Analysis of Targeted Emission Reduction Possibilities in the Paso del Norte

Task 2: PM Emissions from the Ciudad Juarez Cement Plant

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Abstract

Fugitive dust emissions from a south Juarez quarry and cement operation were investigated in this study to supplement the existing PdN PM emissions inventory. The plant possesses a few facilities on-site for quarry and rock-crushing operations and is considered a major contributor of PM emissions in the city.

The exact location and the production and processing operations at this cement plant were confirmed and documented in this study. Soil samples were collected from two different locations in the plant for assessing the emission potentials related to wind erosion, mechanical disturbance, and vehicular movement. It was found that the conditions of the soil at the site are strongly in favor of high dust emissions with high silt loading and extremely low moisture content. PM_{10} emissions from the south Juarez cement and quarry operations were estimated to be 16.8 tons during the peak month of operation. The figure is significantly less for $PM_{2.5}$ at 1.5 tons per month. Dump trucks transporting raw materials on the unpaved roads within the facility accounted for 58 % of the PM_{10} dust generated from the facility. Uncontrolled, infrequent blasting at the quarry created significant puffs of dust, which accounted approximately 25% of the total PM_{10} emissions. It represented 96% of the dust generated by all non-traffic related cement production activities combined, including activities such as quarry drilling, loading and unloading of dump trucks, crushing by primary and secondary crushers, emissions from conveyor, aggregates/materials handling, emissions from active and inactive storage piles, mixing and proportioning of materials, and pneumatic transferring of materials were documented. Transportation of materials to outside sales by heavy-load trucks generated a significantly amount of PM_{10}, which is ranked the 3^{rd} at 1.3 tons per month or approximately 8% of the total PM_{10} emissions.

Three emission mitigation strategies were recommended based on the descriptions and quantifications of the production activities at the plant. They are: 1) Restrictions on the use of vehicles and equipment; 2) Improvement of soil conditions; and 3) Treatment of unprotected surface. Costs associated to these mitigation measures are difficult to substantiate at this juncture due to the plant's unwillingness to discuss and concerns on proprietary confidentiality as well as personnel security.

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1 Introduction

A large percentage of particulate matter (PM) emissions in the Paso del Norte region (PdN) are attributed to the dust emitted from unpaved roads and cement plants from Cd. Juarez. The PdN, which includes El Paso, Texas, Ciudad Juarez, Chihuahua, and Sunland Park, New Mexico, and the cities encompassed in the PdN share a common airshed that has historically had air pollution problems. El Paso, Texas is currently in nonattainment status with regard to federal standards for PM less than 10 micrometer (µm) in aerodynamic diameter (PM_{10}).

A cement plant located in south Ciudad Juárez has been reported to be a major contributor of PM emissions in the city and be responsible for constantly blanketing the neighborhoods with a grey layer of fine dust. The plant possesses a few facilities on-site for quarry and rock-crushing operations. It is estimated that a large percentage of the PM emissions from the plant are produced by aggregate generating processes and equipment movement on unpaved surfaces. The operations at the plant provide an unlimited reservoir for dust emissions either through continual mechanical disturbance to natural surface or through wind erosion on the unprotected bare soil surfaces within the facility boundaries. Emissions from the cement plant have not been systematically documented in the PdN's PM emissions inventory and the contribution to the PM emissions inventory needs to be determined.

In support of the State of Texas' effort to improve the quality of the PM and volatile organic compound (VOC) emissions inventories for the PdN region, the University of Texas at El Paso (UTEP), in collaboration with the Universidad Autonoma de Ciudad Juarez (UACJ) and the Instituto Tecnológico de Ciudad Juárez (ITCJ), was tasked by the Texas Commission on Environmental Quality (TCEQ) to conduct a targeted emission inventory in Cd. Juarez. The objectives of this task were to a) estimate PM emissions from all the PM generating processes, and b) consider operational modifications that could reduce emissions and estimate emissions based on those control strategies for the cement plant.

1.1 Project Description

Cement plants are considered a major source of PM in the PdN region. Fugitive dust emissions from the combined quarry and rock-crushing activities at the cement plant in south Juárez are missing from the existing PdN PM emissions inventory. Currently very few control strategies are applied during the operations of the facility. This project quantifies the fugitive PM emissions from this south Juárez cement plant and provides recommendations on dust control and operational modifications at the facility to reduce PM emissions.

1.2 Project Tasks

Specific tasks completed in this project are listed below:

1.2.1 Document facility operations and identify emission points

UTEP identified the exact location of and acquired the production and processing operations at this cement plant through site visits, staff interviews, and a review of production procedures. Locations and sources of PM emissions within the plant were identified. Activities considered to be sources of PM emissions included 1) quarrying and crushing; 2) raw material preparation, handling and storage; 3) grinding and blending; 4) scalping/screening; 5) finish grinding; 6) washing/scrubbing; 7) packaging and loading; 8) onsite transportation on unpaved surface; and 9) dust emission control practices. The number, size, frequency, and route of each piece of equipment used in the activities listed above were documented.

1.2.2 Quantify PM emissions from the Cement Plant

Soil samples were collected from two different locations in the south Juárez cement plant for assessing the emission potentials related to wind erosion, mechanical disturbance, and vehicular movement. Silt content and soil moisture were determined for use in the development of PM emissions. The U.S. EPA Compilation of Air Pollutant Emission Factors (AP-42) was used in conjunction with the information collected from Subtask 1.2.1 (Mares et al 2013) to develop daily and annual PM emission loadings to the atmosphere.

1.2.3 Develop PM emission control measures for the facility

Based on the results of Subtasks 1.2.1 and 1.2.2, three PM emission control measures were developed and recommended to the facility for fugitive PM emission reduction.

1.3 Structure of the Report

This report presents emissions inventories for fugitive PM_{10} emissions from a cement plant in south Ciudad Juarez. The objectives and tasks for the project are described in Chapter 1. In Chapter 2, the Juarez Cement Plant and Cerro Mexico quarry processes are described, operations parameters are provided, and simplified operations flow charts with identified emissions sources and corresponding AP-42 SCCs and/or sections for calculations are presented. Site specific silt and moisture parameters are described in Chapter 3 along with the methodology for their determination. Emission estimates with sample calculations are reported in Chapter 4. The results are summarized in Chapter 5 and possible mitigation measures described in Chapter 6. Chapter 7 provides a brief summary for the study.

2 Description of Juarez Cement Plant Processes

The Juarez Cement Plant produces Portland cement by the dry process at the foothills of the south-west end of the Juarez Sierra to the north-east of Cerro Mexico on Barranco Azul Street and Ave. de los Aztecas (31.657554°, -106.479087°). Figure 2.1 presents a Google Earth™ image showing the location of the Juarez Cement Plant and its quarries. Adjacent to the Juarez Cement Plant is a small quarry (31.658800°, -106.484844°) that is no longer being developed, and located to the southwest of the plant is the Cerro Mexico quarry (31.642326°, -106.488586°) which is the current main quarry being exploited for limestone (calcium carbonate) rocks. Access to the Cerro Mexico quarry is through a private paved road that leads through a mountain pass to the base of the quarry embedded in Cerro Mexico. Figure 2.2 presents a Google Earth™ image showing the property boundaries of the Juarez Cement Plant and quarries, along with the access road to the Cerro Mexico quarry and main plant road for material drop-off. Extraction occurs such that the exterior face of the mountain is preserved and the quarry development forms a crater behind the exterior face of Cerro Mexico.

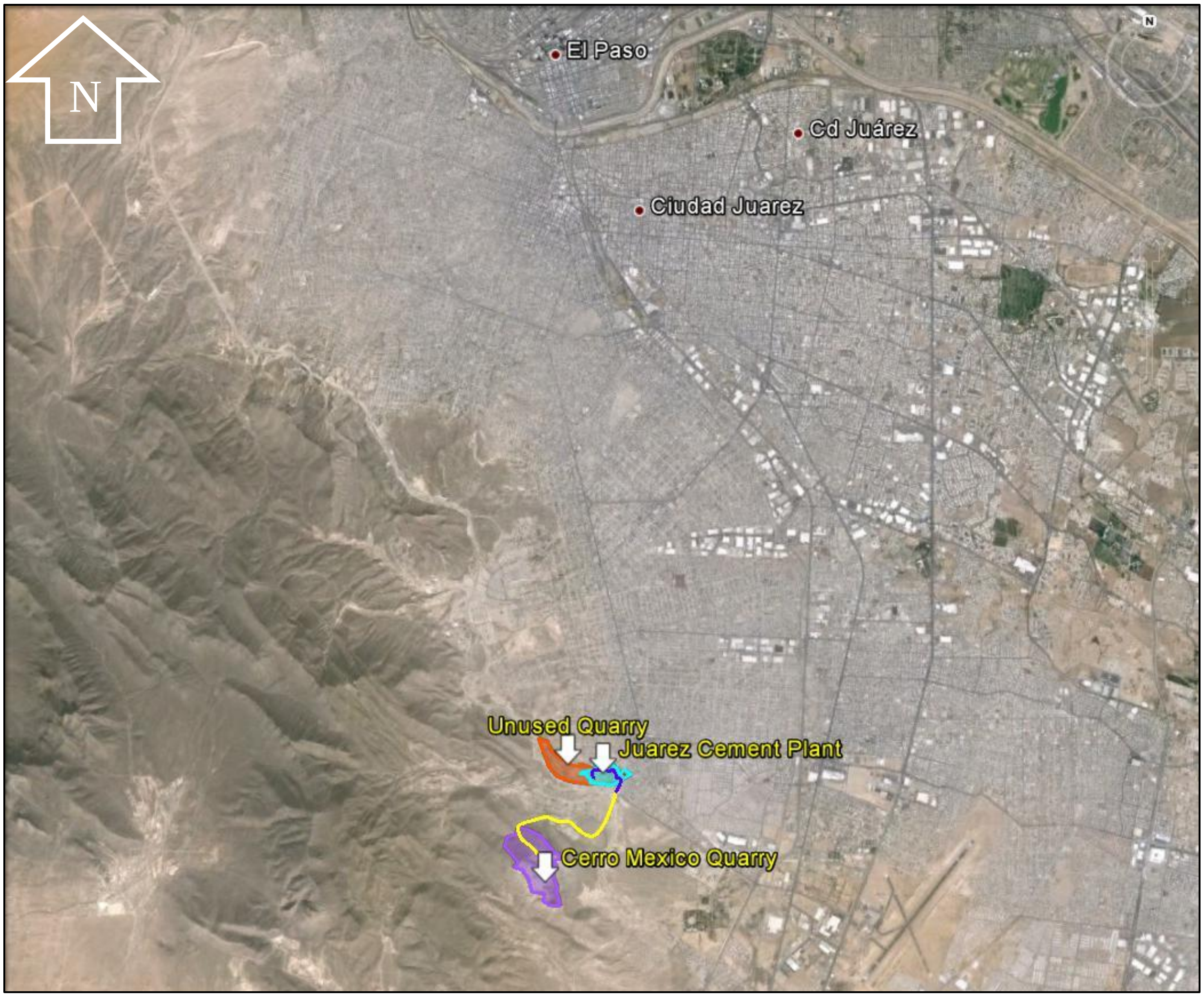

Figure 2.1 Google Earth Image of Ciudad Juarez Showing Location of Juarez Cement Plant and Quarries

Production and process information for the plant and quarries was gathered through three separate visits to GCC Juarez Cement Plant and interviews with the facility personnel (Mr. Julio Enriquez Flores). Due to confidentiality concerns some production figures provided were rounded up by the plant, material proportions for specific products were not given, and property maps were not provided. The plant only provided production figures for the month of July 2012, which was the month with the highest cement yield. Cement production would stop in November and resume in February each year due to kiln maintenance scheduled during low product demand, therefore during the months of January, November and December of 2012 there was no cement production. During production months the precalcinator, kiln, clinker cooler, and clinker conveyor run 24/7; whereas the rest of the plant operates on two shifts during the week days and one morning shift on Saturday. Due to the high electricity charge during peak usage hours, most equipment is shut down for 2 hours during the evening shift and the crew transfers to cleanup type of activities during that time.

During July of 2012, approximately 92% of the material extracted (120,000 tons) from the Cerro Mexico quarry was destined to outside sales with the remaining 8% being used to produce two types of products, Rapidset and Mirosilax. The plant's total cement production for July 2012 was 7,850 tons.

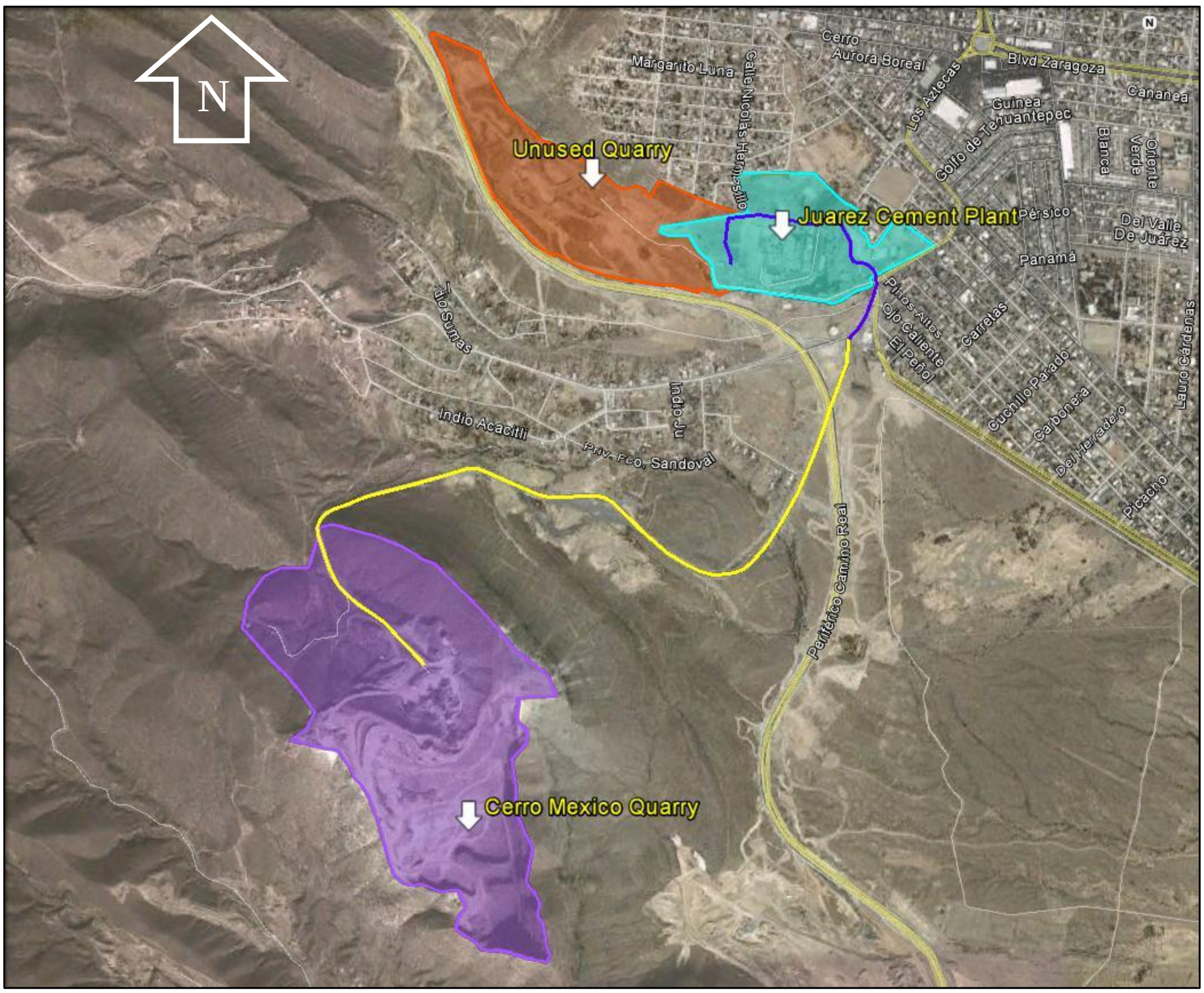

Figure 2.2 Google Earth Image of Juarez Cement Plant, Quarries and Access Road

2.1 Description of Quarries and Extraction Operations

2.1.1 Cerro Mexico Quarry

The Cerro Mexico quarry is located at 31.642326°, -106.488586°, and although the actual boundaries of the Cerro Mexico quarry were not provided, the active quarry site was determined from Google Earth™ images as occupying roughly 0.556 square kilometers. Figure 2.3 presents a Google Earth™ image showing the property boundaries of the Cerro Mexico quarry, its access road, and the location of the limestone crushing installations. Figure 2.4 presents a process flow chart of the extraction to storage operations at the quarry site, along with identified emissions sources with AP-42 Source Classification Codes (SCC) and/or sections for calculations. Emission estimates are presented in Section 4 (Emissions from Cd. Juarez Cement Plant). Individual processes and emission parameters are described below.

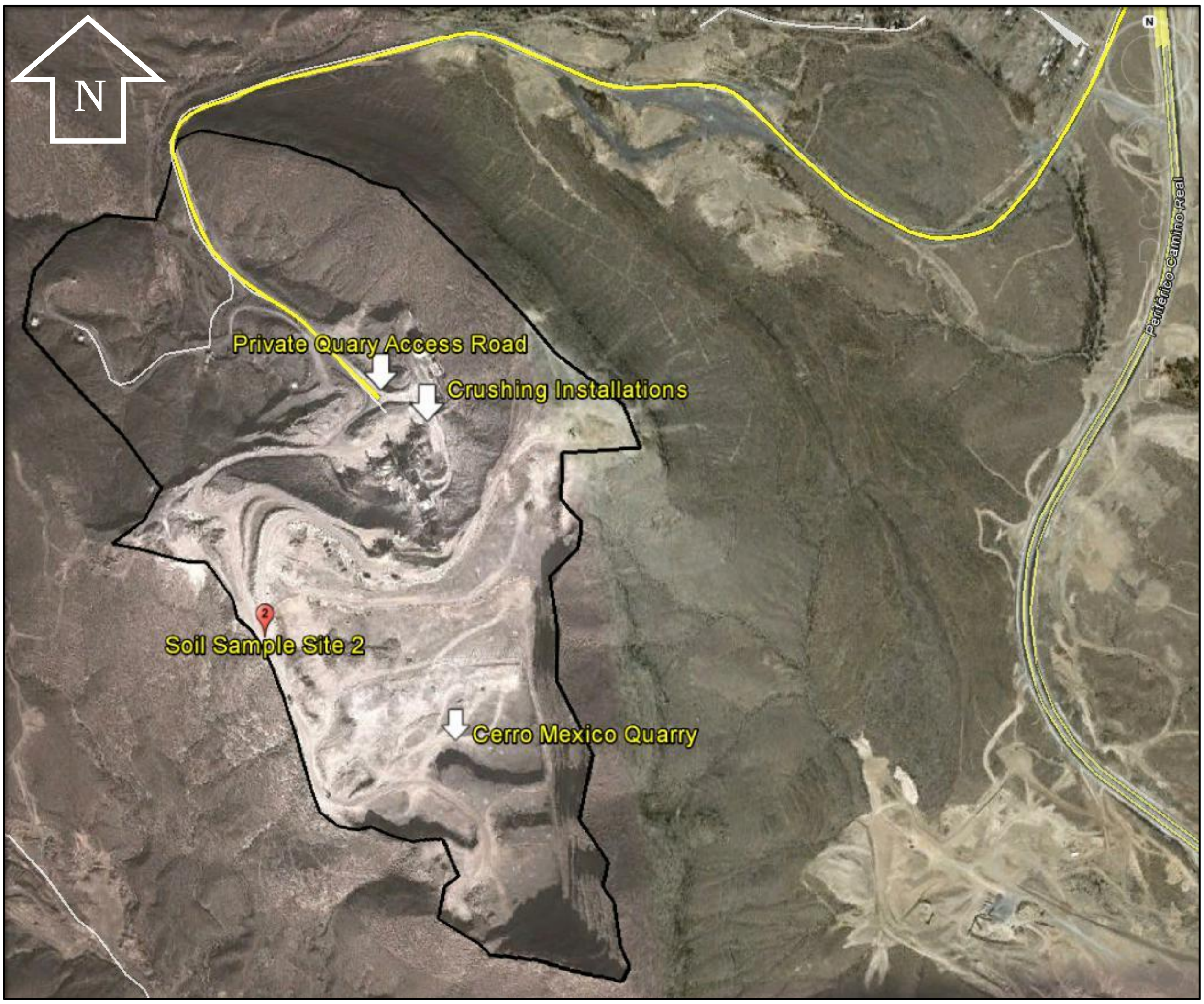

Figure 2.3 Google Earth Image of Cerro Mexico Quarry

In 2012, approximately 120,000 tons of limestone were extracted in the high throughput month (i.e., July 2012) and 85,700 tons were extracted in a low throughput month. Extracted material is lifted by a front loader bulldozer and placed on a Dump-truck with an average payload of 34 tons. The dump-truck transports the material approximately 800 meters from the drilling/mining point to the primary crusher over an unpaved road (1,600m roundtrip); this distance varies as the extraction point changes. While a full dump-truck is headed towards the primary crusher, a second empty dump-truck is headed in the opposite direction. The reported average total round trips per day were 161 during the high throughput month (approximately 1 truck loaded every 5.25 min), and limestone throughput per average truck payload corresponds to a total of 3,530 tips during that month.

$$120{,}000\ \frac{\text{tons}}{\text{mo}} \times \frac{1}{34}\ \frac{\text{truck}}{\text{tons}} = 3{,}530\ \frac{\text{trips}}{\text{mo}}$$

At the primary crusher, material is unloaded and transported by a system of conveyors to either other crushers, where material is crushed to a sequentially smaller rock size and loaded to a delivery conveyor. Figure 2.5 presents a Google Earth ™ image of the Cerro Mexico quarry indicating the location of the quarry's crushers, conveyor system and dust collectors. In general, material is processed through the primary crusher and then the secondary crusher, but rarely through the tertiary crusher. All stone crushers at Cerro Mexico are hammers type, and the primary crusher has a 700 T/hr. capacity while the secondary crusher has a capacity of 500 T/hr. and therefore the latter is the crushing process' bottleneck. During the month of July 2012, the secondary crusher was operated 85% of the time, based on 2 shifts of 8 hr. (minus peak time) on weekdays and 1 shift on Saturdays. July, 2012 had 22 week days and 4 Saturdays and therefore 340 available hours, which at 85% and 500 tons/hr. correspond to 144,500 tons/month: slightly more than the official reported value of 120,000 tons/month. Each crusher is equipped with a dust collector, as is the conveyor system, totaling in four collectors. Each delivery conveyor supplies rocks of a different size grade which depends on customer requirements. In the peak month, 110,000 tons of crushed limestone rocks were delivered to offsite customers by 30-m^3 (approximately 48 tons depending on size grade) trucks. Approximately 10,000 tons of the materials were shipped to the Juarez Cement Plant on 34-ton payload dump-trucks for Portland cement production, corresponding to approximately 290 trips per month (14 per day).

The round trip distance between the base of the quarry and the supply conveyors is approximately 75 m of unpaved road whereas the distance between the base of the quarry and the quarry's gated entrance is approximately 2.6 km of concrete paved road. The material supplied for cement production is hauled on an additional 900 m of paved road from the quarry's gate to a covered material drop inside the plant. The material drop has rubber curtains where dump-trucks fit snuggly, and the material is channeled to an underground conveyor, which eventually rises to above ground (half of which is underground and the other half is covered), that transports the material to the plant's covered Material Storage Facility, the largest structure in the plant.

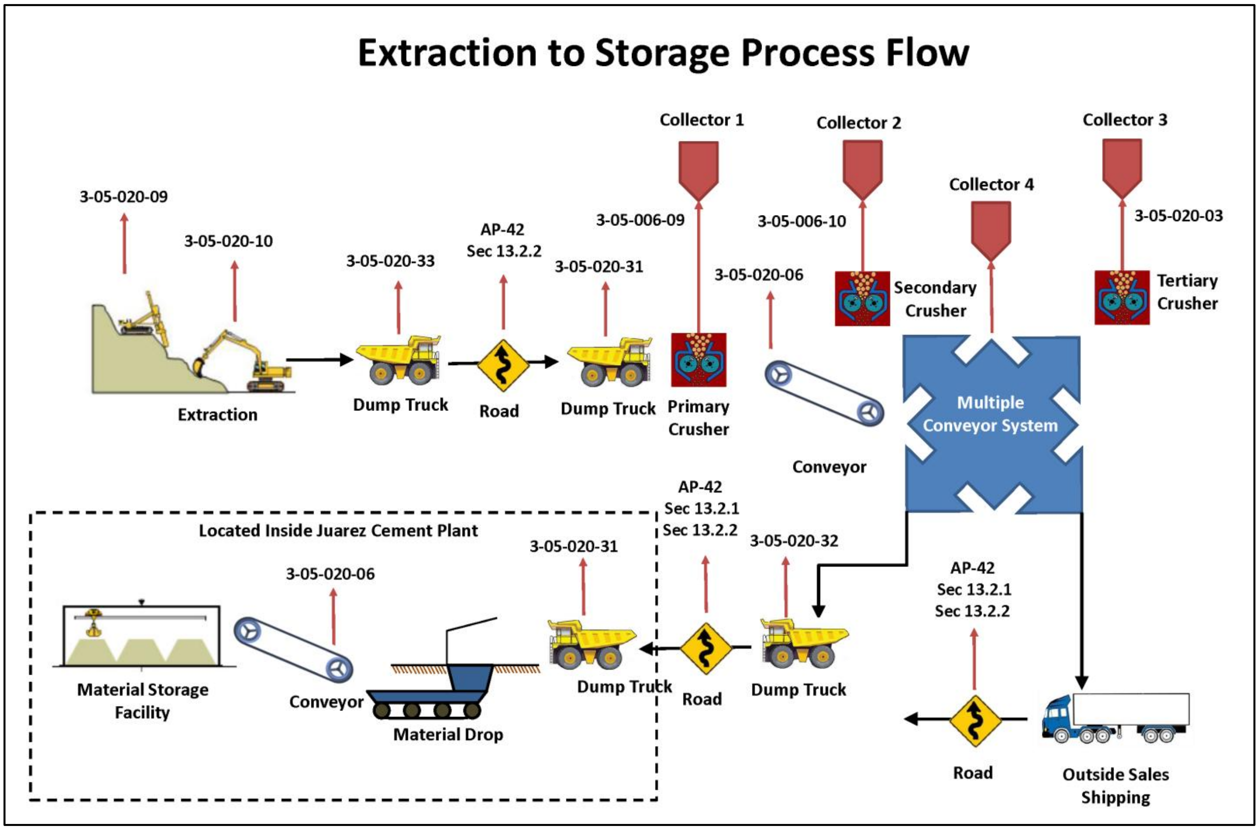

Figure 2.4 Process Flow Chart of the Cerro Mexico Quarry Excavation to Main Storage

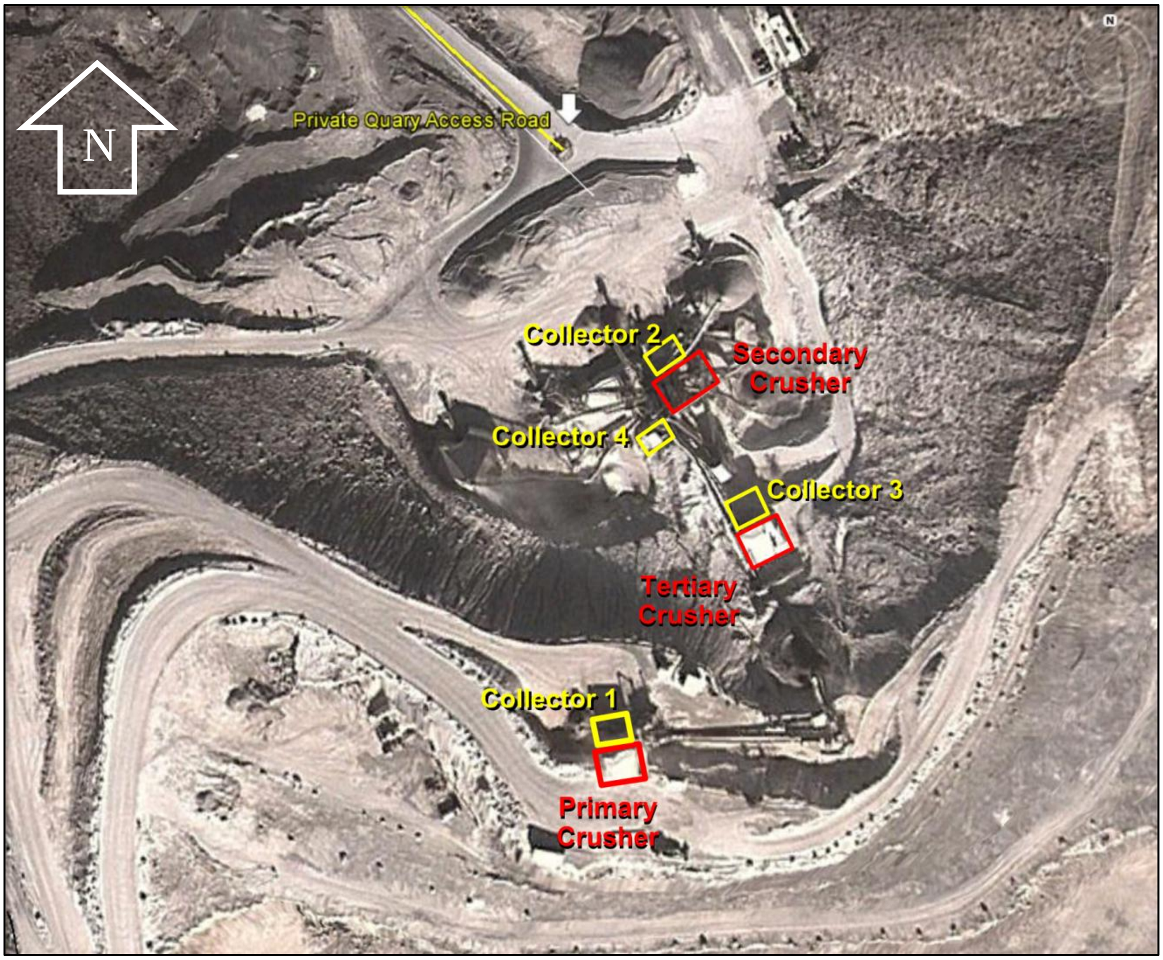

Figure 2.5 Google Earth Image of Cerro Mexico Quarry Indicating the Location of Crushers, Conveyor System and Dust Collectors

2.1.2 Aggregate Storage and Juarez Plant Quarry (Not in Use)

Some small amounts of raw aggregate materials, not prone to wind erosion, are stored onsite and near their point of use, occupying a surface area of roughly 14,000 m^2; this area represents the surface that is actively used for storage, although not all of it is always used due to variation in the amount of material stored this way. These aggregate material handling areas are located inside the Juarez Cement Plant which occupies a total of 0.162 square kilometers. Further information regarding these materials was not provided by the plant due to company's proprietary concern. The three areas used for open storage are shown in Figure 2.6 in red, along with the outline of the Juarez Cement Plant and its main road. Aggregate materials are lifted by front loader bulldozer onto dump-trucks which then transport the material to its point of use (typically the Pettibon crusher) with an estimated 30 m of roundtrip travel on unpaved road. Travel on the unpaved road from the paved road to the Petibon crusher is estimated to be 75 meters in one direction.

Figure 2.6 Google Earth Image of Juarez Cement Plant Indicating in Red the three Aggregate Storage Areas

Figure 2.7 presents a simplified flow chart for the Juarez Plant Quarry and Aggregate Storage processes with identified emissions sources with AP-42 SCCs and/or sections. Emission estimates are presented in Section 4 and individual processes and emission parameters are described below. The quarry adjacent to the Juarez Cement Plant, located at 31.658800°, -106.484844°, is not in use, but the exposed surface from previous development was determined from Google Earth™ images to occupy roughly 0.206 square kilometers (Figure 2.2). If this quarry were to be used, the distance from the most recent point of development to the plant's crusher (Pettibon) is approximately 500 m. The crusher at the Juarez Plant is a Pettibon type crusher fed by a covered material drop above it and is equipped with a collector (Collector A). The material it crushed is placed on the same underground conveyor as the material brought from the main quarry but a few meters before that material drop. Some 3,000 tons of material were processed on the Pettibon crusher during the peak month based on the usage (12 hr.) and equipment's capacity (250 tons/hr.) data provided by the plant. As before, the conveyor transports the material to the storage facility.

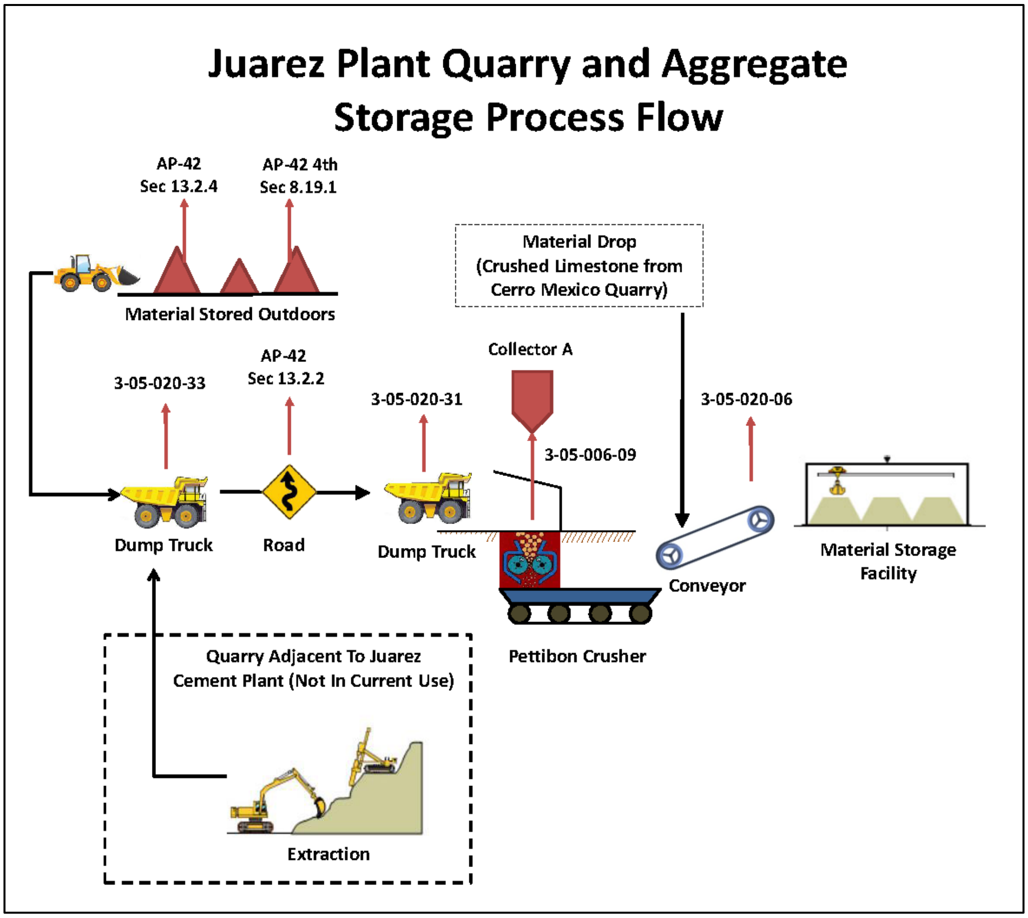

Figure 2.7 Process Flow Chart of Aggregate Storage and Juarez Plant Quarry

2.2 Description of Juarez Cement Plant Production

Figure 2.8 presents a Google Earth ™ image of the Juarez Cement Plant indicating the location of the plant's main facilities and equipment. Figure 2.9(a) presents a photograph of the Juarez Cement Plant as seen from its South side; observable equipment and facilities are identified. The process flow of materials handled at the Juarez Cement Plant is shown in the simplified process flow chart in Figure 2.10, along with identified emissions sources with AP-42 SCCs and/or sections for calculations. Emission estimates are presented in Section 4 (Emissions from Cd. Juarez Cement Plant) and individual processes and emission parameters are described below.

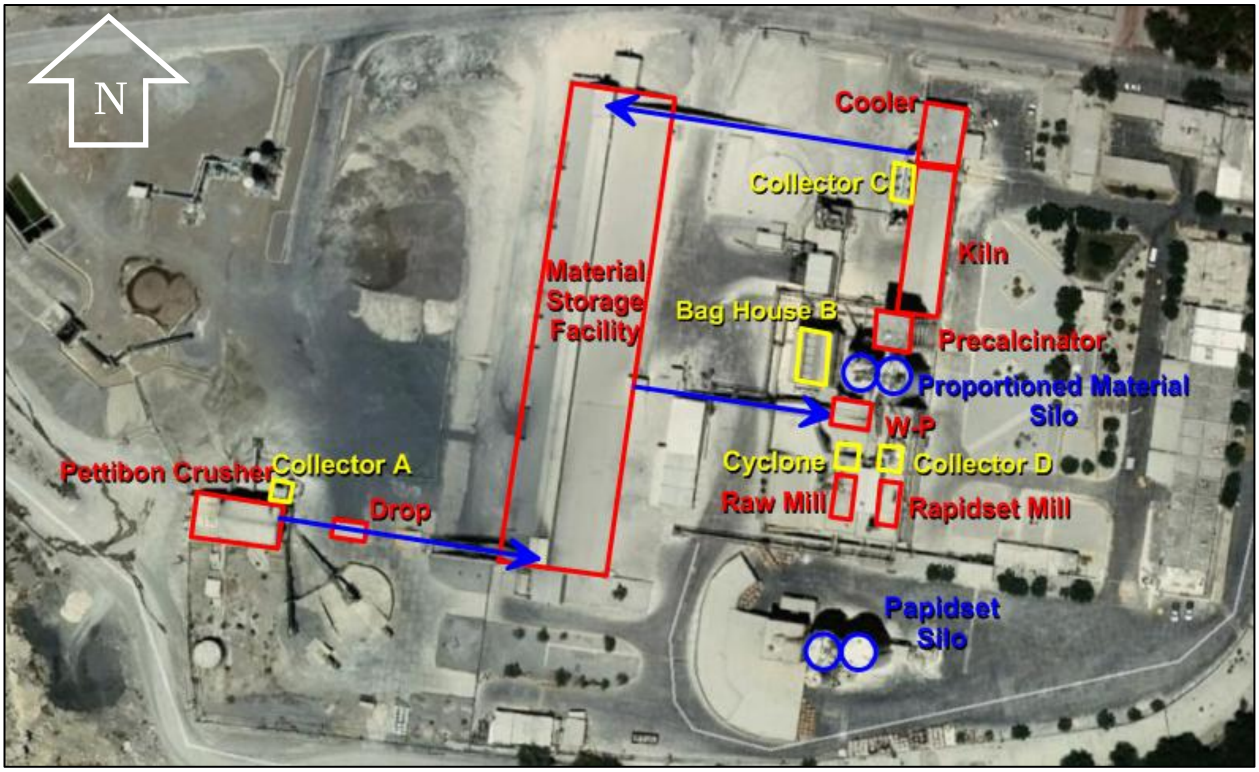

Figure 2.8 Google Earth Image of Juarez Cement Plant Indicating Main Facilities and Equipment

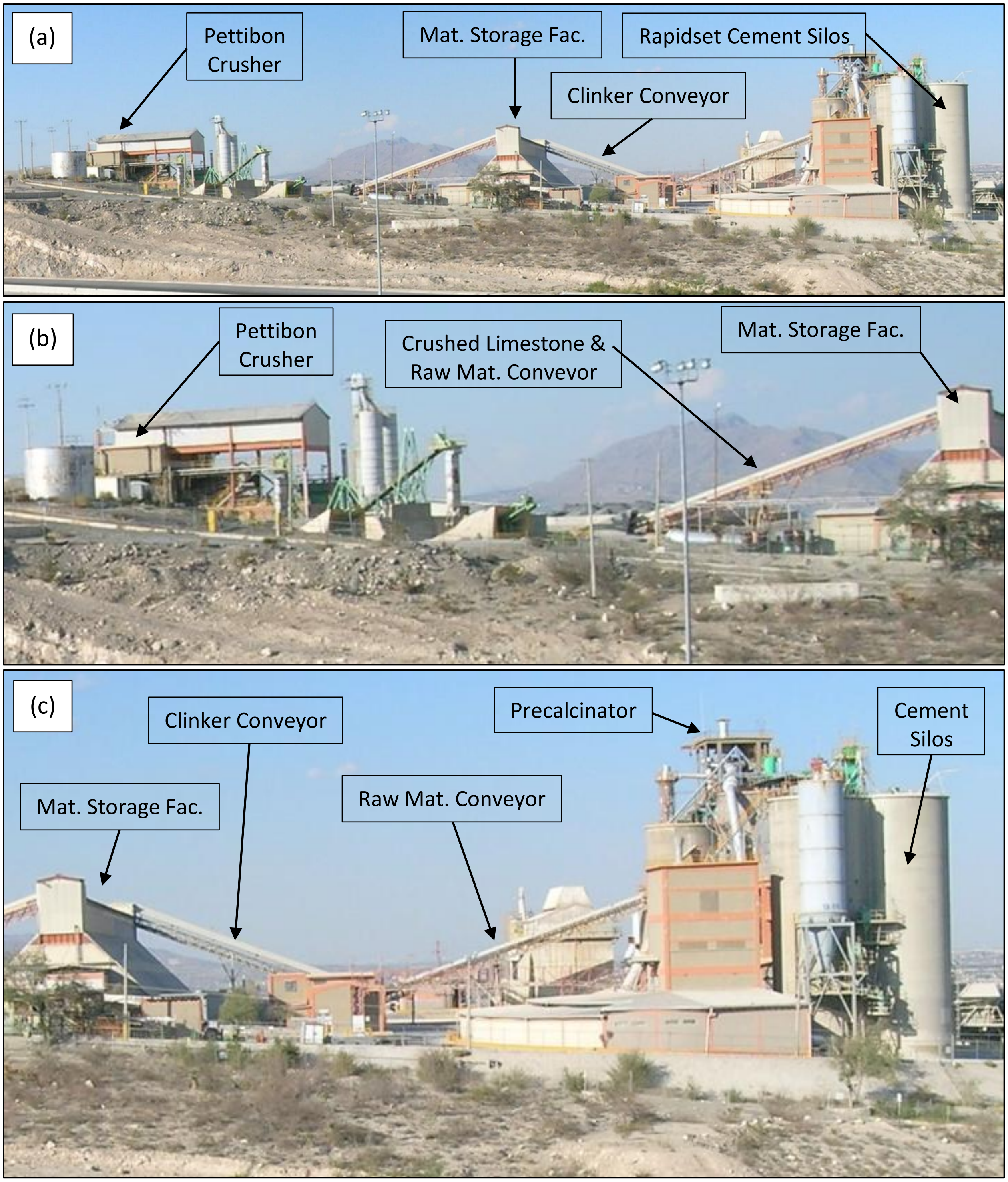

Figure 2.9 Photograph of Juarez Cement Plant's South Side. (a) is Enlarged on (b) and (c).

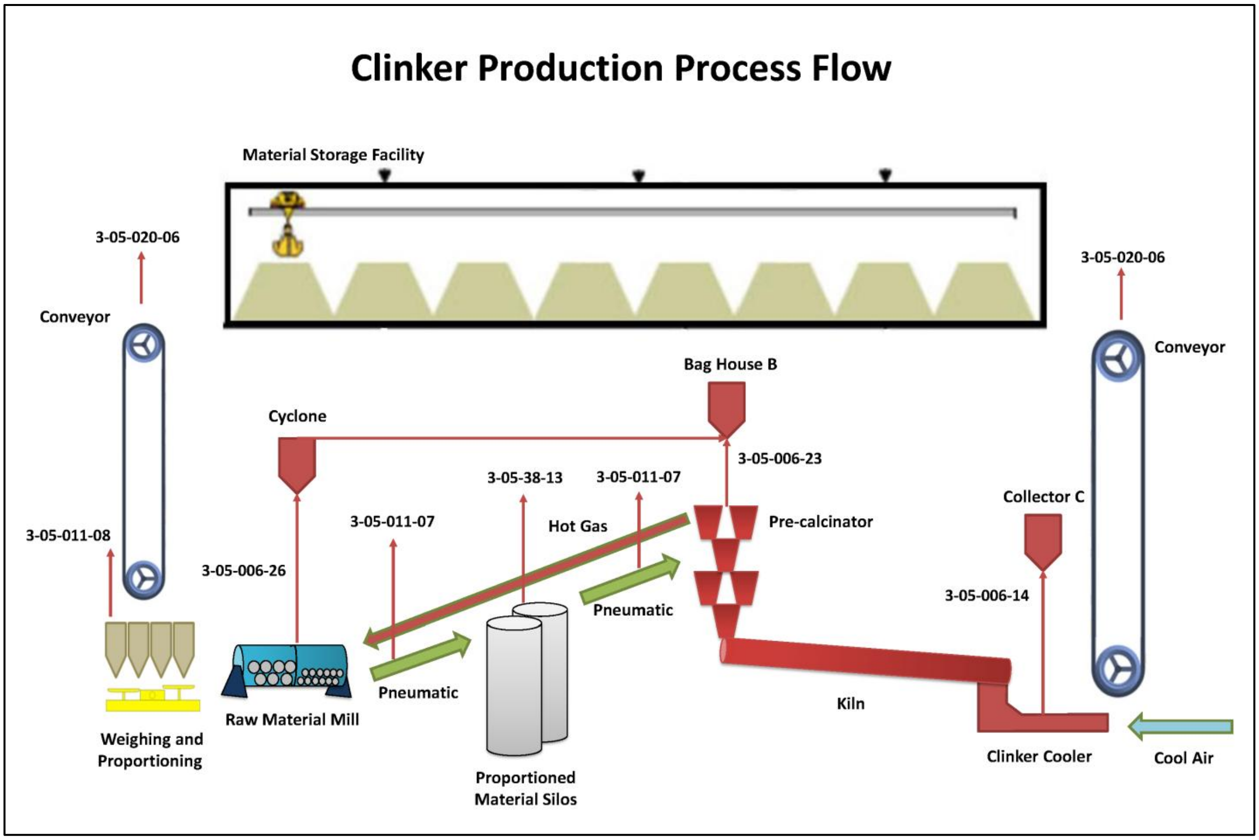

Figure 2.10 Process Flow of Juarez Cement Plant Clinker Production

2.2.1 Material Storage Facility

The covered Material Storage Facility is fed with materials through covered conveyors and it is the largest structure in the plant measuring from one end to the other roughly 150 meters. Approximately 2/3 of the facility is used for storing raw crushed material and the remaining 1/3 for Clinker material. The facility is a SWEEPER system that collects materials and transports them through a covered conveyor to the secondary storage area located inside the processing facility (see Figure 2.8). The Covered Storage Facility has doorways on the back side (West) with mechanized rubber curtains that open the doorway by spreading apart to allow a truck to enter the facility for material withdraw or facility maintenance. Clinker material for the Mirosilax mixture is transported by trucks out of the storage facility through these back doorways to the East side of the Plant where the Mirosilax Cement is processed and packaged.

2.2.2 Weighing and Proportioning

A weighing and proportioning storage area inside the main building allows the material to be dispensed to two mills (one for raw material and the other for Rapidset) in prescribed weight and proportion for production. This secondary material storage area system is completely housed inside the plant's main building.

2.2.3 Raw Material Milling

Raw material in prescribed proportions is fed to the Raw Mill which is a two chambered ball mills housed inside the plant's main building next to the Rapidset Cement Mill and the secondary material storage area. According to the information provided by the plant, the Raw Material Mill has a 43 ton/hr. capacity and was used 194 hr. for the Rapidset mixture, whereas it has a 38 ton/hr. capacity and was used 78 hr. for the Mirosilax mixture. Considering equipment capacities and time used, the two-chamber Raw Material Mill processed approximately 8,400 tons of material for Rapidset and 3,000 tons of material for Mirosilax during the peak month, totaling 11,400 tons. The Raw Material Mill feeds the material to the Milled Proportioned Material Silos in the main building through a pneumatic system powered by hot gases coming from the precalcinator.

2.2.4 Clinker Production

Gases (air) are introduced through the Clinker Cooler (located north of the Kiln), channeled through the Kiln, and then passed through the Preheater. The hot gas exiting the Preheater is divided into two streams, the first (and main) stream is channeled into the bag house B; and the other is used to drive the plant's pneumatic system. The pneumatic system moves material from the Raw Material Mill and Rapidset Cement Mill to their respective silos. Gas exiting the Raw Material Mill is passed through a Cyclone and then channeled to the bag house (Bag House B). Material is transported from the Milled Material Silos to the Precalcinator by means of the pneumatic system, and then fed into the Kiln. The Kiln's capacity for Rapidset (*Sulfoaluminato, Minero B*) Clinker is 400 tons/d; and for Mirosilax (*Ignimbrita, Minero B*) is 300 tons/d. The Kiln is run at near full capacity at 24 hr. a day and 7 days a week during the months of February through October. Clinker output from the Kiln is directly fed to the Clinker Cooler and dust emissions are passed through the cooler's collector (Collector C). The cooled clinker is then transported by a bucket conveyor system, which has half of its length underground, back to the covered Material Storage Facility at the facility's North end. Figure 2.11 presents a photograph of the North-West view of the Juarez Cement Plant in which the observable equipment and facilities are identified.

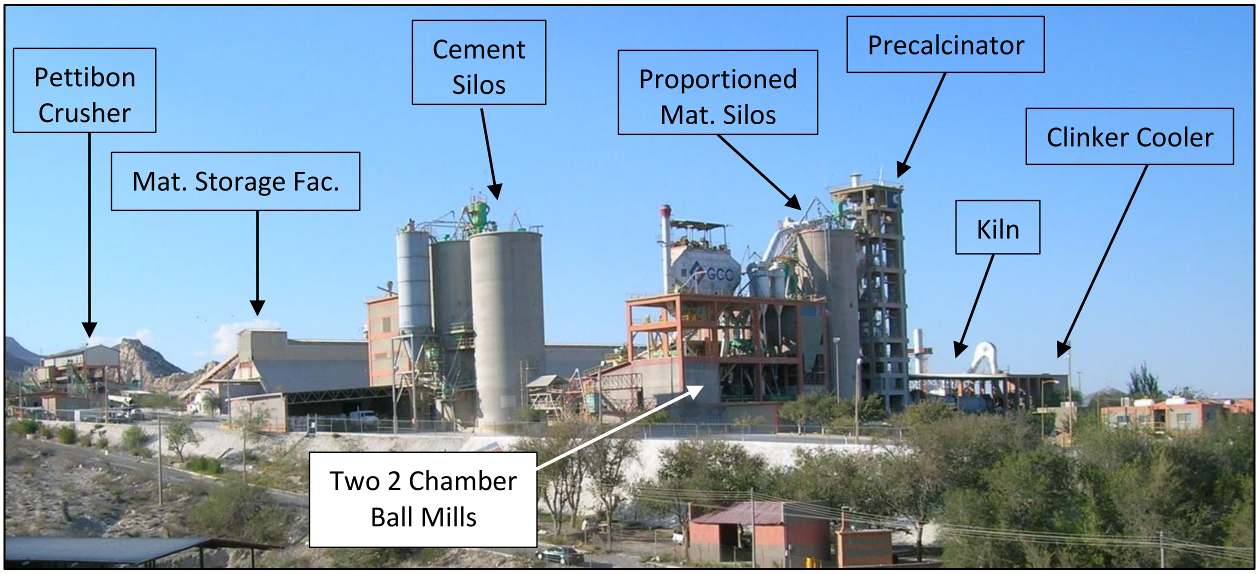

Figure 2.11 North-West View of the Juarez Cement Plant's Main Facilities

2.2.5 Rapidset Cement Mill and Packaging

Figure 2.12 presents a simplified process flow chart for the Rapidset cement milling and packaging operations along with identified emissions sources with AP-42 SCCs and/or sections for calculations. Emission estimates are presented in Section 4 and individual processes and emission parameters are described here. The Cement Mill for Rapidset (*Sulfaluminato, Minero B*) is a two-chamber ball mill with a capacity of 16 T/hr.; it was used 61% of the available time in the peak month (i.e., 682 hr.: 22hr per day and 31 days) and therefore produced some 6,660 tons of Rapidset cement. Maximum usage in 2011 was 80%. Dust coming out from the two-chamber Cement Mill is passed through a collector (Collector D), and material output from the Cement Mill is fed to the Rapidset cement silos to the south of the main building through the pneumatic system with most of the pipes being underground. Rapidset material is then packaged in a building at the south side of the plant at a rate of 18 ton/hr. In the peak month, the equipment was used 51% of the time and 6,300 tons were packaged.

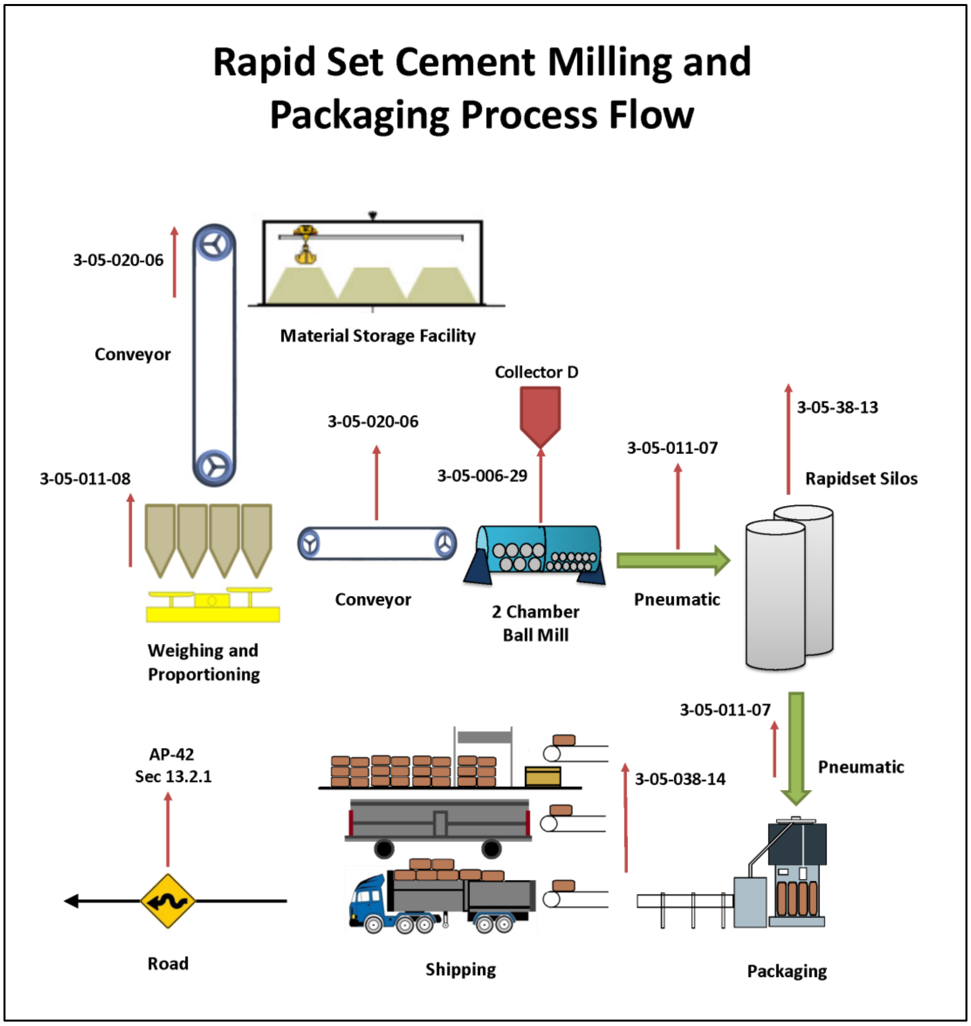

Figure 2.12 Process Flow of Rapidset (Minero B) Milling and Packaging

2.2.6 Mirosilax Cement Mill and Packaging

Figure 2.13 presents a diagram of the Mirosilax cement milling and packaging process operations along with identified emissions sources with AP-42 SCCs and/or sections for calculations. Emission estimates are presented in Section 4 and individual processes and emission parameters are described here. Figure 2.14 presents a Google Earth ™ image of the East side of the Juarez Cement Plant indicating the location of the main Mirosilax processing equipment. Clinker material for the Mirosilax mixture is transported by trucks out of the storage facility through back doorways to the East side of the Plant where the Mirosilax cement (*Ignimbrita, Minero A*) is processed and packaged. The Cement Mill for Mirosilax is a one-chamber ball mill with a capacity of 10 ton/hr.; it was used at 23% of the available time in the peak month (i.e., 682 hr.: 22hr per day and 31 days) and therefore produced some 1,570 tons of Mirosilax cement. Maximum usage in 2011 was 40%. Dust coming out from the one-chamber Cement Mill is passed through a collector (Collector E). Output form the Mirosilax Mill is fed to the contiguous silos through a pneumatic system. Mirosilax material is then packaged in an adjacent building at a rate of 25 ton/hr. In the peak month, the equipment was used 9% of the time and 1,550 tons were packaged.

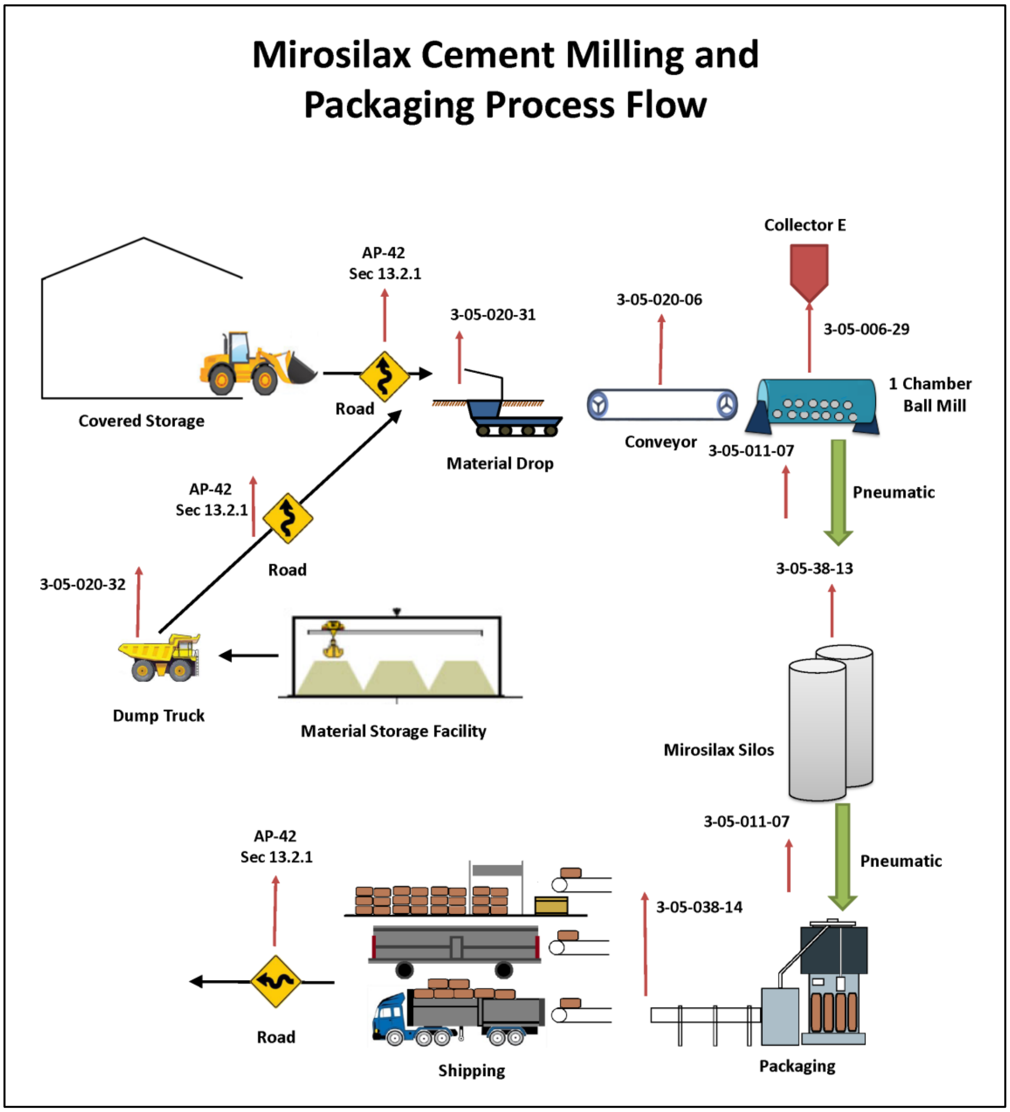

Figure 2.13 Process Flow of Mirosilax (Minero A) Milling and Packaging

Figure 2.14 Google Earth Image of Mirosilax Cement Processing Facilities at the East Side of the Cement Plant

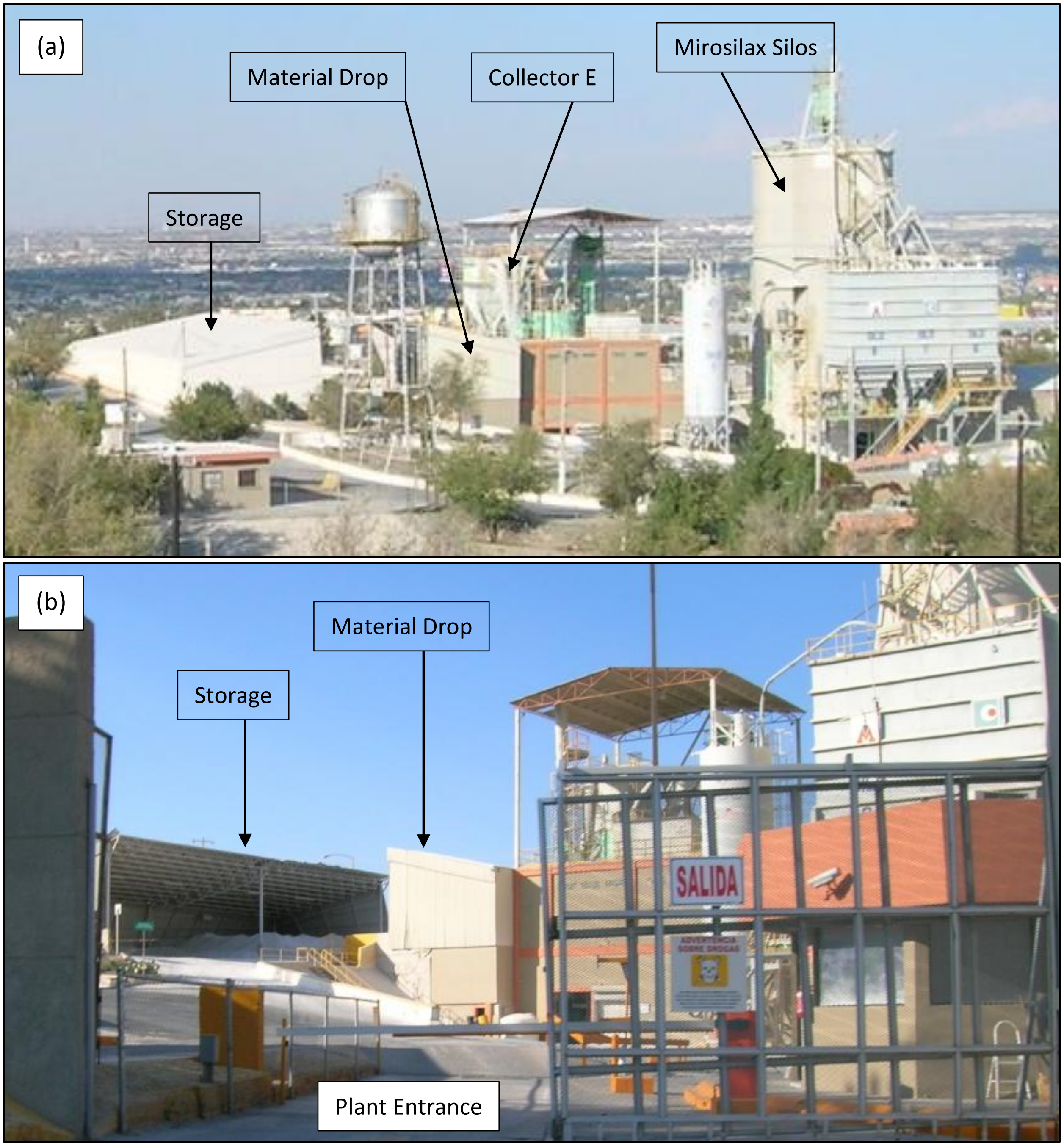

Figure 2.15 Photographs of Mirosilax Installations on the East end of Juarez Cement Plant; (a) from the South; (b) from Plant's Entrance

3 Soil Properties at the Cement Plant Quarry

Dust emissions from the operations at the cement plant vary directly proportional to the percentage of fine particles and to the wetness or moisture content of the soil in the unprotected surface. As discussed in the Task 1 report, the fraction of silt (particles less than 75 µm) and the moisture content in the soil serve as good indicators for the emission potential of the unprotected surface. High silt content and low moisture content in the soil create a large reservoir of materials to be entrained into the air by vehicular movement or wind erosion on the road surface.

3.1 Selection of Soil Sampling Sites

Soil samples were collected from 2 sites within the south Juarez cement plant for silt and moisture content analyses. The selection of these sites was based on the available geographical information about the spatial distribution of the soil types and GIS information on the distribution of the unpaved roads in Ciudad Juarez, as discussed in Task 1 report. The 2 soil sampling sites (Camino a Estación Mendez and Antonio Rabajo sites) are indicated as Sites 1 and 2 on Figure 3.1 (Figure 2.6 and Figure 2.3). The Latitude-Longitude coordinates are Site 1 (Juarez Cement Plant): 31.657028°, -106.481199°; and Site 2 (Cerro Mexico Quarry): 31.643644°, -106.491404°

3.2 Soil Sampling Method

Soil samples were collected on April 10, 2013 following the sampling protocol for unpaved roads, as outlined by the EPA (U.S. EPA 1995) in Appendix C.1 of the AP-42 document. Discussion of sample collection, shipping, handling, preparation, and associated laboratory analyses for silt loading and moisture content can be found in the Task 1 report. Field soil samples log and soil sample laboratory analysis reports are included in Appendices 1 and 2.

3.3 Results

The particle size distribution of the soil collected form the cement plant is shown in Figure 3.2. Table 3.1 Juarez Cement Plant and Cerro Mexico Quarry Soil Sample Properties Additional information for the soil samples is available at UTEP.

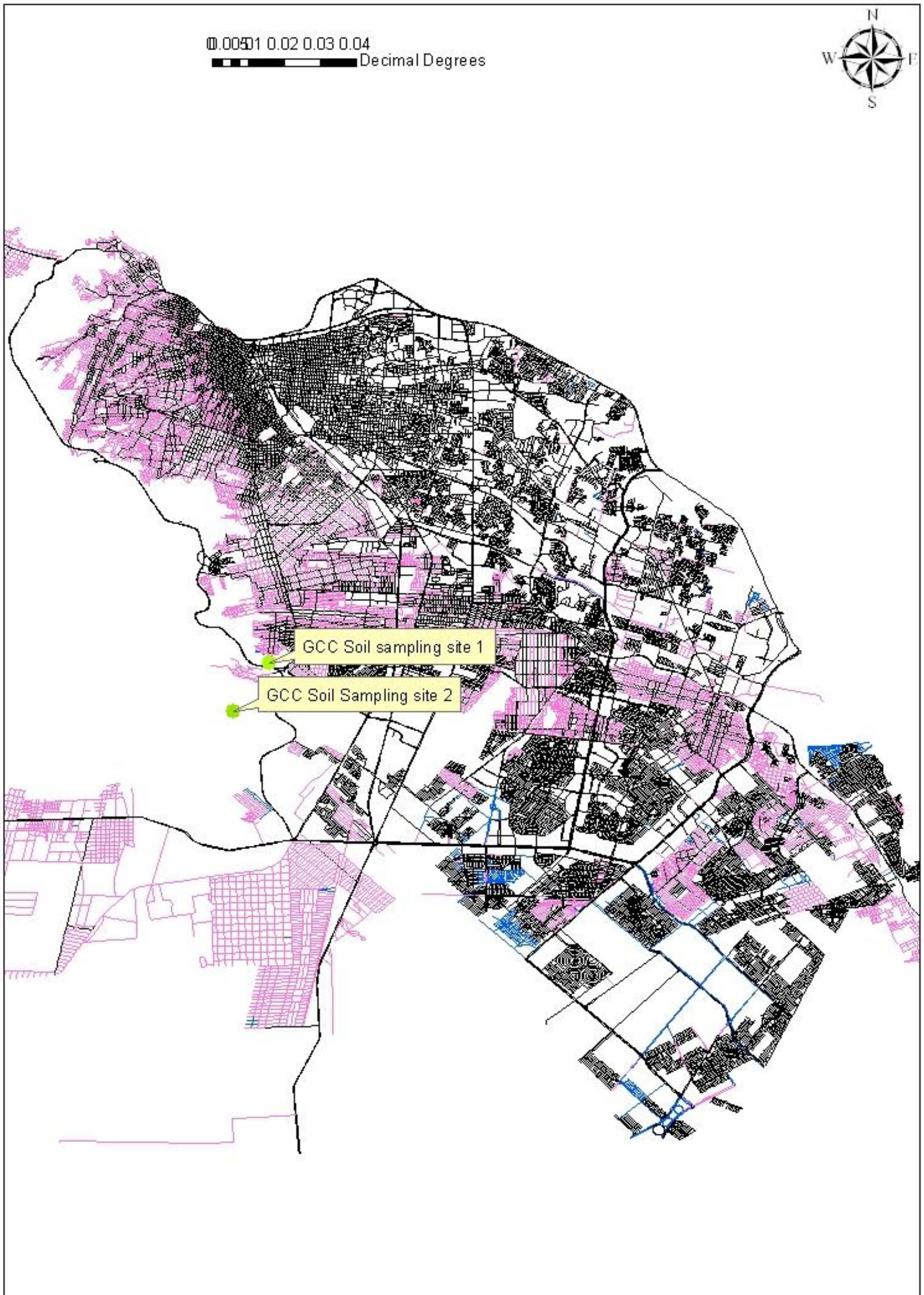

Figure 3.1 Soil Sampling Sites Locations

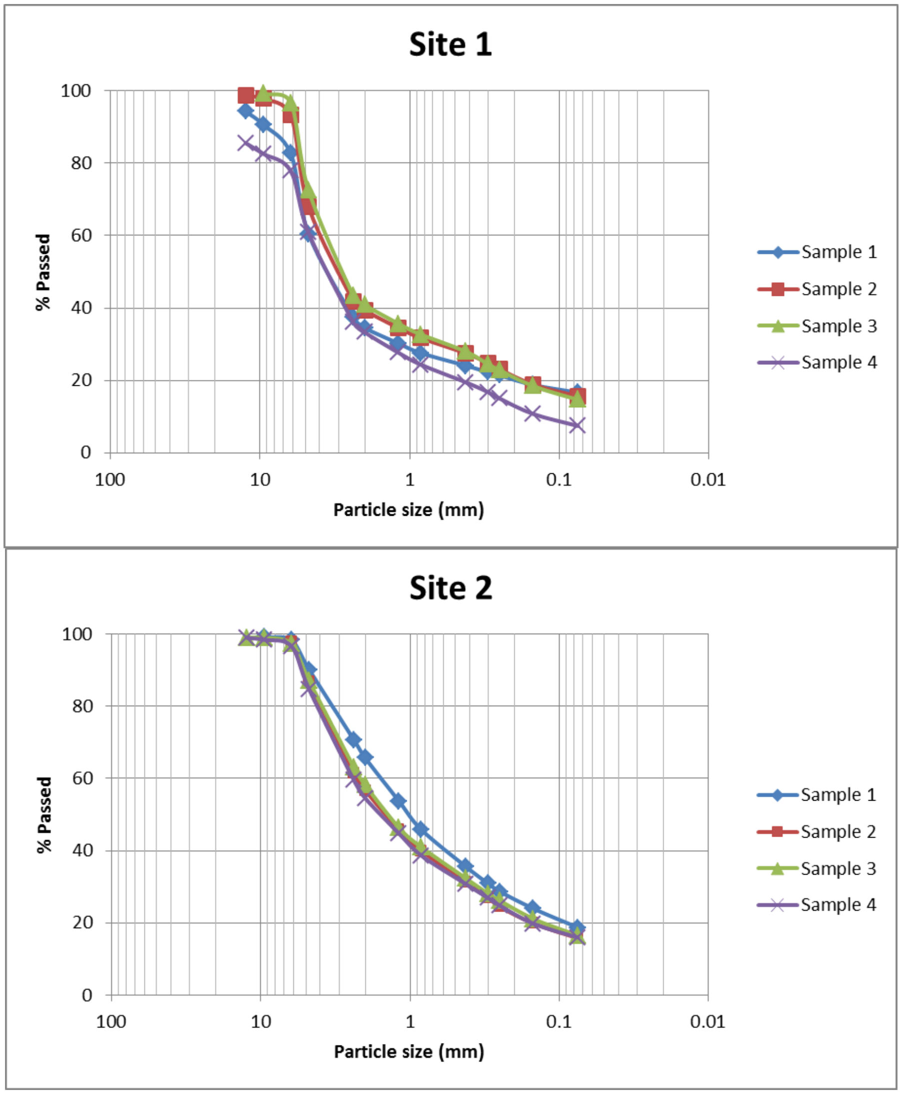

Figure 3.2 Soil Particle Size Distribution

Table 3.1 Juarez Cement Plant and Cerro Mexico Quarry Soil Sample Properties

Site ID	# of Samples	Silt loading content (%)				Moisture Content (%)			
		Avg.	Max.	Min.	Std. Dev.	Avg.	Max.	Min.	Std. Dev.
1	4	13.75	17	7	4.57	0.48	0.52	0.44	0.040
2	4	16.75	19	16	1.50	0.041	0.050	0.031	0.008
All sites	8	15.25	19	7	3.54	0.26	0.52	0.031	0.24

4 Emissions from Cd. Juarez Cement Plant

In this chapter emission estimates were developed for vehicle movement on unpaved industrial roads and paved roads, aggregate handling and piles, and cement production operations. Table 4.1 presents SCCs for all identified activities occurring at the Juarez Cement Plant and Cerro Mexico Quarry with the exception of SCC 3-05-038-14 for which emission factor values were not obtained. The order in which plant operations are presented in Table 4.1 follows the simplified process flow diagrams previously presented (Figure 2.4, 2.7, 2.10, 2.12, and 2.13) and the operations can be identified by the SCC numbers and descriptions. Furthermore, Table 4.1 indicates the AP-42 sections for those operations without SCCs.

4.1 Cement Plant Process PM Emissions

Dust emissions were estimated for limestone extraction, crushing, and cement production, milling and packaging using emission factor from AP-42 Sections 11.6 (Portland Cement Manufacturing), 11.12 (Concrete Batching), and 11.19.2 (Crushed Stone Processing and Pulverized Mineral Processing) (U.S. EPA 1995). Dust emissions were estimated by multiplying the activity rate (production volume in peak month) by the corresponding emission factor for that activity and desired aerodynamic particle size. Emission factors, activity rates and emissions estimates for Total PM, PM_{10} and $PM_{2.5}$ are presented in Table 4.1, although not all emissions factors exist in AP-42 for all particle sizes. A sample calculation is as follows:

$$\textbf{Emission} = \textbf{Emission Factor} \times \textbf{Activity Rate} \tag{4.1}$$

The emissions generated by the Precalcinator-Kiln with a fabric filter combination (SCC 3-05-006-23) operated at the Juarez Cement Plant were estimated based on an emission factor of 0.1 kg/Mg for PM emissions. Considering an activity rate based on a kiln capacity of 400 tons/day for 24 hrs/day and 31 days for the peak month, the PM emissions were estimated to be:

$$\text{PM Emissions} = \frac{400\ \text{tons}}{\text{day}} \times 31\text{days} \times \frac{0.1\text{kg}}{\text{Mg}} = 1{,}240\ \text{kg}$$

Table 4.1 Itemized Emission Estimates [kg] for Juarez Cement Plant and Cerro Mexico Quarry Operations for July 2012

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
	Cerro Mexico Quarry							
SCC 3-05-020-09*	**Quarry Blasting** Blasting - uncontrolled		4,150		120,000		3.45E-02	
SCC 3-05-020-10	**Quarry Drilling** Wet Drilling - Unfragmented Stone - uncontrolled	ND	4.80	ND	120,000	ND	4.00E-05	ND
SCC 3-05-020-33*	**Dump Truck Loading (34 ton)** Truck Loading - Front end loader - uncontrolled	ND	5.45	ND	120,000	ND	3.20E-07	ND
	Unpaved Road Transportation	**AP-42 Sec. 13.2.2; See Section 0 Bellow**						
SCC 3-05-020-31	**Dump Truck Unloading** Truck Unloading - Fragmented Stone -uncontrolled	ND	0.96	ND	120,000	ND	8.00E-6	ND
	Crushing Installations							
SCC 3-05-006-09	**Primary Crusher** Primary limestone crushing with fabric filter		ND	60.0	120,000		ND	5.00E-04
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.78	2.76	8.40	120,000	6.50E-06	2.30E-05	7.00E-05
SCC 3-05-006-10	**Secondary Crusher** Secondary limestone screening and crushing with fabric filter		ND	19.20	120,000		ND	1.60E-04

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.78	2.76	8.40	120,000	6.50E-06	2.30E-05	7.00E-05
SCC 3-05-020-32	**Dump Truck Loading (34 ton)** Truck Loading - Conveyor, crushed stone - uncontrolled		0.50		10,000		5.00E-05	
SCC 3-05-020-32	**Heavy Truck Loading (48 ton)** Truck Loading - Conveyor, crushed stone - uncontrolled		5.50		110,000		5.00E-05	
	Unpaved Road Transportation	**AP-42 Sec. 13.2.2; See Section 0 Bellow**						
	Paved Road Transportation	**AP-42 Sec. 13.2.1; See Section 4.3 Bellow**						
	Juarez Cement Plant							
SCC 3-05-020-31	**Dump Truck Unloading** Truck Unloading - Fragmented Stone -uncontrolled	ND	0.08	ND	10,000	ND	8.00E-06	ND
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.07	0.23	0.70	10,000	6.50E-06	2.30E-05	7.00E-05
	Aggregate Handling							
	Aggregate Material Handling	**AP-42 Sec. 13.2.4; See Section 4.4 Bellow**						
	Active and Inactive Storage Piles	**AP-42 Sec. 8.19.1 (4th Ed.); See Section 4.4 Bellow**						
SCC 3-05-020-33*	**Dump Truck Loading (17 ton)** Truck Loading - Front end loader – uncontrolled	ND	0.14	ND	3,000	ND	4.55E-5	ND

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
SCC 3-05-020-31	**Dump Truck Unloading (17 ton)** Truck Unloading - Fragmented Stone -uncontrolled	ND	0.02	ND	3,000	ND	8.00E-6	ND
	Unpaved Road Transportation	**AP-42 Sec. 13.2.2; See Section 0 Bellow**						
SCC 3-05-006-09	**Pettibon Crusher** Primary limestone crushing with fabric filter		ND	0.15	3,000		ND	5.00E-05
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.02	0.07	0.21	3,000	6.50E-06	2.30E-05	7.00E-05
	Clinker Production							
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.07	0.26	0.80	11,400	6.50E-06	2.30E-05	7.00E-05
SCC-3-05-011-08	**Mixing and Proportioning** Weigh hopper loading		14.82	29.64	11,400		1.30E-03	2.60E-03
SCC 3-05-006-26	**Raw Material Mill** Raw mill air separator with fabric filter		ND	182.40	11,400		ND	1.60E-02
SCC 3-05-011-07	**Pneumatic Transfer** Cement unloading to elevated storage silo (pneumatic) - controlled		27.36	51.30	11,400		2.40E-03	4.50E-03
SCC 3-05-38-13	**Material Silo Storage** Product Storage with Fabric Filter Control	3.72	9.92	68.20	12,400	3.00E-04	8.00E-04	5.50E-03

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
SCC 3-05-011-07	**Pneumatic Transfer** Cement unloading to elevated storage silo (pneumatic) - controlled		29.76	55.80	12,400		2.40E-03	4.50E-03
SCC 3-05-006-23	**Precalinator-Kiln** Preheater/precalcinator process kiln with fabric filter		ND	1240.00	12,400		ND	1.00E-01
SCC 3-05-006-14	**Clinker Cooler** Clinker cooker with fabric filter		ND	843.20	12,400		ND	6.80E-02
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.08	0.29	0.87	12,400	6.50E-06	2.30E-05	7.00E-05
	Rapidset Cement Milling and Packaging							
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.04	0.15	0.46	6,600	6.50E-06	2.30E-05	7.00E-05
SCC-3-05-011-08	**Mixing and Proportioning** Weigh hopper loading		8.58	17.16	6,600		1.30E-03	2.60E-03
SCC 3-05-006-29	**Finish Mill** Finish grinding mill air separator with fabric filter		ND	92.40	6,600		ND	1.40E-02
SCC 3-05-011-07	**Pneumatic Transfer** Cement unloading to elevated storage silo (pneumatic) - controlled		15.12	28.35	6,300		2.40E-03	4.50E-03

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
SCC 3-05-38-13	**Cement Silo Storage** Product Storage with Fabric Filter Control	1.89	5.04	34.65	6,300	3.00E-04	8.00E-04	5.50E-03
SCC 3-05-011-07	**Pneumatic Transfer** Cement unloading to elevated storage silo (pneumatic) - controlled		15.12	28.35	6,300		2.40E-03	4.50E-03
	Paved Road Transportation	**AP-42 Sec. 13.2.1; See Section 4.3 Bellow**						
	Mirosilax Cement Milling and Packaging							
SCC 3-05-020-32	**Dump Truck Loading (34 ton)** Truck Loading - Conveyor, crushed stone - uncontrolled		0.30		6,000		5.00E-05	
	Paved Road Transportation	**AP-42 Sec. 13.2.1; See Section 4.3 Bellow**						
	Unpaved Road Transportation	**AP-42 Sec. 13.2.2; See Section 0 Bellow**						
SCC 3-05-020-06	**Conveyor** Material transfer points and conveying - controlled	0.01	0.04	0.12	1,750	6.50E-06	2.30E-05	7.00E-05
SCC-3-05-011-08	**Mixing and Proportioning** Weigh hopper loading		2.28	4.55	1,750		1.30E-03	2.60E-03
SCC 3-05-006-29	**Finish Mill** Finish grinding mill air separator with fabric filter		ND	24.50	1,750		ND	1.40E-02
SCC 3-05-011-07	**Pneumatic Transfer** Cement unloading to elevated storage silo (pneumatic) - controlled		3.72	6.98	1,550		2.40E-03	4.50E-03

SCC Number	Operations	Emission PM2.5 (kg)	Emission PM10 (kg)	Emission PM (kg)	Activity (T/month)	Factor (PM 2.5) (kg/Mg)	Factor (PM10) (kg/Mg)	Factor (Total) (kg/Mg)
SCC 3-05-38-13	**Cement Silo Storage** Product Storage with Fabric Filter Control	0.47	1.24	8.53	1,550	3.00E-04	8.00E-04	5.50E-03
SCC 3-05-011-07	**Pneumatic Transfer**- controlled Cement unloading to elevated storage silo (pneumatic)		3.72	6.98	1,550		2.40E-03	4.50E-03
	Paved Road Transportation	**AP-42 Sec. 13.2.1; See Section 4.3 Bellow**						

Individual PM emissions are summarized below. Uncontrolled blastings at the quarry contribute the most to the total PM10 emissions from the Juarez cement plant although the quality of the emission estimate is low and frequency of occurrence is low (approximately once in a month according to the staff at the plant).

Table 4.2 Summary of PM Emissions

Emission $PM_{2.5}$ (kg)	Emission PM_{10} (kg)	Emission PM (kg)
7.93	4306.44	2822.29

4.2 PM Emissions from Vehicle Movement on Unpaved Industrial Roads

Emission factors and variables were derived from the EPA guidance document AP-42 Compilation of Air Pollutant Emission Factors, 5th Edition, Section 13.2.2 (U.S. EPA 1995). For vehicles traveling on unpaved surfaces at industrial sites, emissions are estimated from the following equation (AP-42, section 13.2.2, eq. 1a):

$$\boldsymbol{E = k\ \ s\ \ 12^{\ a}\ \ W\ \ 3^{\ b}} \qquad (4.2)$$

where:

E = size-specific emission factor (lb/VMT);
s = surface material silt content (%);
W = mean vehicle weight (tons);

and the empirical constants ***k***, ***a*** and ***b*** are presented in Table 4.3 (following AP-42, Table 13.2.2-2). Site-specific values for s and ***W*** were used in the estimation.

Table 4.3 Constants for Unpaved Industrial Roads

Constants	Aerodynamic Diameter		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45
Quality Rating	B	B	B

1 – Assumed equivalent to total suspended particulate matter (TSP)

Natural mitigation of dust emission due to rainfall, under the simplifying assumption that annual average emissions are inversely proportional to the number of days with measurable precipitation were estimated in accordance to EPA's recommendation (U.S. EPA 1995):

$$\boldsymbol{E_{ext} = E\ \ \ 365 - P\ \ \ 365} \qquad (4.3)$$

where:

E_{ext} = annual size-specific emission factor extrapolated for natural mitigation, (lb/VMT);
P = number of days in a year with at least 0.254 mm (0.01 in) of precipitation.

Equation 4.3 is a rough simplification of natural mitigation factor and does not consider implementation of road watering for mitigation purposes. The approximate number of days with measurable precipitation in the El Paso-Juarez area was assumed to be 60 (US EPA 1995; Section 13.2.2 Unpaved Roads).

Furthermore, using the following metric conversion 1 lb/VMT = 281.9 grams (g) per vehicle kilometer (g/VKT), thus:

$$\boldsymbol{E_{ext} = k\ \ s\ \ 12\ ^{a}(W\ \ 3)^{b}\ \ \ 365 - P\ \ \ 365\ \times \frac{281.9\ \mathrm{g/VKT}}{1\ \mathrm{lb/VMT}}} \qquad (4.4)$$

4.2.1 Cerro Mexico Quarry

Based on the monthly production rate and the type of equipment used at the quarry (as described in Section 2.1.1) it is estimated that a total of 3,530 truck trips per month were made at the quarry. A Caterpillar 770 Off-Highway Truck (as the default model used by the quarry) has an empty weight of 35.5 tons and a payload of 34 tons when full (Caterpillar, 2013). The equipment was used to travel 800 meters in each direction on an industrial unpaved road of an average silt content of 16.75% (Site 2, Cerro Mexico, Table 3.1) in Ciudad Juarez (P=60 from Ap-42). The calculations for PM_{10} are presented below and Table 4.4 shows the emission rates for various PM sizes.

$$\mathbf{PM_{10}\ Emissions\ \ average\ dump\ truck\ weight\ \ from\ Unpaved\ Roads}$$

$$\boldsymbol{= 0.15\ \ 16.75\%\ \ 12\ ^{0.9}\ \ 52.5\ \mathrm{ton}\ \ 3\ ^{0.45}\ \ \ 365 - 60\ \ \ 365\ \times \frac{281.9\frac{\mathrm{g}}{\mathrm{VKT}}}{1\frac{\mathrm{lb}}{\mathrm{VMT}}}}$$

$$\boldsymbol{\times \frac{1\ \mathrm{tons}}{1000000\mathrm{g}} \times \frac{3{,}530\ \mathrm{trips}}{\mathrm{July\ 2012}} \times \frac{1.6\ \mathrm{km}}{\mathrm{trip}} = 312\ \mathrm{tons\ in\ July\ 2012}}$$

Table 4.4 PM Emissions (Tons) from Dump-trucks on Unpaved Roads at Cerro Mexico Quarry in July 2012

	Empty Dump-truck (35.5 tons, 800 meters)			Full Dump-truck (69.5 tons, 800 meters)			Average Dump-truck Weight (52.5 tons, 1.6 km)		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]	$PM_{2.5}$	PM_{10}	PM_{30}[1]	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9	0.15	1.5	4.9	0.15	1.5	4.9
a	0.9	0.9	0.7	0.9	0.9	0.7	0.9	0.9	0.7
b	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
s[%]	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75	16.75
W [ton]	35.5	35.5	35.5	69.5	69.5	69.5	52.5	52.5	52.5
E [lbs/VMT]	0.6	6.2	19	0.8	8.3	25	0.7	7.3	22
P [days]	60	60	60	60	60	60	60	60	60
Eext [lb/VMT]	0.5	5.1	16	0.7	7.0	21	0.6	6.1	19
Eext [g/VKT]	145	1,450	4,430	196	1,960	6,000	173	1,730	5,290
Trips	3,530	3,530	3,530	3,530	3,530	3,530	3,530	3,530	3,530
VKT/trip [km]	0.8	0.8	0.8	0.8	0.8	0.8	1.6	1.6	1.6
Emissions [tons]	0.410	4.10	12.5	0.554	5.54	16.9	0.997	9.77	29.8

1 – Assumed equivalent to total suspended particulate matter (TSP)

4.2.2 Conveyor System Delivery for Plant Production and Outside Sales

Dump-trucks, weighing 35.5 tons, were used to transport 34 tons of crushed limestone from the Cerro Mexico quarry to the Juarez Plant over 75 meters of unpaved road and 3.5 km of paved road and returned empty to the quarry after unloading the materials. A total of 10,000 tons of crushed limestone for cement production in the peak month required 290 dump-truck round trips in a month.

Heavy-load trucks were used for delivering materials to outside sales. They would travel 2.6 km on the private paved quarry access road and another 75 meters on the unpaved road to the quarry's conveyor delivery facility. After receiving a full load of materials (approximately 48 tons), these heavy-load trucks would travel the same distances as before to exit the quarry. During the peak month, these trips would make up to a total of 2,290 trips. The heavy-load trucks have a capacity of 30 m^3 with an estimated empty bin weight of 4.2 tons (MLS Inc., 20113) and truck cabin weight of 8.6 tons (Construction Equipment, 2013), totaling a vehicle weight of 12.8 tons when empty and 60.8 tons when full (or an average weight of 36.8 tons). Table 4.5 presents PM emission estimates for the dump-trucks at a mean weight of 52.2 tons making 290 trips in July, 2012 over 150 m of unpaved roads and Table 4.6 presents PM emission estimates for heavy-load trucks at a mean weight of 36.8 tons making 2,290 trips over 150 m of unpaved roads in the peak month.

Table 4.5 PM Emissions (kg) Dump-trucks Equipment on Unpaved Roads at Conveyor System Delivery

	Average Dump-truck Weight (52.5 tons, 0.15 km)		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45
s[%]	16.75	16.75	16.75
W [ton]	52.5	52.5	52.5
E [lbs/VMT]	0.7	7.3	22
P [days]	60	60	60
Eext [lb/VMT]	0.6	6.1	19
Eext [g/VKT]	173	1,730	5,290
Trips	290	290	290
VKT/trip [km]	0.15	0.15	0.15
Emissions[kg]	7.52	75.2	230

Table 4.6 PM Emissions [kg] from Heavy-load Trucks on Unpaved Roads at Conveyor System Delivery

	Average Heavy-load Trucks Weight (36.8 tons, 0.15 km)		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45
s[%]	16.75	16.75	16.75
W [ton]	36.8	36.8	36.8
E [lbs/VMT]	0.6	6.3	19

P [days]	60	60	60
Eext [lb/VMT]	0.5	5.2	16
Eext [g/VKT]	147	1,470	4,500
Trips	2,290	2,290	2,290
VKT/trip [km]	0.15	0.15	0.15
Emissions[kg]	50.6	506	1,550

4.2.3 Aggregate Material to Pettibon Crusher

The Pettibon crusher at the Juarez Cement Plant processed, in the peak month, some 3,000 tons of material brought to it by heavy equipment on 105 meters of unpaved industrial road (one way). If a mean payload of half its capacity (34/2 = 17 ton) is assumed, then 176 trips would be made from the aggregate's location to the crusher. As before, an empty dump-truck weight of 35.5 tons is assumed. Emissions were calculated using these parameters and an average silt content of 13.75% (Site 1, unpaved road at Juarez Plant, Table 3.1), P=60 (from AP-42), appropriate values from Table 4.3, and Equation 4.4. The results for the peak month are presented in Table 4.7.

Table 4.7 Emission [kg] from Dump-trucks on Unpaved Roads at Juarez Cement Plant in July 2012

	Empty Dump-truck (35.5 tons, 105 meters)			Half Full Dump-truck (44 tons, 105 meters)			Average Dump-truck Weight (39.75 tons, 210 meters)		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]	$PM_{2.5}$	PM_{10}	PM_{30}[1]	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9	0.15	1.5	4.9	0.15	1.5	4.9
a	0.9	0.9	0.7	0.9	0.9	0.7	0.9	0.9	0.7
b	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
s[%]	13.75	13.75	13.75	13.75	13.75	13.75	13.75	13.75	13.75
W [ton]	35.5	35.5	35.5	44	44	44	39.75	39.75	39.75
E [lbs/VMT]	0.5	5.2	16	0.6	5.7	18	0.5	5.4	17
P [days]	60	60	60	60	60	60	60	60	60
Eext [lb/VMT]	0.4	4.3	14	0.5	4.7	15	0.5	4.5	14
Eext [g/VKT]	121	1210	3,860	134	1,340	4,250	1.8	1,280	4,060
Trips	176	176	176	176	176	176	176	176	176
VKT/trip [km]	0.105	0.105	0.105	0.105	0.105	0.105	0.21	0.21	0.21
Emissions [kilograms]	2.24	22.4	71.3	2.57	24.7	78.6	4.72	47.2	150

1 – Assumed equivalent to total suspended particulate matter (TSP)

4.2.4 Mirosilax Clinker to Mirosilax Processing Installations

Mirosilax material is transported from the material storage facility to the east side of the plant, first on a stretch of paved road (see Section 4.3.3), and then on 210 meters of unpaved road (roundtrip). A total of 52 trips by dump-trucks carrying a full load of 34 tons would be needed to transport the 1,750 tons of material processed at Mirosilax's installations. Emissions were calculated using these parameters and an average silt content of 13.75% (Site 1, unpaved road at Juarez Plant, Table 3.1), P=60 (AP-42), appropriate values from Table 4.3, and (4.4). The results for the peak month are presented in Table 4.8

Table 4.8 PM Emissions [kg] from Dump-trucks on Unpaved Roads Delivering Mirosilax Clinker

	Average Dump Truck Weight (52.5 tons, 0.21 km)		
	$PM_{2.5}$	PM_{10}	PM_{30}[1]
k [lb/VMT]	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45
s[%]	13.75	13.75	13.75
W [ton]	52.5	52.5	52.5
E [lbs/VMT]	0.6	6.1	20
P [days]	60	60	60
Eext [lb/VMT]	0.5	5.1	16
Eext [g/VKT]	144.8	1448.0	4603
Trips	52	52	52
VKT/trip [km]	0.27	0.27	0.27
Emissions[kg]	2.0	20.3	64.6

4.3 PM Emissions from Vehicle Movement on Paved Roads

Emission factors and variables were derived from the EPA guidance document AP-42 Compilation of Air Pollutant Emission Factors, 5th Edition, Section 13.2.2 (U.S. EPA, 1995). For vehicles traveling on paved roads, emissions were estimated from the following equation (AP-42, section 13.2.1, eq. 1):

$$\mathbf{E = k(sL)^{0.91} \times W^{1.02}} \qquad (4.5)$$

where:

- $\boldsymbol{E}$ = particulate emission factor (having units matching the units of k)
- $\boldsymbol{k}$ = particle size multiplier for particle size range and units of interest
- $\boldsymbol{sL}$ = road surface silt loading, (g/m^2)
- $\boldsymbol{W}$ = average weight of the vehicles traveling the road, (tons)

Particle size multiplier (*k*) values are presented in Table 4.9 for different PM aerodynamic diameters. A mean road surface silt loading of 12 g/m^2 for concrete batching was used based on AP-42 (Table 13.2.1-3, page 10).

Table 4.9 Particle Size Multiplier for Paved Roads

	Aerodynamic Diameter			
	$PM_{2.5}$	PM_{10}	PM_{15}	PM_{30}
k [g/VKT]	0.15	0.62	0.77	3.23

Natural mitigation due to precipitation is incorporated into Equation 4.5 as:

$$\boldsymbol{E_{ext} = \; k \; sL \;^{0.91} \times W^{1.02} \quad 1 - \frac{P}{4N}} \qquad (4.6)$$

where:

- $\boldsymbol{E_{ext}}$ = particulate emission factor (having units matching the units of k)
- $\boldsymbol{P}$ = number of "wet" days with at least 0.254 mm (o.o1 in) of precipitation during the averaging period
- $\boldsymbol{N}$= number of days in the averaging period (e.g. 365 for annual, 91 for seasonal, 30 for monthly)

4.3.1 Crushed Limestone Transported for Cement Production

Crushed limestone is transported on dump-trucks out of the Cerro Mexico quarry to the material drop located inside the Juarez Cement Plant. Table 4.10 presents PM emission estimates for dump-trucks with a mean weight of 52.2 tons making 290 trips in July, 2012 on 3.5 km of paved roads. A sample calculation is show below:

$$\mathbf{PM_{10}\ Emissions\ \ average\ dump\ truck\ weight\ \ from\ Paved\ Roads}$$
$$\boldsymbol{= 0.62 \quad 12g/m^2 \;^{0.91} \times 52.5^{1.02} \quad 1 - \frac{60}{4 \times 365}} \times \frac{\mathbf{290\ trips}}{\mathbf{July\ 2012}} \times \frac{\mathbf{3.5\ km}}{\mathbf{trip}}$$
$$\times \frac{\mathbf{1\ kg}}{\mathbf{1000\ g}} = \mathbf{409\ \ kg}$$

Table 4.10 Emission [kg] from Dump-trucks on Paved Roads on Cerro Mexico Access Road and Juarez Cement Plant Main Road in Peak Month

	Average Dump-truck Weight (52.5 tons, 3.5 km)			
	$PM_{2.5}$	PM_{10}	PM_{15}	PM_{30}
k [g/VKT]	0.15	0.62	0.77	3.23
sL[g/m^2]	12	12	12	12
W [ton]	52.5	52.5	52.5	52.5
E [g/VKT]	81.8	338	420	1,760
P [days]	60	60	60	60
N [days]	365	365	365	365
Eext [g/VKT]	78.4	324	403	1690
Trips	290	290	290	290
Distance[km]	3.50	3.50	3.50	3.50
Emission [kg]	79.6	329	409	1,710

4.3.2 Crushed Limestone Transported for Outside Sales

Crushed lime stone is transported on heavy-load trucks out of the Cerro Mexico quarry for outside sales deliveries. Emissions estimates were calculated with Table 4.9 and Equation 4.5. Table 4.11 presents PM emission estimates for heavy-load trucks with a mean weight of 36.8 tons making 2,290 trips over 2.6 km of unpaved roads in the peak month.

Table 4.11 Emission [kg] from Heavy-load Trucks on Paved Roads on Cerro Mexico Access Road in Peak Month

	Average Heavy-load Trucks Weight (36.8 tons, 2.6 km)			
	$PM_{2.5}$	PM_{10}	PM_{15}	PM_{30}
k [g/VKT]	0.15	0.62	0.77	3.23
sL[g/m^2]	12	12	12	12
W [ton]	36.8	36.8	36.8	36.8
E [g/VKT]	56.9	235	292	1,230
P [days]	60	60	60	60

N [days]	365	365	365	365
Eext [g/VKT]	54.6	226	280	1,180
Trips	2,290	2,290	2,290	2,290
Distance[km]	2.6	2.6	2.6	2.6
Emission [kg]	325	1,340	1,670	7,000

4.3.3 Mirosilax Clinker to Mirosilax Processing Installations

Mirosilax clinker is transported from the material storage facility to the east side of the plant, on 320 meters of paved road (followed by 210 meters on unpaved road, see Section 4.2.4). A total of 52 trips by dump-truck carrying a full load of 34 tons were made. Emissions were calculated with Table 4.9 and Equation 4.5 and the results are presented in Table 4.12.

Table 4.12 PM Emissions [kg] from Dump-trucks on Paved Roads Delivering Mirosilax Clinker

	Average Dump Truck Weight (52.5 tons, 0.32 km)			
	PM-2.5	PM-10	PM-15	PM-30
k [g/VKT]	0.15	0.62	0.77	3.23
sL[g/m^2]	12	12	12	12
W [ton]	52.5	52.5	52.5	52.5
E [g/VKT]	81.79	338.07	419.86	1761.25
P [days]	60	60	60	60
N [days]	365	365	365	365
Eext [g/VKT]	78.4	324	403	1689
Trips	52	52	52	52
Distance[km]	0.32	0.32	0.32	0.32
Emission [kg]	1.31	5.39	6.70	28.10

4.3.4 Packaged Rapidset Material Shipped-Out

Approximately 6,300 tons of packaged Rapidset cement is transported out of the plant on 540 meters of paved road. Assuming shipments are made on heavy-load trucks carrying 48 tons (with an average weight of 36.8 tons), 132 trips would be made. Emissions were calculated with Table 4.9 and Equation 4.5 and the results are presented in Table 4.13

Table 4.13 PM Emissions [kg] from Heavy-Load trucks on Paved Roads Delivering Rapidset Cement

	Average Heavy Load Trucks Weight (36.8 tons, 0.54km)			
	PM-2.5	PM-10	PM-15	PM-30
k [g/VKT]	0.15	0.62	0.77	3.23
sL[g/m^2]	12	12	12	12
W [ton]	36.8	36.8	36.8	36.8
E [g/VKT]	56.9	235.3	292.2	1225.8
P [days]	60	60	60	60
N [days]	365	365	365	365
Eext [g/VKT]	54.6	225.6	280.2	1175.4
Trips	132	132	132	132
Distance[km]	0.54	0.54	0.54	0.54
Emission [kg]	3.9	16.1	20.0	83.8

4.3.5 Packaged Mirosilax Material Shipped-Out

Approximately 1,550 tons of packaged Mirosilax cement is transported out of the plant on 90 meters of paved road. Assuming shipments are made on heavy-load trucks carrying 48 tons (with an average weight of 36.8 tons), 33 trips would be made. Emissions were calculated with Table 4.9 and Equation 4.5 and the results are presented in Table 4.14

Table 4.14 PM Emissions [kg] from Heavy-Load trucks on Paved Roads Delivering Mirosilax Cement

	Average Heavy Load Trucks Weight (36.8 tons, 0.09 km)			
	PM-2.5	PM-10	PM-15	PM-30
k [g/VKT]	0.15	0.62	0.77	3.23
sL[g/m^2]	12	12	12	12
W [ton]	36.8	36.8	36.8	36.8
E [g/VKT]	56.9	235.3	292.2	1225.8
P [days]	60	60	60	60
N [days]	365	365	365	365
Eext [g/VKT]	54.6	225.6	280.2	1175.4
Trips	33	33	33	33
Distance[km]	0.09	0.09	0.09	0.09
Emission [kg]	0.2	0.7	0.8	3.5

4.4 PM Emissions from Aggregate Handling and Storage Piles

There are 3 storage pile areas (Figure 2.6). Area 1 is located to the west of the Juarez plant between two adjacent hills which provide some degree of wind protection. Material from this area is processed through the Pettibon crusher at a rate of 3,000 tons in the peak month. Area 2 is located to the north of the plant, and Area 3 to the East edge of the plant. For Areas 2 and 3, no production data was provided due to facility's confidentiality concerns, as the proportions of these aggregate materials provide specific product characteristics. For Area 1, aggregate material handling and inactive storage pile wind erosion emissions were calculated; Areas 2 and 3 were considered together and both active and inactive storage pile emissions were calculated.

4.4.1 West Aggregate Material Handling (Area 1)

Emission factors and variables were derived from the EPA guidance document AP-42 Compilation of Air Pollutant Emission Factors, 5th Edition, Section 13.2.4 (U.S. EPA, 1995). Aggregate material handling emissions are estimated from the following equation (AP-42, section 13.2.4, eq. 1):

$$E = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \times A \qquad (4.7)$$

where:

- ***E*** = emission (kg);
- ***k*** = particle size multiplier (dimensionless);
- ***U*** = mean wind speed (m/s);
- ***M*** = material moisture content (%);
- ***A*** = activity (ton/month)

The particle size multiplier ***k*** given in section 13.2.4 is reproduced here in Table 4.15

Table 4.15 Aerodynamic Particle Size Multiplier (*k*)

	Aerodynamic Diameter				
	< 30 µm	< 15 µm	< 10 µm	< 5 µm	< 2.5 µm
k	0.74	0.48	0.35	0.20	0.053

A mean annual wind speed (U) of 4.2 m/s was taken from the Local Climatological Data Annual Summaries for 1977 (from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration/ Environmental Data Service/National Climatic Data Center, as cited in Cowherd et al 1985). Moisture content for the aggregate material was assumed to be the same as that found in the adjacent unpaved road at the Juarez cement plant (i.e. 0.48%). PM emissions were calculated using the approximately 3,000 tons of aggregate material process by the Pettibon crusher, along with the aforementioned parameters, Table 4.15 and Equation 4.7, and the results for the peak month are presented in Table 4.16. A sample calculation for PM_{10} is provided below:

$$\mathbf{PM_{10}\ Emissions\ from\ Aggregate\ Handeling}$$

$$= 0.35\ (0.0016)\ \frac{\left(\frac{4.2}{2.2}\right)^{1.3}}{\left(\frac{0.48}{2}\right)^{1.4}} \times \frac{3{,}000\ \text{tons}}{\text{July}} = 28.7\ \text{kg}$$

Table 4.16 PM Emissions Estimates [kg] for Aggregate Material Handling at Area 1 on Peak Month

	Aerodynamic Diameter				
	< 2.5 µm	< 5 µm	< 10 µm	< 15 µm	< 30 µm
k	0.053	0.2	0.35	0.48	0.74
E [kg]	4.35	16.4	28.7	39.4	60.7

4.4.2 West Aggregate Inactive Storage Pile (Area 1)

Emission factors and variables were derived from the EPA guidance document AP-42 Compilation of Air Pollutant Emission Factors, 4th Edition, Section 8.19.1 (U.S. EPA, 1984). Aggregate material handling emissions were estimated from emission factor in AP-42 4th Ed. Table 8.19.1-1:

Table 4.17 Uncontrolled Particulate Emission Factors for Active and Inactive Storage Piles

Operation	Aerodynamic Diameter	
	< 30 µm	< 10 µm
Active Storage Pile	14.8 kg/hectare/day	7.1 kg/hectare/day
Inactive Storage Pile	3.9 kg/hectare/day	1.9 kg/hectare/day

The emission factors shown in Table 4.17 were developed based on an estimated 8-12 hours of operations at active and inactive storage piles. The emissions from loading of aggregate onto storage piles (batch or continuous), equipment traffic over the storage area, wind erosion of the pile, and use for the Inactive storage pile between the active piles were included in the emission factors. Emissions were estimated as:

$$\boldsymbol{E = A \cdot R \cdot N} \tag{4.8}$$

where:

- ***E*** = emission (kg);
- ***A*** = storage pile area (he);
- ***R*** = emission factor (kg/hectare/day);
- ***N*** = number of days with 8 to 12hr of activity/inactivity.

Emission calculations are performed using values from Table 4.17, considering 26 active days in July, 2012 (31 days minus 5 Sundays) and 36 days with 12 hours of inactivity (Sundays counted twice due to 24 hours instead of 12 hours of inactivity), and a measured area of 2,430 m^2 (0.243 he). The results for the peak month are presented in Table 4.18. A sample calculation for PM_{10} is provided below:

$$\mathbf{PM_{10}\ Emissions\ from\ Inactive\ Storage\ Pile = 0.243\ he \times 1.9\ \frac{kg}{he \cdot day} \times 36\ days}$$
$$\mathbf{= 16.6\ kg}$$

Table 4.18 PM Emission Estimates [kg] for Active and Inactive Periods of Aggregates in Area 1

Operation	Aerodynamic Diameter	
	< 10 µm	< 30 µm
Emissions from Active Storage Pile [kg]	44.9	93.5
Emissions from Inactive Storage Pile [kg]	16.6	34.1

4.4.3 North and East Aggregate Storage Piles (Areas 2 and 3)

Following the procedure outlined in the previous section and combining Area 2 and Area 3 measurements (11,600 m^2, 1.16 he), active and inactive aggregate storage pile emissions were calculated and the results are presented in Table 4.19.

Table 4.19 PM Emissions Estimates [kg] from Active and Inactive Periods of Aggregates in Combined Areas 2 and 3

Operation	Aerodynamic Diameter	
	< 10 µm	< 30 µm
Emissions from Active Storage Pile [kg]	214	446
Emissions from Inactive Storage Pile [kg]	79	163

5 Results and Discussion

Table 5.1 presents a summary of the emissions estimated in this report sorted by the largest contributor. Dust emissions due to dump-trucks traveling on the unpaved roads inside the Cerro Mexico Quarry are, by far, the largest contributor with 9.77 tons in the peak production month. The second highest emission is produced by the cement production processes with 4.15 tons. The third highest emission is produced by the heavy-load trucks moving on the unpaved road around the crushing and conveyer installations with an estimated emission of 4.31 tons in the peak month.

Table 5.1 Summary of Emission Estimates (in tons) for the Peak Month (July, 2012)

Activity	Particle Size				
	$PM_{2.5}$	PM_5	PM_{10}	PM_{15}	PM_{30}[1]
Unpaved Quarry Dump-Truck (52.5 tons, 1.6 km, 3,530 trips)	0.98		9.77		29.85
Cement Production Processes	0.01		4.31		2.82
Paved Outside Sale Heavy -Load Trucks (36.8 tons, 2.6 km, 2,290 trips)	0.33		1.34	1.67	7.00
Unpaved Heavy-Load Trucks (36.8 tons, 0.15 km Unpaved, 2,290)	0.05		0.51		1.55
Paved Lim-Prod Dump-Truck (52.5 tons, 3.5 km, 290 trips)	0.08		0.33	0.41	1.71
Active Storage Pile Area 2 and 3			0.21		0.45
Inactive Storage Pile Area 2 and 3			0.08		0.16
Unpaved Conveyor System Dump-Truck (52.5 tons, 0.15 km, 290 trips)	0.01		0.08		0.23
Unpaved Aggregate Dump-Truck (39.75 tons, 210 meters, 176 trips)	0.005		0.05		0.15
Active Storage Pile Area 1			0.04		0.09
Aggregate Handling to Pettibon Crusher	0.004	0.02	0.03	0.04	0.06
Unpaved Mirosilax Clinker Dump Truck (52.5 tons, 0.21 km, 52 trips)	0.002		0.02		0.06
Inactive Storage Pile Area 1			0.02		0.03
Paved Average Heavy Load Trucks (36.8 tons, 0.54km, 132 trips)	0.004		0.02	0.02	0.08
Paved Average Mirosilax Clinker Dump Truck (52.5 tons, 0.32 km, 52 trips)	0.001		0.01	0.01	0.03
Paved Average Heavy Load Trucks (36.8 tons, 0.09km, 33 trips)	0.000		0.001	0.001	0.003
TOTAL	1.46	0.02	16.80	2.14	44.29

The Juarez Plant ceases cement production during the months of November to January, but the Cerro Mexico Quarry continues limestone extraction and crushing for outside sales. The month with the lowest quarry output, produced 85,700 tons of crushed limestone.

6 PM Mitigation Strategies and Cost Estimates

Based on the descriptions and reviews of the production practices at the Juarez Cement Plant and the Cerro Mexico quarry, there are many ways to help reduce dust emissions from the facilities. The dust mitigation strategies can be classified into 3 general categories: 1) Restrictions on the use of vehicles and equipment; 2) Improvement of soil conditions; and 3) Treatment of unprotected surface.

6.1 Restrictions on the use of vehicles and equipment

Vehicle and equipment movements on unprotected soil surfaces in open space and on unpaved roads are activities generating significant amount of fugitive dust. Unnecessary traffics inside the facility should be discouraged. At GCC's Juarez Cement Plant, traffic inside the plant is ordinarily reduced to paved roads. Employees should be encouraged to come to work by buses or by carpooling. It was discovered that employees at the cement plant are offered meals at the plants cafeteria free of charge, thus reducing traffic at lunch time. It is recommended that both at the Juarez cement plant and the Cerro Mexico quarry, employees should access their job sites by the already paved private road and that the speed within the facilities for both private vehicles and commercial trucks should be restricted to 5 mph (or 8 km/h) since dust emissions from unprotected surface depend strongly on the speed vehicle travels. Reducing vehicle speed within the facility does not incur any additional expense to the plant.

6.2 Improvement of soil conditions

Blasting at the quarry and loading/unloading of aggregates generate puffs of uncontrolled dust emissions. Increase in the moisture content of the material would result in significant decrease in the amount of dust generated. We recommend watering the area prior to and immediately after any blasts at the quarry as well as during the process of loading and unloading of materials by dump trucks or heavy-load trucks.

6.3 Application of dust suppressants for treating surfaces of unpaved roads and storage piles

Depending on the sources of emissions, fugitive dust from the cement plant can be controlled through revised work schedules, installation of enclosures, use of reduced vehicle/equipment speed, application of water, and use of dust suppressing chemicals. Application of water may be intuitively appealing as the choice of dust control, however, it requires frequent applications and becomes ineffective and costly if water is scarce in the region and if the cost for transporting water is expensive. On the other hand, application of dust suppressing chemicals on unpaved roads has been reported to be effective and economical. It was reported that the use of dust suppressants reduced fugitive dust emissions from unpaved roadways by 50 to 75%

and was more protective of the roadway surface by reducing aggregate losses by 42 to 61% (Sanders et al 1997).

Sanders et al (1997) estimated that application of chemical suppressants reduces the annual maintenance cost by 30 to 46% for treated unpaved roads over the untreated roads. Chemical treatment of unpaved road becomes economical for even less travelled road with average daily traffic (ADT) of as low as 120. Depending on the cost of aggregates, the breakeven point for the ADT varies slightly. Figure 6.1 Costs for application of dust suppressants on unpaved roads in terms of average daily traffic (ADTshows that for roughly $6,000 a year per mile of unpaved road, dust emissions from the road surface can be reduced by 50 to 61% by applying any of the three recommended chemicals: Lignosulfonate, CaCl2, and MgCL2. Using this figure and an estimated of 1 mile of unpaved road within the Juarez cement plant, dust emissions from the unpaved road sections within the plant can be reduced by ~50% for a cost of $6,000.

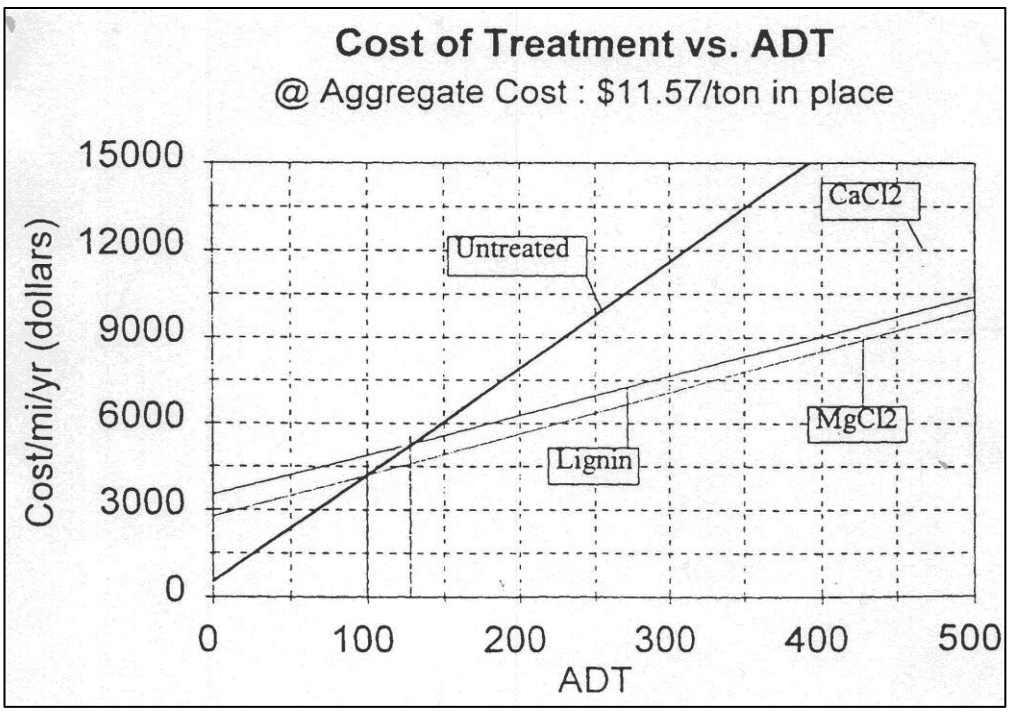

Figure 6.1 Costs for application of dust suppressants on unpaved roads in terms of average daily traffic (ADT) reproduced from Sanders et al (1997).

Surface treatment by means of wet suppression had been implemented on unpaved road at both the plant and the quarry. Through personal communications with Mr. Enriquez it was made know that GCC had a contract with a local company to provide wastewater containing high amounts of sugar for watering the unpaved roads at the quarry. Once water is evaporated, a crust would be formed on the road surface and thus help to reduce dust emissions. However, this contract is no longer in place due to the cost associated with the mitigation measure. Considering the high costs associated with the purchase, transport, and application of water in the water-scarce section of Ciudad Juarez, it may be economical to apply dust suppressants instead of water.

7 Summary and Recommendations

Fugitive dust emissions from a south Juarez quarry and cement operation were investigated in this study to supplement the existing PdN PM emissions inventory. We identified the exact location of and documented the production and processing operations at this cement plant through site visits, staff interviews, and a review of production procedures. Soil samples were collected from two different locations in the plant for assessing the emission potentials related to wind erosion, mechanical disturbance, and vehicular movement. It was found that the conditions of the soil at the site are strongly in favor of high dust emissions with high silt loading and extremely low moisture content. The U.S. EPA Compilation of Air Pollutant Emission Factors (AP-42) was used in conjunction with the information collected to develop PM emission loadings to the atmosphere.

PM_{10} emissions from the south Juarez cement and quarry operations were estimated to be 16.8 tons during the peak month of operation. The figure is significantly less for $PM_{2.5}$ at 1.5 tons per month. Dump trucks transporting raw materials on the unpaved roads within the facility accounted for 58 % of the PM_{10} dust generated from the facility. Uncontrolled, infrequent blasting at the quarry created significant puffs of dust, which accounted approximately 25% of the total PM_{10} emissions. It represented 96% of the dust generated by all non-traffic related cement production activities combined, including activities such as quarry drilling, loading and unloading of dump trucks, crushing by primary and secondary crushers, emissions from conveyor, aggregates/materials handling, emissions from active and inactive storage piles, mixing and proportioning of materials, pneumatic transferring of materials, among many other activities documented in Table 4.1. Transportation of materials to outside sales by heavy-load trucks also generated a significantly amount of PM_{10}, which is ranked the 3rd at 1.3 tons per month or approximately 8% of the total PM_{10} emissions.

Three emission mitigation strategies are recommended based on the descriptions and quantifications of the production activities at the plant. They are: 1) Restrictions on the use of vehicles and equipment; 2) Improvement of soil conditions; and 3) Treatment of unprotected surface. Costs associated to these mitigation measures are difficult to substantiate at this juncture due to the plant's unwillingness to discuss and concerns on proprietary confidentiality as well as personnel security.

References

Caterpillar. 2013. http://www.cat.com/cda/layout?m=308657&x=7 (accessed on July 1, 2013) Page 46

Construction Equipment. 2013. http://www.constructionequipment.com/heavy-duty-trucks-class-7-8-26000-gvw/stylish-kenworth-pulls-heavy-loads (accessed on July 1, 2013)

Cowherd C Jr, Muleski GE, Englehart PJ, Gillette DA. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites, Office of Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, 1985.

MLS Inc. 2013. http://www.mylittlesalesman.com/ForSale/Details/637963/2013_TYTAL-Aluminum-Dry (accessed on July 1, 2013)

Sanders TG, Addo JQ, Ariniello A, Heiden WE, 1997. Relative Effectiveness of Road Dust Suppressants, J. of Transportation Engineering, 1223 (5): 393-397

U.S. Environmental Protection Agency (U.S. EPA). 1984. Compilation of air pollutant emission factors, Volume I: Stationary point and area sources.AP-42, Fourth edition, Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, Research Triangle Park, NC.

U.S. Environmental Protection Agency (U.S. EPA). 1995. Compilation of air pollutant emission factors, Volume I: Stationary point and area sources.AP-42, Fifth edition, Office of Air Quality Planning and Standards, Office of Air and Radiation, U.S. Environmental Protection Agency, Research Triangle Park, NC.

Appendix 1

Soil Samples Field Log

Sampling Data for Unpaved Roads

Date Collected Apr 10 2013 Recorded by J. Flores.

Road Material: Arena, Piedra

Sampling site Number GCC SITE 1 Coordinates -106.481199° 31.657028°

Method:

1. Sampling device: Metal Frame ✓ Dust Pan ✓ Bucket ✓ Plastic Gloves ✓
2. Use disposable plastic gloves in order to sample the site.
3. Throw a coin in the sampling site before placing the frame.
4. Locate the metal frame over the marked area.
5. Collect loose material with a plastic scoop to a depth to a depth (2 cm) : Do not abrade road surface
6. Use the sample container to deposit the soil sample: Bucket with sealable liner.
7. Seal the plastic bucket with plastic to preserve soil moisture.
8. Take the sample to the soil mechanics lab.

Indicate any variations from above

SAMPLING DATA COLLECTED

Sample No.	Time	Location	Depth	Mass of Sample
S. I	11:05	GCC SITE # 1	2.5cm	2 kg Aprox.
S. II	11:11	"	2.5cm	2 kg Aprox.
S. III	11:20	"	2.5cm	2 kg Aprox.
S. IV	11:22	"	2.5cm	2 kg Aprox.

Sampling Data for Unpaved Roads

Date Collected April 10 2013 **Recorded by** J Flores

Road Material: Arena, Piedra

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____

Sampling site Number GCC SITE 2 **Coordinates** -106.491404°, 31.643644°

Method:

1. **Sampling device: Metal Frame** ✓ **Dust Pan** ✓ **Bucket** ✓ **Plastic Gloves** ✓
2. **Use disposable plastic gloves in order to sample the site.**
3. **Throw a coin in the sampling site before placing the frame.**
4. **Locate the metal frame over the marked area.**
5. **Collect loose material with a plastic scoop to a depth to a depth (2 cm) : Do not abrade road surface**
6. **Use the sample container to deposit the soil sample: Bucket with sealable liner.**
7. **Seal the plastic bucket with plastic to preserve soil moisture.**
8. **Take the sample to the soil mechanics lab.**

Indicate any variations from above ______________________________

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SAMPLING DATA COLLECTED

Sample No.	Time	Location	Depth	Mass of Sample
S. I	12:40	GCC SITE #2	2.5 cm	2 kg Apr
S. II	11:52	//	2.5 cm	2 kg Aprox
S. III	11:59	//	2.5 cm	2 kg Apr
S. IV	12:12	//	2.5 cm	2 kg Apr.

Appendix 2

Soil Samples Laboratory Analysis (Grupo LEC)

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: 16/4/2013 Realizo.:Cesar Zamora Reviso.: Ing. Bersain Carreño

Sondeo No.: Sitio #1 Muestra No.: 1

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)

Recipiente No.	3
Recipiente + Muestra	1145.5
Recipiente	83.8
Muestra Humeda	1061.7

Peso de la muestra (despues de secado) (gr)

Recipiente No.	3
Recipiente + Muestra	1140.0
Recipiente	83.8
Muestra Seca	1056.2

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1061.7
Peso de la Muestra Seca (gr)	1056.2
Diferencia de Pesos (gr)	5.5
% Humedad	0.5

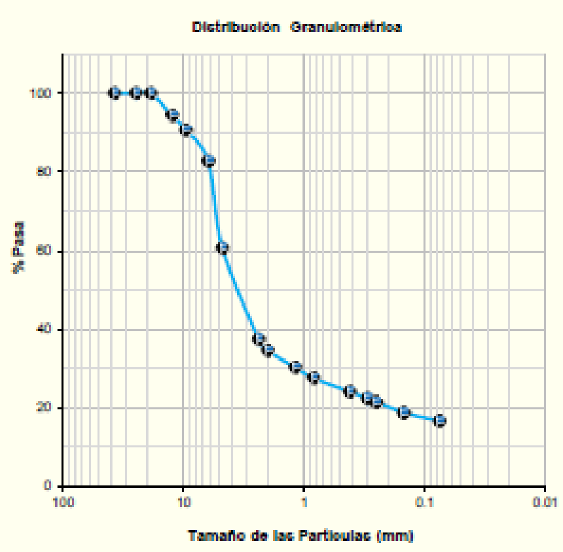
ANALISIS GRANULOMÉTRICO

Fecha.: 16/4/2013

Sondeo No.: Sitio #1 Muestra No.: 1

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	6	N/E	94	N/E
3/8"	9.51	9	N/E	91	N/E
1/4"	6.25	17	N/E	83	N/E
#4	4.76	39	N/E	61	N/E
#8	2.38	63	N/E	37	N/E
#10	2.00	65	N/E	35	N/E
#16	1.19	70	N/E	30	N/E
#20	0.84	72	N/E	28	N/E
#40	0.42	76	N/E	24	N/E
#50	0.30	78	N/E	22	N/E
#60	0.25	79	N/E	21	N/E
#100	0.149	81	N/E	19	N/E
#200	0.075	83	N/E	17	N/E



D10 = N/D Cc = N/D
D30 = 1.161 Cu = N/D
D60 = 4.707

Gravas %	39
Arenas %	44
Finos %	17

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: Arena Limosa con Grava "SM"

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: 16/4/2013 Realizo.:Cesar Zamora Reviso.: Hector Castro

Sondeo No.: Sitio #1 Muestra No.: 2

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	D	Recipiente No.	D
Recipiente + Muestra	1313.9	Recipiente + Muestra	1308.5
Recipiente	102.9	Recipiente	102.9
Muestra Humeda	1211	Muestra Seca	1205.6

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1211
Peso de la Muestra Seca (gr)	1205.6
Diferencia de Pesos (gr)	5.4
% Humedad	0.4

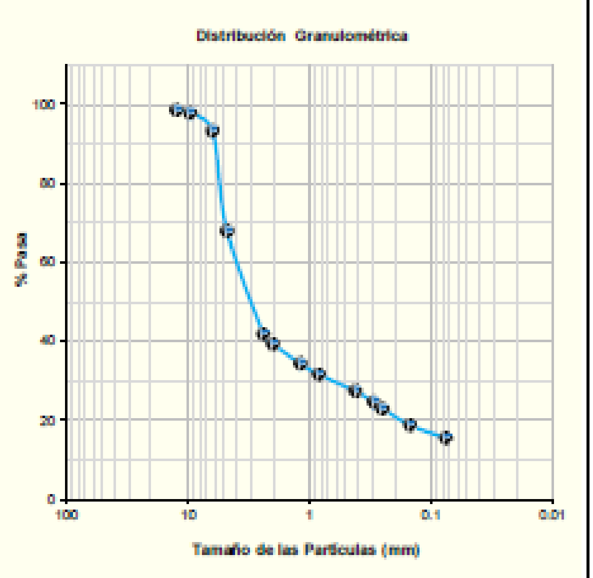
ANALISIS GRANULOMÉTRICO

Fecha.: 16/4/2013

Sondeo No.: Sitio #1 Muestra No.: 2

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	1	N/E	99	N/E
3/8"	9.51	2	N/E	98	N/E
1/4"	6.25	7	N/E	93	N/E
#4	4.76	32	N/E	68	N/E
#8	2.38	58	N/E	42	N/E
#10	2.00	61	N/E	39	N/E
#16	1.19	66	N/E	34	N/E
#20	0.84	68	N/E	32	N/E
#40	0.42	73	N/E	27	N/E
#50	0.30	75	N/E	25	N/E
#60	0.25	77	N/E	23	N/E
#100	0.149	81	N/E	19	N/E
#200	0.075	84	N/E	16	N/E



D10 = N/D Cc = N/D
D30 = 0.671 Cu = N/D
D60 = 4.029

Gravas % 32
Arenas % 52
Finos % 16

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: **Arena Limosa con Grava "SM"**

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: 16/4/2013 Realizo.:Cesar Zamora Reviso.: Hector Castro

Sondeo No.: Sitio #1 Muestra No.: 3

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	24	Recipiente No.	24
Recipiente + Muestra	1266.1	Recipiente + Muestra	1261.3
Recipiente	175.4	Recipiente	175.4
Muestra Humeda	1090.7	Muestra Seca	1085.9

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1090.7
Peso de la Muestra Seca (gr)	1085.9
Diferencia de Pesos (gr)	4.8
% Humedad	0.4

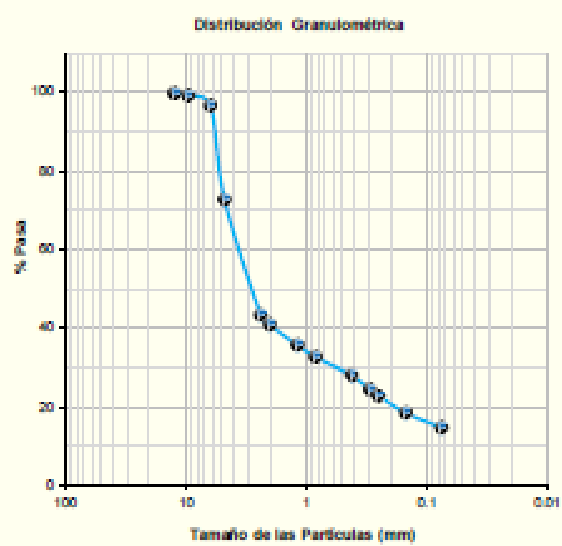
ANALISIS GRANULOMÉTRICO

Fecha.: 16/4/2013

Sondeo No.: Sitio #1 Muestra No.: 3

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	0	N/E	100	N/E
3/8"	9.51	1	N/E	99	N/E
1/4"	6.25	3	N/E	97	N/E
#4	4.76	27	N/E	73	N/E
#8	2.38	57	N/E	43	N/E
#10	2.00	59	N/E	41	N/E
#16	1.19	64	N/E	36	N/E
#20	0.84	67	N/E	33	N/E
#40	0.42	72	N/E	28	N/E
#50	0.30	76	N/E	24	N/E
#60	0.25	77	N/E	23	N/E
#100	0.149	82	N/E	18	N/E
#200	0.075	85	N/E	15	N/E



D10 = N/D Cc = N/D
D30 = 0.602 Cu = N/D
D60 = 3.736

Gravas %	27
Arenas %	58
Finos %	15

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: Arena Limosa con Grava "SM"

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: **16/4/2013** Realizo.:Cesar Zamora Reviso.: **Hector Castro**

Sondeo No.: **Sitio #1** Muestra No.: **4**

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	5	Recipiente No.	5
Recipiente + Muestra	1228	Recipiente + Muestra	1222.9
Recipiente	215.1	Recipiente	215.1
Muestra Humeda	1012.9	Muestra Seca	1007.8

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1012.9
Peso de la Muestra Seca (gr)	1007.8
Diferencia de Pesos (gr)	5.1
% Humedad	0.5

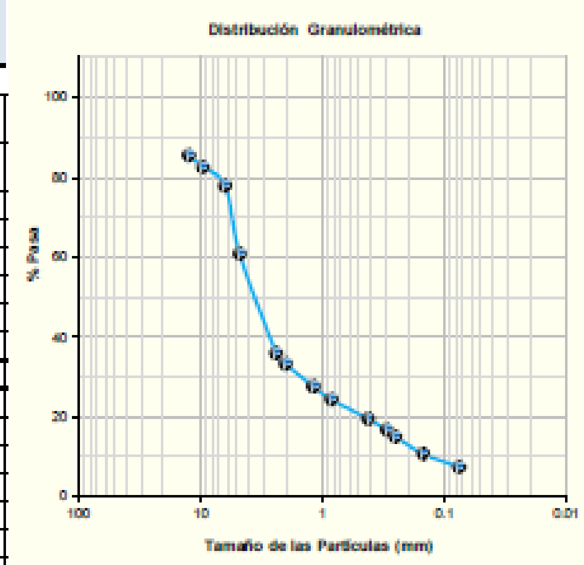
ANALISIS GRANULOMÉTRICO

Fecha.: **16/4/2013**

Sondeo No.: **Sitio #1** Muestra No.: **4**

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	14	N/E	86	N/E
3/8"	9.51	17	N/E	83	N/E
1/4"	6.25	22	N/E	78	N/E
#4	4.76	39	N/E	61	N/E
#8	2.38	64	N/E	36	N/E
#10	2.00	67	N/E	33	N/E
#16	1.19	72	N/E	28	N/E
#20	0.84	76	N/E	24	N/E
#40	0.42	81	N/E	19	N/E
#50	0.30	83	N/E	17	N/E
#60	0.25	85	N/E	15	N/E
#100	0.149	89	N/E	11	N/E
#200	0.075	93	N/E	7	N/E



D10 = 0.133 Cc = 3.757
D30 = 1.527 Cu = 35.271
D60 = 4.678

Gravas %	39
Arenas %	54
Finos %	7

LL: **N/P** LP: **N/P** IP: **N/P**

Clasificación del suelo: **Arena Mal Graduada con Limo y Grava "SP-SM"**

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**
Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: **16/4/2013** Realizo.:Cesar Zamora Reviso.: **Hector Castro**

Sondeo No.: **Sitio #2** Muestra No.: **1**

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	C	Recipiente No.	C
Recipiente + Muestra	1417.9	Recipiente + Muestra	1417.5
Recipiente	108.9	Recipiente	108.9
Muestra Humeda	1309	Muestra Seca	1308.6

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1309
Peso de la Muestra Seca (gr)	1308.6
Diferencia de Pesos (gr)	0.4
% Humedad	0.03

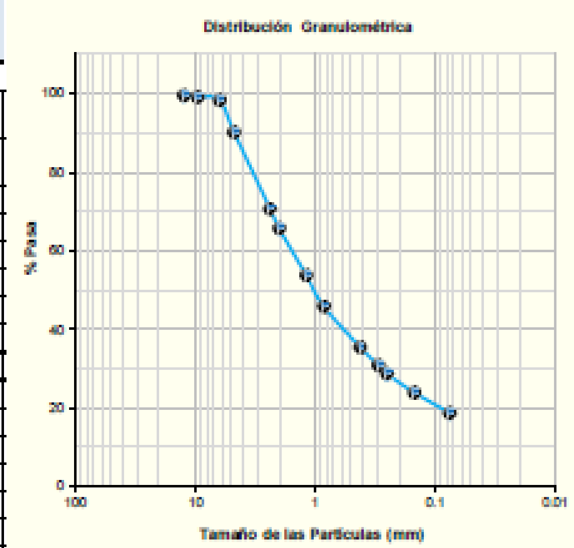
ANALISIS GRANULOMÉTRICO

Fecha.: **16/4/2013**

Sondeo No.: **Sitio #2** Muestra No.: **1**

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	0	N/E	100	N/E
3/8"	9.51	1	N/E	99	N/E
1/4"	6.25	2	N/E	98	N/E
#4	4.76	10	N/E	90	N/E
#8	2.38	29	N/E	71	N/E
#10	2.00	34	N/E	66	N/E
#16	1.19	46	N/E	54	N/E
#20	0.84	54	N/E	46	N/E
#40	0.42	65	N/E	35	N/E
#50	0.30	69	N/E	31	N/E
#60	0.25	71	N/E	29	N/E
#100	0.149	76	N/E	24	N/E
#200	0.075	81	N/E	19	N/E



D10 = N/D Cc = N/D
D30 = 0.278 Cu = N/D
D60 = 1.615

Gravas % 10
Arenas % 71
Finos % 19

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: **Arena Limosa "SM"**

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: 16/4/2013 Realizo.:Cesar Zamora Reviso.: Hector Castro

Sondeo No.: Sitio #2 Muestra No.: 2

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	1002	Recipiente No.	1002
Recipiente + Muestra	1215.6	Recipiente + Muestra	1215.2
Recipiente	151.7	Recipiente	151.7
Muestra Humeda	1063.9	Muestra Seca	1063.5

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1063.9
Peso de la Muestra Seca (gr)	1063.5
Diferencia de Pesos (gr)	0.4
% Humedad	0.04

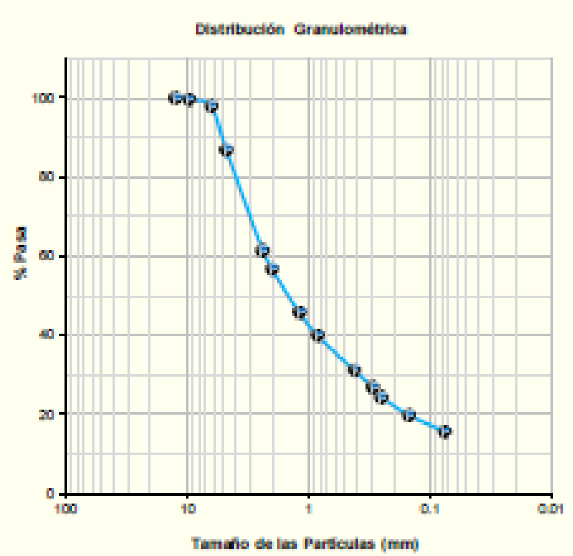
ANALISIS GRANULOMÉTRICO

Fecha.: 16/4/2013

Sondeo No.: Sitio #2 Muestra No.: 2

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	0	N/E	100	N/E
3/8"	9.51	0	N/E	100	N/E
1/4"	6.25	2	N/E	98	N/E
#4	4.76	13	N/E	87	N/E
#8	2.38	38	N/E	62	N/E
#10	2.00	43	N/E	57	N/E
#16	1.19	54	N/E	46	N/E
#20	0.84	60	N/E	40	N/E
#40	0.42	69	N/E	31	N/E
#50	0.30	73	N/E	27	N/E
#60	0.25	76	N/E	24	N/E
#100	0.149	80	N/E	20	N/E
#200	0.075	84	N/E	16	N/E



D10 = N/D
D30 = 0.386
D60 = 1.977
Cc = N/D
Cu = N/D

Gravas %	13
Arenas %	71
Finos %	16

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: **Arena Limosa "SM"**

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**

Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: **16/4/2013** Realizo.:Cesar Zamora Reviso.: **Hector Castro**

Sondeo No.: **Sitio #2** Muestra No.: **3**

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	7	Recipiente No.	7
Recipiente + Muestra	1300.6	Recipiente + Muestra	1300
Recipiente	88.8	Recipiente	88.8
Muestra Humeda	1211.8	Muestra Seca	1211.2

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1211.8
Peso de la Muestra Seca (gr)	1211.2
Diferencia de Pesos (gr)	0.6
% Humedad	0.05

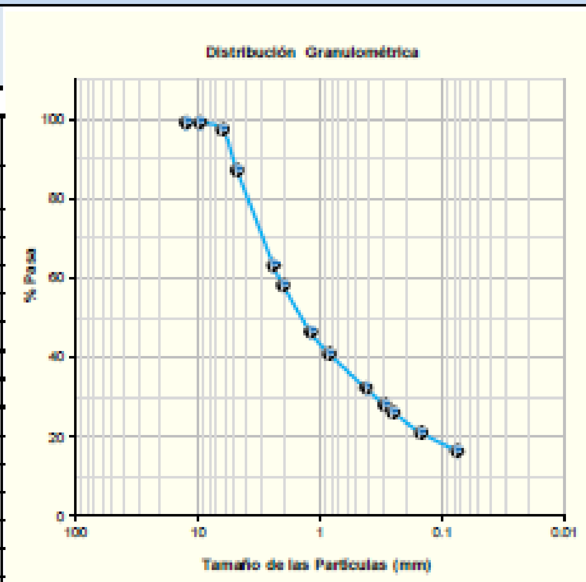
ANALISIS GRANULOMÉTRICO

Fecha.: **16/4/2013**

Sondeo No.: **Sitio #2** Muestra No.: **3**

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	1	N/E	99	N/E
3/8"	9.51	1	N/E	99	N/E
1/4"	6.25	3	N/E	97	N/E
#4	4.76	13	N/E	87	N/E
#8	2.38	37	N/E	63	N/E
#10	2.00	42	N/E	58	N/E
#16	1.19	54	N/E	46	N/E
#20	0.84	59	N/E	41	N/E
#40	0.42	68	N/E	32	N/E
#50	0.30	72	N/E	28	N/E
#60	0.25	74	N/E	26	N/E
#100	0.149	79	N/E	21	N/E
#200	0.075	84	N/E	16	N/E



D10 = N/D Cc = N/D
D30 = 0.354 Cu = N/D
D60 = 2.145

Gravas %	13
Arenas %	71
Finos %	16

LL: **N/P** LP: **N/P** IP: **N/P**

Clasificación del suelo: **Arena Limosa "SM"**

UACJ

GRUPO LEC DEL NORTE

Nombre del proyecto: **Estudio Ambiental**
Clave: **LECJ13-014**
Anexo:

GRUPO LEC

CONTENIDO DE HUMEDAD

Fecha.: **16/4/2013** Realizo.:Cesar Zamora Reviso.: **Hector Castro**

Sondeo No.: **Sitio #2** Muestra No.: **4**

Temperatura del horno

Entrada °c	105	Salida °c	105
Fecha	13/4/2013	Fecha	14/4/2013
Hora	10:00	Hora	11:00

Peso de la muestra (antes de secado) (gr)		Peso de la muestra (despues de secado) (gr)	
Recipiente No.	E	Recipiente No.	E
Recipiente + Muestra	1291.7	Recipiente + Muestra	1291.2
Recipiente	165.4	Recipiente	165.4
Muestra Humeda	1126.3	Muestra Seca	1125.8

Contenido de Humedad

Peso de la Muestra Humeda (gr)	1126.3
Peso de la Muestra Seca (gr)	1125.8
Diferencia de Pesos (gr)	0.5
% Humedad	0.04

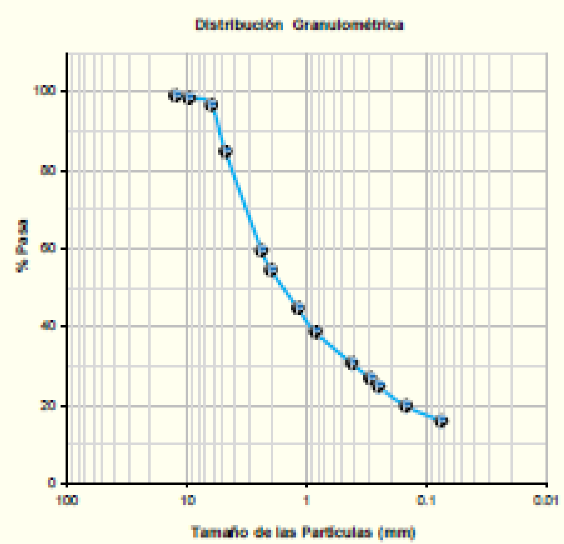
ANALISIS GRANULOMÉTRICO

Fecha.: **16/4/2013**

Sondeo No.: **Sitio #2** Muestra No.: **4**

Análisis Granulométrico (ASTM C 136)

Tamaño de la malla		Retenido		Pasa	
Std.	mm	%	Specs.	%	Specs.
1-1/2"	37.50	0	N/E	100	N/E
1"	25.00	0	N/E	100	N/E
3/4"	18.75	0	N/E	100	N/E
1/2"	12.50	1	N/E	99	N/E
3/8"	9.51	2	N/E	98	N/E
1/4"	6.25	3	N/E	97	N/E
#4	4.76	15	N/E	85	N/E
#8	2.38	41	N/E	59	N/E
#10	2.00	45	N/E	55	N/E
#16	1.19	55	N/E	45	N/E
#20	0.84	61	N/E	39	N/E
#40	0.42	69	N/E	31	N/E
#50	0.30	73	N/E	27	N/E
#60	0.25	75	N/E	25	N/E
#100	0.149	80	N/E	20	N/E
#200	0.075	84	N/E	16	N/E



D10 = N/D Cc = N/D
D30 = 0.399 Cu = N/D
D60 = 2.430

Gravas % 15
Arenas % 69
Finos % 16

LL: N/P LP: N/P IP: N/P

Clasificación del suelo: **Arena Limosa con Grava"SM"**