	20
14.5	MU-Truck	20	15	MU-Truck	20
Average (mph)					20
Average (kmh)					32