Maricopa County

Particulate Matter

Source Study

by

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ABSTRACT

Maricopa County has exceeded the 24 hour National Ambient Air Quality Standard (NAAQS) for Particulate Matter 10 micrometers in diameter or smaller (PM-10) of 150 micrograms per meter cubed (µg/m^3) since 1990. Construction and construction related activities have been recognized as the highest contributors to high PM-10 levels. An analysis of days exceeding 150 µg/m^3 for four of Maricopa County's monitors that most frequently exceed this level during the years 2007, 2008, and 2009 has been performed. Noted contributors to PM-10 levels have been identified in the study, including earthmoving permits, stationary source permits, vacant lots, and agriculture on two mile radius maps around each monitor. PM-10 levels and wind speeds for each date exceeding 225 µg/m^3 were reviewed to find specific weather or anthropogenic sources for the high PM-10 levels. Weather patterns for days where multiple monitors exceed 150 µg/m^3 were reviewed to find correlations between daily weather and high PM-10 levels.

It was found that areas with more earthmoving permits had fewer days exceeding 150 µg/m^3 than areas with more stationary permits, vacant lots, or agriculture. The Higley and Buckeye monitors showed increases in PM-10 levels when winds came from areas covered by agricultural land. West 43rd Avenue and Durango monitors saw PM-10 rise when the winds came in over large stationary sources, like aggregate plants. A correlation between weather events and PM-10 exceedances was also found on multiple monitors for dates both in 2007, and 2009.

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DEFINITIONS

Clean Air Act **–** A legislative Act passed by Congress in 1970 intended to reduce air pollution in the United States.

PM-10 - Particulate matter having an aerodynamic diameter less than or equal to ten micrometers.

PM-2.5- Particulate matter having an aerodynamic diameter less than or equal to 2.5 micrometers.

Exceptional Event - “an event that affects air quality, is not reasonably controllable or preventable, is an event caused by human activity that is unlikely to recur at a particular location or a natural event, and is determined by the Administrator in accordance with 40 CFR 50.14 to be an exceptional event. It does not include stagnation of air masses or meteorological inversions, a meteorological event involving high temperatures or lack of precipitation, or air pollution relating to source noncompliance.” (CAA, 1990)

Atherosclerosis – build up of material along the artery walls

Systemic cytokine release – complications in the body where T-cells release large amounts of cytokine resulting in severe infections with problems like rigor, hypotension, and fever

Ultrafine PM-10 fraction – particulates less than 0.1 micrometers in diameter.

Fine PM-10 fraction **–** particles between 2.5 micrometers in diameter and 0.1 micrometers in diameter

Coarse fraction PM-10 – particles between 10 micrometers in diameter and 2.5 micrometers in diameter.

State Implementation Plan – a plan written by governing bodies outlining how an area will retain compliance with federal environmental standards.

Class I Area – National Parks and wilderness areas

Overburden – the soil covering a mining product

Co-located – two or more companies located within the boundaries of the same mine

Trackout – Dirt from tires deposited onto paved roadways.

EMS – Maricopa County system used for permitting

ACRONYMS

CAA – Clean Air Act

SO_x – Sulfur oxides

NO_x – Nitrogen oxides

PM – Particulate matter

CO – Carbon monoxide

NAAQS – National Ambient Air Quality Standards

EPA –Environmental Protection Agency

µm - micrometer

$\mu g/m^3$ – micrograms per cubic meter

SIP/TIP – State Implementation Plan/ Tribal Implementation Plan

OHV – Off highway vehicles

SPM – Special Purpose Monitor

SLAMS – State and Local Air Monitoring Stations

IMPROVE – Interagency Monitoring of Protected Visual Environments

MCAQD – Maricopa County Air Quality Department

TFV – Threshold friction velocity

VE – Visible Emissions

NOV – Notice of Violation

NTC – Notice to Correct

ADEQ – Arizona Department of Environmental Quality

BMP’s – Best Management Practice

CHAPTER 1

The Clean Air Act (CAA) passed by Congress in 1970 established a system intended to reduce and curb emissions of harmful pollutants into the atmosphere (Environmental Protection Agency (EPA), 2011). It has been amended several times since, the last time being in 1990 (CAA, 1990). This Act contains: standards for criteria pollutants, regulations for acid rain and air toxins, permitting requirements for facilities that have the potential to emit, and guidelines for enforcement on those facilities (EPA, 2011). The six criteria pollutants currently regulated by the United States Environmental Protection Agency (EPA) are: SO_x, NO_x, ozone, lead, particulate matter (PM), and CO (EPA, 2011). These six criteria pollutants have National Ambient Air Quality Standards (NAAQS) that are determined by the EPA to protect the general public.

Regulation for particulate matter is divided into two categories: PM-10 and PM-2.5. PM-10 refers to particulates less than or equal to 10 micrometers (μm) in diameter (Stone, Wilson, Lightbody, and Donaldson, 2003). The current PM-10 NAAQS are set at 150 micrograms per cubic meter ($\mu g/m^3$) per 24 hour period (EPA, 2011). Particulates measuring 2.5 μm in diameter or smaller are designated PM-2.5. NAAQS for PM-2.5 are set at a 24 hour average of 35 $\mu g/m^3$, and also an annual standard of 15 $\mu g/m^3$ (EPA, 2011).

The EPA is tasked to uphold the CAA at the federal level but can delegate enforcement of air quality regulations to local authorities (CAA, 1990). The EPA oversees this local regulation by classifying attainment areas, requiring pollutant monitoring, creating requirements for industry compliance, and establishing national attainment levels (CAA, 1990). The EPA also approves and adopts local regulations allowing the agency the ability to enforce local air quality regulations (CAA, 1990).

Health Effects

The diameter of a single human hair is approximately 70 μm (EPA, 2011). An object with a diameter 1/7th that of a hair cannot be seen by the naked eye or noticed when inhaled during normal respiration. People everywhere are breathing in PM-10 everyday. Prolonged exposure to PM-10 pollution can lead to many types of respiratory problems, cardiopulmonary diseases, and shorten life expectancy (Abba, Sawant, and Srivastava, 2003). The two groups most affected by PM-10 exposure are children and the elderly (Stone et al, 2003). People with healthy immune systems are not as affected by PM-10 exposure as those with compromised immune systems (Stone et al, 2003).

When PM-10 is inhaled through the nose some may be stopped by cilia, but most will make its way to the lungs. When particles enter the lungs the natural response is to expel the particle by coughing. PM-10 is so small it can get down into the bronchioles and even the alveoli of the lungs. These areas of the lungs are so deep it becomes virtually impossible to cough out any intruding particles. It is here, deep in the lungs, that PM-10 begins to impact a person's health. The particles irritate the lungs causing inflammation of the bronchioles or alveoli (Stone et al, 2003). The smallest particles can pass through the lungs into the blood stream (Sun, Hong, and Wold, 2010).

Non-attainment Areas

According to the EPA website, Maricopa County is considered serious non-attainment for PM-10 along with 7 other areas/counties, including two areas in Nevada and five in California (EPA, 2011). Six of these eight serious non-attainment areas have dry, arid climates. 35 of the 38 areas designated moderate attainment for PM-10 by the EPA are located in the western United States (EPA, 2011). Within these 45 non-attainment areas live 25,440,093 people. Of those 25 million people, 19,828,732 are living in areas considered serious non-attainment (EPA, 2011). The non-attainment area of Maricopa County covers the most populous areas of Maricopa County in which reside 3,111,876 people (EPA, 2011).

Maricopa County Non-attainment History

Maricopa County was labeled moderate attainment for PM-10 in 1990 (Maricopa County, 1999). Maricopa County had not reached attainment by its proposed deadline of 1994, and in 1996 the EPA re-designated the area as serious non-attainment (Maricopa County, 1999). In 2002, after Maricopa County repeatedly failed to meet prior attainment deadlines, the EPA tasked the State to submit revisions to the State Implementation Plan (SIP) which would cover the Salt River area (EPA 2002), and set an attainment date of 2006 (Arizona Department of Environmental Quality (ADEQ), 2005).

2006 proved to be the one of the worst years for air quality in Maricopa County history. A longer than normal dry period (Maricopa Association of Governments (MAG), 2007) was recorded and 27 days exceeded the national standard for PM-10. In 2007 a revised SIP submitted to the EPA outlined Maricopa County's 5% plan (MAG, 2007). The 2007 SIP contained provisions to: increase the number of inspections on industries that emit PM-10; rewrite PM-10 regulations; and add ordinances that addressed other PM-10 sources. These ordinances include: diesel idling; regulation of off–highway vehicle (OHV) use; open burning; and the regulation of leaf blowers (MAG, 2007). These changes made the PM-10 regulations in Maricopa County some of the strictest in the country.

In 2009 the State of Arizona sent a document to the EPA asking that twelve of thirteen recorded PM-10 exceedances in 2008 be designated as exceptional events (EPA, 2010). This document demonstrated the reasons as to why certain days over 150 $\mu g/m^3$ were unavoidable, and fit the definition for an exceptional event per the CAA. The CAA defines an exceptional event as

> an event that affects air quality, is not reasonably controllable or preventable, is an event caused by human activity that is unlikely to recur at a particular location or a natural event, and is determined by the Administrator in accordance with 40 CFR 50.14 to be an exceptional event. It does not include stagnation of air masses or meteorological inversions, a meteorological event involving high temperatures or lack of precipitation, or air pollution relating to source noncompliance. (CAA, 1990)

The EPA denied all 12 exceptional events demonstrations leaving Maricopa County with 13 PM-10 exceedance days recorded in 2008 (EPA, 2010). The EPA decided ADEQ did not provide adequate evidence showing these events were naturally occurring (EPA, 2010). ADEQ provided historical wind data for the exceeding monitors, showing the wind speeds contributing to the exceedance to be unusual, wind speeds that occur less than 5% of the time. The EPA denied the unusual winds explanation for those during the summer, stating ADEQ use average summer wind speeds for an unusual determination, instead of the average yearly wind speed data that was provided (EPA, 2010).The EPA also stated that in evidence it had collected from local airports the visibility in the area remained the same throughout the day (EPA, 2010). The EPA stated this was important information proving a weather event was not occurring at the time of the monitor exceedances (EPA, 2010).

In 2011 the EPA was poised to reject the 2007 SIP as Maricopa County failed to reach attainment or meet the provisions set in the 5% plan (McKinnon, 2011). Days before the EPA could formally reject the SIP and impose federal sanctions; the State of Arizona pulled the SIP (McKinnon, 2011). This delayed the sanctions from being implemented for two years. If within the two year time frame a SIP is submitted and approved by the EPA, no sanctions will be imposed on Maricopa County (McKinnon, 2011). The PM-10 problem for Maricopa County therefore remains as an unresolved issue, with substantial penalties looming if the solutions cannot be found.

Monitoring PM-10

Maricopa County uses a monitoring network to collect information about the levels of pollutants in the air shed over Phoenix. Six monitoring objectives are used to locate a monitor:

- determine the highest concentrations on the network
- determine representative samples in highly populated areas
- determine the impact of sources in the area on the air
- determine the background concentration levels
- determine pollutant effects to secondary standards
- determine the impacts of pollutants on less populated areas

  (Maricopa County Air quality Department (MCAQD), 2009)

Along with these six objectives, five measurement scales are used to determine the areas around a monitor:

- micro
- middle
- neighborhood
- urban
- regional (MCAQD, 2009)

These objectives and scales guide the Maricopa County air monitoring division where to place a monitor and in what areas different pollutants should be monitored.

Compliance with the monitoring standards for PM-10 is defined as having an average of less than one exceedance day per year over three years recorded on a monitoring system (CAA, 1990). More than three exceedance days recorded over the course of three years on a system is considered a violation. Any monitor on the system, including background monitors and Special Purpose Monitors (SPM) can contribute to monitoring standard violations. If even one monitor on the system records more than three days over 150 $\mu g/m^3$ over three years the entire area is considered in violation. A State can submit a demonstration to the EPA showing some of the days recorded to exceed NAAQS were exceptional events. This exceptional event designation would prevent a recorded monitoring exceedance from being counted toward a violation of the monitoring standard.

According to 40 CFR Part 58.14 State and Local Air Monitoring Stations (SLAMS) can only be modified every five years. The discontinuation of a SLAMS monitoring station is contingent on the Regional Administrator's review and approval of a five year assessment showing:

- the specific SLAMS monitor: recorded no NAAQS exceedances during the assessment time and is not part of an approved SIP or has a contingency plan outlined in the SIP for monitoring continuation after removal of the monitor
- records lower levels of NAAQS than other monitors on the system
- does not put the monitoring system below the required amount of SLAMS per population density

(CAA, 1990)

A SLAMS monitor cannot be moved if it is recording NAAQS exceedances unless logistical reasons not under the control of the regulatory agency make it impossible to operate in its current location (CAA, 1990). Under this situation the SLAMS monitor may be moved if the new location is located near the old location and represents the same scale measurements (CAA, 1990).

Currently Maricopa County has twenty-five stationary monitors on its system (MCAQD, 2009). Of the twenty-five monitors across Maricopa County, sixteen monitor PM-10 (MCAQD, 2009). Thirteen are continuous Tapered Element Oscillating Microbalance (TEOM) technology monitors with a flow rate of 16.67 L/min (B. Davis, personal communication, April 18, 2011). The remaining three are non-continuous filter based monitors (MCAQD, 2009).

During the time Maricopa County has been deemed serious non-attainment by the EPA it has had at least two days exceeding the standard per year on its monitoring system with a peak in 2006 of 27 exceedance days. Four of the sixteen PM-10 monitors routinely exceed the standard of 150 μ/m^3. The data collected by these monitors shows that Maricopa County not only exceeds the federal PM-10 standard, but it has consistently violated the federal monitoring standard of one exceedance per year.

Monitors Exceeding PM-10 Standards

The Buckeye and Higley monitors were originally placed as background concentration monitors. Both were placed in rural areas on the outskirts of the Phoenix metropolitan area. As the valley's population grew, the rural area where the Higley monitor is located became more urbanized, surrounded by houses and malls. The Higley monitor recorded seven exceedances from 2007 to 2009. Buckeye still remains a rural area with heavy agricultural activity. The Buckeye monitor recorded nine exceedances from 2007 to 2009. The monitor contributing the most exceedances of the standard is the West 43rd Avenue monitor with 18 exceedances from 2007 to 2009. This monitor is located in a low point of the

Phoenix valley near the Salt River along with the Durango monitor. This area is highly industrial and the monitor is surrounded by landfills, aggregate mines, metal recyclers, and vacant lots. These industries along with construction, agriculture, and dirt roads contribute to PM-10 pollution either disturbing the Earth's surface to make silt like dust areas, or crushing materials to create small dust particles. Not all dust particles will be small enough to be considered PM-10, but PM-10 particles can also be created by such processes.

Statement of the Problem

PM-10 An emissions survey conducted by Maricopa County in 2005 found that approximately 35% of the fugitive dust came from construction and construction related sources with 10% coming from unpaved roadways and 3% from agricultural activities (MAG, 2007). In 2008 the economy experienced a downturn and with it came a slowdown in the industry deemed the largest contributor PM-10 emissions in Maricopa County, namely construction. This drop in construction activity, coupled with the strict regulations for construction sites still in operation, led people to believe the PM-10 issue would resolve itself. However, in 2009 the monitoring system for Maricopa County counted seven exceedances, double the PM-10 monitoring allowance for three years. This study will take a closer look at four monitors that contribute the most exceedances to the PM10 standard and will try to identify potential sources, or weather events that may have caused the monitors to read increased PM-10 levels.

Scope

This study takes data from four different monitors in Maricopa County: the Buckeye monitor, the Higley monitor, the West 43rd Avenue monitor, and the Durango monitor. These include the monitors responsible for most of the violations recorded in Maricopa County.

Objectives

- Find all days averaging over 150 $\mu g/m^3$ between January 1, 2007 and December 31, 2009 per monitor.
- Map a two mile radius around the Higley, Buckeye, West 43rd Avenue, Central Phoenix, and Durango monitors for years 2007, 2008, and 2009.
- Review monitor maps to find potential PM-10 emission sources downwind of the monitor on the exceedance days.
- Identify days over 225 $\mu g/m^3$, graph PM-10 fluctuations over the day to identify possible sources contributing to times of increased PM-10.
- Research the sources and dates to find any violations or weather trends relating to PM-10 exceedances.
- Identify control technologies designed to limit PM-10 emissions that might be applicable to the identified sources.

Limitations

This study only takes into account four different types of potential PM-10 emitters: farms, vacant lots, earthmoving permits, and stationary sources. The time frame of the study covers only 2007, 2008, and 2009. The study is limited to data that already exists.

CHAPTER 2

The greater Phoenix area has not been able to meet national PM-10 attainment levels for the last twenty years, and is now labeled as having the worst dust pollution in the country by the American Lung Association (Collom, 2010). The area the American Lung Association is referring to as greater Phoenix is a large area from Buckeye in the west to the Tonto National Forest in the east, the northern Maricopa County border to south of Picacho Peak in Pinal County, as shown in Figure 1 below (Collom, 2010). This area stretches farther than what the EPA designated moderate non-attainment in 1990, Figure 2. The EPA designated PM-10 non-attainment area covers the most densely populated areas of Maricopa County, shown in yellow, and also known as Area A. The background color shows areas of Maricopa County in attainment with the PM-10 NAAQS standard.

Figure 1. American Lung Association High PM-10 Area (Mapquest, 2011)

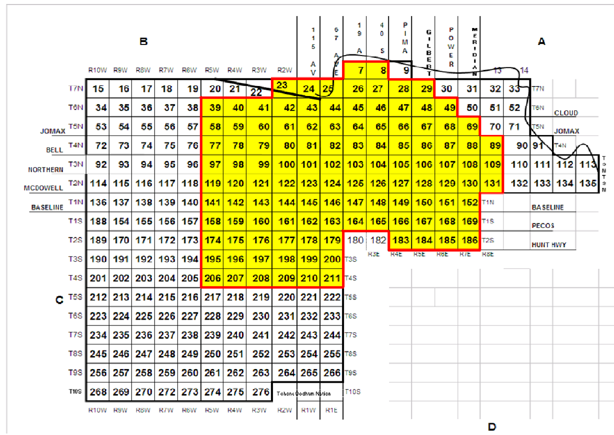


Figure 2. EPA Designated PM-10 Non-attainment Area Maricopa County (MCAQD, 2011)

Health Effects

Populations with exposure to low levels of atmospheric PM-10 do not exhibit the same deleterious effects to individual health as those populations residing in areas with high levels of PM-10 pollution. Everyone is at risk for potential health problems when exposed to PM-10, however the groups most affected by PM-10 problems are children, older citizens, and those with existing respiratory illnesses (Stone et al, 2003).

Asthma, bronchitis, and respiratory diseases can be attributed to PM-10 exposure. If PM-10 passes from the lungs to the blood stream there are increased risks for coronary artery disease, atherosclerosis, and myocardial infarctions (Sun, Hong, & Wold, 2010). There is also an increased potential for problems such as blood thickening and systemic cytokine release, a problem where T-cells release large amounts of cytokine having the effect of a severe infection with complications such as rigor, hypotension, and fever (Barlow, Brown, Donaldson, MacCullum, & Stone, 2008).

Hours after PM-10 pollution events occur increased hospital admission rates for cardiovascular problems have been reported (Sun et al, 2010). These health effects contribute to the elevated levels of mortalities that occur after high levels of PM-10 have been reported (Bell & Davis, 2001).

The size and chemical composition of PM-10 varies depending on location and time (Kleinman, Bhalla, Mautz, & Phalen, 1995). Individual particles of PM-10 can contain aqueous, soluble, and insoluble components (Kleinman et al, 1995). It is this compositional variety of PM-10 that makes PM-10 so hazardous. Early studies have shown that the ultrafine fraction of PM-10, ≤0.1 µm in diameter, contributes more to lung inflammation than the fine (< 2.5 µm in diameter) and coarse (10 µm to 2.5 µm in diameter) fractions of PM-10 (Stone et al, 2003). It is this inflammation that causes many of the health problems associated with PM-10 exposure (Barlow et al, 2008).

While the long term effects PM-10 pollution can have on the body are known, the mechanism of how PM-10 creates the toxicity that causes these effects is not understood. A 2008 study showed that rats instilled with PM-10 had less macrophage mobility than those rats in the control group, who were instilled with sterile saline. The alveolar macrophage is the key component to removing particles deposited in the lungs. This inability of the macrophages to move, means less particles being phagocytosed, resulting in the increased inflammation seen with exposure to PM-10 (Barlow et al, 2008). The study also showed that these macrophages move slower when filled with multiple large particles, leading to less removal of the intruder particles (Barlow et al, 2008). A later study found little correlation of this particle mass to neutrophil activity in the lungs of exposed rats, but did find increased neutrophil activity in the lungs of rats exposed to relatively toxic components attached to PM-10 particles (Duffin et al, 2002).

Pope (1991) found that after the closure of a steel mill in the Utah Valley PM-10 levels dropped considerably. During the period the steel mill was closed a drop in the health effects associated with PM-10 in the neighboring populations was reported (Pope, 1991). When the steel mill reopened both PM-10 levels and its associated health effects began to rise (Pope, 1991). During periods of high coarse fraction PM-10 pollution, it has been reported that elevated numbers of children missed school or needed access to asthma medications (Gordian & Choudhury, 2003). Pope also found that when PM-10 levels reached 100 μg/m^3 over a twenty-eight day period absenteeism increased 2% in elementary school children (Pope, 1991).

A study performed in Anchorage, Alaska found that days with high PM-10 levels resulted in an increase in asthma medication in young school children, and those students previously affected by asthma complications had an increase in other respiratory symptoms (Gordian & Choudhury, 2003). The study also found that PM-10 and decreasing temperatures were the main problem in these increasing asthma attack rates, while PM-2.5 levels during the study period stayed below the EPA's proposed standard, (Gordian & Choudhary, 2003). This data correlates to a study by Goodman, Dockery, and Clancy in 2004 which found that for every 10 μg/m^3 increase in PM-10 and 1℃ decrease in temperature area mortality increased by 2.6% for the following 40 days (Goodman et al, 2004).

Many studies tracking mortality levels after PM-10 events have focused on the few days after the event (Bell & Davis, 2001). Reviewing mortality levels and hospital admissions after the London Fog event of 1952 it was found that these adverse effects to pollution exposure continued for two and a half months contributing to more than 12,000 deaths (Bell & Davis, 2001). During this four day period the levels of PM-10 had risen to approximately 3,000 $\mu g/m^3$ (De Angelo, 2008) Normal PM-10 levels for the time were around 300 $\mu g/m^3$, and today in London are 30 $\mu g/m^3$ (De Angelo, 2008). When the London fog incident occurred in December 1952, not only did the four days see an increased number of fatalities, but weeks after the fog had cleared the death rates were increased (Bell & Davis, 2001).

Abba, Sawant, Srivastava (2003) conducted a study to show the increase of mortality, morbidity, and pulmonary diseases in Mumbai related to the expansion of industry in the area. Their results showed that in industrial areas mortality and morbidity were consistently highest, but also found the results are generalized and could change due to several factors including: age, a person's health, time spent outdoors, and types of activities when outdoors (Abba et al, 2003). Mar, Koenig, Norris, and Larson (2000) published a study conducted over the two year period of 1995-1997 which looked at mortality rates due to cardiovascular problems in people over 65. Mar et al found that cardiovascular related deaths for this age group increased after high PM-10 events especially those events occurring on humid days (Mar et al, 2000).

PM-10 Transport

In 2009 the EPA found portions of Pinal County, located just south of Maricopa County, to be exceeding the PM-10 standard from 2006 – 2008 (ADEQ, 2009). The EPA recommended designating a new PM-10 non-attainment area to include the counties of; Cochise, Gila, Graham, La Paz, Maricopa, Pima, Pinal, Yavapai, and Yuma (ADEQ, 2009). The EPA proposed such a large area as non-attainment citing PM-10's ability to travel long distances without breaking down like chemical pollutants.

In response to the information found about how PM-10 affects health, many recent studies have focused on the origin of the PM-10 that has been recorded in areas with high levels of PM-10. Some have found the PM-10 is a natural source, brought in by dust storms. Other times PM-10 is caused by human activities (Mok & Hoi, 2005).

Borge, Lumbreras, Vardoulakis, Kassomenos, and Rodriquez (2007) found elevated levels of PM-10 in Athens and Madrid, on days where winds arrived at three km above mean sea level and originated from the North African Sahara Desert. This study used four day wind models to determine the origination of the PM-10 (Borge et al, 2007). Other studies have found similar results with PM-10 originating from the Sahara Desert (Zabalza et al, 2006) and large dust storms being tracked coming off of China. Alsusua, Spain recorded twenty exceedances of the EU standard for PM-10 (50 $\mu g/m^3$) in 2002-2003. Thirteen of these exceedances were found to have originated from the North African Sahara Desert. These thirteen exceedances occurred when air masses were entering Spain from this African region, and contained traces of Al and Ti, both good indicators of North African soils. The seven other exceedances were determined to have come from local sources, due to the increase in other pollutants along with PM-10.

Dust storms from the Sahara Desert have been identified as the cause of elevated levels of PM-10 in areas of Northern Spain (Zabalza et al, 2006) and the Mediterranean Sea (Bari, Baumbach, Sarachage- Ruiz, & Kleanthous, 2009). China has also been found as a large contributor to PM-10 pollution in its neighboring countries with Chinese dust storms consistently plaguing Taiwan, Japan, and South Korea (Ottawa Citizen, 2008).

A study in Macau found that it is natural phenomena together with industrialization that is contributing to pollution problems (Mok & Hoi, 2005). Macau is a small island off the southern coast of China. Much like Arizona it has two long seasons (summer and winter) and two short seasons (spring and autumn) (Mok & Hoi, 2005). The Asian monsoons occur in the winter and bring northern winds that are cold and dry from the mainland of China (Mok & Hoi, 2005). It is during these monsoonal times that Macau sees spikes in its PM-10 levels, as opposed to the summer winds that are blowing from the sea masses to the south (Mok 7 Hoi, 2005).

Dust storms are a common occurrence in the areas surrounding Phoenix. Phoenix has dry, hot summers with monsoon episodes, generally occurring in July and August when humidity begins to rise and days over 100℉ become consistent. These monsoon episodes during the summer in Phoenix correspond to certain times with high winds and elevated PM-10 levels, as found in this study.

Most PM-10 will only travel short distances, a few yards to miles, before re-settling to the ground within hours (Pima County, 2011). PM-10 settles at a rate of 1000 feet per hour without sustained turbulent winds (ADEQ, 2009). During dust storms PM-10 is lifted higher and travels farther due to the strong winds, than PM-10 disturbed due to human activity. Different variables contribute to the travel rate of PM-10; these include wind speed, precipitation, and atmospheric mixing height (Rost, Holst, Saehn, Klinger, Anke, Ahrens, & Mayer, 2009). When high winds are mixed with low precipitation and low atmospheric mixing heights some PM-10 may make it to high into the troposphere to travel hundreds of miles.

Many areas cannot blame their PM-10 levels on natural phenomena. Studies conducted in many growing industrial nations are showing that the industries helping the countries grow are contributing the most to the pollution problems also growing in these areas. Abu-Allaban, Lowenthal, Gertler, and Labib (2007) found that across six areas picked to sample in Cairo, the most prevalent sources of coarse PM-10 came from industrial sources, open burning, and geologic material (Abu-Allaban et al, 2007).

Attainment Classification

The CAA states that an area not meeting national attainment levels is given an initial classification of moderate non-attainment. These non-attainment areas are given a time frame by the CAA of no more than five years to meet national standards (CAA, 1990). States or Tribal communities with areas classified non-attainment are required to submit a SIP or a TIP within eighteen months of EPA classification (CAA, 1990). The SIP or TIP will contain: a date the area will meet national attainment levels, an area's historical background and description, air quality data, an emission inventory for pollutant sources, strategies to control emissions and meet attainment, contingency options if an emission control strategy were to fail or the SIP/TIP can explain why the area cannot meet national standards (CAA, 1990). The CAA also delegates to the EPA power to redesignate an area from moderate non-attainment to serious non-attainment if it is determined the area cannot practicably meet attainment standards by the attainment deadline (CAA, 1990). An area will also be redesignated to serious non-attainment if the area fails to meet attainment by the attainment deadline (CAA, 1990).

The EPA determines attainment with NAAQS standards by reviewing monitor data collected from the area's designated monitoring network. These networks consist of SLAMS, and SPM monitors, which record hourly or daily the levels of specified criteria pollutants (CAA, 1990). This data is then saved in an EPA database and can be reviewed by the EPA and local authorities.

The 1977 CAA amendments called for monitoring networks to be installed at National Parks and wilderness areas, termed Class I areas (CAA, 1990). These networks monitored pollutant levels until 1988 when these networks starting monitoring the visibility of these areas. This monitoring network is called the Interagency Monitoring of Protected Visual Environments or IMPROVE, and was set up to track regional trends and visibility conditions in Class I areas (EPA, 2011).

There are 156 Class I areas in the United States (CAA, 1990), 12 of which are located in Arizona (ADEQ, 2010). There are 14 IMPROVE monitoring systems set up in Arizona: Grand Canyon National Park – Hance; Grand Canyon –Indian Garden; Petrified Forest National Park; Sycamore Canyon Wilderness - Camp Raymond; Mazatzal Wilderness - Humboldt Mountain; Mazatzal/Pine Mountain Wildernesses - Ike's Backbone; Sierra Ancha Wilderness - Pleasant Valley Ranger Station; Superstition Wilderness – Tonto National Monument; Superstition – Queen Valley; Saguaro National Park - West Unit; Saguaro National Park - East Unit; Chiricahua National Monument - Entrance Station; Galiuro Wilderness- Muleshoe Ranch; and Chiricahua Wilderness -Rucker Canyon (ADEQ, 2010). In 1999 the EPA instated the Regional Haze Rule for Class I areas (EPA, 2011). The Regional Haze Rule calls for national environmental agencies along with other interested agencies to develop and implement plans to reduce pollution that impairs visibility in Class I areas (EPA, 2011).

Figure 3 Class I Areas across the United States
EPA, 2011

Along with the federally mandated NAAQS and regional haze monitoring systems, Arizona has installed urban haze monitoring systems in the Phoenix and Tucson areas (ADEQ, 2010). Unlike regional haze there are no regulations against urban haze. These urban haze monitors are helping to track amounts and pollutants in urban haze for policy makers and public information (ADEQ, 2010).

Sources

Maricopa County found the largest PM-10 emitters in a 2005 emissions inventory to be construction activity, followed by dirt roads, vacant lots, and stationary sources like sand and gravel operations and aggregate plants (MCAQD, 2007). The emission rates of sources were found through self reporting for permitted facilities or mathematical modeling using acreage data, vehicle trip data, or other source related variables. Farms were found to contribute only minimally to the PM-10 problems facing Maricopa County (MCAQD, 2007). Other sources of PM-10 pollution are golf courses, metal recyclers, vehicle use, and open burning.

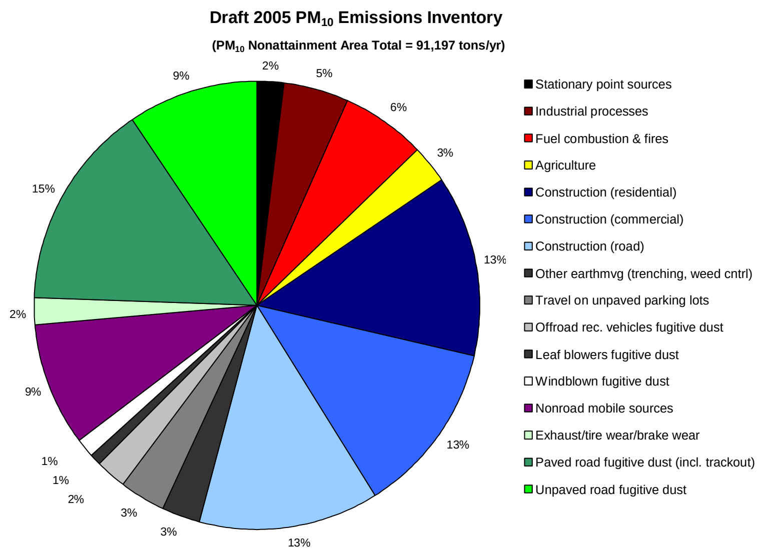


Figure 4 2005 Maricopa County PM-10 Emissions Inventory
MCAQD, 2007

During the time frame of 2005 to 2008 the Phoenix area saw abundant growth. Construction activities like grading, trenching, loading and dumping were occurring on construction sites all across the valley. These activities are just a few of the large dust emitting activities that can occur on construction sites. Maricopa County in 2008 adopted changes to the rule regulating construction activities. These adopted changes made PM-10 regulations in Maricopa County some of the strictest in the country.

Sand and gravel operations are abundant in the Phoenix area. They mine the Salt River bed for rock to make asphalt and concrete. These facilities conduct operations such as overburden removal, mining, hauling, and crushing, all of which can result in dust problems. Overburden removal is a term for the removal of the top layer or layers of soil sometimes tens of feet thick to get down to the rock used to mine the desired formation. Here the facilities mine rock for production. These mining operations can occur above or below ground. Facilities use trenchers to pull rock out and then it is placed on conveyer belts. These conveyers can lead to crushing equipment that grinds up the rocks into small pieces. The final product can range in size depending on the requested product.

People driving on dirt roads, even those roads that are well maintained, can kick up dust when driving at high speeds. Few dirt roads exist within the classified non-attainment area of Maricopa County as this area is more urban than rural, but there are still some areas where the county has expanded that do have unpaved roadways. Since these dirt roads are located outside of the non-attainment area no regulations apply.

Farms and permitted facilities also have unpaved roadways located on them. Some of these roads are covered with asphalt millings, or dust suppressants which are used to create hard surfaces. The right of ways utilities use tend to be unpaved and are found all across the Phoenix area. No speed limits exist on these unpaved right of ways so vehicles can travel at high speeds and create large amounts of dust.

The Hassayampa River located just west of Phoenix is a dry river bed attractive to Off-Highway Vehicle (OHV) drivers on weekends and holidays. These OHV's can disturb the stable desert surface creating silt like areas that easily blow away with a slight breeze. The Hassayampa River isn't the only area in Maricopa County prone to OHV drivers, and silt like unstable conditions.

Agricultural activities also contribute to dust pollution, a precursor to PM-10. Farmers tilling their fields can be seen from miles away due to the dust plumes hundreds of feet high trailing the equipment. Harvesting and truck loading can also create dust from farms.

Maricopa County Regulation

Maricopa County currently has regulations that cover construction activity, aggregate plants, vacant lots and dirt roads, metal recyclers, and open burning. Golf courses may be required by the Maricopa County Air Quality Department (MCAQD) to submit a Dust Control Plan if found to have dust issues.

Maricopa County uses a system called EMS to record, and monitor permitted facilities within its borders. This system records company information, receipts for fees, expiration date, past inspections, violation information, and enforcements for facilities.

MCAQD inspectors use various test methods approved by the EPA to determine whether a violation exists. Stabilization test methods include; vegetative cover, rock test method, threshold friction velocity (TFV), silt- loading silt-content, and visible emissions test (VE) (MCAQD, 2008).

The vegetative cover test is used to determine if the lot has more than 30% vegetative cover (MCAQD, 2008). The drop ball test is used in open areas to determine if an area has silt like conditions. A steel ball about the size of a marble is dropped three times; if the ball sinks into the dirt about half way then other test methods should be used to determine the site’s stability (MCAQD, 2008). The rock test method calculates the coverage of rocks in an area to determine the lots stability (MCAQD, 2008).

If a lot has less than 30% vegetative cover or fails the rock test and drop ball methods a threshold friction velocity (TFV) test is performed to calculate the amount of non-erodible elements on the lot (MCAQD, 2008). A TFV result of more than 43 cm/second is considered stabilized. TFV tests are used mainly for open areas where vehicles do not travel (MCAQD, 2008). This test can be performed on vacant lots and permitted facilities.

If the area in question has evidence of vehicle use an inspector would use the Silt Content/ Silt Loading test. This test determines what percentage of the roadway is silt (MCAQD, 2008). If the Silt Content /Silt Loading test finds less than 6% silt content on a roadway, that road is considered in compliance (MCAQD, 2008). Unpaved parking lots are allowed up to 8% as calculated in the Silt Content /Silt Loading test for compliance (MCAQD, 2008).

Visible Emission (VE) readings are used to determine the opacity of a dust plume coming from an operation or facility. MCAQD rules state that no opacity can exceed 20%. Certain operations conducted on permitted facilities are held to stricter opacity regulations. Crushing operations can discharge no more than 7% opacity from stacks, and conveyer transfer points and no more than 15% opacity from any crushing operation (MCAQD, 2008). Asphalt operations are held to 5% opacity limits unless the production is for rubberized asphalt which is held to 20% (MCAQD, 2008). Other operations are held to a 10% opacity standard (MCAQD, 2008). Vacant lots can have no opacity of any percent cross the property line (MCAQD, 2010). Opacity limitations are one regulation that MCAQD can enforce on agricultural activities, limiting those facilities to the same standards as vacant lots (MCAQD, 2010).

Every six months a person responsible for conducting VE readings must be re-certified to read opacity (40 CFR, 2008). This involves a test reading stack emissions. The test involves a short eye calibration period; each test taker must then read 25 plumes each of white and black smoke, answers are recorded to the nearest 5% (40 CFR, 2008). To pass this test one must read the opacity within 3 deviations, each 5% being a deviation (40 CFR, 2008). If 4 deviations or more then 38 points are missed in a test the test must be re-done (40 CFR, 2008). Both black and white smoke must be passed in sequence to become certified in VE readings (40 CFR, 2008).

Maricopa County Rule 310 covers construction activity. Every site disturbing over 1/10th of an acre is required to obtain an Earthmoving permit from MCAQD (MCAQD, 2010). This permit gives the department the ability to enter a jobsite for routine and complaint inspection purposes whenever needed. Rule 310 regulates every dust generating operation that could occur on a construction activity, and the permit that a company fills out is also used as the dust control plan for that particular jobsite. These dust control plans cover every stabilization regulation required in the rule (MCAQD, 2010). Sites choose which method they will use to maintain compliance with the rule. A site can be found to be in violation of the rule even if they are following their dust control plan (MCAQD, 2010) and may be given a notice to change their plan along with their Notice of Violation (NOV). MCAQD may cite a construction site for emission related violations such as, trackout onto paved public roadways in excess of 25 feet from all combined exits, inadequate trackout control device, failure to stabilize the site, or opacity over 20% (MCAQD, 2010).

Rule 310.01 regulates vacant lots and open areas. Vacant lots are required to be stabilized at all times by covering the lot with gravel, pavement, recycled asphalt, or a dust suppressant (MCAQD, 2010). The rule also requires property owners to prevent trespassers by installing berms, fences, signs, curbs, or dust suppressants (MCAQD, 2010). A Notice to Correct (NTC) is sent to the property owner if the lot is found to be unstable (MCAQD, 2010).

Dirt roads within the non attainment area are regulated when more than 150 trips per day are recorded (MCAQD, 2010). These roads must then be maintained by the property owner to prevent opacity in excess of 20%, and silt loading of more than 0.33 oz/ft^2 or silt content of more than 6% (MCAQD, 2010).

Aggregate facilities are regulated by Maricopa County Rule 316. Rule 316 is currently Maricopa County's largest rule with over 30 pages, and covers three types of operations; asphalt production, crushing and screening, and concrete batch. These operations are regulated under one rule due to their close relation in operation and are quite frequently located or co-located on the same facility. One company may perform all three operations on the same facility or, a facility may house multiple companies so they can more easily use the other's product.

MCAQD has little jurisdiction over agricultural activities. These activities are permitted through the Arizona Department of Environmental Quality (ADEQ) and designated by Arizona Statute to abide by certain Best Management Practices (BMP's) (The Environment, 2009). Regulation of these BMP's falls to ADEQ. MCAQD may cite agricultural activities when the emissions leave the agricultural field. MCAQD has authority to write trackout, and opacity violations over the property line to agricultural fields (MCAQD, 2010).

Control Technologies

Strict regulation of PM-10 regulated industries has caused the emergence of many new technologies and methods for controlling sources of PM-10.

Owens Lake is now a dry lake bed located in central California. Owens Lake has recorded PM-10 levels at 27,000 $\mu g/m^3$ during a short storm with low wind speeds (Kim, Cho, & White, 2000). To curb such high levels of wind erosion on this dry lake Kim, Cho and White (2000) created an experimental laboratory study to find what vegetation cover would curb emissions. Kim et al's study used several vegetation types and coverage to find the best fit for Owens Lake. They believe that by changing the site specific information this method could be used for other arid areas (Kim et al, 2000).

GIS technology has been used in Clark County, Nevada to find vacant lots that were producing PM-10 emissions (Pulugartha & James, 2006). The lots were individually mapped for areas with high emissions and then mapped within Clark County. These maps were then used to help mitigate dust emissions from these vacant lots by locating the specific problem areas that lot owners can stabilize (Pulugartha & James, 2006).

Chemical dust suppressants can be mixed with water and applied on unpaved roads and open areas (Wet Earth, 2003). These chemical dust suppressants act like a glue holding the dirt particles together. Misting/fogging systems have been installed at some mining/ construction facilities. Spray bars on conveying systems have been reconstructed to finer sprays like those of the misting/fogging systems. Finer sprays have been found to attach easier to the similar sized dust particles causing the dust to agglomerate, becoming heavy and falling back to the ground (Marc Technologies, 2009). PM-10 regulated companies are taking new technologies into their own hands and retrofitting equipment like front loaders with spray bars so the dust can be controlled during earthmoving activity.

CHAPTER 3

Methods

For this thesis data was taken from the air quality monitoring system of Maricopa County for four monitors: Higley, Buckeye, Durango, and West 43rd Avenue for their repeated exceedance of the NAAQS PM-10 standard.

Figure 5 Study Monitor Map

Google Earth

The data was collected hourly from 01/01/07 to 12/31/09 and showed wind direction, wind speed, and PM-10 level in µg/m³. Each date that averaged over 150 µg/m³, during a 24 hour period was analyzed for daily wind direction. Wind direction was collected in degrees, 0 equaling due north and 180 equaling due south. Tables of data include; average PM-10 for the day, daily wind direction in degrees, average daily wind speed, and acreages of earthmoving permits, stationary sources, agricultural land, and vacant lots in the areas downwind of the monitor on the exceedance day.

Maps were created using Google Earth, and each monitor for all years received a two mile radius map. Maps were created at a two mile radius to focus on local sources that may have been contributing to the monitor exceedances. A wind compass was placed over the map lining the monitor up in the center of the wind compass. Each date over 150 µg/m³ wind direction was mapped, and the area within the direction of the incoming wind was reviewed for farms, Maricopa County Earthmoving permit sites, Maricopa County Stationary permit sites and vacant lots.

Earthmoving permits were collected through the Maricopa County permit system, EMS. Map area and date range were used to produce a list of Earthmoving permits that were issued during the requested date range. All permits that did not fall within the four mile diameter of the corresponding monitor were deleted.

Stationary permits were found using site investigations and EMS searches. Areas around the monitors were surveyed by visual observations and all stationary permits were logged. Each stationary permit is required to have a project sign stating its permit number and company name, permits where then researched to locate facility acreage.

Farms and vacant lots were found using the Maricopa County Assessors website found by going to the assessors tab under www.maricopa.gov. This website shows aerial photographs of Maricopa County yearly back to 2006.

Those lots in question of either being a vacant lot or a farm received a site visit to make final decision on its classification. The lot's area was found on the Maricopa County Assessors website using the property information tab. The tab displays property area in square feet which is then divided by 43,560 to get the acreage.

Vacant lots, Stationary and Earthmoving permits were reviewed in EMS for emissions related violations falling within the study period. Due to insufficient data records for farms violating BMP's, no records for farm violations could be collected. Harvesting and planting times were collected for crops grown within the study area.

Days recording over 225 $\mu g/m^3$ were graphed to times with peak PM-10 levels. Maps were reviewed for sources downwind of the monitor during these peak PM-10 level times. Weather information was collected for all dates where a majority of monitors, two or more, exceeded 150 $\mu g/m^3$ on the same day. These days all exceeding monitors were graphed to determine if exceedance times correlate to times during the day with recorded high speed gusts.

CHAPTER 4

Results

The two monitors with the most recorded exceedances, West 43rd Avenue and Durango, show most downwind areas covered by vacant lots, or stationary sources. These monitors are also located in a low point of Phoenix. Pollution tends to move down into this area during stagnant periods. These stagnation events lead to increased particulate levels in this low area. The Buckeye and Higley monitors found that on days exceeding 225 µg/m^3 winds came through agricultural areas when high PM-10 levels were recorded. Few emissions related violations were issued to any sites in the study area during the time covered. Only 3 NOV's and 1 NTC were issued at all monitors on days during the study period that exceeded 150 µg/m^3.

The data shows multiple days over the year where three or more monitors exceeded 150 µg/m^3. All 3 study years show multiple monitors exceeding on the same day, with winds recorded blowing from the same direction, and weather data showing high wind events.

Exceedance events dropped from 2007 to 2008, but then increased from 2008 to 2009 on all monitors. This can be attributed to precipitation rates of each year. 2007 recorded 5.05 inches of precipitation (Weather underground, 2011). 2008 recorded 9.58 inches of rainfall, making it one of the wettest years in decade (Weather Underground, 2011). 2009 saw very little rainfall, only 3.26 inches. 2009's small precipitation level explains why exceedance events occurred more often in 2009 than in 2008 with higher than average rainfall amounts. With less moisture in the air, and the ground, more PM-10 will have the ability to become entrained into the atmosphere.

Higley Monitor

The Higley monitor was originally placed as a background monitor due to its location approximately 25 miles outside of Phoenix. As more people moved to the Phoenix valley this area became more populated. 2007 shows areas covered largely by earthmoving permits, showing the effect of this influx into the area. In 2009 some construction activities picked back up in the region to create shopping centers and roadways for the increased population. During 2007 the San Tan Village Shopping mall was under construction, this construction covered over 20 acres directly west of the monitor. There were also multiple large housing developments under construction in 2007, these developments covered over 100 acres both south and east of the monitor.

Few vacant lots existed around the Higley monitor and only one source permit is located within a two mile radius. Two permit holders southwest of the monitor received nine dust related NOV's during 2007. One NTC was written to a vacant lot owner in 2008, and four in 2009. Twenty-three NOV's were issued to Higley area earthmoving permit holders in 2008 and nine were issued in 2009.

Tables 1 displays exceedance activities at the Higley monitor. The Higley monitor exceeded 150 $\mu g/m^3$ on six days in 2007, zero days in 2008, and two days in 2009. The winds in this area typically came from the south, with some winter winds coming from the east in 2009. These southern winds crossed mainly residential areas and earthmoving permitted sites on days averaging 150 $\mu g/m^3$. The number of acres for earthmoving, stationary, vacant lots, and farm land reflect the number of acres within a two mile radius downwind of the monitor Changes in the data reflect changes in the wind direction. Further analysis of wind's and PM-10 levels find winds changing during the day and coming from the east. It is during these easterly wind times the Higley monitor saw its highest levels of PM-10.

Table 1

Higley Monitor Exceedances of 150 µg/m^3

Exceedance Dates	PM-10 µg/m^3	Wind Direction Degrees	Wind Speed mph	Earth moving Acres within 2 miles of the monitor	Stationary Permit Acres Within 2 miles of the monitor	Farm Acres Within 2 miles of the monitor	Vacant Lot Acres Within 2 miles of the monitor
6/6/07	181	230	10.35	503	0	210	54
7/19/07	200	220	5.6	503	0	210	54
8/16/07	196	169	5.4	212	13	162	55
8/23/07	230	170	3.7	212	13	162	55
10/5/07	150	184	10.3	212	13	162	55
10/24/07	175	92	7.1	300	13	610	0
7/17/09	276	160	5.8	223	13	158	65
10/27/09	176	183	8	223	13	158	65

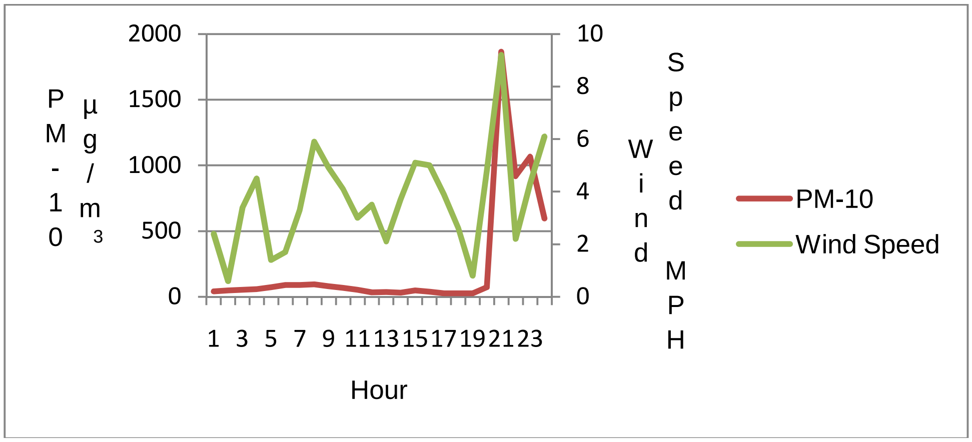


Figure 6 Higley 8/23/07

Figure 6 shows PM-10 data throughout the day on August 23, 2007 where PM-10 levels averaged 230 µg/m^3. The data shows a large PM-10 event beginning at 8 PM with levels reaching 1900 µg/m^3 with winds reaching their fastest speeds. The winds at 8 PM came in from the southwest at around 9 mph, the winds changed direction around 10 pm coming in from the east bringing PM-10 levels of 1000 µg/m^3.

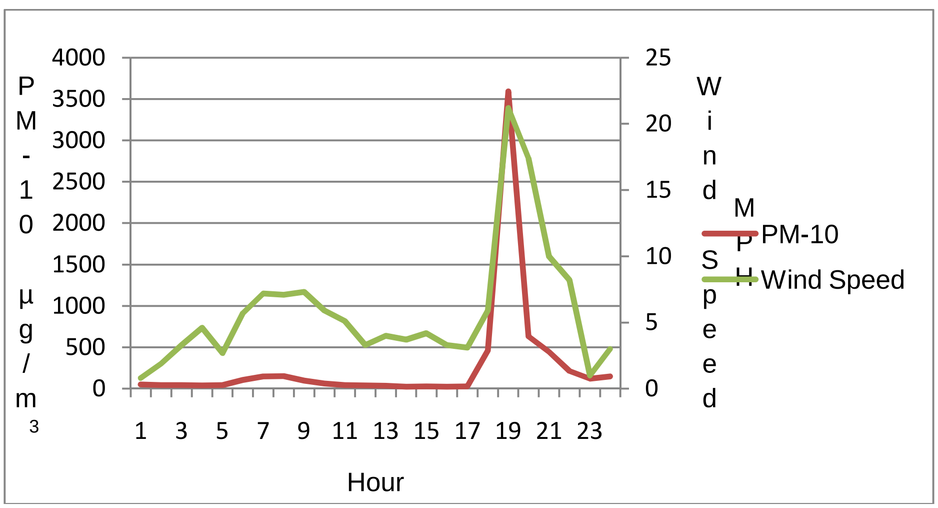
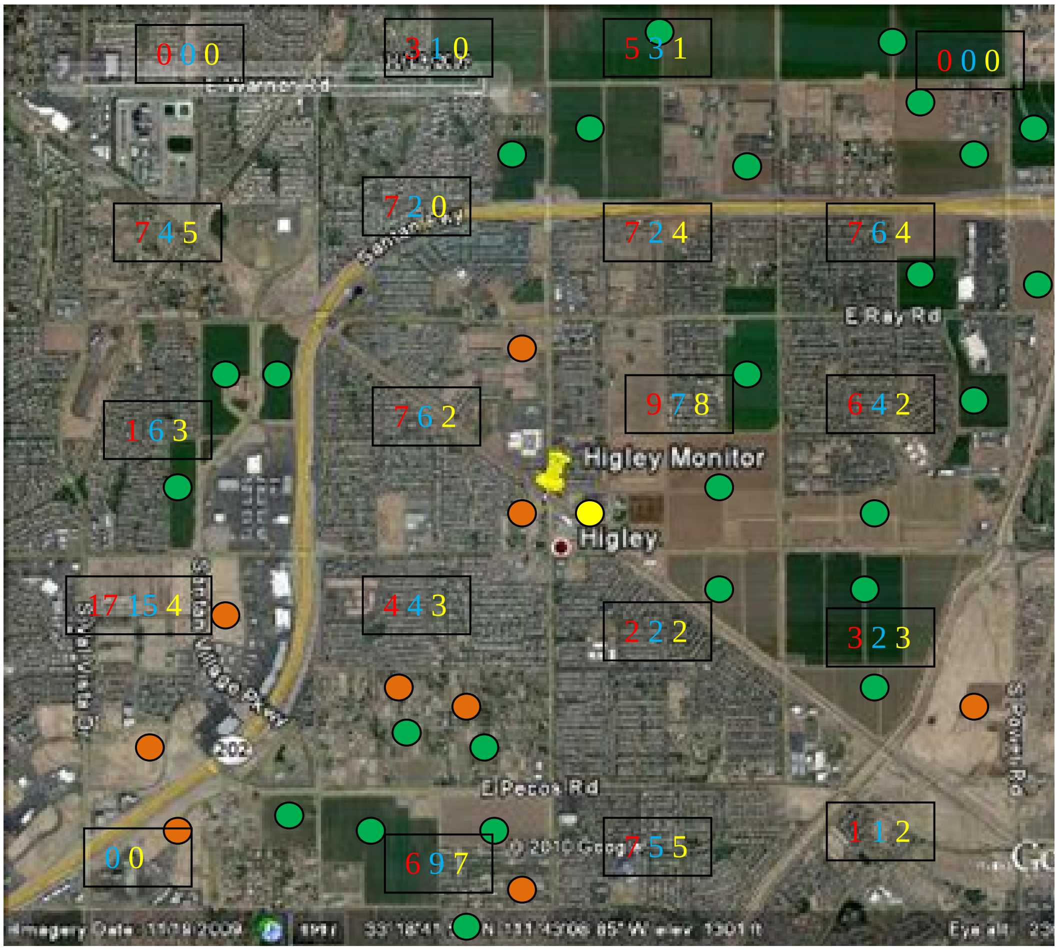


Figure 7 Higley 7/17/09

Figure 7 shows PM-10 levels though out the day of July 17, 2009. The graph shows high PM-10 readings beginning at 5 PM and spiking at 6PM at 3600 $\mu g/m^3$. Winds during this time came in from the East, and wind gusts reached 21 mph at 6 PM. The area to the east of the monitor is largely agricultural.

During periods of large PM-10 readings the wind is either coming from the east, or the south. Most of the area east of the monitor is dedicated to agricultural activities, a contributor to PM-10 pollution. The southern winds cross areas mainly covered by residential areas, and construction sites. Also to the south of the monitor is the largely agricultural area of Pinal County. Further studies could be done to determine transport rates of PM-10 from these agricultural fields and its effect on the Higley monitor.

Other contributors to the Higley monitor exceedances could be related to the railway which the monitor is located next to. This right of way is covered with crushed asphalt; frequent vehicle trips over this area have worn patches in the asphalt millings exposing the dirt from the road below.



Farm land

Stationary Sources

Vacant Lot

2007 Earthmoving Permit
2008
2009

Figure 8 Higley Monitor Map

Buckeye Monitor

The Buckeye monitor is located west of Phoenix in a rural setting. As Phoenix has expanded over the years it has become more populated, creating the need for housing and commercial developments. Most of the land in the area is still dedicated farm land. There are three large sand and gravel operations on the outskirts of Buckeye down near the Salt River.

Table 2 shows that there were three days over 150 $\mu g/m^3$ in 2007, four days in 2008 and three days over 2009. All three years find that most acreage downwind of the monitor on days exceeding 150 $\mu g/m^3$ belonging to agricultural land. In 2007 and 2008 the second largest acreages were attributed to Earthmoving permits, but in 2009 Earthmoving sites in this area were almost non-existent. The wind direction across these three years for exceedances stays relatively consistent with the winds coming mainly from the southwest, and south and occasionally the east.

Table 2

Buckeye Monitor Exceedances of 150 µg/m³

Exceedance Dates	PM-10 µg/m³	Wind Direction Degrees	Wind Speed mph	Earth moving Acres within 2 miles of the monitor	Stationary Permit Acres Within 2 miles of the monitor	Farm Acres Within 2 miles of the monitor	Vacant Lot Acres Within 2 miles of the monitor
4/12/07	152	244	10	90	80	1276	0
7/19/07	195	240	7.1	90	80	1276	0
11/15/07	170	102	7.8	123	12	139	9
3/2/08	160	302	12.7	53	12	2373	0
6/4/08	204	170	11.3	296	63	1460	0
7/1/08	172	135	5.7	296	31	1195	43
7/4/08	224	261	8	296	12	1149	0
7/17/09	401	218	4.2	0	81	1493	0
7/18/09	440	154	5	15	63	1419	43
10/27/09	167	180	9.7	16	63	1460	0

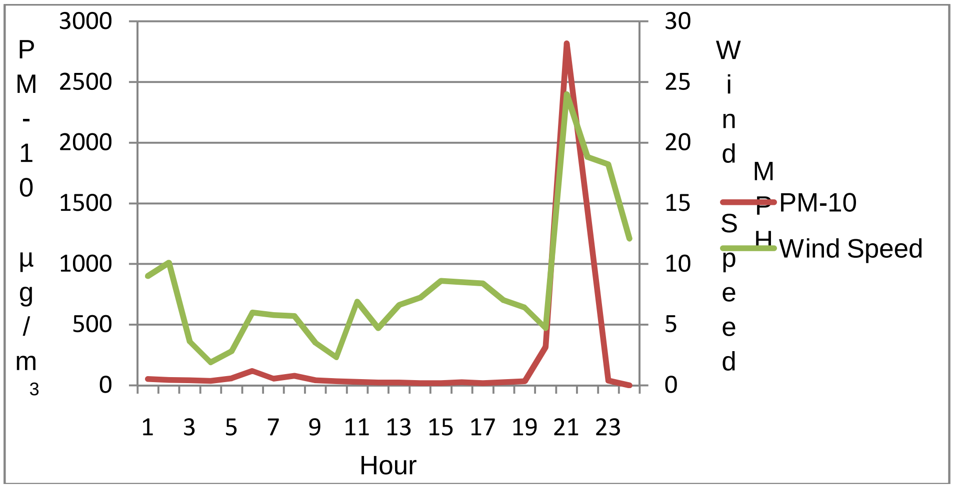


Figure 9 Buckeye 7/4/08

Figure 9 shows PM-10 levels for July 4, 2008. PM-10 levels increased to 2800 µg/m^3 at night with corresponding eastern winds with gusts up to 20 mph. These winds crossed mainly agricultural areas before reaching the monitor. While July 4th is a little late according to Table 3 for harvesting times in Arizona, weather may have permitted harvesting times later than usual in 2008.

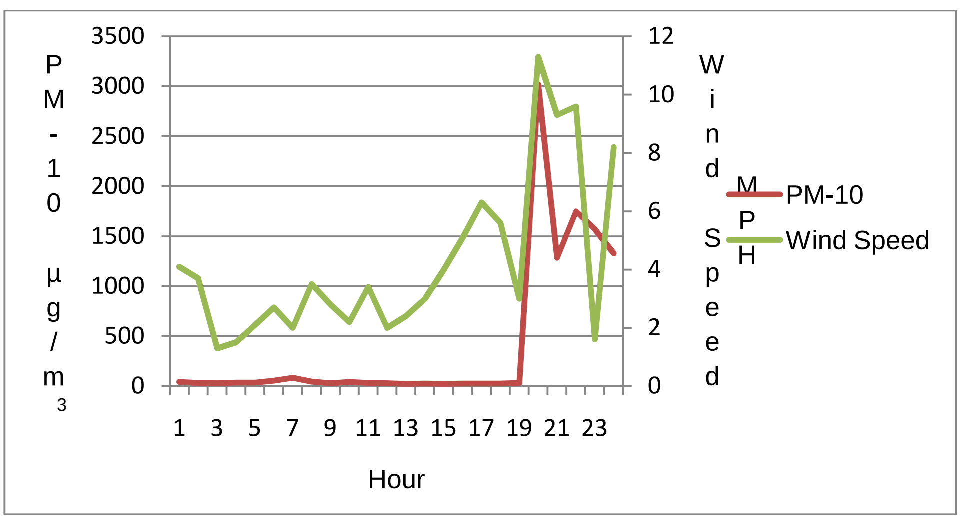


Figure 10 Buckeye 7/17/09

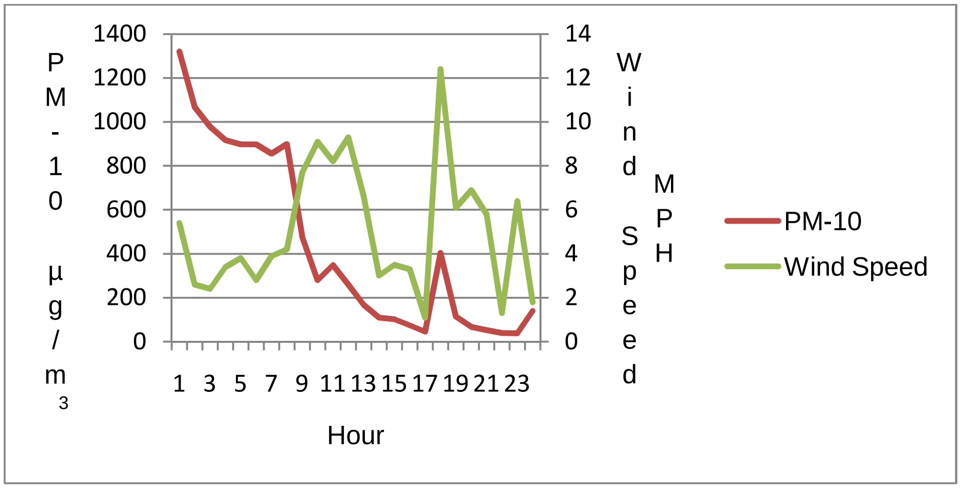


Figure 11 Buckeye 7/18/09

Figures 10 and 11 show a weather event occurring from the night of 7/17/09 and continuing into the morning of 7/18/09 causing the monitor to exceed 150 µg/m^3. This event recorded wind speeds of 11 mph corresponding to the largest PM-10 levels of 3000 µg/m^3 at 7 pm on July 17. Wind speeds began to slow over night keeping PM-10 in the area, when wind speeds starting to increase carrying the PM-10 out of the area PM-10 levels dropped.

There were no NOV's or NTC's issued on any days that exceeded 150 µg/m^3 in the 2 mile radius during the study period.

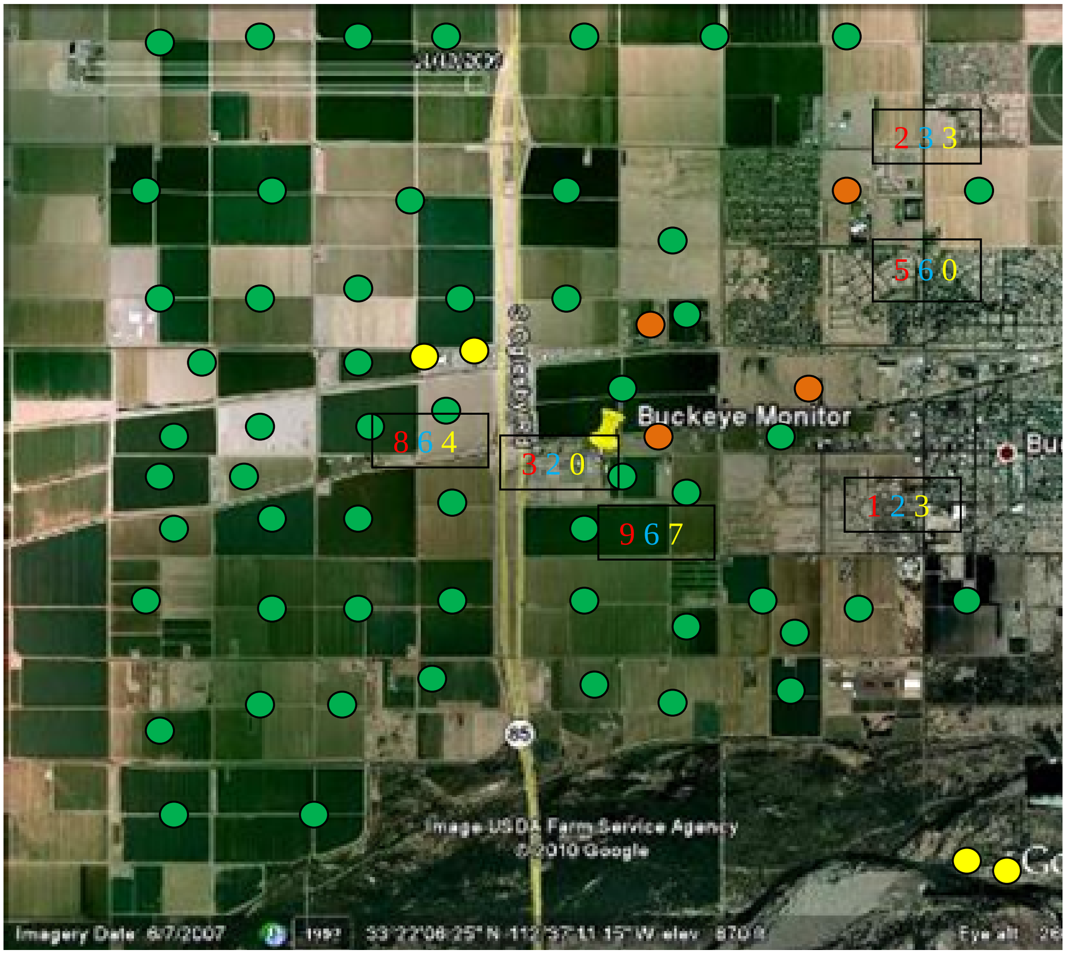
Most of the exceedances that occurred in the Buckeye areas occur during times of either planting or harvesting. Most of the crops grown in Arizona are either planted during the spring and harvested during the fall/winter or planted during the fall/winter and harvested during the spring. These planting and harvesting times correspond to times with high monitor readings. Agriculture can easily be identified as the main contributor to monitor exceedances in the Buckeye area.

Table 3

Arizona: Usual Planting and Harvesting Dates, by Crop

Crop	1996 Harvested Acres	Usual Planting Dates			Usual Harvesting Dates		
		Begin	Most Active	End	Begin	Most Active	End
Barley Fall	54	Nov 10	Dec 1 – Dec 30	Feb 1	May 15	May 30-Jun 15	Jul 1
Corn Grain	40	Mar 15	Apr 1 – May 15	Jun 1	Sep 1	Oct 1 – Nov 1	Dec 1
Corn Silage	15	Mar 15	Apr 1 – May 15	Jun 1	Sep 1	Oct 1 – Nov 1	Dec 1
Cotton	356	Mar 15	Apr 1 – Apr 30	May15	Sep 15	Oct 10 – Nov 10	Dec 25
Hay Alfalfa	160				Feb 15		Dec 1
Hay Other	19				Feb 15		Dec 1
Potato	9	Dec 15	Jan 1 – Jan 30	Feb 15	Apr 15	May 15 – Jun 15	Jul 1
Wheat Durum	164	Nov 10	Dec 1 – Dec 30	Feb 1	May 15	May 30 – Jun 15	Jul 1
Wheat Winter	14	Nov 10	Dec 1 – Dec 30	Feb 1	May 15	May 30 – Jun 15	Jul 1

(United States Department of Agriculture (USDA),1997)



Farm land

Stationary Sources

Vacant Lot

2007 Earthmoving Permit
2008
2009

Figure 12 Buckeye Monitor Map

Durango Monitor

The Durango Monitor is located in South Phoenix near the West 43rd Avenue Monitor. The Durango monitor is about one mile north of the lowest point in the valley, the Salt River. The West 43rd Avenue monitor is located a few hundred yards south of the Salt River. This area is highly industrial and with many vacant lots.

The Durango Monitor shows three days exceeding the standard in 2007, two days in 2008, and three days in 2009 as shown on Table 4. The Durango Monitor recorded winds coming mainly from the south and southwest regions. The south and southwest areas have large sand and gravel operations that operate on the Salt River. Acreages on Table 4 show the most acreage in the wind's path belonging to stationary permits and vacant lots on days where the monitor reads 150 $\mu g/m^3$ or higher.

Table 4

Durango Monitor Exceedances of 150 µg/m³

Exceedance Dates	PM-10 µg/m³	Wind Direction Degrees	Wind Speed mph	Earth moving Acres within 2 miles of the monitor	Stationary Permit Acres Within 2 miles of the monitor	Farm Acres Within 2 miles of the monitor	Vacant Lot Acres Within 2 miles of the monitor
7/19/07	152	227	7.8	105	747	0	643
11/8/07	152	211	1.4	105	747	0	643
11/15/07	156	129	6.3	164	407	51	282
11/7/08	248	176	1.3	172	348	25	202
11/9/08	170	201	4.4	109	348	25	353
7/17/09	162	195	5.2	112	761	52	186
7/18/09	278	142	4.3	6	643	52	333
10/27/09	158	242	5.4	12	164	57	279

The vacant lot owners around the Durango monitor received four NTC's in 2007 and five in 2009. Earthmoving permit holders were issued eleven NOV's for 2007, seven in 2008, and seven in 2009. Stationary permit holders received two NOV's in both 2007 and 2008, and six in 2009. No notices written to sources within a two mile radius of the Durango Monitor were issued on a date exceeding 150 µg/m³.

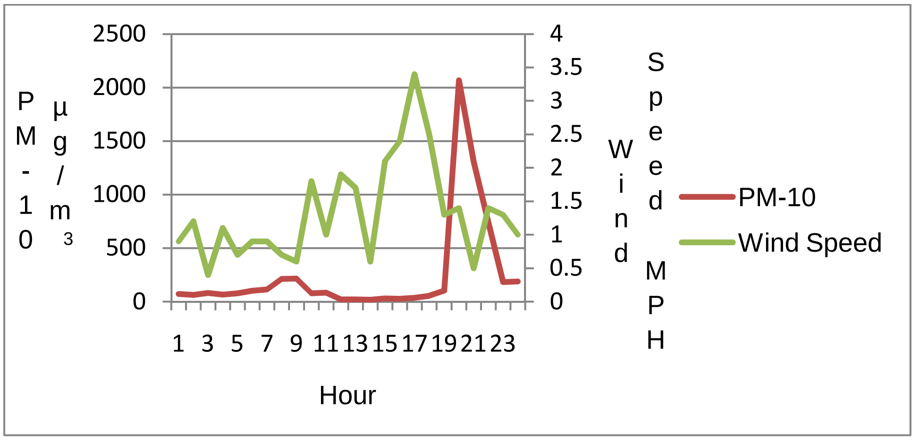


Figure 13 Durango 11/7/08

Figure 13 above shows an exceedance event occurring at the Durango monitor starting around 6 pm with PM-10 levels reaching 2000 µg/m^3 by 7pm. Wind speeds at 7pm were only 1.4 mph and came from the south. With such low wind speeds this exceedance does not seem to be due to a weather event but more of a local source origin or a stagnation event.

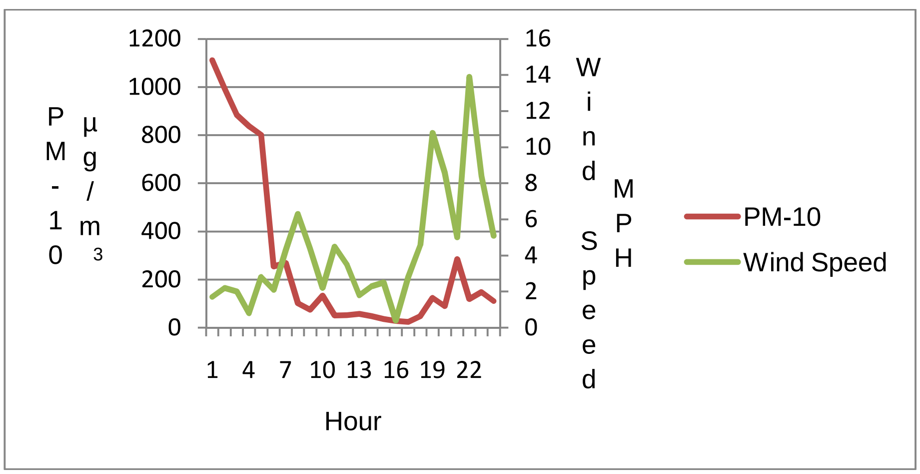
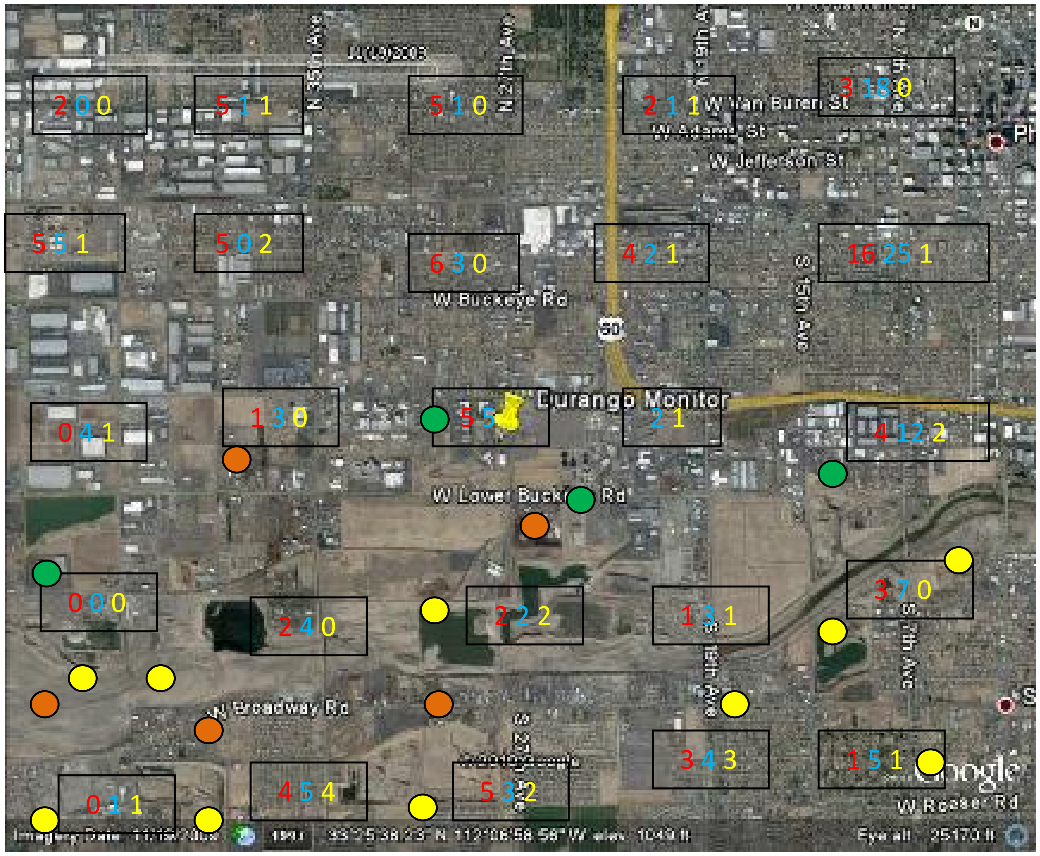


Figure 14 Durango 7/18/09

On July 18, 2009 the Durango Monitor recorded high levels of PM-10 in the early morning. July 17, 2009 exceeded 150 µg/m^3 during the night when a monsoon came through the valley around 9 pm bringing PM-10 into the low elevation around the Durango Monitor. The winds slowed around 10pm and stayed slow until 6am. When the winds picked up in the morning the PM-10 levels dropped. This wind stagnation trapped PM-10 in the area causing high PM-10 readings on the Durango monitor.



Farm land
Stationary Sources
Vacant Lot
2007 Earthmoving Permit
2008
2009

Figure 15 Durango Monitor Map

West 43rd Avenue Monitor

The West 43rd Avenue monitor recorded the most days exceeding 150 µg/m^3 for all years. Like the Durango monitor, Tables 5 and 6 below show stationary sources and vacant lots covering most areas in the wind's path to the monitor on high level PM-10 days. It was also found that earthmoving permits declined from 2007 to 2009 and exceedance events also declined over the course of the study, with nine in 2007, three in 2008, and seven in 2009.

The West 43^{rd} Avenue Monitor is located in the lowest part of the Phoenix valley. During stagnant times pollution accumulates in this low area. This accumulation causes high readings at the West 43^{rd} Avenue. These stagantion events can occur at any time of the year, showing why this monitor has consistent exceedances throughout the year.

Table 5

West 43rd Avenue Monitor 2007 Exceedances of 150 µg/m³

Exceedance Dates	PM-10 µg/m³	Wind Direction Degrees	Wind Speed MPH	Earth moving Acres within 2 miles of the monitor	Stationary Permit Acres Within 2 miles of the monitor	Farm Acres Within 2 miles of the monitor	Vacant Lot Acres Within 2 miles of the monitor
3/27/07	228	213	11	107	112	68	97
4/12/07	203	217	11	163	419	81	83
5/4/07	197	232	11	163	419	81	83
6/5/07	154	206	7	107	112	68	97
6/6/07	226	239	13	163	419	81	83
8/16/07	215	210	5	107	112	68	97
11/7/07	153	153	2.4	186	221	68	203
11/8/07	154	208	1.8	107	112	68	97
11/15/07	155	122	6	186	221	68	203

Table 6

West 43rd Avenue Monitor 2008-2009 Exceedances of 150 μg/m³

Exceedance Dates	PM-10 μg/m³	Wind Direction Degrees	Wind Speed MPH	Earth moving Acres within 2 miles of the monitor	Stationary Permit Acres Within 2 miles of the monitor	Farm Acres Within 2 miles of the monitor	Vacant Lot Acres Within 2 miles of the monitor
3/14/08	251	216	8.4	12	201	69	226
6/4/08	194	201	9	4	99	5	116
11/9/08	248	262	5	22	711	211	173
3/22/09	199	251	9.5	7	711	211	173
3/26/09	210	211	12	6	711	69	216
4/3/09	196	224	8.3	6	711	69	216
7/17/09	186	217	5.2	6	711	69	216
7/18/09	318	135	4.6	10	135	219	170
9/3/09	175	242	7.7	6	247	69	216
10/27/09	187	246	6	6	247	69	216

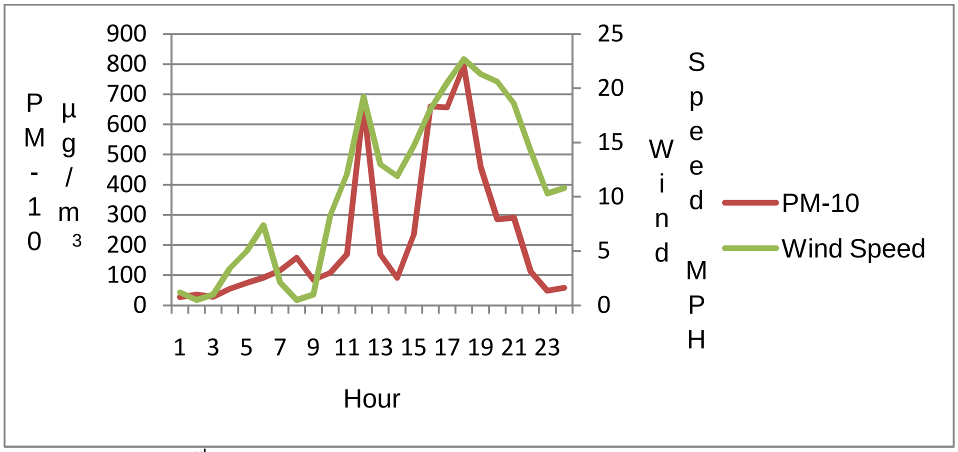


Figure 16 West 43rd Avenue 3/27/07

On March 27, 2007 two exceedance events occured over the course of 24 hours. Figure 16 finds an exceedance occur midday with PM-10 reaching over 600 µg/m^3, and a second exceedance occurs around 6PM with PM-10 levels at almost 800 µg/m^3. Wind speeds in the area got up to 20 miles an hour around noon coming from the west. Just to the west of the monitor is a large aggregate facility. The evening exceedance also experienced winds from the west coming over this large aggregate facility, with speeds consistent at 20 mph.

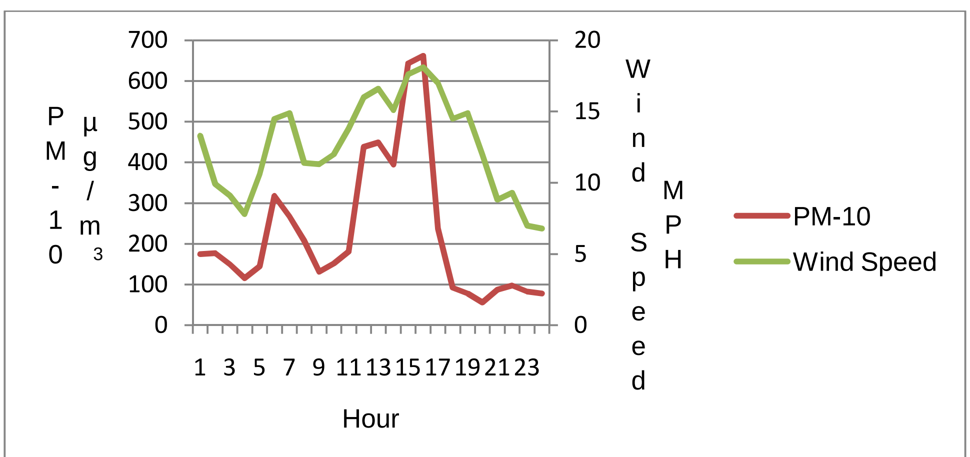


Figure 17 West 43rd Avenue 6/6/07

On June 6, 2007 the West 43rd Avenue monitor found PM-10 increasing throughout the day, with consistently high wind speeds. PM-10 got as high as 450 µg/m^3 at noon. Winds came in through out the day from the south west of the monitor. This area is covered largely by industrial activity and vacant lots.

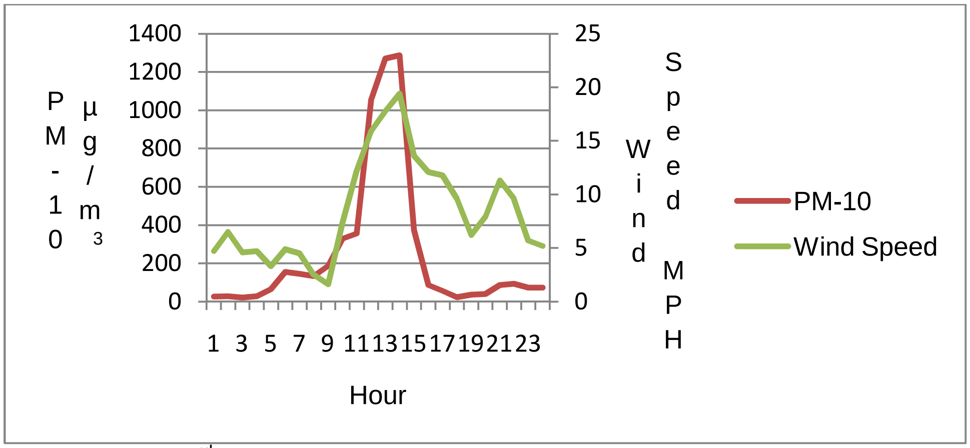


Figure 18 West 43rd Avenue 3/14/08

On March 14, 2008 an exceedance event was recorded as starting at 9 AM and reaching a peak level at 1PM with PM-10 readings of 1286 µg/m^3. Winds during this time reached almost 20 mph, from the west.

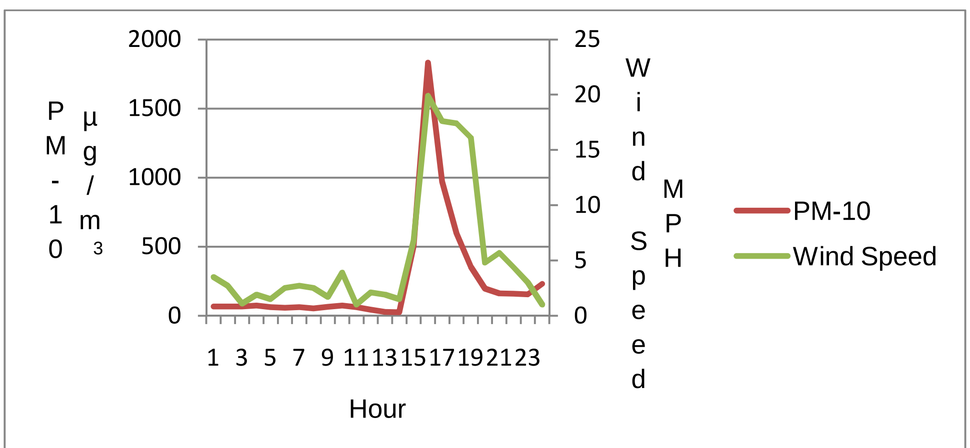


Figure 19 West 43rd Avenue 11/9/08

November 9, 2008 saw a large increase of PM-10 at 3pm, recording more than 1800 µg/m^3. Wind speeds peaked at this same time on the monitor and the sharp drop off of both winds and PM-10 levels after 3pm indicate a quick moving storm passing the monitor contributing to the exceedance.

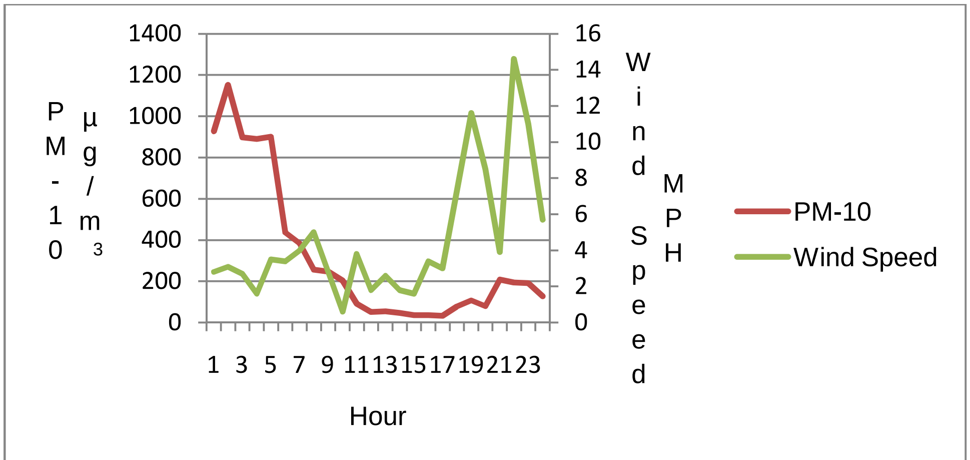
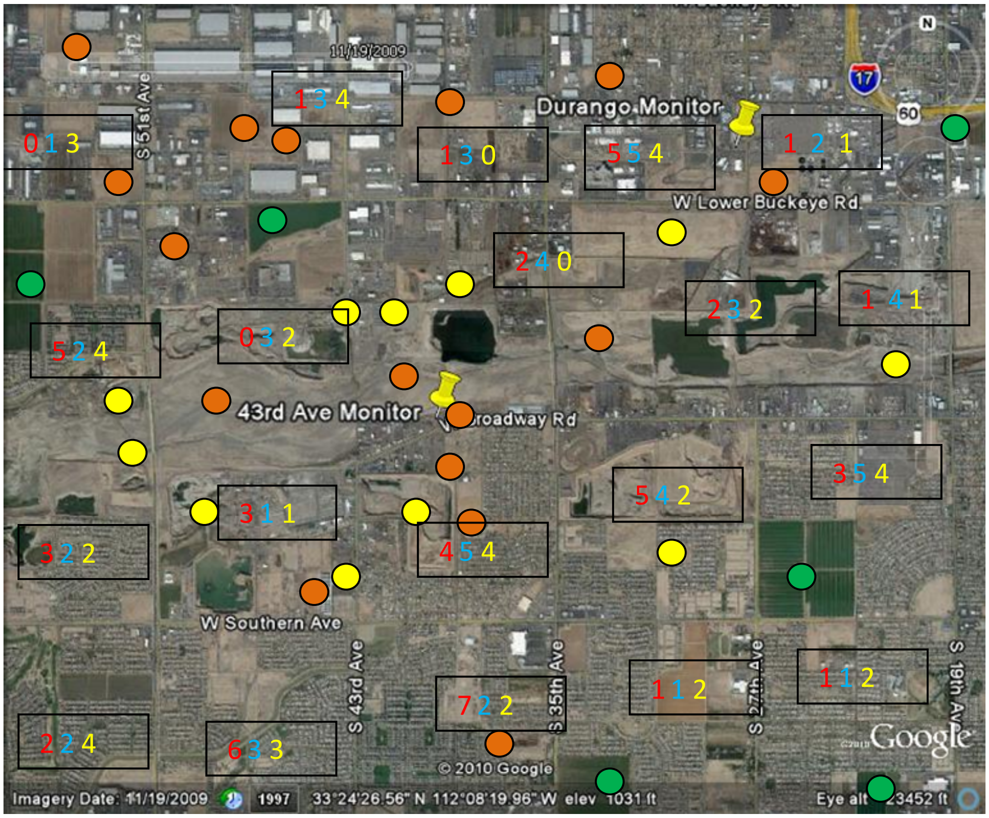


Figure 20 West 43rd Avenue 7/18/09

The exceedance event at West 43rd Avenue on 7/18/09 can be attributed to the storm system that entered the valley aroun 9pm on 7/17/09. PM-10 levels were highest at 2 AM, when wind speeds were slow, after a period of high wind speeds that brought more PM-10 into the area. These slow wind speeds caused PM-10 to remain in the area. When the wind speeds picked up PM-10 was moved out of the area, causing monitor readings to drop.

In 2007 NOV's were issued to fourteen earthmoving permit holder, two stationary permit holderes and three NTC's to vacant lot owners. In 2008 eight NTC's were written to vacant lot owners, with five NOV's issued to earthmoving permit holders and zero to stationary permit holders. In 2009 seven NTC's were written to unstable vacant lot owners, eight NOV's were given to earthmoving permit holders, and five NOV's to stationary source permit holders. Although many NOV's and NTC's were issued throughout the three year period few violations were written on monitor exceedance dates. 2009 was the only year with an NTC for a vacant lot written on an exceedance day. No violations were written to an earthmoving permit or a stationary permit on an exceedance day for all three years.



Farm land

Stationary Sources

Vacant Lot

2007 Earthmoving Permit
2008
2009

Figure 21 West 43rd Avenue Monitor Map

Weather Conditions

For 2007 one day recorded more than 150 μg/m^3 across three or more monitors; July 19. July 19, 2007 is in the middle of monsoon season in Phoenix.

Around 10:20 pm the day turned from cloudy to windy with areas of widespread dust recorded.

Table 7

July 19, 2007 Weather Data

Time MST	Wind Direction	Wind Speed MPH	Gust Speed MPH	Conditions
11:51 AM	West	13.8	19.6	Scattered Clouds
12:51 PM	West	15	20.7	Scattered Clouds
1:51 PM	WNW	8.1	19.6	Scattered Clouds
2:51 PM	WNW	15	21.9	Scattered Clouds
3:51 PM	West	17.3	24.2	Scattered Clouds
4:51 PM	West	18.4	23	Scattered Clouds
5:51 PM	West	16.1	-	Mostly Cloudy
6:51 PM	West	18.4	-	Scattered Clouds
7:51 PM	West	16.1	-	Scattered Clouds
8:51 PM	West	10.4	-	Scattered Clouds
9:51 PM	WSW	9.2	-	Scattered Clouds
10:57 PM	South	31.1	43.7	Light Rain
11:58 PM	SSE	23	32.2	Light Thunderstorms

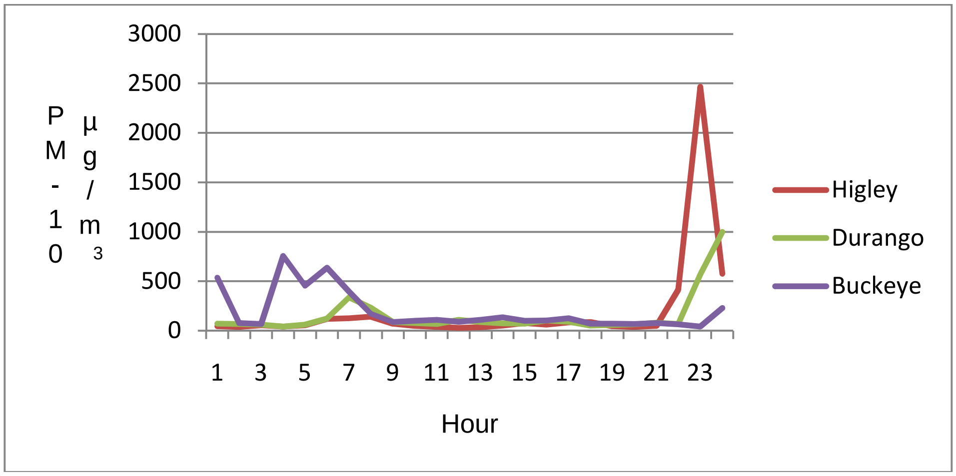


Figure 22 7/19/2007

The data in Figure 22 stays consistent with the weather event recorded on Table 7. A late storm started to see increased PM-10 levels around 10pm. The chart shows Higley seeing higher PM-10 levels and as the winds make their way west the Durango monitor spikes, then Buckeye, being the furthest west.

2009 recorded three days on which three or more monitors exceeded 150 µg/m^3. The first two dates to exceed were July 17 and 18. On July 17, 2009 widespread dust conditions were recorded to start at 7 pm, with multiple gusts reaching up to 40 mph recorded. July 18, 2009 found widespread dust events occurring around 7 pm with wind gusts reaching up to 30 mph by 10 pm.

Figure 23 shows monitor responses to a storm system that came through the valley in the evening. Monitors began reading elevated PM-10 levels between 4 and 6pm. These PM-10 levels remained high through the night. Table 8 below shows the hourly weather as recorded at the Sky Harbor weather center in downtown Phoenix. The weather data shows a storm that begins early afternoon, reaching top wind speeds by 10 pm, and remaining windy throughout the night.

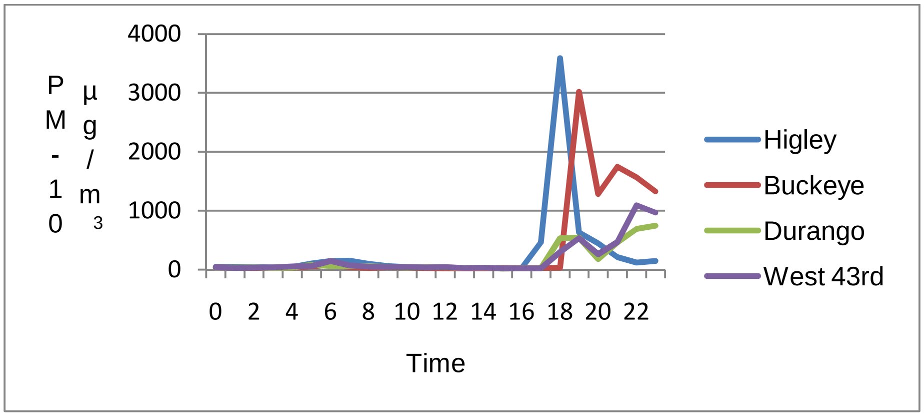


Figure 23 7/17/2009

Table 8

July 17, 2009 Weather Data

Time MST	Wind Direction	Wind Speed	Gust Speed	Conditions
2:51 PM	SSE	8.1	-	Mostly Cloudy
3:51 PM	SSW	5.8	-	Mostly Cloudy
4:51 PM	Variable	4.6	-	Mostly Cloudy
5:51 PM	WSW	9.2	-	Mostly Cloudy
6:51 PM	West	16.1	-	Mostly Cloudy
7:51 PM	WNW	17.3	-	Widespread Dust
8:51 PM	East	15	23	Mostly Cloudy
9:51 PM	East	16.1	28.8	Mostly Cloudy
10:51 PM	ENE	9.2	-	Mostly Cloudy
11:51 PM	WSW	11.5	-	Mostly Cloudy

Figure 24 and Table 9 find the storm from 7/17/09 remained in the early morning and caused high monitor readings on 7/18/09. The Buckeye, Durango, and West 43rd Avenue monitor all recorded high levels of PM-10 with stagnant wind periods. The storm system from 7/17/09 brought PM-10 into the area, when the winds slowed the PM-10 was left in the area until winds picked up again in the later morning.

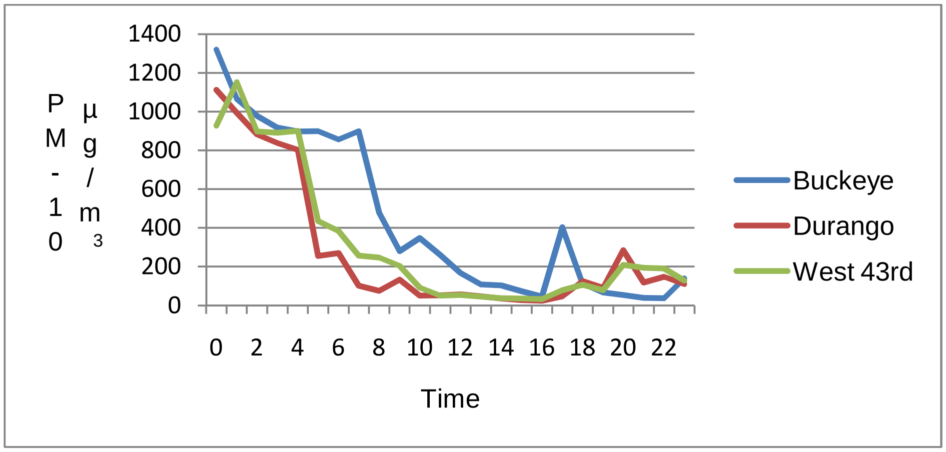


Figure 24 7/18/2009

Table 9

July 18, 2009Weather Data

Time MST	Wind Direction	Wind Speed	Gust Speed	Conditions
12:51 AM	Calm	Calm	-	Widespread Dust
1:51 AM	Calm	Calm	-	Widespread Dust
2:51 AM	ESE	3.5	-	Widespread Dust
7:09 PM	South	12.7	21.9	Widespread Dust
7:33 PM	SW	8.1	-	Widespread Dust
7:39 PM	WSW	10.4	-	Widespread Dust
7:51 PM	WNW	17.3	-	Widespread Dust
8:44 PM	ESE	13.8	26.5	Mostly Cloudy
8:51 PM	East	15	23	Mostly Cloudy
9:51 PM	East	16.1	28.8	Mostly Cloudy
10:51 PM	ENE	9.2	-	Mostly Cloudy
11:51 PM	WSW	11.5	-	Mostly Cloudy

Figure 25 and Table 10 review weather data for 10/27/09, a day where all four monitors recorded exceedance events. Figure 25 shows the monitors reading high PM-10 levels around 3pm. Weather data for the day as shown in Table 10 shows wind gusts up to 33 mph during this time. Another peak occurring around 10 pm shows Buckeye monitor exceeding the most, but small PM-10 spikes from all four monitors.

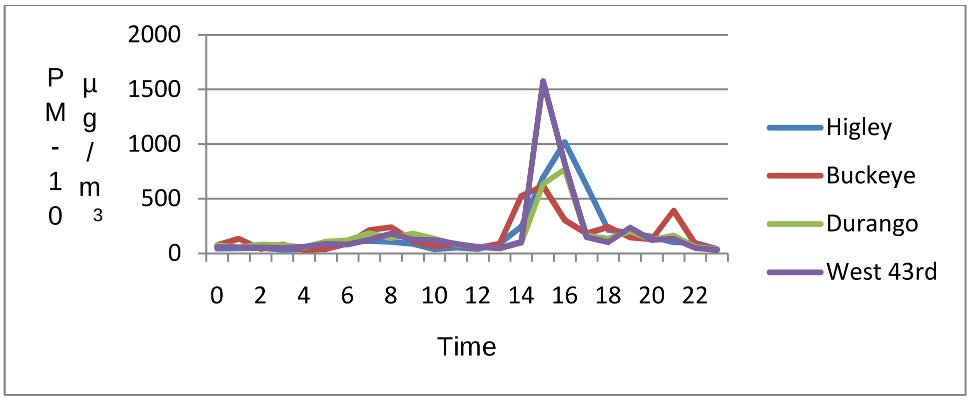


Figure 25 10/27/09

Table 10

October 27, 2009Weather Data

Time MST	Wind Direction	Wind Speed	Gust Speed	Conditions
11:51 AM	SSE	10.4	-	Mostly Cloudy
12:51 PM	East	5.8	-	Mostly Cloudy
1:51 PM	NNW	4.6	-	Mostly Cloudy
2:51 PM	West	4.6	-	Overcast
3:51 PM	WSW	26.5	33.4	Overcast
4:51 PM	WSW	24.2	32.2	Overcast
5:51 PM	SW	18.4	29.9	Mostly Cloudy
6:51 PM	WNW	19.6	-	Mostly Cloudy
7:01 PM	WNW	18.4	-	Mostly Cloudy
7:51 PM	WNW	21.9	33.4	Mostly Cloudy
8:51 PM	WNW	20.7	29.9	Overcast
9:51 PM	NNW	23	31.1	Overcast
10:51 PM	NNW	19.6	26.5	Mostly Cloudy
11:51 PM	NW	13.8	-	

These weather episodes may not fit the EPA's criteria for an exceptional event exemption due to recorded near normal wind speeds, but this data shows a strong correlation between weather events and high PM-10 readings on monitors within Maricopa County. The data shows multiple monitors exceeding 150 $\mu g/m^3$ on the same days, and days that were recorded storm episodes. The data is also consistent throughout the day recording highest PM-10 levels when weather data showed strongest wind gusts and periods of wide spread dust.

CHAPTER 5

Conclusion

The purpose of this study was to review the area around four monitors within Maricopa County to find possible areas where PM-10 emissions may have been originating during the years 2007, 2008, and 2009. Days averaging over 225 μg/m^3 were reviewed to find specific sources contributing to high monitor readings using wind speeds, and PM-10 increases. This study also looked at weather patterns for days with more than three monitors exceeded 150 μg/m^3.

Construction activities had been found in Maricopa County's 2005 emission inventory as the greatest contributor to PM-10 levels in the ambient air over Phoenix. This study covered the period of 2007 – 2009. Construction activity decreased during this time due to economic conditions. A decrease in monitored PM-10 exceedances from 2007 to 2009 was found, but Maricopa County still recorded more than double the three year violation allowance for each year in the study.

2009 found fewer exceedance days then 2007, and found earthmoving permit acreage decline. The Higley Monitor had more earthmoving permit acreage throughout the study period and less exceedances than the Durango and West 43rd Avenue Monitors, which is mainly stationary permit, and vacant lot land, or the Buckeye Monitor which is mainly agricultural land. All four monitors say days exceeding 225 μg/m^3. The Higley and Buckeye monitors found times with increased PM-10 levels corresponding to winds coming from agricultural lands. Durango monitor found large permitted sources and vacant lots in the winds path when the monitor recorded rising PM-10 levels. The West 43rd Avenue monitor found winds coming from the west over stationary source permitted facilities when PM-10 levels rose.

The study found that weather did have a significant impact on exceedances. 2007 received 5.05 inches of rain and saw the most exceedance events of all years (Weather Underground, 2011). 2008 recorded 9.58 inches of rain and the least amount of exceedance events, while 2009 recorded the lowest precipitation with only 3.26 inches, and saw exceedance event occurrences rise. Each year found days were weather contributed to high PM-10 levels. All monitors in the study exceeded 150 $\mu g/m^3$ on 10/27/2009. Weather data on 10/27/09 showed a storm, with increased wind speeds correlating to PM-10 spikes on all four monitors.

Maricopa County has a long history of non-compliance with the Federal PM-10 NAAQS. After large expansion of the Phoenix area strict regulations were adopted in 2008 in the hopes of curbing PM-10 levels. After three years of regulating facilities with these strict new standards, Maricopa County has seen improvements with its PM-10 levels as 2010 recorded only one exceedance day on the Maricopa County PM-10 monitoring system. Industries with no regulations or under weak regulations need to be included in the strict dust regulations for further decline of exceedance days and continued compliance with the PM-10 NAAQS standard in Maricopa County.

Recommendations for Future Study

- Tracking PM-10 levels during planting and harvesting days while doing real time observations of the areas heavily occupied by farm activities.

- Comparing emergency room visits for respiratory and cardiac issues during the winter months versus the summer months.
- Other PM-10 sources like Golf Courses and open areas of permitted facilities not regulated by dust regulations should be studied for emission rates.
- Monitors could be placed to track PM movements north into Maricopa County from the heavily agricultural areas of Pinal County.
- Studies could be conducted to create new technologies for dust suppression.

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