

Assessing Fugitive Dust Generated from Earthwork in Desert Construction Sites

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Airborne dust from construction sites is a problem due its negative health impacts, in addition to pollution, creation of unsafe working conditions and an increase in associated costs. The problem is exacerbated in desert environments with a high airborne particulate count. Desert construction sites that are close to other inhabited or critical site will require more severe dust control measures. However, currently there is very limited data or field measurement of the extent of the dust control problems in desert environments. This paper examines the dust created from excavation and backfilling equipment on construction sites in a desert environment, and provides the results of experimental studies using dust measurement devices carried out on typical desert construction site. The results are compared to measurements obtained under different temperature and wind conditions. The results show that the problem of dust generation in desert environment can be partially addressed by limiting working times to certain environmental conditions.

Key Words: Dust Control, Earthmoving, Construction Equipment, Pollution, Sustainable Construction Practices

Introduction

Construction activity is one of the major contributors to the environmental impacts, which are typically classified as air pollution, waste pollution, noise pollution and water pollution (Cooper and Alley, 2002). Previous research efforts have focused on many aspects of the environmental impact of construction activity. Khalfan (2002) reported that the waste generated by the building and demolition of construction projects assumes a large proportion of environmental waste in Hong Kong. [Kohler, 1999] suggested that construction activities have a significant impact on the environment across a broad spectrum of off-site, on-site and operational activities. Off-site activities concern the mining and manufacturing of materials and components, the transportation of materials and components, land acquisition, and project design. On-site construction activities relate to the construction of a physical facility, resulting in air pollution, water pollution, traffic problems, and the generation of construction wastage. [Craven et al, 1994] observed the construction industries environmental impacts under the categories of ecology, landscape, traffic, water, energy, timber consumption, noise, dust, sewage, and health and safety hazards.

On the other hand, [Huovila, 1999] classified construction environmental impacts as the extraction of environmental resources such as fossil fuels and minerals; extending consumption of generic resources, namely, land, water, air, and energy; the production of wastes that require the consumption of land for disposal; and pollution of the living environment with noise, odors, dust, vibrations, chemical and particulate emissions, and solid and sanitary waste. [Abuhafeetha 2009 and Gangolells 2008] considered the five largest toxic air emissions from construction, including sulfur dioxide (SO2), nitric dioxide (NO2), volatile organic compounds (VOC), toxic releases to air, and hazardous waste generated. They noted that these environmental emissions are particularly from the four largest construction sectors in the United States, namely, highway, bridge, and other horizontal construction; industrial facilities and commercial and office buildings; residential one-unit buildings and other construction such as towers, sewer and irrigation systems, and railroads.

This paper focuses on the air pollution aspect of construction activities and presents the results of field measurement regarding airborne particulate matter on desert construction sites. There is currently very limited data or field measurement of the extent of the dust control problems in desert environments. A typical desert construction site is therefore selected and the impact of temperature and wind on particulate matter generation is assessed. In the next section we present an overview of air pollution on construction sites. Then we proceed to describe the experiment and the results.

Air Pollution from Construction Activities

Heavy construction is a source of dust emissions that may have substantial temporary impact on the local air quality. Emissions during construction of a building or a road can be associated with land clearing, drilling and blasting, ground excavation, cut and fill operations (i.e., earth moving), and construction of a facility itself. Dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and prevailing meteorological conditions [Rees 1999]. According to [US EPA 1995], pollutants produced by construction industries could be divided into; Particulate Matter Emissions, Volatile Organic Compounds (VOCs), Nitrogen Oxides (each), Sulfur Dioxide, Carbon Monoxide, Lead, and Hazardous Air Pollutants (HAPs). Dust control includes practices used to reduce or prevent the surface and air transport of dust during construction, Dust control measures for construction activities include minimization of soil disturbance, applying mulch and establishing vegetation, water spraying, surface roughening, applying polymers, spray-on tackifiers, chlorides, and barriers. Dust control measures may be applied at any construction site, but is particularly important for sites with dry exposed soils which may be exposed to wind or vehicular traffic. [Shen and Tam 2002].

Particulate matter is the term used for mixture of very-small-diameter solid particles found in the air. PM-10 is of particular interest here and this refers to particulate matter with an aerodynamic diameter less than 10 microns in diameter. Major sources of airborne particulate matter are windblown dust, grinding and excavating operations, combustion by power plants and mobile sources, including diesel buses and trucks [cooper and alley, 2002]; Particulate Matter (PM) is one of the most significant air pollutants in Pima County, PM is made up of tiny particles (a fraction of the thickness of a human hair) that float in the air we breathe. The fine particles can pass through human body’s defense system, travel into the deepest parts of lungs, and cause damage.

Studies have linked particulate matter, specially fine particles (alone or in combination with other air pollutants), with a series of significant health problems, including; premature death, respiratory related hospital admission and emergency room visits, aggregated asthma, acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, decreased lung function that can be experienced as shortness of breath, and work and school absences [Spencer 1995]. Inhaling elevated concentrations of fine particulate matter has been attributed to increase hospital admissions, emergency room visits and premature death among sensitive populations. Particles have a major cause of visibility impairment in many parts worldwide, for example at United States of America, visual range had been reduced with 70% from natural conditions [Karke, 2002], fine particles can remain suspended in the air and travel long distances.

In the construction industry, water application is the most common method for reducing PM-10 emissions. Common practice for dust control involves usage of water trucks to spray water on active working area, materials stock piles, excavation and vacant lands. Water is also used to maintain optimum soil moisture content so that soil maybe properly compacted before building foundations are emplaced. Soils with particles sizes that do not become airborne easily generally take less water to compact and to control, the percent of moisture necessary to compact soils indicates the physical properties of the soil that allow the particles in the soil to adhere together.

Dust largely arises from the mechanical disturbance of granular material exposed to the air (example of disturbance points on loaders and dump trucks are shown in figure 1 below). Dust generated from open sources is termed ‘fugitive’, because it is not discharged into atmosphere in a confined flow stream; common sources of fugitive dust include unpaved roads, agricultural tilling operations, aggregates storage piles, heavy construction rock crushing and processing operations.

The impact of a fugitive dust source on air pollution depends on the quantity and drift potential of the dust particles injected into the atmosphere, in addition to large dust particles that settle near the source (often creating a local nuisance problem), considerable amounts of fine particles are also emitted and dispersed over much greater distances from the source [EPA fact sheet, 1997]. The potential drift distance of particles is governed by the initial injection height of the particle, the terminal settling velocity of the particle, and the degree of atmospheric turbulence. This paper therefore aims at addressing the effect of temperature and wind velocity on PM-10 levels.

Figure 1: Dust Generation Sources in Typical Loaders and Dump Trucks

Experimental Field Studies

Previous studies showed that the most widely used equipment on desert construction sites are loaders, dumping trucks, and wheel or hydraulic excavators. Therefore a typical desert construction site with this equipment in use was selected for field measurement. The site was located in a new development in the suburbs of Cairo, Egypt. Two separate locations (parcels) on a large residential development with a total area of about 420,000 square meters were selected. Measurements were taken over a period of about six months. The earthwork carried out on the site was mainly excavation work using a Caterpillar 992K loader and three 54 ton Caterpillar 773 dump trucks. The excavation work layout and the measuring points are shown in figure 2 below.

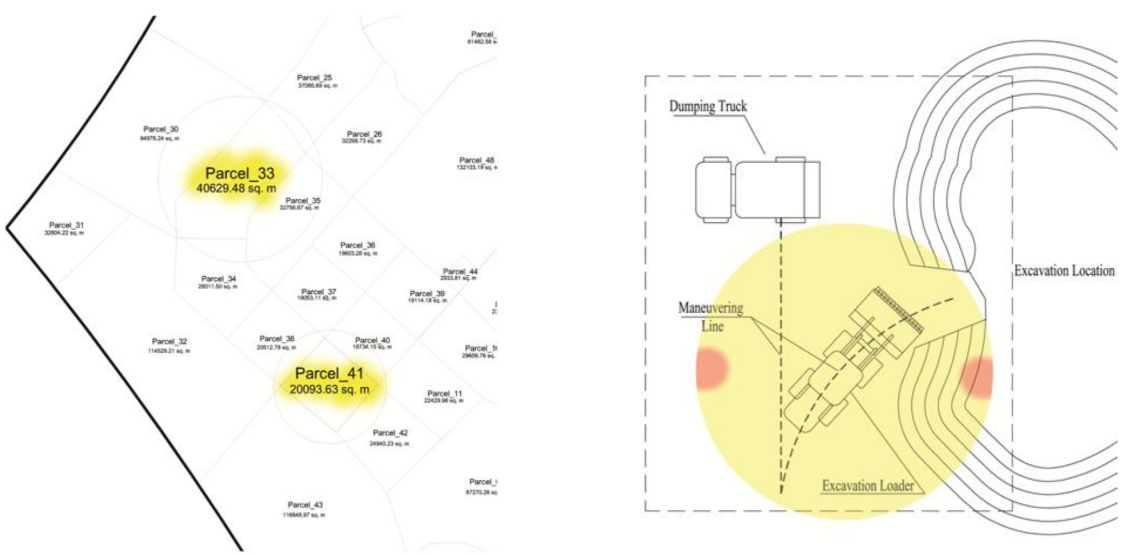

Figure 2: Measuring points on the construction site

A preliminary analysis of wind direction was conducted and the wind rose for the site was identified. It was clear that the prevailing wind direction is north (figure 3) and therefore both parcels had the same orientation, i.e. both parcels were facing north. Six readings were taken in the downwind side (S side = B side), three at the ground level and three at 3m above the ground and two readings were taken in the upwind side (NE side = A side) at 0m and 3m above the ground. Wind speed readings using the anemometer were taken on the A side and B side.

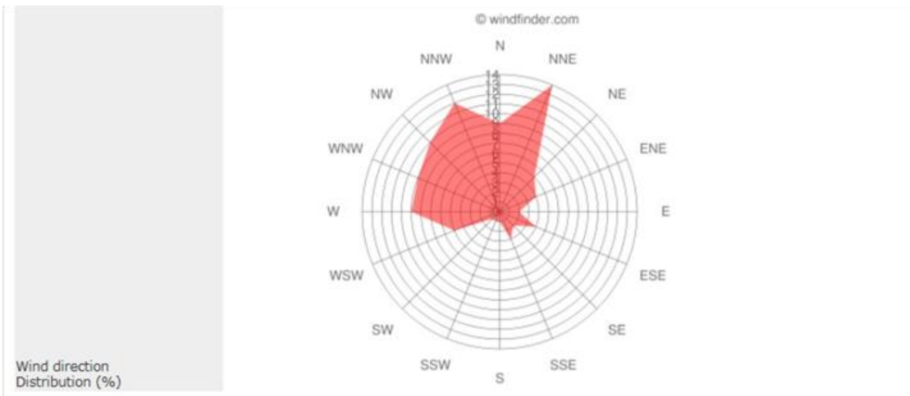

Figure 3: The wind rose for the selected sites

Continuous 'real-time' measurement of ambient particulates concentration and wind speeds was carried out using an anemometer and an SIBATA LD-2 photometer dust indicator (figure 4 below). The LD-2 is a Photometer built to measure concentration of aerosol in industrial hygiene. It uses the light scattering method to measure dust concentration and has a measuring range from 0.001mg/m3 to 100mg/m3 and therefore is capable of easily measuring PM-10. SIBATA wind boy anemometer, which was used to measure wind speed, is a device to measure both of wind speed and wind direction and micro location where the experiments held. It works according to sensing antenna directly connected into a processing unit to show digitally readings. The SIBATA LD-2 dust indicator it's an air sampler pump, depends on internal pump sucking air according to time interval could be assigned by device user to show the PM-10 concentration in a fixed volume of air.

Figure 4: Temperature, Wind Speed and Particulate Matter measurement devices

Samplers of the soil were taken from the construction site to characterize the ground. Samples from natural ground surface at the site location were where taken for sieving analysis to study the local soil grain and percentage of fine soil at excavation area. Samples taken from parcel 33 & parcel 41 were analyzed using the procedures as described in ASTM D2487 – 11 Standard Practice for Classification of Soils for Engineering

The results of this test provided also the particle size distribution in percent of sand, silt and clay. The soil report shows that the percent passing Number 4 sieve (4.74 mm) is about 98% and the percent passing the number 200 sieve (0.075 mm) is about 2%.

Results

Fugitive dust generated by the construction equipment is traditionally determined by measuring the horizontal flux from an emitting area such as a road or a excavation area. This is accomplished by locating the sampling equipment with the desired size-selective inlet at various elevations downwind of the dust-emitting area (in our case ground and 3 meters). Monitors located upwind are used to determine the flux into the emitting domain. Each of the downwind samplers is used to represent the amount of dust carried by the wind component perpendicular to a plane parallel to the source. Both the wind speed and concentration vary with height above ground level, so the horizontal flux is calculated through an area that extends above and below each sampler. These fluxes are added to obtain the aggregate emission rate from the source, after the flux of particles into the emitting area has been subtracted (J.G. Watson et al. 1996, Chuen-Jinn et al. 2002). The mass of particles emitted from the area of exam will be calculated by summing the different flux planes through which particles might pass. The PM10 in each flux planes is represented by the valued measured in each sampler. The PM10 emission factor can be expressed as:

$$E = \frac{1}{A}\sum_i^n (C_i - C_b) u_i(z)\,(cos\ v)\Delta h_i L_i \qquad (1)$$

E	the emission factor (g/m^2)
C_i	average concentration (g/m^3)
A	Area of the construction site (m^2)
C_b	background concentration (upwind concentration) (g/m^3)
L_i	flux plane length (m)
$u_i(z)\,(cos\ v)$	wind speed perpendicular to the flux plan (m/sec)
Δh_i	height increment of the flux plane i (m)

Table 1

Sample Results from the Field Measurements

	Dust measurements at parcel 33 at (5th of June.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
1	5.6.2011	9:00	27	4.98 m/s	5.08m/s	297.8 mg/m^3	292.03mg/m^3	150 mg/m^3
	5.6.2011	15:00	31	4.77 m/s		315.2 mg/m^3		
	5.6.2011	21:00	23	5.48 m/s		263.1 mg/m^3		
	Dust measurements at parcel 33 at (5th of July.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
2	5.7.2011	9:00	29	3.34 m/s	3.61 m/s	305.1 mg/m^3	318.00 mg/m^3	150 mg/m^3
	5.7.2011	15:00	35	3.92 m/s		360.4 mg/m^3		
	5.7.2011	21:00	24	3.54 m/s		288.5 mg/m^3		
	Dust measurements at parcel 33 at (5th of Aug.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
3	5.8.2011	9:00	31	3.89 m/s	3.85m/s	324.6 mg/m^3	344.6 mg/m^3	150 mg/m^3
	5.8.2011	15:00	37	3.67 m/s		410.2 mg/m^3		
	5.8.2011	21:00	26	3.98 m/s		299.0 mg/m^3		
	Dust measurements at parcel 41 at (5th of Jun.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
4	5.8.2011	9:00	27	4.91 m/s	4.92m/s	290.3 mg/m^3	289.43mg/m^3	150 mg/m^3
	5.8.2011	15:00	31	4.71 m/s		301.9 mg/m^3		
	5.8.2011	21:00	23	5.15 m/s		276.1 mg/m^3		
	Dust measurements at parcel 41 at (5th of Jul.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
5	5.8.2011	9:00	29	3.78 m/s	3.77m/s	312.6 mg/m^3	328.96mg/m^3	150 mg/m^3
	5.8.2011	15:00	35	3.67 m/s		375.7 mg/m^3		
	5.8.2011	21:00	24	3.88 m/s		298.6 mg/m^3		
	Dust measurements at parcel 41 at (5th of Aug.2011)							
	Date	**Time**	**Temp.**	**Wind speed**	**AV**	**Dust Cons.**	**Av.dust**	**Limits**
6	5.8.2011	9:00	31	3.58 m/s	3.70m/s	336.9 mg/m^3	358.3 mg/m^3	150 mg/m^3
	5.8.2011	15:00	37	3.67 m/s		427.3 mg/m^3		

	5.8.2011	21:00	26	3.84 m/s		310.8 mg/m^3		

Table 1 showed sample results from the field measurements. All readings shown above show that the limits of dust concentration results from using excavation loaders and dumping trucks at the site subject of study exceeded recommended values. Preliminary analysis of the data collected from the site's measurement shows an increase of PM-10 dust concentration associated with temperature through July and August. A preliminary analysis also shows that the wind speed and wind direction are exacerbating factors for fine dust concentration.

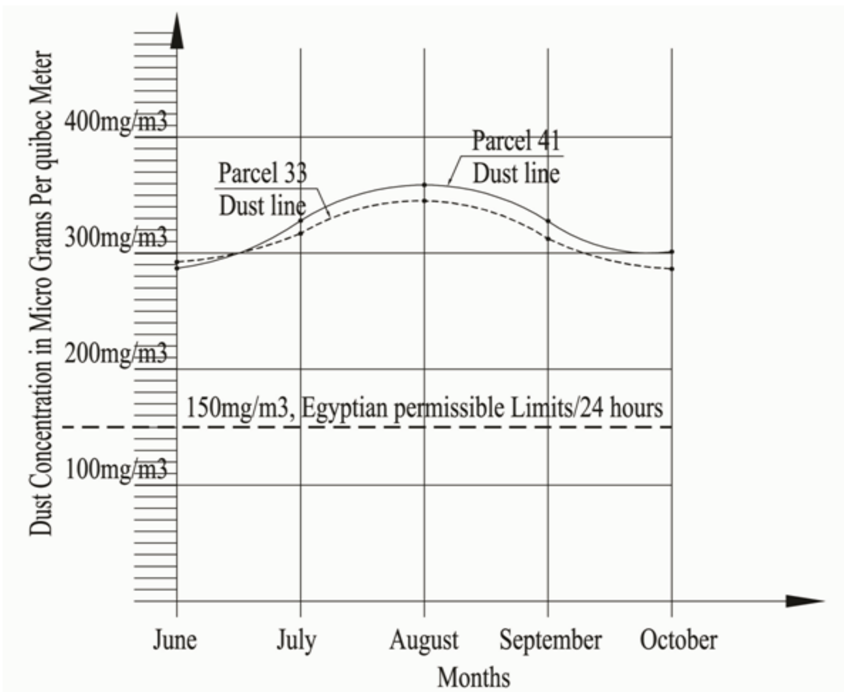

Figure 5: Dust concentration versus month

By calculating variation ratio of dust concentration measured at both of site's subject to study, it's found that the measurements increased gradually during the summer months as shown in figure 5. According to the Egyptian 4th law of 1994, which is defined the permissible limits for fine dust concentration (150mg/m3) for exposure duration of 24 hours; this site is practicing a daily environmental violation.

Conclusions and Future Research

Dust (PM-10 specifically) generated from construction site is a major problem on many construction sites. There is a need to develop techniques or systems that could be followed or installed for working equipments during soil cutting or excavations to reduce dust emissions to the minimum limits. One of the most obvious solutions is to work in a harmony with construction's site microclimate. In order to assess the extent of the problem and reach workable solutions to the PM-10 emission problem, this study focused on collecting extensive data from actual construction sites. While, we are still in the process of analyzing the large amount of data collected, it is evident that weather, and particularly temperature and wind speed, are determining factors in the amount of PM-10 emissions generated. Future research will focus on further analysis of the collected data, as well as considering other environmental factors such as humidity, air pressure and environmental turbidity.

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